Capital Regional District

Core Area Wastewater Treatment Program
Feasibility Study for Heat Recovery for James Bay and Downtown Victoria

Stantec

Executive Summary

The proposed secondary wastewater treatment facilities for the Core Area present an opportunity for the recovery of heat from raw wastewater or from treated effluent to provide heat for use in buildings and for process heat at the wastewater treatment facility. Previous studies have recommended that this option be examined in further detail to determine its technical and cost viability. In order to further examine this concept, a more detailed feasibility study on the recovery of heat for use for the James Bay and Downtown area was carried out.

Available Heat and Heat Demand

The existing average sewage flow during the fall and winter period (October 2008 to March 2009) at the proposed McLoughlin Point wastewater treatment plant is 83.4 ML/d. The projected average dry weather flows are 84.2 ML/day for 2030 and 87.5 ML/day for 2065. The amount of saleable heat is estimated at 70% of the available heat since space heating is not required for the summer months though domestic hot water, which often sources off end users boiler systems, is required year-round in the downtown core especially in the residential buildings and the hotels. Some of the available heat will also be used for process related functions such as digester heating and biosolids drying. The estimated saleable heat that can be extracted from the treated effluent at McLoughlin Point is summarized in Table E.1.

Table E.1 – Estimated Saleable Heat (GJ/yr)

Year	Total Annual Heat Available	Estimated Saleable Heat
2009	1,505,951	1,054,166
2030	1,521,516	1,065,061
2065	1,581,147	1,106,803

Figure E.1 shows the diurnal variations in sewage flows and extractable heat at the McLoughlin Point wastewater treatment assuming a wastewater temperature of 12C.. This figure also shows the hourly variations in winter heat demand for the Downtown and James Bay Areas based on the capacity of the existing hot water boiler in the James Bay and Downtown area.

At the 2030 average day flow of 84.2 ML/d, the consistent heat output from treated effluent would be approximately 23,000 KW. This is insufficient to meet the winter heat demand for the Downtown/James Bay areas. Early in the morning, the supply would satisfy less than 20% of the demand. This would rise in mid-day to approximately 50% of the winter demand.

In order to increase the supply of heat in the early morning, a cursory analysis of supplementing with heat extracted from sea water was carried out. However, because of the high cost, this was not retained for further analysis and the options for a District Energy System for the James Bay and Downtown area were sized on the basis of supplying 23,000 KW.

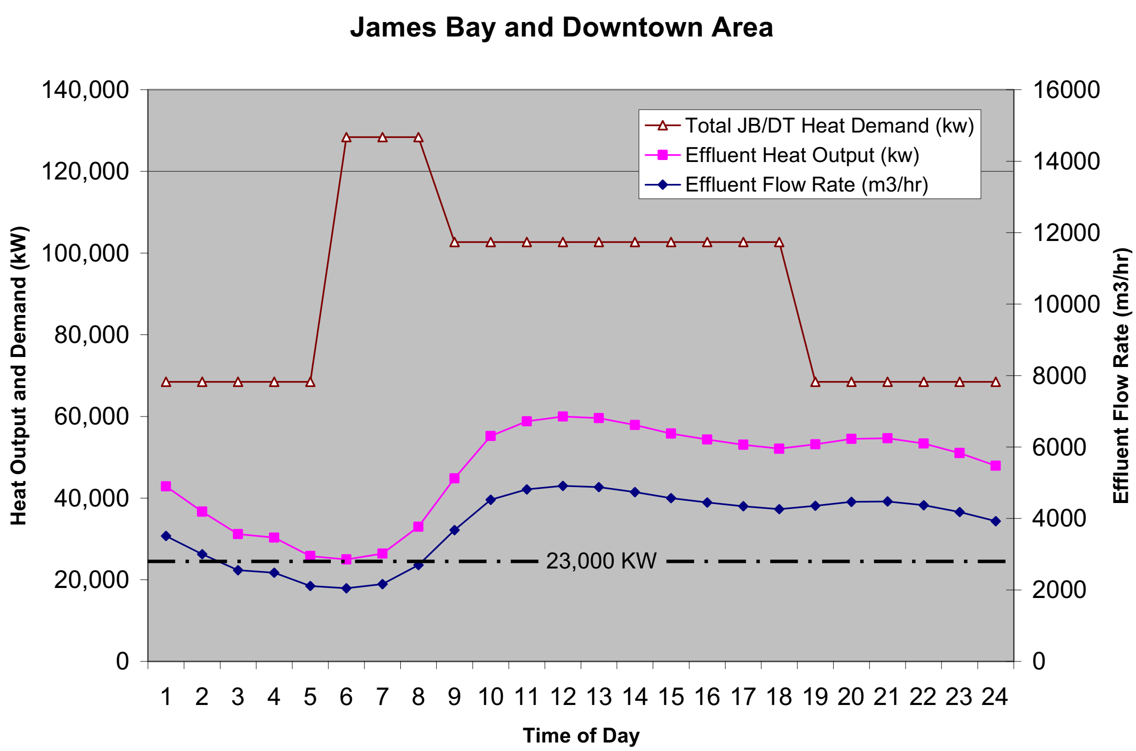

Figure E.1 – Hourly Variations in Heat Demand and Heat Available from Effluent

Options for a District Energy System for James Bay and Downtown Area (Options 1 to 3)

Based on the case studies carried out during the course of this project, it appears that most of the existing boiler systems in the James Bay and Downtown core are operating at design temperatures of 80^{0}C or more. Modern day systems are designed at lower temperatures of 60C to conserve energy. As a result, a District Energy System (DES) would be required to supply heat at this temperature in order to meet the peak winter demand of potential customers and still continue to use existing mechanical heating systems. Modern energy efficient boilers are now designed to operate at lower temperatures of 60^{0}C. There are three options on how this could be achieved for high temperature DES serving the James Bay and Downtown areas:

- Option 1 – Distribute the heat at ambient temperature (up to 20 ^{0}C) and install heat pumps at each point of use to boost the water temperature to 80^{0}C.

- Option 2 – Install dual system heat pumps at the wastewater treatment plant and distribute water heated to 80^0C.
- Option 3 – Install heat pumps at the wastewater treatment plant for the first lift in temperature, distribute the heat at 35^0C and install a second set of heat pumps at the point of use to lift the temperature to 80^0C.

In all cases, it would be necessary to install two sets of heat pumps. It is noted that a dual heat pump system to boost water temperature to 80^0Cconsumes significantly more power than a system with only one lift to a lower temperature such as 65^0C.. The first set of heat pumps would boost the temperature from 12 -14^0C to 35^0C. The second heat pump would lift temperature to 80^0C. Options 1, 2 and 3 would require the installation of a 6.5 km long dual pipe closed loop system from the proposed McLoughlin wastewater treatment plant to the biosolids treatment facility in the Upper Victoria Harbour. The cost associated with piping the heat over such a length would be very high at $14.9 million considering that excavation would be required in busy downtown streets, which already have a significant amount of underground utilities. There is also a concern that mechanical rooms in existing buildings may not have the available space to install the heat exchangers and heat pumps that would be needed to connect to the DES. A case study review of several buildings in the Downtown core indicated that this was indeed the case.

Option for a District Energy System for North Downtown (Option 4)

For the above reasons, a fourth option, referred to as Option 4 was identified. With Option 4, the service area would be reduced in scope to include only the biosolids handling facility located in the Upper Victoria Harbour and the north portion of the downtown area north of Pandora Street. This portion of the downtown area is not as developed as the area located further south and it is anticipated that that most of the customers of a DES would consist of new buildings instead of older buildings. These new buildings would be designed with modern more energy efficient boilers operating at a lower temperature of 60^0C. There would be no requirement for the significant retrofit costs as is the case in the downtown core with older buildings. This option would result in lower capital and operations costs.

Cost Summary

The capital cost, the annual operating and maintenance (O&M) cost and the estimated revenues for the four options are summarized in Table E.2. The capital costs include interim financing estimated at 4% of all direct and indirect costs. The O&M costs shown in Table E.2 do not include the annual debt servicing. However, it should be noted that based on interest rate at 6% and an amortization period of 25 years, the annual debt servicing would be at $54,000 for each $1 million of capital cost not covered by senior government grants. A triple bottom line analysis was carried out on all four options and is summarized in Table E.3.

Table E.2 – Summary of Costs and Revenues

	Option 1 - Ambient Temp. (<20°C)	Option 2 -Moderate Temp. (80°C)	Option 3 - Low Temp. (35°C)	Option 4 - Hybrid North Downtown Only
	James Bay and Downtown			
Capital Cost	$54,410,000	$45,632,000	$50,737,000	$29,274,000
Annual O&M Cost (1) (3)	$4,078,000	$3,933,000	$4,017,000	$2,521,000
Annual Revenues (1)	$4,596,000	$4,228,000	$4,412,000	$3,018,000
Annual Net Revenues (1)	$518,000	$295,000	$395,000	$497,000
Annual Carbon Credit (2)	$495,000	$451,000	$473,000	$314,000

(1) Based on selling 90% of available heat. Initially it is anticipated that revenues will be much lower at start up, perhaps in the 25% range and will ramp up as new development occurs and energy prices increase. Green developments may also accelerate the demands for recovered heat.

(2) Based on selling 90% of available heat and assuming carbon credit at $25/tonne $C0_2$

(3) Annual debt servicing of $54,000 per $1 million of capital cost not covered by senior government grant is not included in the annual O&M cost.

Table E.3– Summary of Triple Bottom Line

	Option 1 - Ambient Temp. (<25°C)	Option 2 -Moderate Temp. (80°C)	Option 3 - Low Temp. (35°C)	Option 4 - Hybrid North Downtown Only
	James Bay and Downtown Area			
Economic	49	62	51	88
Environmental	63	53	57	67
Social	36	70	45	70
Total	147	185	153	225

<u>Analysis of Options for a Large DES System for James Bay and Downtown (Options 1 - 3)</u>

The difference in capital and in O&M costs between the three options for a large District Energy System for James Bay and Downtown is not significant. The capital cost of Option 2 is the lowest of the three options for a large DES mainly because of the economies of scale resulting from having all equipment and the heat pumps at one location.

It appears that most existing boiler systems are operating at "legacy" temperatures of 80^0C or more. As a result, a DES would be required to supply heat at this temperature in order to meet the peak winter demand of potential customers. If the DES were to supply heat at a lower temperature, either ambient temperature or up to 60ºC, a combination of heat exchangers and heat pumps or a back-up-boiler would be needed on the customer's private property to increase temperatures. It appears, however that in most cases, the mechanical rooms in existing buildings would not be large enough to accommodate this equipment. For existing infrastructure areas such as James Bay and Downtown Victoria, it would be preferable for a DES to supply heat at a temperature of 80^0C.

The net revenues generated by the sale of heat to the existing buildings in James Bay and Downtown Victoria are low in comparison to the capital cost of $45 million that will be incurred for the extraction and distribution of this resource based on Option 2. When the value of the carbon credit is added, the annual net revenues would increase from $295,000 to $746,000. However, the payback period exceeds 50 year.

It is anticipated that these revenues will be realized given the Province's desire to move towards being carbon neutral but it will take some time before this occurs. A reasonable estimate is to assume initially that no more than 30% of the available heat will be used and this would include the heat used for heating of digesters which is estimated at 14 % of peak demand. There are several reasons why the capital, O&M costs and payback period are large for a district energy system serving the James Bay and Downtown area:

- The length and resulting cost of the heat transmission main from the WWTP to the most distant point of use which would be the digesters located in the Upper Harbour. This transmission main cannot be phased since the biosolids facility which would be connected to the heat recovery system is at the far end of the pipe. Also this pipeline is expensive to construct because the heat loop must be installed in developed roadways with a number of utilities, some of which will require relocation.

- The heat extracted from the effluent must be lifted twice from a temperature difference (potential) of 7ºC in winter (12ºC – 5ºC) to the required end user temperature of 80ºC. The size and cost of the equipment to accomplish these two lifts is significant. In addition, the electrical power consumption for the pumps and heat pumps is significant and increases operating costs substantially.

- The diurnal low flows early in the morning limit the amount of consistent available heat that can be extracted from the effluent. Since the peak demand occurs when flows are lowest and therefore the amount of heat that can be extracted, the net sales are limited. These low net sales adversely affect the payback on the significant capital costs for equipment.

- Cost of buildings to house the heat pumps either at the wastewater treatment plant for a moderate temperature heat distribution system or at each point of use for other options. In the case of ambient or low temperature distribution, it will be necessary to expand the mechanical rooms in many existing buildings to provide additional space for the heat pumps.

- Energy and carbon prices for heating with current energy sources are still too low to be able to charge more for a DES unit of energy. If energy prices were more in line with European prices, revenues would be higher and the payback period would be reduced. At some time in the future a DES may become more attractive if energy prices increase.

<u>Analysis of Option for a Smaller DES System (Option 4)</u>

Modern heating systems, primarily in the last decade or so, are designed using condensing boilers which operate at significantly lower temperatures of approximately 60^0C (140^0F). As well, the proposed digesters will be designed to operate at 55^0C (131^0F). These temperature levels align much better with the temperature-coefficient of performance (COP) constraints of modern high quality heat pumps. The COP at these temperatures would make the business case more favorable as factors like transmission heat loss, equipment size and needed electrical energy would be reduced. Since the potential customers of a DES in the north portion of the downtown core would likely consist of new development as opposed to retrofitting existing buildings, the temperature of the DES could be reduced to 60-65ºC making Option 4 more financially attractive.

<u>Conclusions</u>

The existing buildings in the James Bay and Downtown core are served by high temperature (>80^0C) or steam heating systems. It would be very challenging and cost prohibitive to implement a district energy system to service the James Bay and Downtown area. The huge capital cost needed to lift wastewater heat to 80ºC and convey it through a 13 km pipe loop does not make a good business case based current energy prices and carbon credit at $25/tonne. The payback period exceeds 50 years.

The business case and economics of construction favour construction of a smaller scale District Energy System to serve the north portion of the downtown core in close proximity to the proposed biosolids facility (Option 4). Consideration should be given to constructing a smaller energy system to service the north portion of the Downtown area. This smaller energy system could be integrated with the energy requirements of the biosolids facility located in the Upper Victoria Harbour.

Heat extracted from the effluent would be conveyed to the biosolids facility at ambient temperature (<20^0C) thus eliminating heat losses along this line. The transmission line would go through Esquimalt and Victoria West eliminating the need to include it in the tunnel under Victoria Harbour. The pipe could be attached to the Bay Street Bridge.

A district heating facility housing the heat pumps could be located at the biosolids facility and hot water at a temperature of 60-65^0C would be distributed to the biosolids process equipment and the nearby north portion of the downtown area. This system would be designed to take into account the lower operating temperature of newer heating systems.

The capital cost of this smaller DES system is estimated at $29,274,000. This system can be phased with the cost of the first phase estimated at $12,258,000. This amount includes the construction a non-insulated ambient temperature transmission line from the WWTP to the biosolids facility and sized for the needs of the biosolids facility and the north downtown area. This amount includes the heat exchangers and the heat pumps sized for the biosolids facility only. In a second phase, estimated at $17,016,000, a loop to serve the north downtown area with an insulated line to a temperature of 65^0C together with additional heat exchangers and heat pumps would be constructed.

Since it is proposed to use only two thirds of the extractable heat to provide process heat to the biosolids facility and the north Downtown area, a significant amount of energy would be available for other developments in Victoria West and Esquimalt.

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Section 1.0 Introduction

1.1 Introduction

The Capital Regional District (CRD) is planning the construction of a secondary wastewater treatment facility at McLoughlin Point. The proposed location for this plant is on a parcel of land owned by Imperial Oil and used as an oil delivery terminal. The site at McLoughlin Point is too small to accommodate the biosolids treatment portion of the plant. One of the options under consideration is to locate the digesters and the other solids handling processes at a separate site in the Upper Victoria Harbour.

The recovery of heat from raw sewage or from treated effluent to supply heat to large users is one of the areas where resources from wastewater can be recovered. Several earlier preliminary assessments have indicated that there may be an opportunity pending further investigation to use a significant amount of the heat generated from the wastewater. This may potentially be utilized by large users in the James Bay and Downtown area to meet some of their needs for space heating and domestic hot water., thereby offsetting the use of natural gas and reducing the carbon footprint of these buildings.

Heat recovery requires infrastructure to: (1) transfer the heat from the effluent to a clean heat transport liquid through heat exchangers, (2) lift the temperature of the clean liquid to a level that is usable by boiler systems through the use of heat pumps, (3) pumping of heated liquid, (4) distribution of the heated liquid through a network of pipe, and (5) connection to the customers.

This report examines various options and requirements for the various components of the infrastructure needed to deliver heat to potential users in the James Bay and Downtown areas.

1.2 Challenges and Opportunities

Perceptions of treated effluent as a waste material can affect the willingness of clients, public, potential customers and regulators to embrace the idea that treated effluent is a resource that can be utilized for heat or cooling. Open loop geo-exchange systems often rely on water from aquifers in the earth that is usually pumped from wells at approximately 12^0C, the very same expected lowest temperature of treated effluent water! Treated effluent represents an excellent source of water for operating heat pumps and when the effluent is between 12^0C and 25^0 C in summer and shoulder seasons, heat pumps operate even more efficiently than with 12^0 C source water. Heat pumps do however consume electricity for their operation and this power consumption can be significant.

Before options for a treated effluent utility are described in detail, the technical, regulatory and perception challenges of heat exchange from wastewater must be addressed. Previous effluent heat recovery projects and studies have identified the following challenges:

- The lowest treated effluent flows occur in the early hours of the morning when heating demands are generally the highest. Buildings typically experience a demand spike in the morning to heat up the building for user comfort. Effluent flow, and therefore heat supply typically lag demand by a few hours in the early morning. Treated effluent flows can also vary from season to season and even during certain weather conditions if inflow and infiltration into the sanitary sewer system are an issue. Therefore, the careful selection of design constraints that consider peak and lowest treated effluent flows is essential to a successful system.

- Total required heating power demand (KW) far exceeds the heat supply. This shortfall would have to be compensated by either reducing demand (e.g. reducing number of buildings connected) or increasing supply by employing an “energy source mix” from, for example, sea water, backup boiler possibly fired with bio-methane or natural gas, solar thermal and/or geothermal.

- Treated effluent can be corrosive and any metal components can corrode if proper materials are not specified. Entrained air is present in large quantities in treated effluent, thus making the design of high capacity air venting systems essential for any closed loop or circulating pipelines. The presence of available entrained air, and thus oxygen accelerates the corrosion of any metal components in the pipeline system.

- Secondary treated wastewater contains small amounts of suspended solids, thus the fouling of any heat transfer or heat exchange surface can be an ongoing concern reducing heat transfer efficiency. Treatments for this condition include online heat exchanger cleaning systems, spiral “tube in tube” heat exchangers similar to those used in the pulp and paper industry, and heat exchangers with a high internal scouring velocity in order to prevent fouling.

- Pipelines for conveyance of the treated effluent are costly and must have proper clearance from watermains and other utilities, in order to avoid cross contamination with domestic water utilities and satisfy regulatory requirements.

Ministry of Environment standards dictate the quality and temperature of discharged effluent, as well as the requirement to not contaminate the discharged effluent in any way. Usually, any treated effluent heat exchangers must be of the double wall type, adding cost and complexity to whatever heat recovery system is installed.

Section 2.0 Example of Existing Heat Recovery Installations

The following are examples of a district energy systems and /or heating system using heat extracted from treated effluent. Similar systems are in operation throughout North America and Europe.

Okanagan College

There are existing operating systems and projects that utilize treated effluent water as a source for heat pumps. One such example is Okanagan College's Clearwater system, designed by Stantec in 2002.

Okanagan College's KLO Campus is located in Kelowna, BC, and was retrofitted with a heat pump heating system that utilizes treated effluent water from the adjacent City of Kelowna Wastewater Treatment Facility. The "Clearwater" system was first operational in 2003/2004 and is used to provide about 40% of the peak heating demand for the campus.

The Clearwater system utilizes a small fraction of the available City of Kelowna wastewater flow. About 3.3 ML/d of treated effluent water are drawn from a pipeline that flows at approximately 71 ML/d, thus lowering the temperature of the discharged effluent by only 0.47°F. The heat pumps in the Clearwater system provide heat to approximately 3,500 m^2 of campus buildings, and distribute that heated water through existing underground insulated district heating piping.

Kelowna Wastewater Treatment Plant Maintenance Building

A second example of treated effluent heat recovery utilizing heat pump technology is the City of Kelowna's Wastewater Treatment Facility new Maintenance Building. The new building is targeting LEED™ Silver registration, and one of the main components of the facility's energy reduction system is the heating and cooling systems that utilize heat pumps connected to treated effluent water. The plant maintenance facility is located on the same site as the wastewater treatment plant.

Okanagan Centre for Learning

A third example of treated effluent heat recovery is Okanagan College's new Centre for Learning. This new facility is targeting LEED™ Gold registration, and incorporates a heat pump heating and cooling system that is connected to receive treated effluent water from the City of Kelowna's Wastewater Treatment Facility. The Centre for Learning building has been operating since mid 2009.

The Okanagan College Clearwater system is an example of an "ambient" temperature district heating system. The Clearwater system currently has two main usage points or customers. The main usage is through the College's Central Heating Plant Building that houses the heating boilers and heat pumps for the main campus, and the second usage is for the new Centre for Learning Building, where new heat pumps and treated effluent heat exchangers are installed.

The ambient distribution system utilizes purple pigmented ("purple pipe") non-potable AWWA C900 Class 150 PVC piping with push on bell and spigot joints. C900 piping is commonly utilized in municipal water works distribution piping, although it is coloured bright blue for that application. Piping for distribution of the treated effluent water is pigmented with purple dyes, and is marked "Non-potable" along the spine of the piping, with the spine turned upward in the trench during underground installation to ensure that it cannot be mistaken for potable water piping during later excavation.

The purple PVC piping is installed in the same manner as conventional water works piping, utilizing common excavation, installation and backfilling methods, and is installed below the frost level without external insulation.

The treated effluent water is piped to utility customers using the C900 piping, where a heat exchanger separates the treated effluent water from the customer's closed loop piping systems.

Whistler Athlete's Village

The Whistler Athlete's Village district energy system consists of a two pipe closed loop energy system operating at ambient temperature and using heat extracted from the Whistler WWTP as the primary source of energy. The secondary source of energy consists of natural gas boiler. The source of gas would be either the landfill or natural gas. The secondary source is required to maintain the capacity of the DES when the effluent flow and temperature are inadequate.

The district energy system is designed to provide 70% of the peak building load. Electric duct heaters are installed within the buildings to provide standby heat and will also be sized to meet approximately 70% of the peak building load. As such, the electric duct heaters would more than adequately supplement the DES to meet both peak demand and any upset operating conditions. The supplemental heat provided by the duct heaters will only be required for short periods during the coldest weather. The system also has back up natural gas fired boilers, which can be used to provide additional supplemental heat as necessary to the loop.

Saanich Peninsula STP Thermal Energy Recovery

The proposed district energy sharing system will be a closed loop system with the supply water temperature into the loop between 11^0C and 30^0C. Plate heat exchangers located at the sewage treatment plant will inject heat into the system. The effluent will be pumped through the primary side of the heat exchangers and the liquid will be circulated into the system using VFD controlled water pumps.

Each building that is connected to the system will require a heat pump to increase the water temperature. The heat pumps at each point of use will be located in separate enclosures within the building if the mechanical room is large enough. The heat pumps will be integrated with the existing systems so that, should the heat pump system fail, the existing mechanical systems within the buildings would keep operating effectively.

The main users for the recovered heat will be the Panorama Recreation Centre and the Saanich Peninsula sewage treatment plant. These will have externally located metal enclosures containing heat pumps. Pumping and controls will be arranged such that both heat sources complement each other. If the rink refrigeration system can produce warmer water than the effluent, then part of the DES will be allowed to rise in temperature to improve the efficiency of the nearby heat pumps. The system may be extended into residential areas at a later date.

Section 3.0 Heat Analysis

3.1 Available Heat

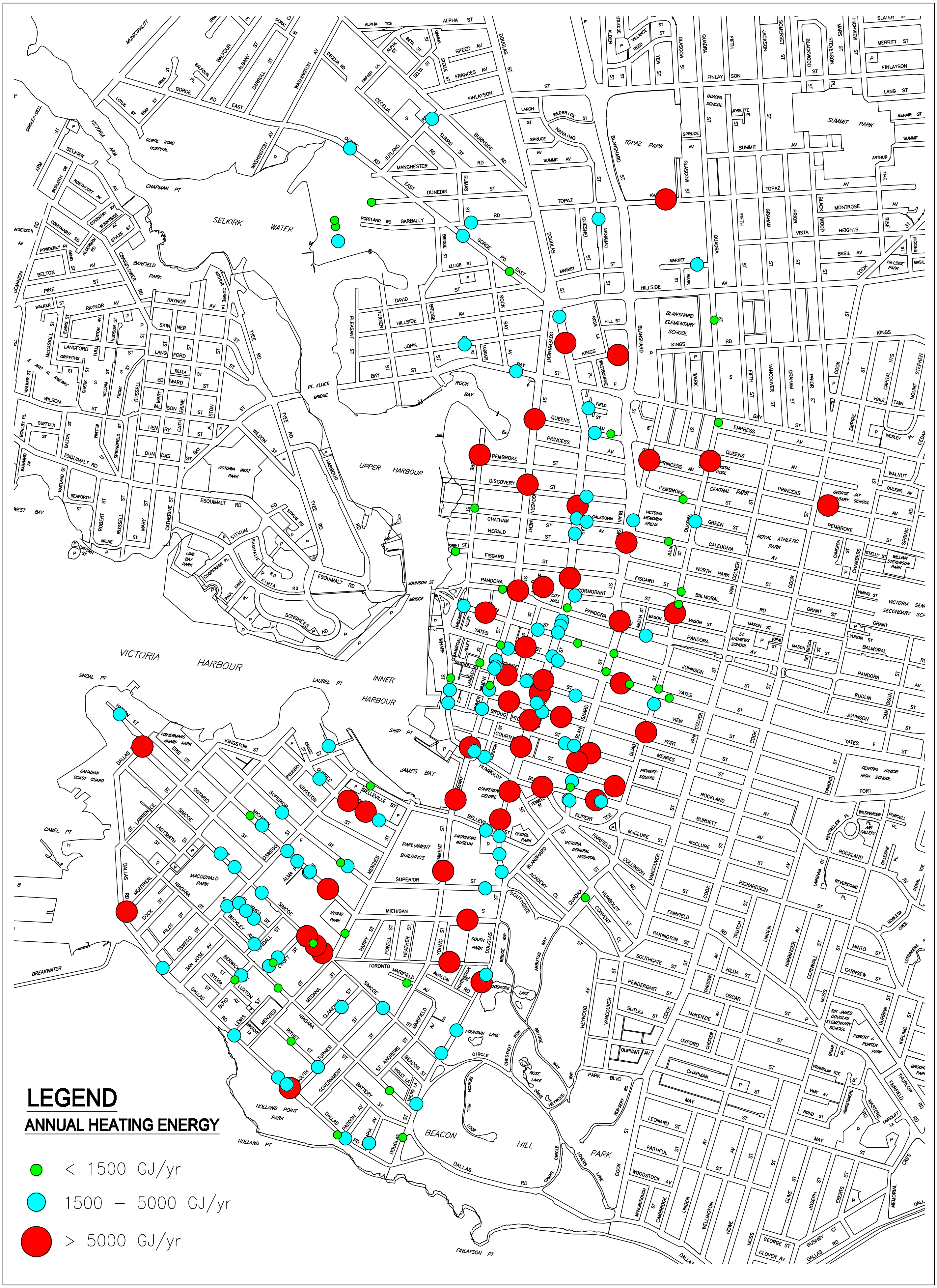
The existing average sewage flow at the proposed McLoughlin Point wastewater treatment plant during the winter months (MPWWTP) is estimated at 83.38 ML/d. This estimated existing flow has been calculated by summing the flow records at Clover Point and Macaulay Point outfalls and subtracting the estimated flow from the proposed Saanich East plant that will be diverted to the new Finnerty outfall. This flow includes the flow from the West Shore which will initially be serviced by the plant at McLoughlin Point. Based on this flow, the total annual heat available is 1,636,904 GJ/yr. Heat losses through a transmission system operating at 80^{0}C are estimated at 8% leaving 1,505,951 GJ of available heat for the entire year. The existing flows as calculated above are similar to the projected dry weather flow for the facility of 84.2 ML/day for 2030 and 87.5 ML/day for 2065. This increases the year-round available heat to 1,521,516 GJ and 1,581,147 GJ respectively. The amount of saleable heat is estimated at 70% of the available heat since space heating is not required for the summer months though domestic hot water, which often sources off end users boiler systems, is required year-round in the downtown core especially in the residential buildings of James Bay and in hotels.

Table 3.1 – Estimated Saleable Heat from MPSTP (GJ/yr)

Year	Total Annual Heat Available	Estimated Saleable Heat
2009	1,505,951	1,054,166
2030	1,521,516	1,065,061
2065	1,581,147	1,106,803

* Assuming status quo consumption practices and 1% per year compounded growth projections

The estimated heat available from treated effluent is based on the following assumptions: (1) temperature of treated effluent of 12 ºC, and (2) allowable minimum temperature of effluent of 5 ºC prior to ocean discharge. At first glance, it appears that the heat demand density in the downtown and James Bay areas would provide an excellent opportunity for the viability of a district heating system (DHS). For these areas, and along a corridor towards the proposed biosolids facility located in the Upper Victoria Harbour, installed boiler power data obtained from the BC Safety Authority indicates a demand of 223,162 GJ/year for James Bay and 859,155 GJ/year for the downtown area. Based on site visits at three installations in the James Bay and Downtown, it appears that the BCSA boiler data is not current. It should be noted that boilers west of Quadra Street and north of Gorge Avenue were not included as they were considered too remote and too small for connection to the DHS loop. Based on demand density, the best location for the DHS loop would be along Douglas Street. The BCSA data provides a good overview of current boiler installations in the James Bay and Downtown area. The boiler information is shown in Figure 3.1.


LEGEND
ANNUAL HEATING ENERGY
< 1500 GJ/yr
1500 – 5000 GJ/yr
> 5000 GJ/yr
SELKIRK WATER
UPPER HARBOUR
VICTORIA HARBOUR
INNER HARBOUR
JAMES BAY
BEACON HILL PARK
TOPAZ PARK
SUMMIT PARK
ROCK BAY
PARLIAMENT BUILDINGS
HOLLAND POINT PARK
FINLAYSON PT
BREAKWATER

A more detailed analysis has been performed on the flow data at McLoughlin and "boiler power" demand for Downtown and James Bay. This was undertaken due to concerns over the significant variations in the amount of heat that may be available from wastewater throughout the day in the winter months. The hourly variations in sewage flow and therefore the available heat are shown in Figure 3.2. As can be seen, sewage flows from midnight until 8:00 am are low, with the lowest flow occurring around 5 am. This limits the supply of heat at a critical time early in the morning when most buildings begin to ramp up their heating systems to meet the occupied demand.

Figure 3.2 also shows the hourly variations in winter heat demand for the Downtown and James Bay Areas. The heating systems go into set-back mode between the hours of 8 pm - 5am. This is when demand is at its lowest. At approximately 5 – 6 am, there is a sharp spike in demand as the boilers ramp-up to heat the buildings for the occupants arriving between 7 am and 9 am. The system reaches a daytime equilibrium and then drops in the evening. Unfortunately, the morning peak heating demand occurs while the sewage flows are still low. This situation is the reverse to what would be optimal, where supply would lead demand.

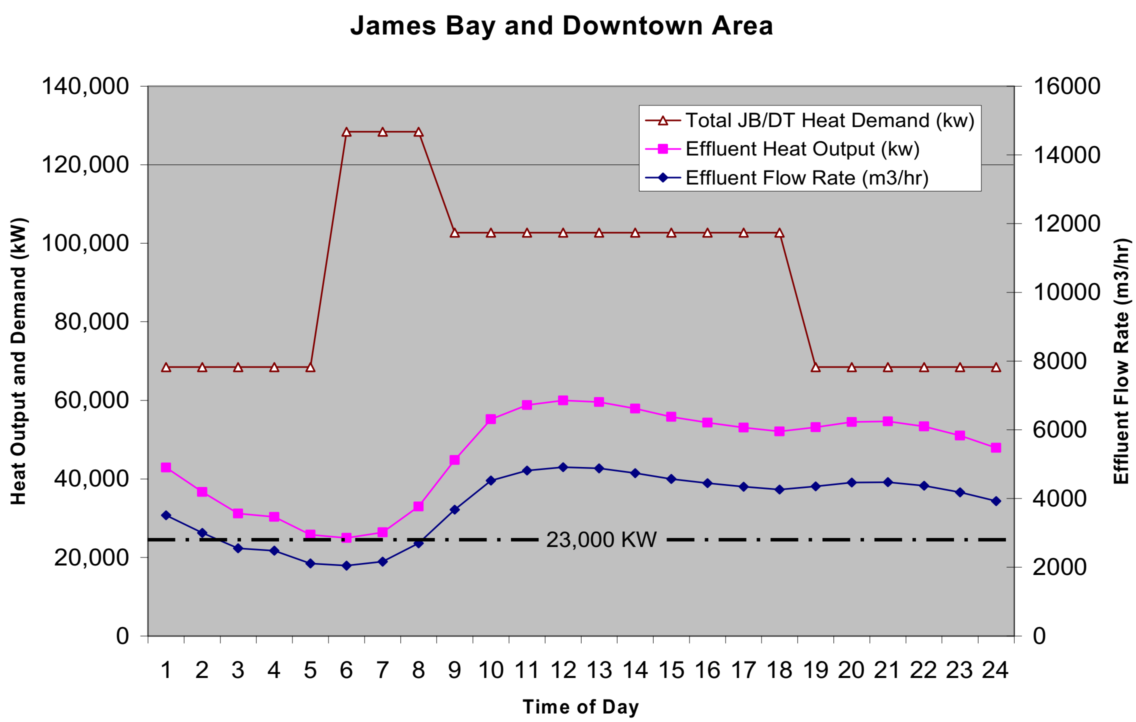


Figure 3.2 – Hourly Supply / Demand Relationship for James Bay and Downtown (2009)

Even at the 2030 average day flow of 84.2 ML/d, the consistent heat output from treated effluent would be approximately 23,000 KW. This is still insufficient to meet the winter heat demand for the DT/JB areas. Early in the morning, the supply would satisfy less than 20% of the demand. This would rise in mid-day to approximately 50% of the winter demand. As such this must be considered when the business case evaluation of the capital investment for these facilities is completed.

As discussed in subsequent sections, the proposed approach is to examine options to service a portion of the DT/JB and the demand of the biosolids treatment facility which may be located in the Upper Victoria Harbour area.

A case study review of select buildings in the downtown core was completed. Three of the buildings investigated in the DT/JB area use hot water heating systems and typically operate at temperatures of 82ºC (180ºF). The older Government and Legislature buildings are serviced by a high temperature steam plant. Steam heating systems operate on a closed loop at a much higher temperature and cannot utilize moderate temperature hot water which can be produced from recovered effluent heat.

As discussed in later sections, the highest hot water temperature that can be supplied from heat pump devices is 80 ºC (176 ºF) without major reductions in the coefficient of performance (COP). This temperature could have a significant impact on the amount of heat that may be delivered within a building from the existing heating equipment. Retrofit of existing buildings will involve significant capital costs.

Due to the curve-linear heat transfer relationship that exists for heating equipment, any reduction in system temperature impacts the amount of heat delivered significantly. The amount of space heating, however, may be sufficient for most of the shoulder season. During the coldest winter days, the boilers would need to be fired to meet demand in existing buildings designed for higher system temperatures. Further testing of specific building systems would be required to confirm both the effects of the lower temperature water on heat supply to the buildings and to see how much of the shoulder heating season the available heat from wastewater and temperature level can cover.

3.2 Sea Water Exchange for Additional Heat Source

As indicated above, a total of 23,000 KW of heating power is available from the sewage at current 2009 flows. The available heat drops through the night and is at its lowest level at 6:00 am which is also the time when the heat demand spikes. In order to provide a more consistent and reliable utility, a number of supply options would be available:

- Heat extraction from sea water
- Gas fired back-up boilers
- Solar thermal collectors
- Building heat reclaim

- Geo-thermal, and
- Effluent storage tanks

The option of supplementing the low sewage flows in early morning heat supply by extracting heat from seawater was briefly examined. In order to source the additional 25,000 KW of heat to reach a consistent 50,000 KW throughout the day in winter, approximately 1265 L/s (20,000 gpm) of seawater would need to be pumped through a titanium-stainless steel heat exchanger. The seawater would be drawn through a 900 mm diameter intake pipe laid on the seabed with the inlet being closer to the surface (shore) and the outlet running deeper to take advantage of the temperature difference. In an open loop, submersible pumps would lift the seawater to the heat exchangers and then return it directly to the ocean after the heat has been extracted. There would be no cross contamination of the seawater.

On the other side of the heat exchangers, a clean fluid pipe loop with pumps would be controlled by a Direct Digital Control (DDC) system to extract the heat in an identical way to the system that extracts heat from the effluent. A redundant pump would be installed on both the seawater and clean fluid closed loop side of the heat exchangers to compensate for periodic maintenance and unexpected failure. This is shown schematically in Figure 3.3.

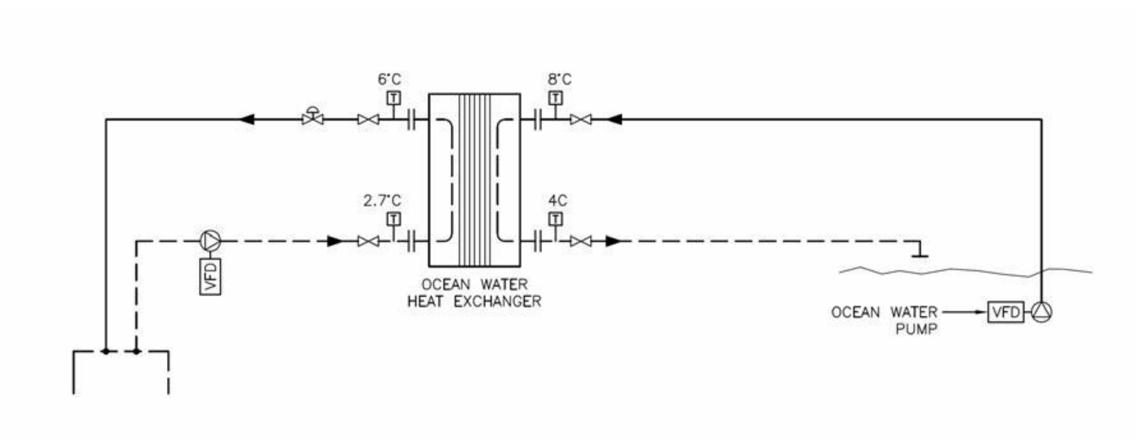


Figure 3.3 – Sea Water Heat Exchange

The costs for this system depend heavily on what type and quality of heat exchanger that is selected. The costs are estimated to be in the range of $12 to $15 million as follows:

• Ocean Intake and outlet –assumes 150 m each	$2.1 million
• Titanium-stainless steel heat exchangers and water pumping	$6.0 million
• Building	$0.7 million
• Contingency, engineering, financing, inflation to 2014	$4.4 million.
• Estimated cost	$13.2 million

This amount does not include the cost of heat pump to lift the temperature from 7^0c to 80^0F and the larger distribution pipe to carry the additional extracted heat to the various users in the James Bay and Downtown area. Because of the high cost, extraction of heat from seawater was not considered further.

3.3 Types of Heat Exchangers and Heat Pumps

Wastewater to Water Heat Pumps

The wastewater-to-water system of heat exchangers and heat pumps relies on a source of heat that has a stable temperature range and a higher level than air in winter months. The temperature of treated effluent during the winter months would be in the range of 12^0C to 14^0C with minor variations. Raising the water temperature to 55^0C (131 F) could be achieved with heat pumps having a coefficient of performance in the range of 2.5 to 3. It appears that a COP of 3 is the upper limit and could only be achieved with more expensive high quality products, under very specific conditions of steady loads that allow operation at peak efficiency. The drawback of water-to-water heat exchange is the considerable variation in diurnal sewage flows which in turn result in variations in available heat. As discussed earlier in this report, it is proposed to resolve this problem by sizing a district energy system on the basis of the minimum available heat of 23,000 KW which would occur early in the morning.

Existing buildings in James Bay and the downtown core have hot water boiler systems that operate at temperature of 80^0C or more. In order to boost the temperature to this level, two sets of heat pumps are required and the resulting COP would be in the range of 2.7 to 2.9. The dual heat pumps not only are more expensive from a capital cost perspective but they also increase operating costs significantly.

Air to Water Heat Pumps

An air-to-water system would rely on an air source that would have significant variations since outside air temperature will vary throughout the day and on a weekly and monthly basis. With an average outside air temperature of 4^0C during the month of January and a heating water temperature of 55^0C, a COP of 2.3 would be at the upper limit and only be achieved with high quality equipment. However, temperature at night often dips below freezing and under these conditions the COP would be lower.

One of the main disadvantages of air-to-water heat exchange in our coastal winter climate is that high humidity in combination with sub-freezing temperatures of the refrigerant will result in the build-up of frost on the unit. This can quickly result in an interruption of service since the heat exchanger cannot deliver heat when defrosting. For this reason, it is the practice to have two units where the constant supply of heat is critical. Additional considerations include the size of the coil, high amounts of air that need to be circulated to extract heat (air has low specific heat).

Comparison of Efficiency of Heat Pumps

It appears that the previous comparison completed by other of the efficiency of air-to-water with wastewater-to-water heat pumps indicating an overall weighted performance factor of 1.4 in favour of wastewater-to-water heat pumps is based on the following:

- Water temperature is boosted to 55^0C only.
- Treated effluent temperature of 14^0C
- Air temperature of 4^0C
- Upper limit of coefficient of performance for heat pumps using high quality products

However the wastewater-to-water heat pumps require a significant infrastructure in order to extract and convey the heat including heat exchangers to transfer the heat from the effluent to a clean liquid before the temperature of the liquid can be raised by a heat pump. Following the heat pump, this higher temperature liquid must then be conveyed to each point of use. At the point of use, another heat exchanger is required to transfer the heat from the DES to the heating system of the building.

3.4 Cooling Demand

Building cooling can be accomplished by exhausting heat to the effluent.

Cooling demand in Victoria's mild summer climate is significantly less than heating; approximately a 70/30 split or less. As well, few buildings, other than the largest high rises and larger complexes have centralized systems which would be necessary for a district cooling system (DCS) to tap in to. Most modern hotels and residential complexes employ small in suite heat pumps for cooling.

To add to the complexity, large high rise buildings in the downtown core may have their centralized cooling equipment located in rooftop mechanical rooms. To bring the DCS fluid to the rooftop may involve major re-piping within the end-users facility which would be very costly.

Another disadvantage to the cooling business case is that cooling is conducted with hydro supplied electrical power which has a low carbon footprint associated with it. The carbon cost for cooling therefore is low and has little impact on the business case for a second cooling loop or ambient system.

Section 4.0 Case Studies

A preliminary evaluation on how existing buildings could be connected to a potential District Energy System (DES) was carried out by assessing several buildings in the downtown core. This analysis was carried out in two stages:

- Review of existing boilers within the James Bay/Downtown area to identify how many boilers operating with hot water (as opposed to steam) were located in the downtown area. The location of these boilers was then shown on a plan in order to determine a preliminary alignment for the heat distribution piping.

- Building Owners and/or managers were contacted to arrange a site visit of the existing boiler installations. The purpose of the site visit was to confirm the type of boiler and heating system such as the operating temperature, the age of the boilers, how domestic hot water was produced, the physical arrangement of the boiler room including available area for heat extraction equipment and how piping connections could be done.

The intent of the site visits was to obtain a first hand appreciation of the types of challenges that may be faced with connecting to existing older mechanical systems with the DES. These issues would be representative of the conditions to be encountered in retrofitting buildings in the James Bay/ Downtown core area.

<u>Case Study No. 1 – Harbour Towers Hotel</u>

The Harbour Towers Hotel is located at 345 Quebec Street in the James Bay area. This building was converted from a residential apartment building to a hotel several decades ago. Space heating is provided by 3 boilers. The original boiler from the 1970's operates at 82ºC. This boiler is scheduled to be replaced in 2011. Domestic hot water is provided by a separate gas fired boiler connected to a hot water storage tank. A similar third and separate boiler heats the swimming pool. Both DHW and Pool boilers are newer and operate at a lower temperature of 60ºC. Space cooling is provided by individual units in each room and there is no central cooling system.

The mechanical room is located in the centre of the underground parking. It appears that the mechanical room is large enough to accommodate the heat exchangers that would be required in order to extract heat from the DES and transfer it to the building's heating system. The heat pumps, however, may require more space than is available. Also, the hotel is considering upgrading the old boiler plant in the next year with a new boiler which would be located in the same location as the new space heating boiler plant. Piping connections between the DES system and the mechanical room would require the installation of pipes attached to the ceiling of the parking area. The edge of the parking is located near the street and the piping connection from the building to the DES piping in the road would be a relatively short distance.

Based on discussions with the Chief Engineer of the hotel, the preference would be for a DES to supply heat at a temperature of 82ºC to match the existing system design. If 82ºC heating water could not be generated, the existing boiler would have to remain in place as a back-up to the DES during cold winter days.

This building would be a good candidate to connect to the DES system because the mechanical room is easily accessible and could be enlarged if necessary by encroaching into the parking areas.

Case Study No. 2 – Legislative Precinct

The Legislative precinct is serviced by a DHS that is fed by steam. The central boiler room is located in a separate building on Superior Street between Government Street and Douglas Street. This system provides heat and domestic hot water to the Legislature Buildings, the Royal BC Museum, the Douglas Building, the Douglas Building Annex, the Queen's Printer and other smaller government buildings located on the south side of Superior Street.

The Douglas Building Annex is heated by hot water that has been condensed from the steam boilers prior to being distributed into the building. The Royal BC Museum is heated by newer electric boilers. In these two buildings, the heating systems operate at a temperature of over 93ºC (200ºF). These two building could potentially be connected to a DHS during the shoulder heating season, but would need to switch back to the steam plant source for the coldest winter days. The buildings that are heated with steam cannot be converted to hot water because the piping and the radiators are sized for much higher temperatures and would be too small to provide enough heat, likely even in the shoulder season, if hot water was used instead of steam. As a result, buildings heated with steam cannot be connected to the DHS.

In order to connect the Museum and the Douglas Building Annex to the DES, the following work would be necessary. The manner in which these two buildings could be connected to a District Energy System depends on the temperature of the heating loop. This is discussed further in Section 6.

Action	Option 1 - Ambient	Option 2 - 80ºC	Option 3 - 35ºC
Trench in non-insulated pipes from the road to the heating plant and install pipes to building mechanical room	X		
Trench in insulated pipes and install pipes to bldg mechanical room		X	X
Find floor space for and install heat exchanger(s)	X	X	X
Install heating water conveyance pumps	X	X	X
Install control systems	X	X	X
Find floor space for and install heat pumps for 1st temperature lift	X		
Find floor space for and install heat pumps for 2nd temperature lift	X		X
Connect to existing building space heating system	X	X	X
Connect to existing DHW system, etc.	X	X	X

Only the Museum and the Douglas Building Annex could be connected to a district energy system. However because these building are heated with water at 93ºC (200ºF, the DES which would operate at 80^0C would only be capable of providing heat in the shoulder seasons. It is recommended not to connect these building to the DES because the benefits appear to be minimal.

Case Study No. 3 – Jack Davis Building

The Jack Davis building, located at 1810 Blanshard Street is a provincially owned 8000 m^2 office building constructed in 1992. Space heating and domestic hot water is provided by a boiler system operating at a temperature of 82 °C (180 °F). The boiler room is located in a mechanical penthouse on the roof and there is no available space for additional equipment in the existing boiler room.

In order to connect this building to the DES, the hot water supply would need to be pumped eight floors up to the roof. This would require the installation of two pipes (loop) from the street level to a newly constructed mechanical penthouse where the new heat exchangers would be housed.

The installation of hot water pipes to the mechanical penthouse and the addition of the mechanical room to allow for the installation of the heat exchangers required for the connection to a DES could result in significant expenditures. For this reason, it is recommended not to connect this building to a district energy system,

Case Study No. 4 – Richard Blanshard Building

The Richard Blanshard building is located at 1515 Blanshard Street. This is a provincially owned 2400 m^2 office building constructed in the mid 90's. Space heating and domestic hot water is provided by a boiler system operating at a temperature of 82 °C (180 °F). The boiler room is located in the below ground level. The boiler room is spacious and there is enough space to install heat exchangers but not heat pumps for Options 1 or 3.

Piping connections between the DES system and the mechanical room would require the installation of pipes attached to the ceiling of the parking area. The edge of the parking is located near the street and the piping connection from the building to the DES piping in the road would be relatively short.

This building would be a good candidate to be connected to a district energy system since the mechanical room is easily accessible and appears to have sufficient space to accommodate the heat exchangers.

Based on a review of the case study buildings noted above, it appears that in most instances significant retrofit costs would be incurred in the existing buildings to accommodate the heat generated by a DES. The age of the existing buildings and the original design criteria for these older systems does not make it cost effective to consider retrofit of these heating systems.

Section 5.0 Market Considerations

The use of heat reclaimed from wastewater must be analyzed for each end-customer's specific requirements as conditions at different sites can vary dramatically as noted in the previous section 4. What is feasible or works in one location may not necessarily work at another location. Temperature, capacity and reliability are important issues for all customers. The potential customers have stated, with respect to reliability and connect-ability of a district energy system that: "…making the ability to connect to the system as attractive as possible for the end users is of utmost importance".

Based on the case studies carried out during the course of this study, it appears that most existing boiler systems are operating at "legacy" or original design temperatures of 80^0C or more. As a result, a District Energy System (DES) would be required to supply heat at this temperature in order to meet the peak winter demand of potential customers. There are three options on how this could be achieved for a DES serving the James Bay and Downtown areas:

- Option 1 – Distribute the heat at ambient temperature and install heat pumps at each point of use to boost the water temperature to 80^0C.
- Option 2 – Install the heat pumps at the wastewater treatment plant and distribute hot water heated to 80^0C.
- Option 3 – Install heat pumps at the wastewater treatment plant for the first lift in temperature, distribute the heat at 35^0C and install a second set of heat pumps at the point of use to lift the temperature to 80^0C.

All of the options require dual heat pumps to boost the temperature to the desired 80^0C. This presents several challenges including another set of heat pumps as well as significantly increased operating costs as high power consumption is required to boost temperatures to 80^0C.

Options 1, 2 and 3 would require the installation of a 6.5 km long dual pipe distribution system from the proposed McLoughlin wastewater treatment plant to the biosolids treatment facility in the Upper Victoria Harbour. The cost associated with piping the heat over such a length will be high considering that excavation would be required in busy downtown streets which already have a significant amount of underground utilities. There is also a concern that many of the mechanical rooms in existing buildings may not have the available space to install the necessary heat exchangers and heat pumps that would be needed to connect to the DES. The practical realities of constructing such a system and retrofitting existing building that were designed for use of high temperature water are significant and costs are prohibitive.

For these reasons, a fourth option was identified where the service area would be reduced in scope to include only the biosolids handling facility located in the Upper Harbour and the north portion of the downtown area north of Pandora Street. This area is not as developed as the portion of the downtown core located further south and it is anticipated that most of the customers of a DES would consist of new buildings. New buildings are typically designed using lower temperature heating systems.

Modern heating systems, primarily in the last decade or so, are designed using condensing boilers that operate at significantly lower temperatures of approximately 60ºC (140^{0}F). As well, the proposed digesters will be designed to operate at 55^{0}C. These temperature levels align much better with the temperature-coefficient of performance (COP) constraints of modern heat pumps and there is no need to have a dual boost heat pump system. The COP at these temperatures could make the business case more favorable as factors such as transmission heat loss, equipment size and needed electrical energy would be reduced.

Section 6.0 Alternatives for Heat Extraction

6.1 In-Pipe Heat Exchanger

The extraction of heat from raw sewage using heat exchangers built into the conveyance piping was investigated. This included gravity mains, forcemains or treated effluent outfall pipes using the Rabtherm® product. This product consists of a pipeline with the heat exchanger tubing built into the pipe wall. Currently this patented product must be imported from Europe, however, the North American representative has indicated that it could be manufactured in Canada using imported parts.

Due to the high cost of removal and the product, the use of this in pipe heat exchanger would be limited to newly conveyed mains. In the case of the Mc Loughlin Point WWTP, without considering the significant cost, the in-pipe heat exchanger could be used.

There is one significant limiting factor to the cost vs. heat extraction business metric for this product. The heat potential in raw sewage is constrained by the temperature to which it can be dropped. For the sewage treatment process, the temperature of the raw sewage can only be reduced to 10 ºC before the treatment process is impacted. Since effluent is at the end of the sewage treatment process, its temperature can be reduced to near seawater temperature levels of 5 ºC before it is ejected. This additional 5 ºC temperature difference has a significant effect on both the size of the Rabtherm heat exchange system and on the amount of heat that can be extracted from the wastewater. The in-pipe heat exchanger for a forcemain is shown on Figure 6.1. The heat exchanger tubing is built into the pipe wall with separate inlet and outlet connections for each 5 m long section of pipe.

Figure 6.1 – Rabtherm, Forcemain Heat Exchanger (Left) and Gravity Pipe Exchanger (Right)

If a 900 mm diameter heat exchange pipe was installed in the proposed 2.8 km long forcemain between Clover Point and Ogden Point, the amount of extractable heat would be 10,000 KW. With an 1800 mm diameter heat exchange pipe installed in the land portion of the outfall between McLoughlin Point and Macaulay Point, the amount of extractable heat would be 13,420 KW. The material cost of a 3 m long section is $18,400 for a 900 mm pipe and $34,000 for an 1800 mm diameter pipe. The cost of material alone is estimated at $16.8 million for the 900 mm pipe and $11.3 million for the 1800 mm pipe.

As shown in Figure 6..1, each section of the forcemain heat exchanger must be connected to two heat loop pipes parallel to the pipe and installed in the same trench. A service building to house the water pumps, heat pumps and controls is required.

The cost of material does not include the installation cost or the dual parallel heat conveyance pipes that have to be installed in the same trench as the heat extraction pipe. Because of the high cost of this product, it is recommended to carry out heat exchange using other proven and locally available types of heat exchanger products as discussed in Section 6.2.

6.2 Direct Heat Exchangers

There are various options available for direct heat exchange to closed loop piping systems from treated effluent, seawater and groundwater. Potential options include: brazed plate, plate & frame, tube in tube coiled helical, and shell and tube heat exchanger technology. Each heat exchanger technology has various characteristics that make them either more or less suitable for duty in various functions of the proposed heat distribution system. Each technology is discussed in the sections below.

6.2.1 Brazed Plate Heat Exchangers

Plate and frame heat exchangers are a sandwich of very thin plates of stainless steel that have a thin layer of brazing alloy fitted between each plate during manufacturing. The raw assembly of loose plates are stacked together, and “sintered” or fused together at high temperature in a combination oven/hydraulic press. The resulting assembly is very light in weight for a given output and arguably the most compact of all heat exchangers.

High internal velocities result from the closely spaced thin plates, with a high heat transfer rate. These heat exchangers can be utilized with fluids that contain suspended solids, as their high internal scouring velocities promote continuous cleaning. Brazed plate heat exchangers cannot tolerate coarse suspended solids such as sand or marine organisms, as the plate tolerances are so small that the exchanger will clog quickly.

This product is limited by the quality of the treated effluent including suspended solids. For the MPWWTP plant, it is proposed to construct an ultra-filtration membrane plant that will produce a high quality effluent with turbidity that approaches drinking water quality. The main drawback of brazed plate heat exchangers using treated effluent systems, however, is that the high pH and high amount of entrained oxygen in the effluent will accelerate the corrosion of the brazing alloy that forms the bond between plates. Life expectancy is about 5-6 years for treated effluent applications. They have excellent usage as a customer’s heat exchanger, due to their suitability in closed loop systems that are treated with corrosion inhibitors, pH monitored, and with no oxygen present.

The image above has been reprinted from Mueller, www.muel.com.

6.2.2 Plate and Frame Heat Exchangers

Plate and frame heat exchangers are characterized by their multiple plate configuration, gaskets between plates, frame/header assembly, compact size (relative to conventional shell/tube configurations), availability in a wide variety of plate and header metallurgy for different applications, availability in double wall atmospheric vented construction for leak detection, and ability to be disassembled in the field for cleaning and gasket replacement. This use of this product is limited by suspended solids. The ultra-filtration membrane plant, however, would eliminate this problem.

Biofouling from organisms found in effluent can be an issue with plate and frame exchangers, including the supply and return pipelines. Products are available that prevent biofouling. One such product is from Blame Worldwide Services. Their product provides both anti-fouling and anti-corrosion protection through the generation of trace amounts of copper ions and the dissipation of trace aluminum hydroxide into the pipeline system. The Blume system will be discussed in further detail below, in the "Heat Exchanger Cleaning Options" section of this report. The image above has been reprinted from Mueller, showing their Accu-Therm models, www.muel.com.

6.2.3 Tube in Tube Heat Exchangers

Another product available for heat exchange are the helical or coiled "tube-in-tube" models shown in the photos below. Their high scouring velocity could make them usable for heat exchange between the treated effluent and closed loop systems. Provided that large enough models are available, the high scouring velocity is of particular benefit for the treated effluent side of the heat exchangers. The treated effluent will contain micro-organisms that can foul heat exchange surfaces. Also of interest is their availability in a variety of metallurgy options, and thus the ability for construction in corrosion resistant options for treated effluent duty.

The images above have been reprinted from Sentry Equipment Corp. www.sentry-equip.com

6.2.4 Shell and Tube Heat Exchangers:

Shell and tube heat exchangers are characterized by their outer shell and inner tube bundle construction, complete with headers. They typically require substantially more floor space than other heat exchanger technologies, both because they are long and narrow and also because the tube bundles are removable from one end of the exchanger. Usually, the space that a shell and tube exchanger requires for tube bundle removal must be incorporated into the building or space in which the exchanger is installed, and the length required for the total installation is twice the operating length of the exchanger. Their main advantage is that they are the easiest of all the heat exchangers to clean and maintain, when the heat exchanger is handling a fluid with suspended solids. Shell and tube heat exchangers are available in a wide variety of metallurgy options, and thus can easily be adapted to treated effluent heat recovery usage.

The preliminary cost estimates are based on shell and tube heat exchanger. The final selection of the heat exchanger should be carried out at the time of detailed design.

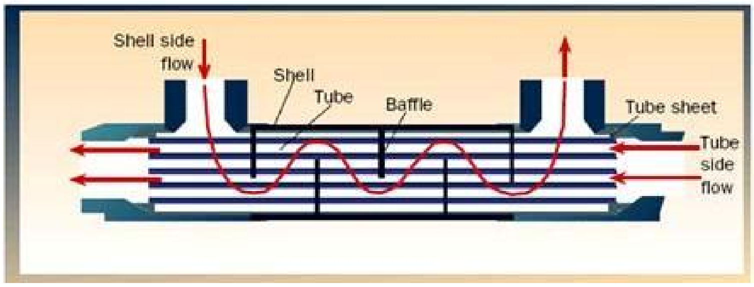
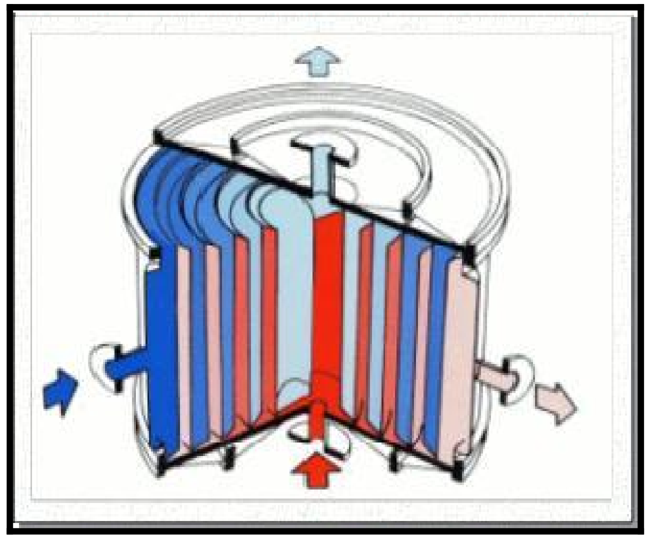


Diagram of shell and tube heat exchanger operation, and photos of shell and tube heat exchangers is courtesy of Logichem Process Engineering, www.heatexchangers.co.za.

6.2.5 Spiral Heat Exchangers:

Spiral heat exchangers (SHE) are configured using helical (coiled) tubes. In general, the device consists of a pair of flat surfaces that are coiled into two channels in a counter-flow arrangement. Each of the channels has a long curved path that is connected at the outer arms of the spiral to the loop.



Main advantages of the SHE is its highly efficient use of space and anti fouling characteristics. As well, a notable tradeoff is capital cost vs operating cost. A compact SHE has a smaller footprint, and thus lower capital cost to house it. SHE's can therefore be oversized to lower pressure drop, lower required pumping energy and have higher thermal efficiency.

SHEs are often used in heating fluids that contain solids. Other heat exchangers have a tendency to foul in such environments. The SHE uses a "self cleaning" mechanism, whereby fouled surfaces cause a localized increase in fluid velocity, thus increasing the drag friction on the fouled surface. This helps dislodge small blockages and keeps the heat exchanger clean. "The internal walls that make up the heat transfer surface are often rather thick, which makes the SHE very robust and durable in demanding environments." The units are also easily cleaned and opened easily so any foulant can be removed with pressure washing.

The SHE is suited for applications such as digester heating, heat recovery and effluent cooling. For most applications SHEs are smaller than other types of heat exchangers.

6.2.6 Heat Exchanger Cleaning Options

The heat exchangers will be prone to fouling from suspended solids and bacteria in the treated effluent. Treated effluent heat exchangers will require either manual cleaning, some form of automatic cleaning system or an anti-fouling system to maintain heat transfer efficiency for reduction of manual cleaning by maintenance staff. It is recommended that the treated effluent be piped through the tubes and not the shell side of the exchanger. There are options available for "online timed" interval cleaning of the heat exchanger internal tube surfaces:

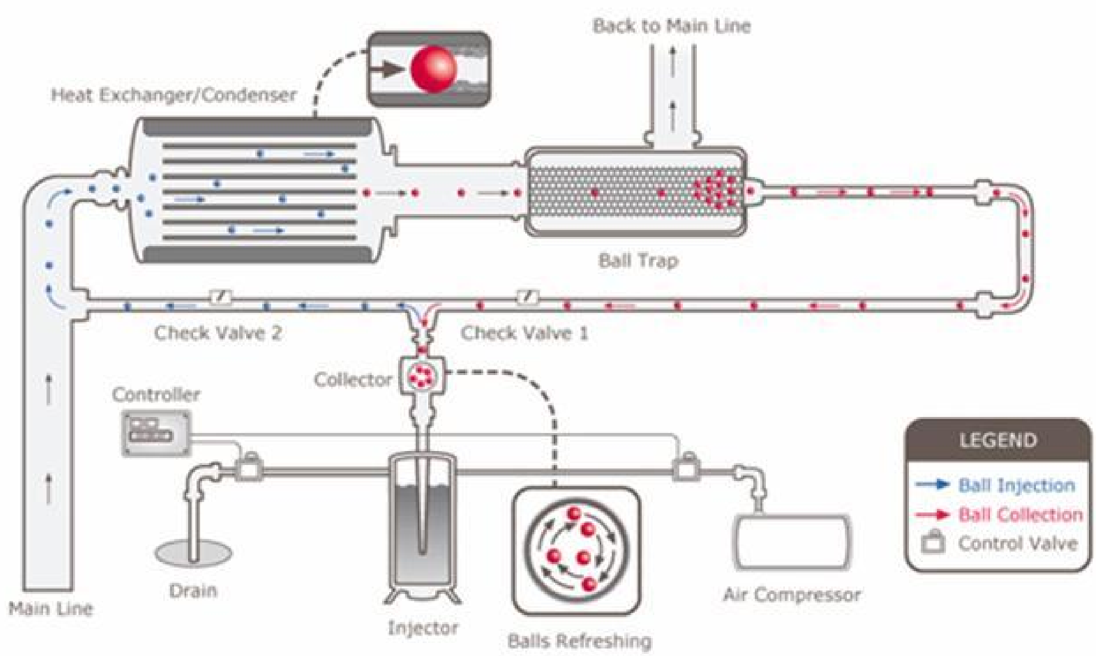
- One such cleaning system manufactured by CQM Tech is called "ATCS Ecodenser". The ATCS system works by injecting foam balls into the fluid stream periodically, and automatically collecting and cleaning the balls for repeated automatic usage. A more detailed description of this system follows.

- Blume Worldwide manufactures an anti-corrosion/anti-fouling system specifically for seawater systems and undersea structures such as offshore oil platforms. It is recommended that an anti-corrosion and anti-fouling system be fitted to the seawater heat exchangers for this project.

It should be noted that both the Blume and ATCS systems will not eliminate maintenance from the treated effluent heat exchangers entirely, however, these automatic systems do have the potential to reduce maintenance substantially and keep internal heat exchanger surfaces clean enough to promote maximum heat transfer efficiency.

How ATCS Works

The CQM ATCS is installed on the chiller's condenser and keeps tubes clean without human intervention. The system periodically injects into the tubes sponge balls that are slightly larger in diameter then the tubes themselves. The natural pressure head pushes the balls through the tube, which is thus rubbed clean. The balls are then trapped in the outlet of the heat exchanger, where they are prepared for the next cleaning cycle.



Section 7.0 Alternatives For Heat Supply System

7.1 General

In this study, four options for a district heat distribution system are evaluated:

Option 1: Ambient temperature distribution system to service the James Bay and Downtown area (up to 20 ºC);

Option 2: Moderate temperature distribution system to service the James Bay and Downtown area (80 ºC);

Option 3: Low temperature distribution system to service the James Bay and Downtown area (35 ºC), and

Option 4: Hybrid system with ambient temperature pipeline from the wastewater treatment plant to the biosolids facility and 60^0C temperature for the distribution system to service the North Downtown area.

These district heating systems would generally consist of the following components:

1. Heat exchangers – to transfer heat from the treated effluent to a clean liquid in a district heating loop;
2. Water pumping – a first set of pumps to flow effluent through the heat exchangers and then a second set of pumps to flow the clean fluid though the district heating loop;
3. Heat pumps – the temperature of the clean liquid has to be “lifted” to the requirements of the building heating system in order to be useful for the end customer;
4. Distribution piping – to distribute the clean heating liquid from the wastewater treatment plant to the end users;
5. Various treatment, expansion and buffer tanks, and
6. Direct Digital Control (DDC) System.

The following system component options have been identified and are further discussed in Section 7.2 to 7..5.

Components	Option 1 - Ambient Temp. (up to 20^{0}C)	Option 2 - Moderate Temp. (80^{0}C)	Option 3 - Low Temp. (35^{0}C)	Option 4 - Hybrid Option for North Downtown
Heat exchangers	At sewage treatment plant and end user's facility	At sewage treatment plant and end user's facility	At sewage treatment plant and end user's facility	At sewage treatment plant and end user's facility
Water pumps	At sewage treatment plant	At sewage treatment plant	At sewage treatment plant	At sewage treatment plant
Heat pumps	At end user's facility	At sewage treatment plant	First lift heat pump at STP and second heat pump at point of use	At end user's facility
Distribution piping	Non insulated pipe - PVC or HDPE	Insulated welded steel pipe	Insulated PVC or HDPE	Non insulated pipe - PVC or HDPE

7.2 Option 1 – Ambient Temperature System for James Bay and Downtown

Option 1 is shown schematically in **Figure 7.1** and consists of an ambient temperature system that will provide the Owner of the district energy system (DES) with the ability to meter utility customer's usage in both heating and cooling modes or heating only, if a customer chooses this option.

With this option, a closed loop distribution piping consisting of 750 mm diameter non-insulated pipe system would be required. Utility customers could draw water from the DES utility and water would be fed to a heat exchanger(s) in each building. Customers could in turn use heat pumps for both heating and cooling within their facilities, and the customers heat pumps would be connected on the load side of the heat exchanger. The heat exchangers in each customer's building would serve two purposes:

- As a means to separate the DES closed loop treated water from the customer's hydronic (fluid based) heating and cooling systems in order to ensure that any customer issues with maintaining their water chemistry does not impact CRD's systems.
- As a means to separate the DES systems from systems with a higher operating pressure. For example, customers with high buildings might exert a higher than anticipated static pressure on the DES distribution systems if there were no heat exchangers fitted to the piping network. The benefit of separating higher pressure

systems from the DES results from being able to utilize pipeline components with lower pressure ratings where possible.

System Basics:

This option is termed a "net-metering" solution. Thus, it is expected that customers with differing heating and cooling load profiles would connect to the same network of closed loop piping, and the DES closed loop utility would allow energy sharing between buildings that simultaneously require heating and cooling.

For example, a transit repair shop connected to the utility might have a large makeup air heating requirement, with a heating load from the makeup air that might occur at any ambient temperature below 15 degrees Celsius. Nearby, a large office building may have many interior areas with no interaction to the envelope of the building, and resulting heating/cooling load variations with weather, time of year, and solar effects. The interior spaces of the large office building would normally be filled with people, lighting and computers that would require cooling year round, independent of outside temperature, and would thus be rejecting heat either from heat pump or central chiller operation.

Conventional stand alone HVAC systems for each building would dictate that the transit repair shop systems be designed to utilize natural gas fired equipment for makeup air heating, while the nearby office building would be operating a cooling tower or closed circuit fluid cooler almost year round in order to reject heat from the interior spaces. With an energy sharing utility, energy can be transferred between customers. Each utility customer would require their buildings to be fitted with a heat pump, either water to air or water to water type. It is anticipated that the best candidates for a water source heat pump system are those with existing hydronic heating and cooling systems within their facilities.

Facilities with rooftop packaged, or unitary equipment are not anticipated to be potential customers due to the high costs of system retrofit. However, it should be noted that as CO2 emissions penalties legislated by the BC Provincial Government grow over time, a treated effluent utility coupled with heat pumps fed from renewable hydroelectric power may become more attractive to potential customers, both for reasons of economics and for environmental stewardship. During periods of low cooling load operation, customer bypass valves can be used on the load side of customer heat exchangers to potentially provide chilled water directly from the customer heat exchanger, by operating the seawater exchanger to provide chilled water.

System Operation:

As mentioned above, the proposed system type is a closed circuit utilizing tap water treated with corrosion inhibitors as a heat transfer fluid. Water would be circulated amongst all buildings connected to the utility, and temperature of the closed loop would be monitored and adjusted by automatic temperature control systems. Common water source heat pumps have the ability to operate within a wide temperature range at their water inlet, of approximately 2^0C to 20^0C in heating mode, and between 15.5^{0}C and 32^{0}C in cooling mode. Therefore, it is expected that the closed loop utility would operate in a temperature range between 5^{0}C and 20^{0}C during all conditions. Automatic valves, recirculation valves and temperature controls on the utility heat exchanger and customer connection would ensure that the fluid temperature at the inlet to each customer heat pump would be maintained within an optimum range.

If return water temperature at any point in the system moved near to the limits of either 5^{0}C or 25^{0}C operating range, automatic controls would use a combination of additional flow and the addition or rejection of energy to the loop via the treated effluent to maintain proper closed loop operating temperatures.

The DES would meter water usage with both flow meters and accurate temperature measuring devices in order to bill the customers for usage. The added advantage of a “closed loop net-metering solution” is that separate customers demanding both heating and cooling simultaneously can be charged for their usage, while the DES only energy cost is for circulating the fluid to the customers. Two or more customers “share” energy. The potential impact of eliminating natural gas usage from combustion for heating, while sharing energy with a customer that is simultaneously requiring cooling is significant. The only penalty of this approach is that pumping energy is needed for fluid transfer between customers, and heat pump energy is required for heating.

System Advantages:

- Can be expanded to an energy management system;
- Heating and cooling capability with a single pipe loop;
- Conveyance loop does not require welded steel insulated pipe; pipe is cheaper; and
- Essentially no transmission heat loss.

System Disadvantages:

- More costly for end customer to connect since a heat pump is required at each point of use and may require costly building modification to expand the mechanical room to accommodate the heat pumps;
- Conveyance is more difficult with larger pipe and therefore cost implications;
- Will need backup boiler for coldest winter months; and
- May need very expensive “single lift” heat pump to achieve required DHS temperatures.

- There will be higher electrical usage at the end user's plant. This may trigger the need for improved electrical infrastructure such as transformers and improved distribution network.

7.3 Option 2 – Moderate Temperature System (80ºC) for James Bay and Downtown

This is the classic type of DES that runs at higher temperatures incorporating an insulated distribution loop and a simple heat exchanger at the end customer's facility. This system is shown schematically in **Figure 7.2**.

System Basics:

The system consists of heat exchangers and heat pumps at the wastewater treatment plant, which extract heat from the treated effluent. The heated water is then pumped through an insulated closed loop piping system to the end customer where it can be extracted to the existing building heating system. This extraction by the end customer is accomplished with a simple low maintenance heat exchange system, incorporating pumps and heat exchangers.

System Operation:

The closed loop transmission fluid temperature would be increased in 2 stages. The first stage would be through heat pumps or chillers to accomplish the first lift to 35 ºC. The second lift would be through modular heat pumps to raise the fluid temperature to 80 ºC. This 80 ºC water would then be transmitted through an insulated 500 mm diameter closed loop pipe to the end customers in the James Bay and Downtown areas.

The two temperature lifts would be controlled by a direct digital control system with temperature meters on supply and return lines in order to optimize the coefficient of performance (COP) between heat output and required electrical power. As well, calibrated temperature and flow meters would be employed to measure consumption so that the customer could have accurate consumption and billing information.

System Advantages:

- Simpler end customer hook up: At the end customer's facility, only heat exchangers, pumps and controls would be installed. Heat pumps would not be required at the end users facility as the district loop water has already been lifted to the required temperature. Less equipment means less initial capital cost for the end customer and therefore greater incentive to connect;

- End customer does not need to find copious amounts of space in existing mechanical rooms to house heat pumps and related equipment.

- Less maintenance and lower initial capital cost for end customer to get connected;

- Maintenance of heat pump equipment is centralized at the sewage treatment plant – this is an ongoing incentive for the end customer;
- Due to the presence of the insulated pipe loop, a fully modulating back-up boiler could be located at the wastewater treatment plant and maintained centrally. The moderate or higher temperature water from the back-up boiler could boost system capacity and be transmitted to the end user to accommodate more of the shoulder/winter season demand;
- End customers do not have to pay direct capital costs for heat pumps at their facility or pay hydro costs for extracting heat at their facility with heat pumps, and
- The pipe diameter for the transmission loop is smaller than for the ambient system. This reduces conveyance costs.

System Disadvantages:

- There will be higher heat losses in the conveyance pipe at this elevated temperature Conductive heat loss is proportional to the square of the temperature (i.e. $Q_{loss} \alpha T^2$);
- There will be a lower coefficient of performance (COP) from the heat pumps at higher temperatures, and
- There is no ability to both heat and cool at the same time with this system unless a second insulated loop is installed to solely carry cooling water. Installation of a second loop would have a significant effect on conveyance costs. With the mild summer temperatures in Victoria, mechanical cooling does not appear financially viable or worthwhile for this option.

7.4 Option 3 - Low Temperature System (35ºC) for James Bay and Downtown

The 35ºC low temperature system is similar to the 80ºC system above, but with minor differences that affect the conveyance cost, transmission losses and end customer operations. See attached system schematic on **Figure 7.3.**

System Basics:

This is a lower temperature system than the 80ºC system above, but it carries more heat capacity per fluid volume in the distribution pipe than the ambient system. Since temperatures are lower, a less expensive plastic pipe can be used for the distribution loop instead of welded steel. The distribution pipe still requires insulation; however transmission losses due to the lower fluid temperature are significantly reduced.

The heat extraction and first temperature lift of the distribution loop is conducted at the sewage treatment facility and 35ºC water is then pumped through the loop. The end customer must then conduct the final temperature lift with a heat pump located within their facility. Operating parameters can then be controlled by the end user to satisfy their specific heating system(s) needs of operating temperatures and demand.

System Operation:

The system operation is similar to the 80 ºC loop, however the second temperature lift occurs in a different location; at the end users facility.

The fluid carried in the closed 600 mm diameter transmission loop is increased to 35ºC in a single stage. Then a second lift is conducted at the end customer's facility to 80ºC. Chillers accomplish the first lift, pumps convey the 35ºC fluid to the end users facility where the second lift is provided by modular heat pumps to raise the fluid temperature to 80ºC.

The temperature lifts, which occur in separate locations, would be controlled by separate direct digital control systems. The system at the end users facility, located before the customer's heat pumps, would employ calibrated temperature and flow meters to measure consumption so that the customer could have accurate consumption and billing information.

System Advantages:

- The system would incur less transmission losses than with the 80ºC system;
- There is lower conveyance and pumping costs due to more heat capacity in fluid and smaller diameter pipe;
- The end customer has more control over temperature and COP with control over both the heat exchanger and the heat pump, and
- The insulated plastic transmission pipe should be more economical than the welded steel pipe of the 80ºC system.

System Disadvantages:

- The cost of the insulated transmission pipe is likely more expensive than the ambient pipe. The conveyance of the larger ambient pipe my have significance however;
- There is more heat loss in the low temperature system transmission pipe than for the ambient system;
- A better COP could be achieved in early shoulder seasons than in the higher temperature system

- The ability to heat and cool at the same time is reduced as the system would require a second (expensive) insulated distribution loop. Having the end user's DHW system connected to the boiler makes cooling in summer infeasible.

- There will be higher electrical usage at the end user's plant. This may trigger the need for improved electrical infrastructure such as transformers and improved distribution network.

- For this option, significant direct digital control systems with feedback loops would need to be installed in the wastewater plant and in the end users plant. This will nearly double the controls cost and impact operations and maintenance.

7.5 Option 4 – Hybrid District Energy System for North Portion of Downtown

With this option, a closed loop distribution piping consisting of 600 mm diameter non-insulated pipe system would be installed through Victoria West between the wastewater treatment plant at McLoughlin Point and the solids handling facility in the Upper Victoria Harbour for a distance of 3.5 km. From this point, the dual loop could be extended by approximately 1.6 km to service the north portion of the downtown area. This would reduce the overall length of the dual piping system from 6.5 km to 5.1 km and avoid the high cost associated with crossing Victoria Harbour in a tunnel. The heat pipes could be attached to the Bay Street Bridge but this would have to be confirmed with the City of Victoria.

The projected energy demand for the north downtown area, which covers approximately 65 ha averages 10,000 GJ/ha/y for the year 2030 and 25,000 GJ/ha/yr. It is also assumed that 70% of the annual demand would be for space heating and domestic hot water. Based on these assumptions, the future total energy demand would be 450,000 GJ/yr in 2030 and 1,135,000 GJ/yr in 2065. The energy demand for the biosolids facility is estimated at 84,000 GJ/yr. The amount of sealable heat that can be extracted from the effluent is 1,100,000 GJ/yr.

Considering the difficulties in accurately forecasting the 50-year total energy demand for the north downtown area, it is proposed to size the ambient temperature pipe on the basis of providing capacity for two-thirds of the heat available from treated effluent and to use a dual 600 mm diameter non insulated pipe loop.

<u>Systems Basics</u>

The 600 mm diameter ambient temperature pipe loop could initially end at the biosolids facility in the Upper Harbour. Heat pumps could be installed to supply heat to the biosolids facility. The heat demand of this facility includes sludge and digester heating, space heating for buildings and sludge drying. The peak demand for process heat at the biosolids facility corresponds to 21% of the available heat capacity of a 600 mm diameter pipe.

To service the north Downtown area, a separate District Energy System originating at the biosolids facility could be constructed at a later stage. The north Downtown DES would include heats pumps located at biosolids facility followed by a closed loop insulated heat distribution system operating at the temperature required for the heating system of the new buildings. It is anticipated that the heating systems of most new buildings would be designed to operate at 60^0C. Thus the DES for the north Downtown area could be designed to distributed heat at this temperature of higher if required. The heat piping could be located on roads located north of Pandora Street such as Government Street and Douglas Street. The actual routing the DES would depend on where new developments would be located.

The ambient temperature pipeline from the wastewater plant to the biosolids site would likely follow existing roads through Esquimalt and Victoria West. This would allow tapping into the ambient temperature pipe to extract the heat and distribute it through separate local DES system(s) in Esquimalt or in Victoria West.

<u>System Operation – Ambient Temperature Loop from McLoughlin Point to Biosolids Facility</u>

This portion of the system is conceptually similar to Option 1 and is shown schematically in **Figure 7.1**.

The proposed system type is a closed circuit utilizing tap water treated with corrosion inhibitors as a heat transfer fluid. Water would be circulated from the wastewater treatment plant to the biosolids site and the temperature of this closed loop would be monitored and adjusted by automatic temperature control systems. Common water source heat pumps have the ability to operate within a wide temperature range at their water inlet, of approximately 2 C to 20 C in heating mode, and between 15.5 C and 32 C in cooling mode. Therefore, it is expected that the closed ambient temperature loop would operate in a temperature range between 5 C and 25 C during all conditions. Automatic valves, recirculation valves and temperature controls on the utility heat exchanger and customer connection would ensure that the fluid temperature at the inlet to each customer heat pump would be maintained within an optimum range.

<u>System Advantages:</u>

- Can provide a source of heat for localized district energy systems, each operating a temperature that best meet the specific needs of the specific future developments;
- Potential areas to be services with localized DES include the north Downtown area, Victoria West and Esquimalt;
- A separate set of heat pumps could be installed to meet the energy demand of the biosolids treatment facility. These could operate at a different temperature than those required by the local DES;
- Heating and cooling capability;

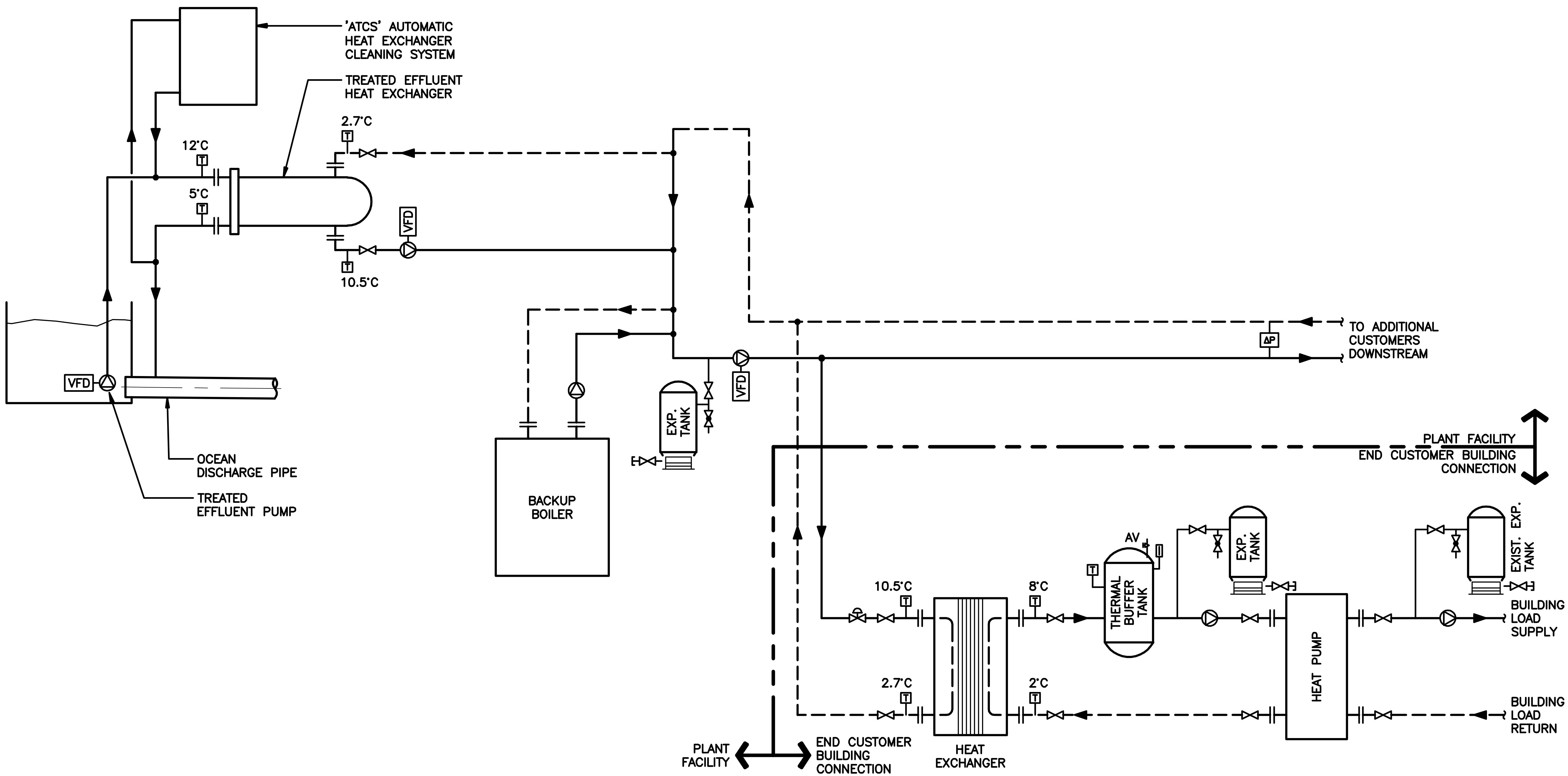
- Conveyance loop does not require welded steel insulated pipe; pipe is cheaper;
- Avoiding the added cost of tunneling in order to cross Victoria Harbour, and
- Essentially no transmission heat loss between the plant and the biosolids facilities.

System Disadvantages:

- This system would not service James Bay and the south downtown areas;
- There will be higher electrical usage at each of the local DES. This may trigger the need for improved electrical infrastructure such as transformers and improved distribution network.

System Operation – District Energy System for North Downtown Area

This portion of the system is conceptually similar to Option 2 and is shown schematically in **Figure 7.2**. The only difference could be that this system may operate at a lower temperature than 80^0C if it services only new development with heating systems designed to operate at a temperature of 60^0C. The advantages and disadvantages are similar to Option 2.



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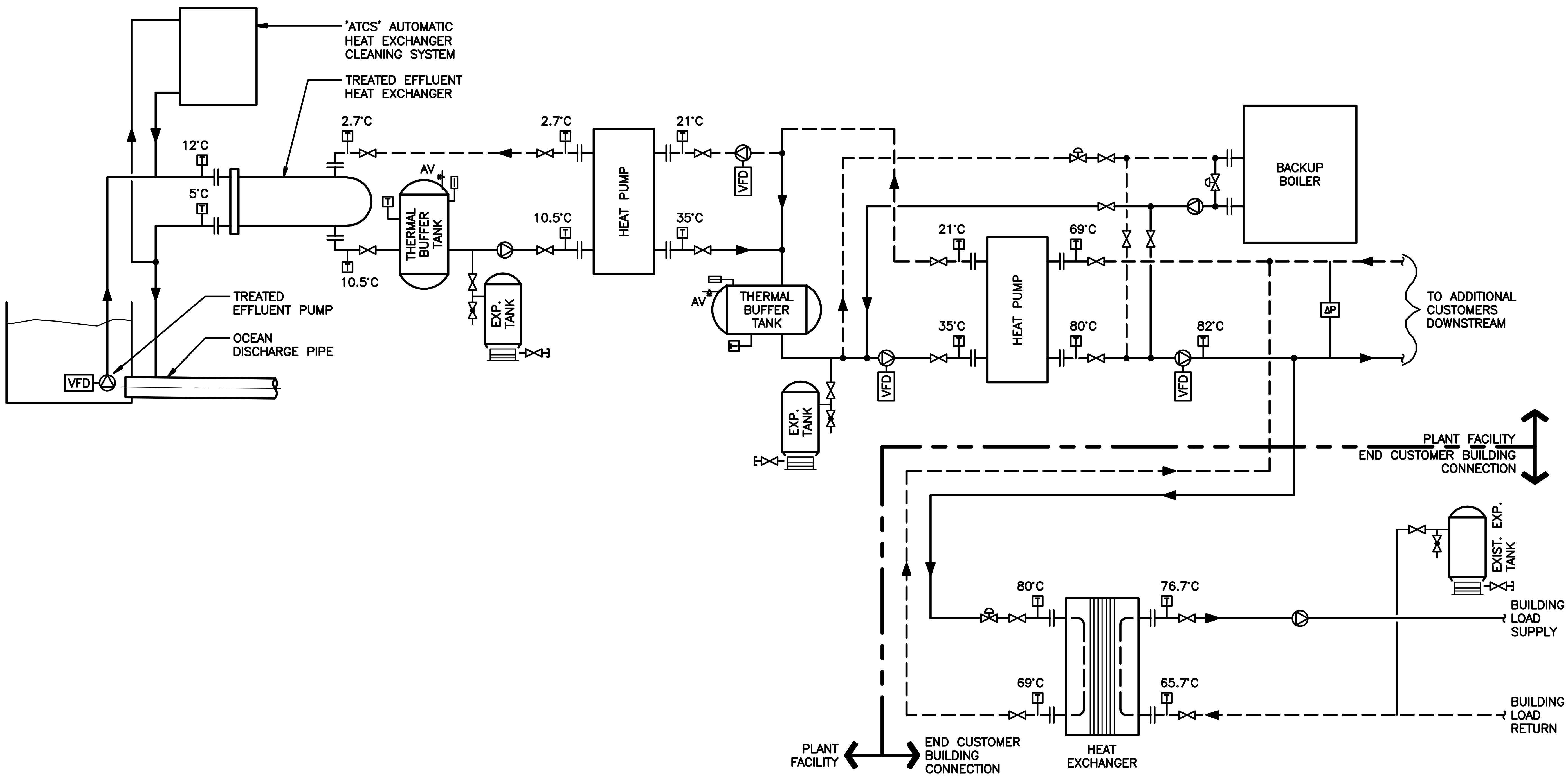
CORE AREA WASTEWATER TREATMENT PROJECT

HEAT RECOVERY – AMBIENT TEMPERATURE WATER LOOP – DOWNTOWN OPTION 1

CONTRACT NUMBER 149009002 | DRAWING NUMBER Fig 7.1 | ISSUE X | SHT. No. 1 OF 3



Capital Regional District | Environmental Services				CORE AREA WASTEWATER TREATMENT PROJECT
DESIGNED	MG	SURVEYED	–	HEAT RECOVERY – LOW TEMPERATURE(80°C) WATER LOOP – DOWNTOWN OPTION 2
DRAWN	DFC	DATE	23/11/09	
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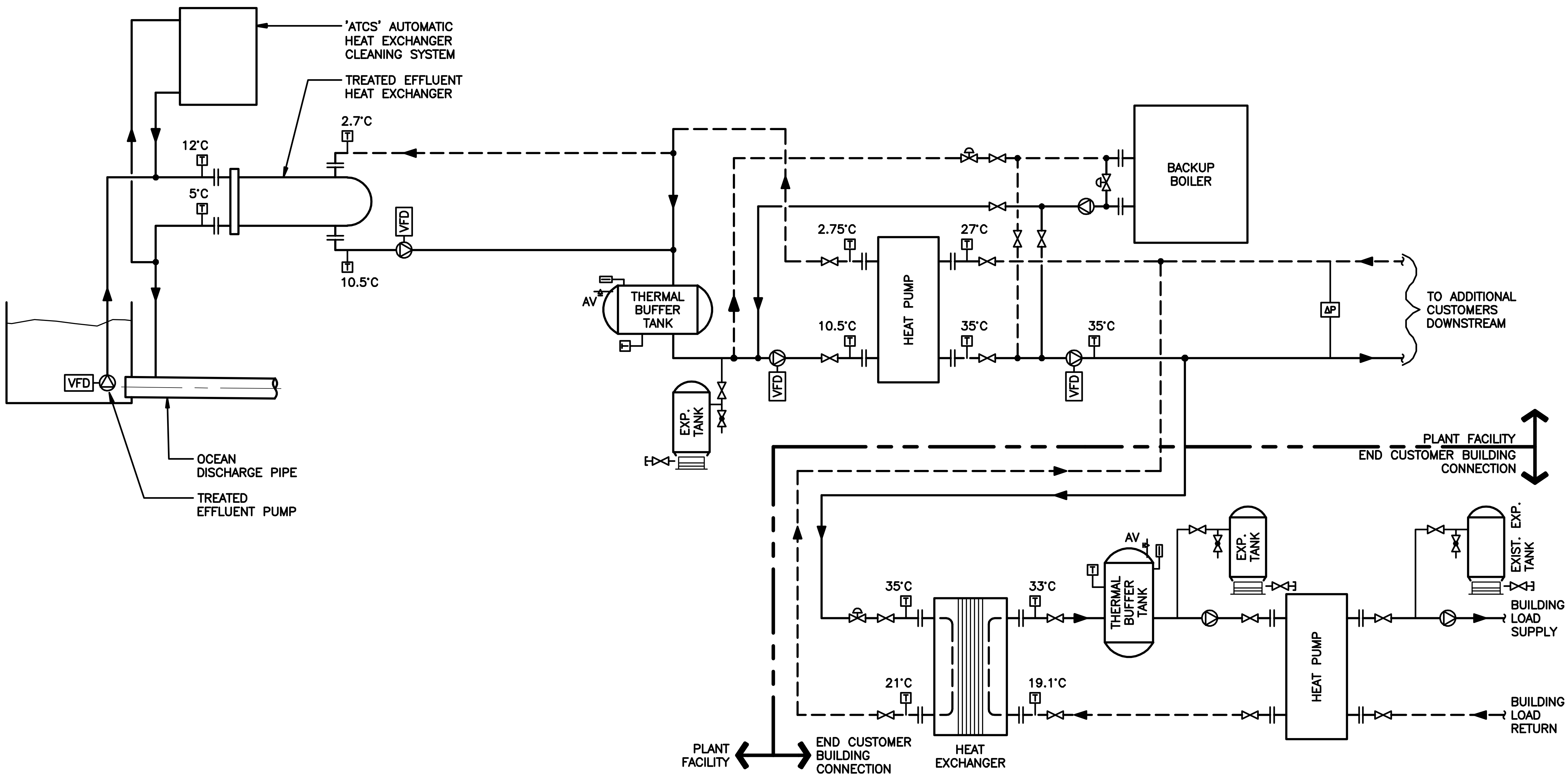

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CORE AREA WASTEWATER TREATMENT PROJECT

HEAT RECOVERY – LOW TEMPERATURE(35°C) WATER LOOP – DOWNTOWN OPTION 3

CONTRACT NUMBER	DRAWING NUMBER	ISSUE	SHT. No. OF
149009002	Fig 7.3	X	3 OF 3

Section 8.0 Opinion Of Probable Cost

8.1 Capital Cost

To enable completion of the triple bottom line assessment and to obtain an initial indication of capital cost for each of Options 1, 2, 3 and 4, cost estimates were prepared for each option. The basis of the estimates includes the following:

Direct Cost

- Capital construction cost
- Design and construction contingency costs at 25% of construction cost

Indirect Cost

- Engineering at 15% of direct cost
- Administration and miscellaneous at 6% of direct cost

Financing Cost

- Interim financing at 4% of direct and indirect cost
- Inflation to midpoint of the construction of the McLoughlin Point treatment facility at 2% per annum to 2015 (14%)

Furthermore, the following assumptions have been made regarding the cost of equipment that must be installed on private property at each point of use:

- The cost of equipment required at each point of use has been included. Depending on the option, this includes (1) heat exchangers, (2) pumping, piping, valves and controls and (3) heat pumps, and
- For Option 1, an allowance of $40,000 per customer has been added for building modifications/addition to the mechanical room in order to allow the installation of equipment needed to connect to the DES. For Options 2 and 4, this allowance has been reduced to $20,000.

The capital cost estimate for the four options of a District Energy System (DES) is shown in **Table 8.1**. In order to allow a comparison of a DES serving the James Bay and Downtown area with a smaller DES serving only the north portion of the Downtown area, assumptions were made regarding the number of customers connected to each system. For Options 1, 2 and 3, the cost of work at each point of use is based on 50 customers. For a smaller system serving the north portion of the downtown area, it was assumed there would be 30 customers.

Table 8.1 –Capital Cost of DES Including Equipment Required at the Point of Use

	Component	Option 1 - Ambient Temp. (<20^{0}C)	Option 2 - Moderate Temp. (80^{0}C)	Option 3 - Low Temp. (35^{0}C)	Option 4 - Hybrid Option
		James Bay and Downtown Area			North Downtown
1	Heat pumps at STP	-	$5,950,000	$1,225,000	
2	Heat exchangers and water pumping system at STP	$2,340,000	$3,540,000	$3,100,000	$1,750,000
3	Buildings at STP to house equipment	$720,000	$2,790,000	$1,530,000	$500,000
4	Closed Loop Distribution piping:				
	Option 1 - 750 mm dia PVC pipe non-insulated; L= 13000 m	$14,376,000	-	-	
	Option 2- 500 mm welded steel insulated pipe; L= 13000 m	-	$11,905,000	-	
	Option 3 - 600 mm HDPE insulated; L= 13000 m	-	-	$13,054,000	
	Option 4 – 7 km of 600 mm dia PVC non-insulated and 3.2 km m of 300 mm dia insulated steel				$7,048,000
5	Heat pumps at point of use	$7,500,000		$5,670,000	$4,000,000
6	Allowance for building addition at point of use for heat pumps	$2,000,000	-	$1,000,000	$600,000
7	Pumping system and heat exchangers at point of use	$4,620,000	$2,280,000	$3,847,000	$3,080,000
	Sub total - Items 1 to 7	$31,556,000	$26,465,000	$29,426,000	$16,978,000
8	Design and construction contingencies (25%)	$7,889,000	$6,616,000	$7,356,000	$4,244,000
	Sub total - Items 1 to 8	$39,445,000	$33,081,000	$36,782,000	$21,222,000
9	Engineering and project management (21%)	$8,283,000	$6,947,000	$7,724,000	$4,457,000
10	Interim financing and inflation to 2014 (14%)	$6,682,000	$5,604,000	$6,231,000	$3,595,000
	TOTAL ESTIMATED COST	**$54,410,000**	**$45,632,000**	**$50,737,000**	**$29,274,000**

The cost of a heat extraction and distribution system to provide process heat to the biosolids facility only is shown in Table 8.2. This cost estimate includes the over-sizing the ambient temperature piping between the wastewater treatment plant and the biosolids facility from 450 mm to 600 mm dia to allow for future servicing of the north downtown area. Servicing the biosolids facility only could be the first phase of a smaller district energy system to service the north portion of the downtown area.

Table 8.2 – Cost of Heat Extraction System for Biosolids Process Heat Only

	Component	Estimated Cost
1	Heat exchangers and water pumping system at STP	$600,000
2	Buildings at STP to house equipment (water pumps and heat exchanger)	$300,000
3	Closed Loop ambient temperature distribution piping from WWTP to biosolids facility (oversized to supply north downtown area); 600 mm dia PVC pipe non-insulated; L= 7,000 m including bridge crossing	$2,740,000
4	Heat pumps at point of use	$1,150,000
5	Pumping system and heat exchangers at point of use	$720,000
6	Allowance for building addition at point of use to house heat pumps	$900,000
	Sub total - Items 1 to 7	$7,110,000
8	Design and construction contingencies (25%)	$1,777,000
	Sub total - Items 1 to 8	$8,887,000
9	Engineering and project management (21%)	$1,866,000
10	Interim financing and inflation to 2014 (14%)	$1,505,000
	TOTAL ESTIMATED COST	**$12,258,000**

The smaller DES to service the north portion of the downtown area only as described in Option 4 could be constructed in two stages as follows.

<u>Stage 1 – Heating Needs of Biosolids Facility Only</u>

- Heat exchangers at the wastewater treatment plant to meet heat demand of the biosolids facility only;

- Ambient temperature dual loop piping from the wastewater treatment plant to the biosolids facility through Victoria West and Esquimalt – pipe sized for the future heating needs of the north downtown area;
- Heat pumps to meet the requirement of the biosolids facility only and including building and controls, and
- Estimated cost of $12,258,000 as per table 8.2 above

Stage 2 - Expansion of District Energy System into North Downtown Area

- Additional heat exchangers at the WWTP to provide heat for north downtown area;
- Additional heat pumps at the biosolids facility to provide heat for the north downtown area including building;
- Moderate temperature (65^{0}C) insulated piping loop through north portion of downtown, and
- Estimated cost of $17,016,000

For the large DES to service the James Bay and downtown area as described in Options 1, 2 and 3, it is anticipated that it could take several years before there are enough customers to use all the available heat. Considering the high capital cost of such a system, the construction of a district energy system could be staged as shown in Table 8.3

Table 8.3 –Staging of Large DES for the Downtown & James Bay Area

	Stage 1	**Stage 2**	**Stage 3**
Heat pumps, heat exchangers and pumping systems	Sized for 30% of available heat + plant use	Sized for 60% of available heat + plant use	Sized for 100% of available heat
Building at STP to house equipment	Sized for 30% of available heat	Sized for 60% of available heat	Sized for 100% of available heat
Distribution piping	Sized for 100% of available heat	Sized for 100% of available heat	Sized for 100% of available heat

8.2 Operations and Maintenance Cost

The operations and maintenance costs, and the estimated revenues at 30%, 60% and 90% of heat sold, are detailed in **Tables 8.4 to Table 8.6**.

As indicated in these tables, the power cost is a major expenditure and can represent over 80% of the O&M cost. This is because a significant amount of power is required to run the heat pumps.

With Options 2 and 3, heat pumps are located on private property at each point of use. In order to allow a direct cost comparison between the various options, the cost of power cost to run the heat pumps located on private properties is included in the O&M cost.

The capital costs include interim financing estimated at 4% of all direct and indirect costs. The O&M costs do not include the annual debt servicing. However, it should be noted that based on interest rate at 6% and an amortization period of 25 years, the annual debt servicing would be at $54,000 for each $1 million of capital cost not covered by senior government grants.

Table 8.4 – O&M Cost at 30% of Available Heat Sold

	Component	Option 1 - Ambient Temp. (<20^{0}C)	Option 2 - Moderate Temp. (80^{0}C)	Option 3 - Low Temp. (35^{0}C)	Option 4 - Hybrid Option
		James Bay and Downtown Area			North Downtown
1	Annual power cost based on $0.08/kwh	$1,224,000	$1,188,000	$1,207,000	$743,000
2	Labour cost	$96,000	$96,000	$96,000	$80,000
3	Equipment and buildings maintenance and repairs	$46,000	$39,000	$46,000	$38,000
4	Distribution system maintenance and repairs	$71,000	$59,000	$65,000	$48,000
5	Vehicle allowance and miscellaneous	$12,000	$12,000	$12,000	$10,000
	TOTAL ESTIMATED COST	**$1,449,000**	**$1,394,000**	**$1,426,000**	**$919,000**
	Revenues Based on 30% of Heat Sold	*$1,532,000*	*$1,410,000*	*$1,410,000*	*$1,006,000*
	Net Revenues	*$83,000*	*$16,000*	*- $16,000*	*$87,000*

Table 8.5 – O&M Cost at 60% of Available Heat Sold

	Component	Option 1 - Ambient Temp. (<20⁰C)	Option 2 - Moderate Temp. (80⁰C)	Option 3 - Low Temp. (35⁰C)	Option 4 - Hybrid Option
		James Bay and Downtown Area			North Downtown
1	Annual power cost based on $0.08/kwh	$2,448,000	$2,376,000	$2,413,000	$1,485,000
2	Labour cost	$128,000	$128,000	$128,000	$100,000
3	Equipment and buildings maintenance and repairs	$93,000	$78,000	$91,000	$68,000
4	Distribution system maintenance and repairs	$71,000	$59,000	$65,000	$48,000
5	Vehicle allowance and miscellaneous	$18,000	$18,000	$18,000	$13,000
	TOTAL ESTIMATED COST	**$2,758,000**	**$2,659,000**	**$2,715,000**	**$1,714,000**
	Revenues Based on 60% of Heat Sold	*$3,064,000*	*$2,819,000*	*$2,941,000*	*$2,012,000*
	Net Revenues	*$306,000*	*$160,000*	*$226,000*	*$298,000*

Table 8.6 – O&M Cost at 90% of Available Heat Sold

	Component	Option 1 - Ambient Temp. (<20⁰C)	Option 2 - Moderate Temp. (80⁰C)	Option 3 - Low Temp. (35⁰C)	Option 4 - Hybrid Option
		James Bay and Downtown Area			North Downtown
1	Annual power cost based on $0.08/kwh	$3,672,000	$3,564,000	$3,620,000	$2,228,000
2	Labour cost	$160,000	$160,000	$160,000	$130,000
3	Equipment and buildings maintenance and repairs	$154,000	$129,000	$152,000	$97,000
4	Distribution system maintenance and repairs	$72,000	$59,000	$65,000	$48,000
5	Vehicle allowance and miscellaneous	$20,000	$20,000	$20,000	$18,000
	TOTAL ESTIMATED COST	**$4,078,000**	**$3,933,000**	**$4,017,000**	**$2,521,000**

	Revenues based on 90% of Heat Sold	*$4,596,000*	*$4,228,000*	*$4,412,000*	*$3,018,000*
	Net Revenues	*$518,000*	*$295,000*	*$395,000*	*$497,000*

The following assumptions were made when estimating projected revenues from the sale of heat:

- An incentive price of $10/GJ for the sale of heat generated by effluent;
- The transmission losses are 8% for Option 2 and 4% for Options 3 and 4;
- The process heat for the digesters and the space heating at the plant are excluded from the revenues, and
- The heat supplied to the digester is included in the revenues.

8.3 Business Model

A potential business model for a District Energy System would consist of the following:

- Ownership of District Energy System by the CRD;
- Governance oversight by the Board of Director of the CRD;
- Operations managed by the Environmental Services Department, integrated with other operations of the Department;
- Capital funding provided by grants from senior levels of government and annual revenues including carbon credit.
- Operating and maintenance cost funded by annual revenues including carbon credit

Because of high capital cost, it appears that the business model will have to be based on 25-year period. The above business model is similar to the model adopted by the City of Vancouver for the South East False Creek DES. Another option may be to consider construction and operation of a DES by a private sector partner who would be responsible for construction and operation of the system.

Section 9.0 Triple Bottom Line Analysis

9.1 Carbon Footprint Analysis

A carbon footprint analysis was performed as a part of the evaluation of the environmental impacts of the four alternatives. A carbon footprint measures the amount of greenhouse gas (GHG) released or stored as a result of a process or activity. A detailed description of the carbon footprint analysis methodology can be found in the September 16, 2009 report by Stantec Consulting and Brown and Caldwell titled "*Core Area Wastewater Treatment Assessment of Wastewater Treatment Options 1A,1B and 1C.*"

The emission factors used to calculate the GHG emissions/savings associated with the heat recovery project are as follows:

- Heat pumps and water pumps for district heating 0.000072 tonne/kwhr (electricity)
- Saleable heat for district heating offset 0.0503 tonne CO_2/GJ (based on natural gas)

In addition, there are one-time emissions associated with construction activities as follows:

- Concrete 0.272154 tonne CO_2/m^3
- Steel (re-bar, piping, equipment 0.0032 tonne CO_2/tonne product
- Excavation 0.000981 tonne CO_2/m^3

The estimated annual carbon footprint in tones of CO_2 associated with each heat recovery system option, based on current available heat is summarized in Table 9.1. The value of carbon credit based on $25/tonne and $50/tonne is shown in Table 9.2.

Table 9.1 – Summary of GHG Emissions for Heat Recovery System Options (Tonnes of CO_2)

	Option 1 - Ambient Temp. (<25^{0}C)	Option 2 - Moderate Temp. (80^{0}C)	Option 3 - Low Temp. (35^{0}C)	Option 4 - Hybrid Option
Power for heat pumps and conveyance (pumping)	3,672	3,564	3,619	2,904
Saleable Heat for District Heating	- 25,686	- 23,632	- 24,659	-16,866
Total Annual Emissions (Excluding Construction)	- 22,014	- 20,068	- 21,040	-13,962

Table 9.2 – Value of Carbon Credit

	Option 1 - Ambient Temp. (<25^{0}C)	Option 2 - Moderate Temp. (80^{0}C)	Option 3 - Low Temp. (35^{0}C)	Option 4 - Hybrid Option
Based on $25/tonne of CO_2	$550,350	$501,700	$526,000	$349,050
Based on $50/tonne of CO_2	$1,100,700	$1,003,400	$1,052,000	$698,100

9.2 Triple Bottom Line Methodology

This chapter outlines the triple bottom line analysis that was used to evaluate the four options for a heat extraction and distribution system for the James Bay and Downtown area. A complete listing of impacts included in the model and sorted by the three categories is provided in Table 9.3.

TABLE 9.3 - Impacts Evaluated for Triple Bottom Line Analysis

Criteria Group	No.	Criteria Categories	Measure Description
Economic	EC-01	Capital Costs	Construction cost and markup for soft costs adjusted to midpoint of construction
	EC-02	Capital Costs Eligible for Grants	Not available at this time
	EC-03	Present Worth of Net O&M costs	O&M costs
	EC-04	Flexibility for Future Expansion	Cost and number of additional buildings to accommodate future equipment
Environmental	EN-01	Carbon Footprint	Tons of eCO2 created/saved
	EN-02	Power (energy) usage	Heat energy replacing natural gas
	EN-03	Heat loss in distribution piping	Loss of revenues
	EN-04	System Reliability	Number of water pumps and heat pumps
	EN-05	Non-renewable Resource Use	Gallons of diesel consumed per year
	EN-06	Non-renewable Resource Generated	Net sale of heat
Social	SO-01	Operations Traffic in Sensitive Areas	Cost of traffic inconvenience during operations
	SO-02	Disruption on Private Property and Customer Acceptability	Construction cost of work on private property
	SO-03	Loss of Usable Building Space on Private Property	Cost of building space required on private property for heat pumps and building
	SO-04	Cultural Resource Impacts	Risk cost of a cultural site find

9.2.1 Economic Factor

EC-01 Capital Costs

Capital costs measure the construction cost and soft costs for each option escalated to the midpoint of construction. Data input included the estimated construction cost and a 2014 midpoint of construction. Assumptions included an inflation rate of 3%. The scoring for capital costs was scaled based on the NPV of costs for all three options with an NPV of $12 million worth three points, higher NPVs worth fewer points and lower NPVs worth more.

EC-02 Capital Costs Eligible for Grants

This impact was intended to measure the value of grants to offset construction costs but at this time, insufficient information is available to adequately account for this impact.

EC-03 Present Worth O&M Costs

Present worth included annual expenditures for operations and maintenance (O&M), and for replacement and refurbishment (R&R) projects. Data input included annual O&M and R&R costs. Assumptions included a 3% rate of inflation for each annual cost. The scoring was scaled based on the annual costs with an annual cost of $88 million worth 3 points, a higher annual cost worth fewer points and lower annual costs worth more.

EC-04 Flexibility for Future Expansion

This impact was intended to measure the flexibility for each option to allow for expansion of the heat recovery system. To measure this, the cost of providing equipment on private property such as heat exchangers and heat pump was estimated for each option. Scoring was based on the following scale:

EC-04 Scoring	
1	More than $12 million
2	$9 to 12 million
3	$6 to 9 million
4	$3 to 6 million
5	Less than $3 million

9.2.2 Environmental Factors

EN-01 Carbon Footprint

The details of the carbon footprint calculation are presented in Section 7.1. Scoring was based on the annual value of offsets for equivalent tonnes of carbon dioxide emitted (assuming $25 per tonne) using the following scale.

EN-01 Scoring:	
1	Less than -$5 million
2	-$5 million to -$10 million
3	-$10 million to -$15 million
4	-$15 million to -$20 million
5	More than -$20 million

EN-02 Power (energy) Use

This impact compares the electrical energy usage for each option. Data input included annual power consumption and a $0.08/kW-hr cost of power. Assumptions included a 3% rate of inflation for power costs. The NPV for electrical costs was calculated for each option and then scaled as follows:

EN-02 Scoring:	
1	More than $60 million
2	$45 to $60 million
3	$30 to $45 million
4	$15 to $30 million
5	Less than $15 million

EN-03 Heat Losses in Distribution Piping

Some of the heat extracted from the effluent will be lost in the transmission lines between the heat exchange at the sewage treatment and the point of use. The NPV of the loss in revenues resulting from heat losses was estimated. The following 1 to 5 score was used.

EN-03 Scoring:	
1	More than $1.5 million
2	$1 to $1.5 million
3	$0.5 to $1 million
4	Less than $0.5 million
5	No loss

EN-04 System Reliability

This impact measures the relative risk carried for each option in terms of system complexity. The number of water pumps and heat pumps required varies for each option. The complexity of each option was compared by multiplying the number water pumps by the number of heat pumps. A $15,000 risk cost per unit was assumed. The following 1 to 5 score scaled was used.

EN-04 Scoring:	
1	More than $100,000
2	$75,000 to $100,000
3	$50,000 to $75,000
4	$25,000 to $50,000
5	Less than $25,000

<u>EN-05 Non-Renewable Resource Use</u>

This impact measured diesel fuel consumption during construction and operations. Diesel consumption during construction was assumed to be 2% of construction costs and diesel consumption during operations was assumed to be 2% of O&M costs. Therefore, data inputted was construction costs and O&M costs. A 3% inflation rate was assumed and a NPV was calculated for each option. The options were scored using the scale below.

EN-05 Scoring:	
1	More than $5 million
2	$4 to $5 million
3	$4 to $4 million
4	$2 to $3 million
5	Less than $2 million

<u>EN-6 Non-Renewable Resource Generated</u>

Non-renewable resource generated measured the available heat to sell for each option after taking into account the heat lost in the transmission. The sale price for heat was assumed at $10 per GJ. The NPV based on annual revenue for each option was calculated and scores were given based on the following scale.

EN-6 Scoring:	
1	Less than $50 million
2	$50 to $75 million
3	$75 to $100 million
4	$100 to $125 million
5	More than $125 million

9.2.3 Social Impacts

<u>SO-01 Construction Disruption</u>

Traffic during construction can be particularly noisome to neighboring residents and businesses. To measure this disruption, the volume of traffic potentially impacted by the district energy system construction was estimated by using traffic counts at nearby intersections for each site. These traffic counts came from CRD's 2005 evaluations. The number of construction trips was calculated by estimating one construction trip per day for every $2,500 of construction budget. The traffic count was multiplied by the daily construction traffic at each site and a plant construction disruption cost was calculated assuming a $1 cost per trip delayed, a 1% probability of delay due to construction and a 12 month construction period.

SO-01 Scoring:	
1	More than $5 million
2	$4 to $5 million
3	$3 to $4 million
4	$2 to $3 million
5	Less than $2 million

SO-02 - Disruption on Private Property and Customer Acceptability

In order to connect to the heat recovery system, equipment and piping may be required at the site of each potential customer. Depending on the option for the distribution system, the equipment at each point of use could include heat exchangers and heat pumps. In many cases, the existing mechanical rooms have to be expanded to allow construction of this work adding to the cost of the system. The cost of this one-time expense of work on private property at each point of use was estimated and a qualitative 1 to 5 score was given as shown below.

SO-02 Scoring:	
1	More than $16 million
2	$12 to $16 million
3	$8 to $12 million
4	$4 to $8 million
5	Less than $4 million

SO-03 Loss of Usable Building Space on Private Properties

The installation of heat pumps and other equipment in the mechanical room on private properties may preclude the use of the building space for other types of use. To measure this impact, the loss of usable building space was estimated and an assumption of a $1,500 per square meter for using the space for heat recovery equipment. The scale used to compare options is presented below.

SO-03 Scoring:	
1	More than $4 million
2	$2 to $3 million
3	$1 to $2 million
4	$0.5 to $1 million
5	Less than $0.5 million

SO-04 Cultural Resource Impacts

A cultural resource find would cause additional cost and delay to site construction. The probability of a cultural find for each site and the resulting delay was estimated along with the estimated construction cost. An assumed 3% inflation rate was used to quantify the delay cost of a cultural find. By multiplying the delay cost by the probability of a find, the risk cost of a cultural find was calculated for each option and compared using the following scale.

SO-04 Scoring:	
1	More than $400,000
2	$300,000 to $400,000
3	$200,000 to $300,000
4	$100,000 to $200,000
5	Less than $100,000

9.3 Results

The results of the triple bottom line analysis is summarized in Table 9.2. The discussion of the results can be found in Section 10.

Table 9.2 – Summary of Triple Bottom Line

	Option 1 - Ambient Temp. (<25^{0}C)	**Option 2 - Moderate Temp. (80^{0}C)**	**Option 3 - Low Temp. (35^{0}C)**	**Option 4 - Hybrid Option**
Economic	49	62	51	88
Environmental	63	53	57	67
Social	36	70	45	70
Total	147	185	153	225

Table 9.3 **Triple Bottom Line Analysis for Heat Recovery**

Criteria Group	No.	Criteria Categories	Measure Description	Weight	Option Results 1	2	3	4
Economic	**EC-01**	Capital Costs	Construction cost and markup for soft costs adjusted to midpoint of construction	9	2.2	2.6	2.4	4.1
	EC-02	Capital Costs Eligible for Grants	Not available at this time	-				
	EC-03	Present Worth of O&M costs	O&M costs	9	2.9	3.2	3.0	5.0
	EC-04	Flexibility for Future Expansion	Cost and number of additional buildings to accommodate future equipment	2	2	5	1	3
				Economic Subtotal (100 pts max)[1]:	**49**	**62**	**51**	**88**
Environmental	**EN-01**	Carbon Footprint	Tons of eCO2 created/saved	3.34	4	4	4	3
	EN-02	Power (energy) usage	Heat energy replacing natural gas	3.34	1	1	1	3
	EN-03	Heat loss in distribution piping	Loss of revenues	3.33	5	3	4	5
	EN-04	System Reliability	Number of water pumps and heat pumps	3.33	4	3	3	3
	EN-05	Non-renewable Resource Use	Gallons of diesel consumed per year	3.33	2	2	2	4
	EN-06	Non-renewable Resource Generated	Net sale of heat	3.33	3	3	3	2
				Environmental Subtotal (100 pts max):	**63**	**53**	**57**	**67**
Social	**SO-01**	Operations Traffic in Sensitive Areas	Cost of traffic inconvenience during operations	5	1	1	1	2
	SO-02	Disruption on Private Property and Customer Acceptability	Construction cost of work on private property	5	1	5	2	4
	SO-03	Loss of Usable Building Space on Private Property	Cost of building space required on private property for heat pumps and building	5	2	5	3	4
	SO-04	Cultural Resource Impacts	Risk cost of a cultural site find	5	3	3	3	4
				Social Subtotal (100 pts max):	**35**	**70**	**45**	**70**
				TOTAL SCORE (300 pts max):	**147**	**185**	**153**	**225**

1 - Economic weighting is proportional to NPV results

Section 10.0 Analysis of Results and Conclusions

10.1 Triple Bottom Line Assessment

The difference in capital and in O&M costs between the three options for a large District Energy System for James Bay and Downtown is not significant. The capital cost of Option 2 is the lowest of the three options for a large DES mainly because of the economies of scale resulting from having all equipment and the heat pumps at one location. Another factor is the lower cost of the transmission line from the sewage treatment plant through downtown to the biosolids facility since hotter water requires a smaller pipe and the added cost of insulation does not offset the cost of larger pipe size for Options 1 and 3.

Option 2 has a lower environmental score of the three options for a large DES because of the heat losses in the transmission main. These heat loss estimated at 8% will result in a corresponding reduction in the amount of saleable heat and a higher energy consumption. The main drawback of Options 1 and 3 is the need to install heat pumps in existing buildings at each point of use. It is likely that the mechanical rooms in many existing buildings will be too small to accommodate the equipment. The need to install equipment on private property could result in significant disruption and could affect the marketability of the heat recovery system. On the basis of the triple bottom line analysis, if a large DES was constructed, Option 2 would be the preferred configuration. With this option, heat pumps are located at the wastewater treatment facility and the hot water at a temperature of 80^0C is distributed throughout the area.

However, the capital costs for Option 4 are much lower since the district energy system would be serving a smaller area, namely the north portion of the downtown area and the biosolids facility. This system would be designed to operate at a lower temperature with lower capital and operating costs. Since that portion of the downtown core will likely see major re-developments, the heating systems of these new developments could be designed on the basis of the requirements of a district energy system. This includes the installation of equipment at the point of use and a heating system designed to operate at lower temperatures. This option has the highest score as a result of the lower capital and O&M cost, less disruption on private properties and higher customer acceptability.

10.2 District Energy System for James Bay and Downtown

As indicated in previous sections of this report, the use of heat reclaimed from wastewater must be analyzed for each end-customer's specific requirements as conditions at different sites can vary dramatically. What is feasible or works in one location may not necessarily work at another location. Temperature, capacity and reliability are important issues from all customers. The potential customers have stated, with respect to reliability and connect-ability of a district energy system that: "…making the ability to connect to the system as attractive as possible for the end users is of utmost importance".

Based on the case studies carried out during the course of this study, it appears that most existing boiler systems are operating at "legacy" temperatures of 80^0C or more. As a result, a DES would be required to supply heat at this temperature in order to meet the peak winter demand of potential customers. If the DES were to supply heat at a lower temperature, either ambient temperature or up to 60ºC, a combination of heat exchangers and heat pumps or a back-up-boiler would be needed on the customer's private property to increase temperatures. It appears, however that in most cases, the mechanical rooms in existing buildings would not be large enough to accommodate this equipment. As well, it is doubtful that a building owner would want to operate, maintain and pay for a second system such as a back-up-boiler for the 30 coldest winter days. This additional expense of a parallel system would seriously affect the marketability of such a DES. It is our opinion therefore that for existing infrastructure areas such as James Bay and Downtown Victoria, a DES must supply heat at a temperature of 80^0C and that Option 2 would be the preferred option for a large system.

The average and maximum process heat demand for the biosolids facility corresponds to 11% and 14% respectively of the available heat of 25,000 KW. In an 80^0C heat distribution system with the long transmission lines proposed, heat losses amount to approximately 8%. Therefore, on average, only 81% of the heat that can be extracted from treated effluent is available for sale. For the purpose of this analysis, however, it has been assumed that the heat required by the digesters would be considered revenue for the DES

The heat supply and distribution system for the Downtown and James Bay area has been sized as follows:

- A 13 km long pipe loop (6.5 km double pipe) sized to convey all the available heat that can extracted from treated effluent in early morning hours (25,000 KW);
- The equipment, such as heat exchangers, heat pumps and water pumps, could be installed in three stages to supply 30%, 60% and 100% of the available heat, and
- The building to house the equipment could be staged as well.

Based on the above staging, the capital cost of a large DES based on Option 2 is estimated as follows:

- Stage 1 $29,314,000
- Stage 2 $8,787,000
- Stage 3 $7,531,000
- **Total** **$45,632,000**

The operating and maintenance cost and the estimated revenues at 30%, 60% and 90% of viable heat sold are summarized in **Table 10.1**. The value of the carbon credits based on $25 and $50 per tonne of CO_2 are also shown in **Table 10.1.**

Table 10.1 – Summary of O&M Cost and Revenues for DES for James Bay & Downtown

	O& M Cost	Revenues	Net Revenues	Carbon Credit	
				$25/tonne	$50/tonne
30% of heat sold	$1,394,000	$1,410,000	$1600	$150,000	$300,000
60% of heat sold	$2,659,000	$2,819,000	$160,000	$301,000	$602,000
90% of heat sold	$3,933,000	$4,228,000	$295,000	$451,000	$902,000

When the value of the carbon credit is added to the net revenues, the revenues could increase significantly. However the payback period is in excess of 50 years assuming net revenues of $295,000 and a carbon credit of $25/tonne.

In order to reduce the payback from 50 years to 12 years, the following conditions would be required:

- The revenues would have to increase from $10/GJ to $15/GJ
- The value of the carbon credit would have to increase from $25/tonne to $50/tonne
- The cost of electricity to run the heat pumps would remain at $0.08/kWh

There are several reasons why the capital, O&M costs and payback period are high:

- The length and resulting cost of the insulated transmission main of 13 km distributing heat (pipe loop, 6.5 km each direction) from the WWTP to the most distant point of use, which would be the digesters located in the Upper Harbour;
- The heat extracted from the effluent must be lifted twice from a temperature difference (potential) of 7ºC in winter (12ºC – 5ºC) to the required end user temperature of 80ºC. The size and cost of the equipment to accomplish these two lifts is significant. In addition, the electrical power consumption for the pumps and heat pumps is significant and increases operating costs substantially;
- The low flows early in the morning limit the amount of consistent available heat that can be extracted from the effluent. Since the peak demand occurs when flows are lowest and therefore the amount of heat that can be extracted, the net sales are limited. These low net sales adversely affect the payback on the huge capital costs for equipment, and

- Energy prices for heating with current energy sources, mainly natural gas, are too low to be able to charge more for a DES unit of energy. If energy prices were more in line with European prices, revenues would be higher and the payback period would be reduced.

10.3 District Energy System for the North Downtown Area

Modern heating systems, primarily in the last decade or so, are designed using condensing boilers which operate at significantly lower temperatures of approximately (140^{0}F). As well, the proposed digesters will be designed to operate at 55^{0}C. These temperature levels align much better with the temperature-coefficient of performance (COP) constraints of modern heat pumps. The COP at these temperatures would make the business case more favorable as factors like transmission heat loss, equipment size and needed electrical energy would be reduced. This would allow the DES to operate a lower temperature of 60-65^{0}C instead of 80^{0}C. A recent example is the South East False Creek DES which is designed to supply water at a temperature of 65^{0}C.

Further to this, there is an opportunity to start with a smaller DES designed for a smaller heat load that would include the digesters and future building developments. The heat extracted from the effluent could be conveyed to the digesters by a shorter route through Esquimalt and Victoria West. In a second phase, the DES loop could be extended into the north portion of the downtown area where it is anticipated that significant residential and commercial developments will occur. These developments would likely include lower temperature heating systems which correspond to higher COP's from heat pumps.

The heat supply and distribution system for the north portion of the Downtown area has been sized as follows:

- A 7 km long ambient temperature pipe loop to convey heat extracted from the wastewater treatment plant at McLoughlin Point to biosolids handling facility in the Upper Harbour area. This would convey two-third of the available heat that can extracted from treated effluent in early morning hours (16,750 KW);

- In a first stage, heat pumps could be installed to provide process heat to the biosolids facility.

- In a second stage, a separate 3.2 km long pipe loop could distribute heat at a temperature of 60 to 65^{0}C. Additional heat pumps would be installed as the demand for heat increases.

Option 4 improves the business case in several aspects as follows:

- The supply temperature to future infrastructure in Downtown North would be at lower temperatures allowing higher coefficients of performance, less heat loss and smaller equipment sizes and therefore, less equipment cost and lower power consumption.

- This is reflected in the lower capital and O&M cost and increased revenues for Option 4 as follows:
  - Capital cost $29,274,000 (based on conveying 16,750 KW)
  - O&M Cost $2,521,000
  - Revenues $3,018,000 (based on selling 90% of heat)
  - Net Revenue $497,000
  - Carbon credit $314,000 (based on $25/tonne)

10.4 Conclusions

It would be very challenging to implement a district energy system to service the James Bay and Downtown area. The huge capital cost needed to lift wastewater heat to 80ºC and convey it in a 13 km pipe loop does not make a good business case based current energy prices and carbon credit. The payback period for system serving the James Bay and downtown area exceeds 50 years based on current electricity and natural gas prices and the value of the carbon credit of $25/tonne.

Consideration should be given to constructing a smaller energy system to service new developments in the north portion of the Downtown area. This smaller energy system could be integrated with the energy requirements of the biosolids facility that could potentially be located in the Upper Victoria Harbour. Heat extracted from the effluent would be conveyed from the wastewater treatment plant to the biosolids facility at ambient temperature thus eliminating heat losses along this 3.5 km long line. This system could be constructed once further market assessment for heat demand in the North downtown core is completed.

A district heating facility housing the heat pumps could be located at the biosolids facility and hot water at a temperature of 60-65^{0}C would be distributed to the biosolids process equipment and the nearby north portion of the downtown area. This system would be designed to take into account the lower operating temperature of newer heating systems.

The capital cost of this smaller DES system is estimated at $29,274,000. This system can be phased with the cost of the first phase estimated at $12,258,000. This amount includes the construction a non-insulated ambient temperature transmission line from the WWTP to the biosolids facility and sized for the needs of the north downtown area. This amount includes the heat exchangers and the heat pumps sized for the biosolids facility only. In a second phase, estimated at $17,016,000, a loop to serve the north downtown area with an insulated line to a temperature of 65^{0}C together with additional heat exchangers and heat pumps would be constructed.

Since it is proposed to use only two thirds of the extractable heat to provide process heat to the biosolids facility and the north Downtown area, a significant amount of energy would be available for other developments in Victoria West and Esquimalt. This could be incorporated into the energy loop between the plant and the biosolids facility by upsizing this 3.5 km long line from 600 mm to 750 mm at an additional cost of $2.5 million.