Community Energy System
Design Recommendation

for

City of Saint John

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Submitted to:

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Prepared By
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Information contained herein is
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The above tables show thousands of current (un-escalated) dollars, except where otherwise noted.
1. Executive Summary
Recommended Design for District Heating

The recommended Community Energy System (CES) design would be financially viable and beneficial to Saint John for the following reasons:

- Saint John has a dense, compact uptown core with a sufficient number of buildings in close proximity that are compatible with the proposed CES
- Buildings need a significant amount of heating in Saint John\(^1\)
- Most of the recommended CES Customers would otherwise burn natural gas, which is expensive in Saint John
- Money spent on natural gas mostly leaks from the community, versus the much higher local content of CES service

The proposed energy source is the Irving Pulp & Paper (IPP) Mill (the Mill), a major employer, located approximately 4 kilo-metres from uptown. This is a viable distance for modern hot water based district heating, given the size of the thermal demand. Back up and peaking capacity would be provided by an Energy Centre, located on the City owned car park adjacent to the Saint John Energy Transformer Station on Smythe Street.

The return on investment has been confirmed to be good for a project of this type. Furthermore, the Federal Green Infrastructure Fund (FGIF) has committed a grant of a third of the capital cost to a maximum of $9.8 million.

The CES would be an economic development advantage because new building developments could save the capital cost of installing their own heating plants.

Owners of the buildings served, including the City of Saint John, would save money, look forward to more stable, predictable costs in the long-term and enjoy an easier, more reliable and safe way to heat their buildings.

The CES would work very simply, as follows. Water would be circulated in a loop through heat exchangers at the Mill, where it would be heated using low cost

\(^1\) Reference 1 - annual heating degrees days below 15°C; 3,797 Saint John c.f. 2,807 Toronto or 3,810 Corner Brook
process energy streams. The hot water loop would connect customers' buildings in parallel. Heat exchangers in each building between the loop and internal HVAC systems would transfer energy from the hot water loop into the buildings, eliminating the burning of natural gas, fuel oil or electricity for space heating and domestic hot water.

Twenty-five buildings have been identified as suitable customers, representing approximately 3.4 million square feet of floor space. The fuels used by the recommended CES customers to generate the heat they need aggregate in a typical year to approximately 149,000 Giga-Joules (GJ) of natural gas, 248,000 litres of fuel oil and 2.9 million kilo-Watt hours (kWh) of electricity. Implementation of the recommended CES will reduce the estimated fuel consumption to generate the same amount of heating nearly completely, carbon dioxide emissions would be reduced by an estimated

Without a CES each of the customers would continue to operate their existing heating and domestic hot water production facilities over the life of each building. Table 1 shows estimates of what it would cost the target customers to produce heating on-site in the Business-as-Usual way at current utility rates. These costs would be avoided by connection to the proposed CES. Instead, the customers would pay CES service charges, expected to provide net savings versus Business-as-Usual.

### Table 1 Business-as-Usual Heating Cost (’000$)

<table>
<thead>
<tr>
<th></th>
<th>Fuel/Electricity Annual</th>
<th>O/M Annual</th>
<th>Capital</th>
<th>Annualized Capital (8%)</th>
<th>Total Annual</th>
</tr>
</thead>
</table>

CES service charges will be determined at the next stage of project development, which will include marketing, final project definition and completion of a detailed Business Plan. Table 2 presents a preliminary cash flow based on prices equivalent to fuel cost only.

---

2 Unless otherwise noted, all tables in this report show thousands of present-day dollars
Table 2 Projected Cash Flow for CES (’000$)

<table>
<thead>
<tr>
<th></th>
<th>Revenue</th>
<th>Expenses</th>
<th>Margin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The total investment required for the CES would be to install heat extraction equipment at the IPP Mill plus the Energy Centre (collectively referred to as Plant), distribution pipe systems (DPS) and energy transfer stations (ETS) located in each customer building. Table 3 shows the estimated cost of the CES, heating only for the full build-out to serve 25 buildings.

This capital would be invested during the CES construction period, projected to be over a period of 8 years (2010 through 2017). However, even more customers are likely to be connected over time, leading to more investment and correspondingly more customer savings and revenue.

Table 3 CES Capital Cost Estimates (’000$)

<table>
<thead>
<tr>
<th></th>
<th>Plant</th>
<th>Piping</th>
<th>ETS</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital</td>
<td>10,804</td>
<td>16,777</td>
<td>6,063</td>
<td>33,644</td>
</tr>
</tbody>
</table>

The investment to serve the 25 customers identified to date, net of the FGIF grant, is projected to be approximately $23.8 million. The Federation of Canadian Municipalities has indicated interest in lending for this type of project. Owner's equity, debt or other financing will be determined in the Business Plan.

The City would avoid approximately $2.4 million in capital costs for heating plant refurbishments that would otherwise be needed for Market Square and the Canada Games Aquatic Centre. An estimated $1 million in capital could be avoided for heating equipment that would be otherwise needed for the new buildings that are planned for the Coast Guard Site.

The before tax return on investment (ROI), without the grant, is projected:

This is a good rate of return for this type of project, considering the revenue stream would be locked in by firm customer contracts. Typically, District Heating systems earn a ROI in the range of 8-12%.

The Mill has been in business for 90 years and is considered a very reliable and secure source of energy, with the capacity to meet the expected district heating needs.
demand for many years. Notwithstanding, once a district heating system becomes established, it has various options for supply. The supply mix may change over time. In this case, long-term supply alternatives might include:

1) Should the Mill cease production of forest products, its power plant could continue in operation to generate electricity and district heating.

2) An independent biomass fuelled power plant could be established to generate electricity and district heating.

3) The Irving Oil Refinery has possibilities to supply waste heat.

Other Energy Source Options Evaluated

The following alternative energy source options were evaluated: raw sewage, seawater (for cooling), waste heat from buildings and underground thermal energy storage (UTES). UTES is strictly not an “energy source”. It would be a necessary component to a system using waste heat from buildings, and could be an optional enhancement to a seawater cooling system.

The alternative heat energy sources would use heat pumps, which involve electric driven mechanical compression of refrigerants. Heat pumps are limited in their temperature range such that they would need to be supplemented with fossil fuel consumed in boilers to meet the peak heat demand of a district heating system serving a broad customer base that includes older buildings with higher temperature requirements. In this case, it is estimated that supplementary fossil fuel consumption would range up to approximately 70% of the total annual energy.

The consumption of electricity to drive the compressors plus supplementary fossil fuel consumption causes the economic and environmental performance of the alternatives to be not as good as the recommended option.

Furthermore, these options are deemed to have higher risk factors for capital cost and performance.

District Cooling

It is recommended that the City of Saint John proceed cautiously in development of district cooling. The business case is not as good as for district heating and the
potential environmental benefits are not as great. Therefore, the City’s immediate focus will be to develop a GTU based on district heating.

The use of seawater for direct cooling part of the year and pre-cooling and condenser cooling would shorten the payback for district cooling. The City intends to investigate the benefits of using seawater for district cooling by applying it to the cooling of Market Square. This fits with the conversion of Market Square to district heating because “free cooling” from seawater could satisfy the demand except in summer. The chillers would not need to run to produce heat.

Cold UTES could shorten the payback further depending on a number of technical parameters to be established. Prior to proceeding with cold UTES, it is recommended that the GTU conduct field trials of cold UTES as applied to the cooling system of Market Square when using seawater. The principle is to store cold energy from the Harbour from winter to summer at a temperature below the normal temperature of the ground in summer. This cold energy could be used in summer for pre-cooling, i.e. the chillers would still need to run to meet the summer peak demand, but their load would be reduced, i.e. the electricity input required to generate the required cooling energy would be reduced.
2. Definitions and Abbreviations

ATES – Aquifer Thermal Energy Storage

BTES – Borehole Thermal Energy Storage

Btu – British thermal unit; the amount of energy required to raise 1 pound (lb) of water by 1° Fahrenheit (F)

Chiller – a machine for generating cooling energy in the form of chilled water used in air conditioning, its efficiency is often expressed in terms of COP (see below).

CHP - Combined Heat and Power, also known as cogeneration, means simultaneous generation of both useful heat and power in a single process.

Conversion from Degrees (°) Fahrenheit (F) to Celcius (C) – subtract 32 then divide by 1.8; from °C to °F, do the opposite, i.e. multiply by 1.8 then add 32.

COP – Coefficient of Performance, the ratio of thermal output divided by electrical input; used to express the efficiency of chillers or heat pumps.

CE – Community Energy means supply of heating and/or cooling to multiple buildings, also known as District Energy

CES – Community Energy System means a system to supply CE, consisting of three main sub-systems: an Energy Centre, where thermal energy is recovered or generated, DPS and ETS (see definitions below), also known as a District Energy System

Diversified Peak Load – the sum of the peak thermal loads, e.g. expressed in kWt, (i.e. heating or cooling) of all buildings served by a CES multiplied by a factor to reflect the fact that different buildings’ peak demands are not coincident. For district heating, a factor of 0.8 to 0.85 has been found to be appropriate.

Degree Days – a measure of how hot or cold a location has been within a stated period of time, relative to a reference temperature; Heating Degree Days (HDD) may be quoted below 15°C, and Cooling Degree Days above 15°C, if that happens to be the outside air temperature below which heating is generally turned on and above which cooling is turned on.
DPS - Distribution piping system, for heating and/or cooling, consists of supply and return pipes (of the same diameter), together with all necessary valves, vents, drains and fittings, often mostly buried underground, always insulated for heating, between the energy source(s) and customer buildings, with supply and return branches for each customer to the outside walls of each customer building, usually just penetrating through, where they join the inside piping that connects the DPS to the building ETS (see below).

ΔT – delta T – difference in temperature, e.g. as between the supply and return lines of a district heating or district cooling loop.

EFLH - Equivalent Full Load Hours, annual energy consumption divided by peak load; heating EFLH for a building is a function of the local annual outside air temperature profile, the outside air temperature when heating is turned on, domestic hot water consumption and any other non-space heating uses of heat.

ETS - energy transfer stations in each customer building, including heat exchangers, energy meters, controls, valves and inside piping.

Heat Pump – a machine (very similar to a chiller) used for generating useful heat from energy sources that are too low in temperature to be useful directly.

GJ – Giga-Joule, a billion Joules, a unit of heat commonly used in the natural gas industry in Canada.

GTU – Green Thermal Utility, a term used to refer to the entity that will supply DE services in Saint John

HVAC – heating, ventilation and air conditioning; the acronym is an indicator that these functions must be viewed holistically.

kJ – kilo-Joule, a thousand Joules, 1 kJ per second = 1 kW

kWe – kilo-Watts of electricity

kWt - kilo-Watts thermal, heat or cooling, depending on context

L/s – litres/second; 1 L/s = approximately 13.2 Imperial Gallons per Minute (IGPM)
MBH – a thousand Btu per hour, commonly used in the HVAC industry to express the capacity of boilers; can refer to input fuel consumption or output of thermal energy

m – metres; approximately 1,609 m = 1 mile

m² – square metres, 1 m² = 10.746 square feet, 10,000 m² = 1 hectare

MMBtu – 1 million Btu

MWe – Mega-Watts of electricity -

MWt – Mega-Watts thermal, heat or cooling, depending on context

MWhe – Mega-Watt hours of electricity

MWht – Mega-Watt hours thermal, heat or cooling, depending on context; 1 MWht = 3.6 GJ = 3.412 MMBtu

(kWe, kWt, MWe, MWt and MBH are units of peak load or capacity, while kWhe, kWht, MWhe, MWht, MMBtu and GJ are units of energy)

Primary or Primary Side – refers to the hot water and/or chilled water system on the supplier’s side of the ETS

psig – pounds per square inch gauge, used, e.g., as a measure of steam pressure

Secondary or Secondary Side – refers to the hot water and/or chilled water system on the customer’s side of the ETS, i.e. to distribute space heating or domestic hot water within the building – this is not greatly changed as a result of connection to DE and remains the responsibility of the building owner/operator – some changes to enhance efficiency may be suggested or required by the CES operator, such as replacing 3 way valves with 2 way valves and/or installation of VFD’s

Ton – a unit of cooling demand or capacity commonly used in the HVAC industry; 1 ton = 3.516 kWt or 1 MWt = 284 tons

Ton-hour – a unit of cooling energy; 1 ton-hour = 3.516 kWht or 1 MWht = 284 ton-hours

Tonne – a unit of mass = 1,000 kilo-grams
UTES – Underground Thermal Energy Storage (includes ATES or BTES and other types, hot or cold, seasonal or daily)

VFD – variable frequency drives, efficiently provides for pumps to vary water flow according to demand in heating and cooling systems on the primary and/or secondary side
3. Potential Community Energy System Demand

3.1 Original Phase 1 Customers

The RFP scope of work stipulated that the following buildings were to be used as a baseline to develop the conceptual design of the CES:

Existing Buildings

- Market Square and Hilton Hotel
- Canada Games and Aquatic Centre (CGAC)
- Harbour Station Arena

New Developments (all expected in-service in 2012)

- New Irving Oil Headquarters (HQ)
- Police Headquarters (HQ)
- Law Court
- Coast Guard Site

For the existing buildings, energy audits (references 2, 3 and 4) were reviewed and site visits, inspections and evaluations of the HVAC systems made. Meetings and discussions were conducted with the mechanical engineers responsible for the HVAC design of the new developments, except Coast Guard Site for which there is no design as yet. Discussions were conducted with the development manager for the Coast Guard Site.

The suitability of each of the above listed buildings to connect to CE was assessed, including their thermal energy demand and potential avoided cost of capital and operating cost. Comments are made below on each building followed by a summary and conclusions.

Market Square/Hilton Hotel

These comments apply to the combined heating and cooling systems of Market Square and the adjacent Hilton Hotel, which is served from Market Square.
The HVAC system is suitable for connection to district heating because it is a low temperature hydronic system. The low supply and return temperatures mean that most of the district heating energy demand for Market Square specifically can be supplied from waste or low cost heat.

Also, the energy audit (reference 2) recommended replacement of the existing electric boilers with a gas fired condensing boiler and isolation of thermal storage from the internal distribution system, estimating the total capital cost of these improvements to be approximately $600,000. This expenditure would be avoided by connection to district heating.

Most of the heat is produced in heat recovery chillers, which are theoretically very efficient. But there are indications this system is difficult to operate correctly. The chillers are running more than would be necessary if they were producing only cooling. Therefore, it is estimated that district heating would save 1.4 million kWh per year in total from the chiller plant and electric boilers.

Market Square is one of the few buildings in Saint John possibly suitable for district cooling if a district cooling system could be developed economically. It has old chillers and appears to use year-round cooling, possibly because of the intensive lighting load of the retail areas. However, since heating and cooling seem to be supplied to the same final elements concurrently, the true year-round cooling load is uncertain.

Along with connection to district heating, measures should be taken so that cooling does not need to be supplied at the same time as heating. If any cooling is needed in the heating season, it should be satisfied with some form of free cooling. A seawater cooling system would satisfy this requirement and it is understood that is the City’s intent.

The energy audit recommended replacement of one of the 400 ton heat recovery chillers with a more modern efficient unit. A more solid business case for either district cooling or new chillers at Market Square could be developed after it had been operated on district heating for at least a year, with or without the assistance of seawater cooling.
Canada Games and Aquatic Centre (CGAC)

CGAC currently consumes approximately 12,000 GJ per year of natural gas in central boilers for space heating, pool heating and domestic hot water.

A refurbishment of this system was recently recommended (reference 3) for an estimated capital cost of $1,800,000 related to the heating system.

The natural gas bills and refurbishment project could both be avoided by connection to district heating.

CGAC has no cooling system.

Harbour Station

Harbour Station is a sports arena that is rated as marginal suitability for DE because space heating and cooling are accomplished mostly through a series of 40 distributed heat pumps, backed by two 400 kWe auxiliary electric boilers and heat recovery from a 150 ton ice-making chiller.

Domestic hot water is pre-heated by heat recovered from the ice-making chiller, then boosted in temperature by the auxiliary electric boilers. There are also distributed electric domestic hot water tanks.

Some electricity consumption could be saved through elimination of the auxiliary electric boilers and more efficient operation of the heat pumps, but it is doubtful this would be sufficient to justify extending the heating DPS to Harbour Station from the Law Court, installing an ETS and making the necessary modifications on the secondary side.

The energy audit (reference 4) allocated approximately 950 MWhe consumption per year for space heating and domestic hot water. The total value of this electricity, taking into account demand charges, would be in order of $95,000 per year, but a lot of that would not be displaced (i.e. the portion for the heat pumps and distributed domestic hot water tanks). Therefore, the recommendation is that Harbour Square not be connected to district heating.

Harbour Station is rated a poor prospect for district cooling because it already has space cooling equipment installed in the form of distributed heat pumps, which the
energy audit did not recommend to be replaced or refurbished. The duty of the 150 ton chiller is to make ice, and this function cannot be displaced with district cooling. District cooling cannot offer capital avoidance for Harbour Station. Capital avoidance is usually necessary to justify district cooling in Canada.

New Developments

As a general rule, new developments tend to be good prospects for CE because they can avoid the capital cost of installing on-site boilers, chillers or heat pumps. They also have relatively low temperature heating systems, which maximizes the use of waste or low cost heat delivered through a district heating system.

In this case, the heating plant capital can be saved for the new development only if the Energy Centre and initial DPS can be assured of completion prior to the need dates of the new developments and the building owners are willing to rely on the CES to meet their initial need dates.

Irving Oil HQ

During the course of this study, development of the new Irving Oil HQ was indefinitely postponed. Although discussions with the HVAC engineers indicated that it would have been a good prospect for CE, no further comments are offered on this project specifically.

The site is excellently located for future development of some kind; therefore, the loads estimated for the new Irving Oil HQ will be taken into account in sizing the DPS, but not in the immediate Business Plan.

Police HQ

Distributed heat pumps backed by a gas fired boiler are currently planned for the new Police HQ, which is a City controlled project. The estimated annual consumption of energy commodity inputs for heating are 2,700 GJ of natural gas and 164,000 kWh of electrical energy. The annual electricity consumption allocated to cooling is estimated to be 53,000 kWh.

Although the HVAC system of the Police HQ has been designed, it is understood the City is willing to request contractors to offer the alternative of a 4-pipe fan coil unit heating and cooling system. Heating would be provided by district heating and
cooling by a small, efficient central chiller/cooling tower system. The HVAC capital cost would be lower, the cost of natural gas would be eliminated and the cost of electricity reduced.

Replacement of the dispersed heat pumps with simpler fan coil units reduces the need for maintenance personnel to access the building. The ETS could be in a small, enclosed room with access restricted to the CES operator and only directly from the outside. Similarly, the central chiller would be housed in a restricted space and the cooling tower would be external to the building. These features would enhance security, which the Police Commission will appreciate.

**Law Court**

The new Law Court, which is a Province of New Brunswick project, will have a low temperature hydronic HVAC system that is estimated to require energy commodity inputs of 6,900 GJ per year of natural gas for heating and 70,000 kWh of electricity for cooling per year.

The capital cost of the boiler and the consumption of natural gas can be avoided by district heating.

The cooling load is rather small (230 tons) and the owners are planning to install a very efficient chiller. During this study, FVB suggested a more direct pipe route to the Law Court, which may make supply of district cooling more feasible. However, it is recommended that the district cooling project as a whole be approached cautiously. Provision of district cooling to the Law Court is seen as a possible future development, rather than an immediate priority.

**Coast Guard Site**

This brown-field redevelopment will be composed of 9 separate buildings: including 2 existing heritage buildings to be leased back to the Canadian Coast Guard, an office block, a hotel and 5 mid-rise condominiums. The office is the first phase planned for construction completion in 2012. Other phases will follow as dictated by market conditions.
Saint John Community Energy System Design Recommendation

Subject to more detailed study, the 2 existing heritage buildings are considered possible prospects for CE, but in the “currently unknown additional” category. Their relatively small size meant they were not a critical focus of this study.

For the 7 new buildings, design can be optimized with district systems; (1) saving capital from elimination of on-site heating and cooling systems and (2) using a low temperature hydronic heating system to maximize use of waste heat.

If district cooling is developed later, the new buildings on this site would be candidates, because they could avoid capital cost for chillers and cooling towers and they are close to the envisaged site of the possible chiller plant.

**Summary and Conclusions Re Original Phase 1 Buildings**

After elimination of Harbour Station and the new Irving Oil HQ, the remaining customers aggregate approximately 130,000 m² (1.4 million square feet), 30% short of the RFP goal of 2 million square feet connected in Phase 1. The total estimated diversified heat load would be 5.6 MWt; by itself, this would be a relatively small district heating system. At the same time, the GTU (i.e. low carbon) philosophy desired by the City of Saint John will be quite capital intensive.

Although further new development is envisaged in uptown Saint John, the actual rate and extent of additional new development is too uncertain to use as a basis for planning a DES. Therefore, in order to project reasonable economies of scale for district heating in a Business Plan, it is proposed that Phase 1 of the CES include other existing buildings, which the RFP requested be identified for future phases.

The remaining original Phase 1 customers have an estimated total cooling load of 4.1 MWt (1,100 tons). Cooling EFLH in Saint John has been estimated to be 525. Therefore, the annual cooling energy sales to these customers would be low, relative to other Canadian cities where district cooling is being implemented.

Other uptown buildings that have central chiller systems may be prospects when they need to replace equipment.

The full build-out potential for each of district heating and district cooling are discussed separately in more detail in the following subsections.
3.2 Potential for District Heating

The RFP scope of work specified that additional customers be identified for future phases. In response to that, another 33 buildings in Saint John were visited (all above 1,500 m² in size and mostly non-industrial in use – see Figure 1). Information was assembled on their floor area, use, type of heating system and, where possible, fuel consumption, installed heating and cooling equipment capacities and HVAC design temperatures. Basic building data and their locations are shown on Figures 2 and 3.

Notes from the preliminary building surveys are attached in Appendix 2. More detailed surveys will be required during the engineering stage.

From this data and FVB's general experience, energy intensities and hence load and energy consumption were estimated.

The list of prospective customers was thereby increased from 5 to 25. A preliminary system phasing plan was developed. The criteria for customer identification were; (1) reasonable proximity to the envisaged DPS and (2) hydronic heating systems (with the exception of two steam heated satellite buildings to St Joseph's hospital, for which conversions are proposed).

Taking a long-term view, it may become economic to connect even non-hydronic buildings. It is also likely there are other prospects not identified in this preliminary survey, including new as yet unknown developments. Therefore, for the purpose of the DPS master plan as it affects hydraulic analysis and DPS costing, even the non-hydronic buildings will be taken into account that are in reasonable proximity to the envisaged DPS.

Concurrent with the efforts to define customer demand, suitable energy source options were being investigated and it was recognized that waste heat from the IPP Mill was the best option available. Identification of this preferred energy source, 4 kilo-metres by road west of uptown, influenced system planning (see System Overview Pipe Sizing, Figure 4).

3 All figures including long lists, maps, schematics and charts are in Appendix 1
Saint John Community Energy System Design Recommendation

Since a major up-front capital investment in a hot water transmission loop would be required, it became economically very desirable to assemble as much load as possible that could be connected as soon as possible, i.e. located close to the envisaged DPS.

There are 3 hydronic buildings uptown very close to Market Square; i.e. the Centrebeam Building, Brunswick House and City Hall. And there are 5 potentially suitable customers along the pipe route from the Mill to uptown: Harbourview High, New Brunswick Museum, Lord Beaverbook Arena, Fort Howe Hotel and Hillyard Place.

Therefore, it is recommended that Phase 1 of the district heating project include the 5 customers identified in the RFP for Phase 1 that were deemed suitable (as discussed individually above in subsection 3.1), the 3 additional nearby uptown customers and the 5 customers along the supply route.

The proposed connection dates, peak load and annual energy consumption of recommended Phase 1 CES customers are shown in Table 4.

Table 4 Recommended Phase 1 Customers

<table>
<thead>
<tr>
<th>Map#</th>
<th>Connection Year</th>
<th>Name</th>
<th>kWt</th>
<th>MWht</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2011</td>
<td>Police HQ</td>
<td>400</td>
<td>720</td>
</tr>
<tr>
<td>6</td>
<td>2011</td>
<td>Law Court</td>
<td>800</td>
<td>1,440</td>
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<td>2012</td>
<td>Market Square/Hilton Hotel</td>
<td>2,000</td>
<td>3,461</td>
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<tr>
<td>10</td>
<td>2012</td>
<td>City Hall</td>
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<td>2012</td>
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<td>7</td>
<td>2013</td>
<td>Coast Guard Site</td>
<td>2,500</td>
<td>4,500</td>
</tr>
<tr>
<td>14</td>
<td>2013</td>
<td>Harborview High</td>
<td>600</td>
<td>1,080</td>
</tr>
<tr>
<td>19</td>
<td>2013</td>
<td>NB Museum</td>
<td>100</td>
<td>180</td>
</tr>
<tr>
<td>24</td>
<td>2013</td>
<td>Lord Beaverbook arena</td>
<td>300</td>
<td>540</td>
</tr>
<tr>
<td>22</td>
<td>2013</td>
<td>Fort Howe Hotel</td>
<td>100</td>
<td>180</td>
</tr>
<tr>
<td>23</td>
<td>2013</td>
<td>Hillyard Place</td>
<td>300</td>
<td>540</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Totals</td>
<td>10,200</td>
<td>19,142</td>
</tr>
</tbody>
</table>

The Coast Guard Site will not all be completed for connection by 2013; the full anticipated demand (load and energy) is listed above for planning purposes.

These 13 customers aggregate 2 million square feet per the goal of the RFP for Phase 1. It is suggested the connections be staggered between 2011, 2012 and 2013. If it is desired to attempt to avoid heating plant capital for the new developments
(Police HQ, Law Court and possibly the first stage of the Coast Guard Site) some urgency is needed in construction of the Energy Centre to provide an interim supply system as early as the winter of 2011/12 (e.g. for construction heat). This would be provided from the Energy Centre in the event that it takes until 2012 to complete the 4 kilo-metre supply line from the Mill.

Fuel for the Energy Centre would be saved by commissioning the system with the smallest loads possible. Available local resources may also make it necessary to spread out in time the work of installing 13 ETS, together with necessary secondary side improvements. It is not absolutely critical that all 13 customers be in-service exactly by the end of 2013, but it is clearly financially advantageous to serve as much load as possible as soon as possible after the capital for the Mill supply line has been invested.

From inspection of the relative locations of suitable district heating customers, the green circles on Figure 3, a number of early expansion options can be identified as listed in Table 5. The loads and locations of these customers relative to the energy sources allow for a preliminary DPS route and sizing, as illustrated in Figure 4 (for heating and cooling), to be confirmed with further engineering at the next stage.

**Table 5 Future Phases for District Heating**

<table>
<thead>
<tr>
<th>Map#</th>
<th>Connection</th>
<th>Name</th>
<th>kWt</th>
<th>MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>2014</td>
<td>300 Union</td>
<td>900</td>
<td>1.709</td>
</tr>
<tr>
<td>16</td>
<td>2014</td>
<td>Prince Edward Square Mall</td>
<td>900</td>
<td>1.694</td>
</tr>
<tr>
<td>17</td>
<td>2014</td>
<td>Prince Edward Square Apts</td>
<td>700</td>
<td>1.494</td>
</tr>
<tr>
<td>26</td>
<td>2015</td>
<td>St Joseph's Hospital</td>
<td>1500</td>
<td>3.713</td>
</tr>
<tr>
<td>27</td>
<td>2015</td>
<td>Cathedral</td>
<td>200</td>
<td>0.36</td>
</tr>
<tr>
<td>28</td>
<td>2015</td>
<td>Saint Vincent's School</td>
<td>1200</td>
<td>2.160</td>
</tr>
<tr>
<td>25</td>
<td>2016</td>
<td>Customs Building</td>
<td>400</td>
<td>0.720</td>
</tr>
<tr>
<td>11</td>
<td>2016</td>
<td>Saint John High</td>
<td>600</td>
<td>1.080</td>
</tr>
<tr>
<td>15</td>
<td>2017</td>
<td>City Market</td>
<td>100</td>
<td>0.180</td>
</tr>
<tr>
<td>18</td>
<td>2017</td>
<td>Imperial Theatre</td>
<td>200</td>
<td>0.360</td>
</tr>
<tr>
<td>13</td>
<td>2017</td>
<td>St Malachy's High</td>
<td>600</td>
<td>1.080</td>
</tr>
<tr>
<td>20</td>
<td>2017</td>
<td>Sydney Arms</td>
<td>100</td>
<td>0.180</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Totals</strong></td>
<td>7,400</td>
<td>14.729</td>
</tr>
</tbody>
</table>

Building #’s 12 – 17 are suggested as the next immediate progression because they also lead to #’s 26 – 28, thereby yielding an additional 5 MWt of load connected within a couple of years.
Part of St Joseph’s Hospital, the Cathedral and Saint Vincent’s School will require conversion from steam to hot water heating. This work might be undertaken prior to the DPS expansion. Building #’s 26 – 28, with related owners, might have 1, 2 or 3 ETS between them. These details can be decided later.

The total district heating potential for all phases per Tables 4 and 5 is therefore 17.6 MWh of connected load. Using a factor of 85%, the diversified peak load would be 17.6 * 0.85 = approximately 15 MWh. The total annual thermal energy deliveries add to approximately 33,870 MWh and this is in accordance with the heating load duration curve analysis for the conceptual Saint John district heating system based on these 25 customers, as depicted in Figure 12.

It is expected that the district heating system will eventually expand beyond the customers listed herein. There are doubtless other suitable existing buildings that have not yet being surveyed (e.g. Chippen Suites, Vitos Restaurant and offices on Union adjacent the Parking Garage) and new development potential. As the DPS expands it moves closer to more buildings, hence possibly more customers.

The University of New Brunswick (UBN) and Saint John Regional Hospital (SJRN) both have large heat demands and are located approximately 3,800 metres north of the envisaged DPS. At some time, it may be worth integrating them with the Saint John GTU. However, since this would be complex and major undertaking, predicated on the prior success of the Saint John GTU, it is best left aside until that success has been achieved.

3.3 Potential for District Cooling

From the building surveys, the remaining original Phase 1 buildings suitable for district cooling have approximate cooling demands as summarized in Table 6.

<table>
<thead>
<tr>
<th>Map#</th>
<th>Name</th>
<th>Tons</th>
<th>kWt</th>
<th>MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Police Headquarters</td>
<td>85</td>
<td>300</td>
<td>158</td>
</tr>
<tr>
<td>6</td>
<td>Law Court</td>
<td>228</td>
<td>800</td>
<td>420</td>
</tr>
<tr>
<td>1</td>
<td>Market Square/Hilton</td>
<td>302</td>
<td>1,062</td>
<td>1,275</td>
</tr>
<tr>
<td>7</td>
<td>Coast Guard Site</td>
<td>520</td>
<td>1,829</td>
<td>860</td>
</tr>
<tr>
<td></td>
<td>Totals</td>
<td>1,135</td>
<td>3,991</td>
<td>2,812</td>
</tr>
</tbody>
</table>
Calculation of the estimated cooling energy shown in Table 6 takes into account building specific features and the estimated cooling EFLH of 525 for Saint John, derived from weather data and a building balance point of 15°C (i.e. cooling is turned on above 15°C), except for the Market Square/Hilton, where the EFLH is estimated to be 1,200.

City Hall, Brunswick House, the Mercantile Building, the Aliant Dial building, and Brunswick Square are all located within a reasonable proximity of the envisaged district cooling loop (see map, Figure 5) and all have chillers of a size such that they may be interested in a district cooling service at some time in future. Their estimated cooling demands are listed in Table 7. Caution: at this stage, these figures should be viewed as very preliminary. Aliant Dial has a free cooling system, and it has so far not been confirmed exactly how much electricity it uses to generate cooling energy.

Table 7 Potential Cooling Customers Among Existing Uptown Buildings

<table>
<thead>
<tr>
<th>Map#</th>
<th>Name</th>
<th>Tons</th>
<th>kWt</th>
<th>MWhr</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>City Hall</td>
<td>236</td>
<td>828</td>
<td>435</td>
</tr>
<tr>
<td>9</td>
<td>Brunswick House</td>
<td>170</td>
<td>597</td>
<td>313</td>
</tr>
<tr>
<td>40</td>
<td>Mercantile Building</td>
<td>313</td>
<td>1,100</td>
<td>577</td>
</tr>
<tr>
<td>35</td>
<td>Aliant Dial Equipment Room</td>
<td>313</td>
<td>1,100</td>
<td>577</td>
</tr>
<tr>
<td>34</td>
<td>Brunswick Square</td>
<td>1,195</td>
<td>4,200</td>
<td>2,204</td>
</tr>
<tr>
<td></td>
<td>Sub-total of above (Phase 2)</td>
<td>2,226</td>
<td>7,825</td>
<td>4,107</td>
</tr>
<tr>
<td></td>
<td>Totals – Phases 1 and 2</td>
<td>3,381</td>
<td>11,816</td>
<td>6,919</td>
</tr>
</tbody>
</table>

The best chance of selling district cooling to the buildings in Table 7 would be if or when they need to replace their chillers. The challenge is to have a viable district cooling alternative ready when that time comes, and this challenge is made more difficult by the fact that they are not likely to happen to need chiller replacements all at the same time.

If the GTU could capture all of the potential customers per Tables 6 and 7 for a total connected load of approximately 12 MWh (4,500 tons), the district cooling system would have reasonable economy of scale. There would be a greenhouse gas reduction benefit; but, in perspective, it would be only about 1/5th of that of the potential district heating project.
And if the customers were willing to pay service fees approximately equivalent to their full avoided cost, including capital replacement, using seawater cooling, the economic payback might be in the order of 20 years (as laid out in more detailed in Section 6, Financial Analysis).

Given the uncertainties inherent in these propositions, a careful, step-by-step approach is recommended to reduce uncertainty prior to committing the district cooling component of the GTU. Installation a seawater cooling system for Market Square only would be a good way to gain a better understanding of the potential for seawater cooling in Saint John.
4. Temperature Requirements for District Heating

In addition to collecting information allowing estimates of load and energy consumption, the building surveys also noted design temperatures (supply and return) of HVAC systems. The district heating system must be capable of meeting the requirement of the highest temperature needed by any customer on the secondary side and the blended return temperature on the primary side will determine how much energy can be recovered from any given energy source. In the case of this study, it turned out that the temperature requirements had a major influence on selection of the preferred energy source. Therefore, this issue is discussed at some length below, prior to considering the relative merits of the various energy sources.

There is a trend in the design of modern district heating systems to use as low supply and return temperatures as possible in order to maximize use of low environmental impact energy sources. There is an economic trade-off between that objective and capital cost minimization through maximization of ΔT between supply and return, bearing in mind severe practical limitations on the possibilities for lowering return temperatures of older buildings.

Whereas the Phase 1 buildings envisaged in the RFP represented approximately 2 million square feet of floor space, deletion of Harbour Square and the previously planned new Irving Oil HQ reduced this to 1.4 million square feet. The City's goal for the GTU as expressed in the RFP is to eventually connect up to 6 million square feet of floor space. This would require a large portion of the load eventually consisting of existing, older buildings.

About two-thirds of the Phase 1 load per Table 4 can be regarded as low temperature and the CES primary return temperature (a blend of these building's design secondary return, with 5°C approach) is anticipated to be approximately 65°C on peak, possibly lower in the off-peak seasons. This is still sufficiently low to make some use of resources such as waste heat at the Mill, or heat pumps, with outputs around 70°C; but the fraction of energy that can be recovered from these low temperature resources would be limited to around 30% (see Figure 6) at a supply temperature of 95°C, somewhat less at higher supply temperatures. It could
be more if lower temperatures can be achieved and maintained, but this cannot be prudently assumed at this time.

Other CES serving older buildings have been designed to supply up to a maximum of 120°C. So far, in Canada, it has been only those CES that will serve entirely new construction that have been designed with supply temperatures as low as 95°C. Many older buildings including those in Saint John have secondary supply temperatures of 82°C (180°F) for peak conditions. The primary supply temperature should ideally be well above the secondary for a wide ΔT across the ETS and DPS, in order to reduce sizes and capital costs.

In the case of supply of uptown Saint John from the IPP Mill, the design intent would be to keep the temperature as low as possible, aiming to be not many degrees, if any, above the maximum that IPP are willing to supply, which is 95°C. Since IPP have indicated unwillingness to supply more than 95°C, this removes the possibility of dropping a pipe size (from 250 mm to 200 mm) on the transmission loop from the Mill to uptown, which is the largest part of the DPS. Therefore, the only savings from higher ΔT would be in the uptown portion of DPS and ETS.

Higher supply temperatures would be achieved to the extent necessary by polishing the supply from the Mill, or from heat pumps, using standby boilers. Fuel costs and greenhouse gas emissions will be increased proportionally to the extent standby boilers are used.

Analysis based on the impact of different supply temperatures, together with corresponding capital cost impact estimates, suggests that keeping the supply temperature down will save fuel and lower greenhouse gas emissions. However, at this stage of project conception, FVB recommends keeping open the possibility of using higher temperatures if necessary. Therefore, although hydraulic analysis has been performed assuming 98°C, any registration process with regulatory authorities ought to allow for operations up to 120°C if necessary. This recommendation is made subject to further engineering and consultation with regulatory authorities as necessary.

To be clear, this comparative feasibility study assumes 98°C primary supply but stresses that the possibility to use higher temperatures ought not to be foreclosed.

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Buildings do not need their highest design temperature year-round, only on the coldest days. In order to maximize use of low temperature resources and minimize DPS losses, it is a common, proven practice in modern district heating to set-back the set-point temperature in accordance with the outside air temperature using a curve, which for a 98°C maximum temperature system would be as shown in Figure 7.

The set-back schedule is based on the fact that building heating systems are usually turned off when the outside air temperature is at 15°C or more, allowing for the internal gains from people, lighting and computers. At that point and above, it is only necessary to heat domestic hot water to 60°C to meet code requirements for storage tanks. A primary supply temperature of 65°C is normally sufficient for this. As the outside air temperature falls below 15°C, primary supply temperature is ramped up to put heat into the building only as fast as necessary to offset increasing heat losses as the outside temperature falls.

The distribution of hours at different outside air temperatures in Saint John in a typical year is shown in Figure 8. Application of the set-back schedule depicted in Figure 7 to the distribution of hours in Figure 8 results in a projected typical distribution of hours at different supply temperatures as shown in Figure 9. The data set in Figure 9 was then used to estimate the potential for energy recovery from different source temperatures as discussed above.

We have considered other possibilities where heat pumps are designed to achieve outputs of 80°C by lifting from evaporation temperatures of around 30°C, e.g. using building waste heat from chillers as an energy source in combination with UTES. Heat pumps extracting heat from this higher temperature source might thereby provide a higher portion of the overall heat energy (than, say, heat pumps from a lower temperature source such as raw sewage). However, there are other overwhelming factors that limit the amount of energy that can be generated from building waste heat, as discussed further in Section 5.

Unlike the heat pump based energy source options, the industrial waste heat opportunity in Saint John at the IPP Mill has another supplementary option, which is low pressure (LP) steam extracted from its CHP units. This energy source has the technical capability of raising the temperature well above 100°C. However, the
Mill's energy manager, who will determine the final configuration that is acceptable to their process, has expressed a very strong preference to limit the supply temperature to 95°C.

The variable cost of the LP steam is quite low. Further raising the temperature slightly above 95°C to around 98°C using the Energy Centre would have a minor cost impact, raising fuel costs by about $22,000/year and greenhouse gas emissions by about 50 tonnes per year and incurring about 143 hours of run-time at the Energy Centre.

There are other issues to recognize. Accepting a supply temperature at a maximum of 95°C from the Mill with a return temperature of 65°C limits the ΔT on the transmission loop to 30°C, which would limit the capacity of a 250 mm (10 inch NPS) transmission loop between the Mill and uptown to 18 MWt. This is not a serious limitation on the Saint John CES potential because (as may be deduced from the energy versus load duration curve, Figure 14), 18 MWt base load capacity would still provide 90% of the energy for a CES with a peak demand of more than 30 MWt, which is ample for the potential customers identified so far, even allowing for significant additional load as yet not identified and it would represent connection of approximately 6 million square feet of floor space, per the City's ultimate goal for the GTU.

During the off-peak season, if the return is still as high as 65°C and the supply were dropped to 70°C, i.e. 5°C ΔT, the transmission line capacity would fall to around 3 MWt, which would probably still be sufficient for the overall system off-peak demand. The branch lines and ETS sizing would take into account flows at the expected range of ΔT and corresponding building loads. Of course, the ΔT could still be increased by a few degrees as required using the LP steam.

The 5 customers, totaling 1.3 MWt in load, along the supply line between the Mill and uptown, upstream of the Energy Centre, would not have the benefit of a supply temperature raised by the boiler. For these customers, the ETS and HVAC modifications would be designed to use the temperatures available from the Mill.

Similar strategies can be employed for "outliers" anywhere on the system as an alternative to the brute force option of raising the temperature using the boilers.
The business case for each can be evaluated on its individual merits, together with environmental benefits and possibly additional government funding applied for on behalf of the buildings for energy efficiency retrofits, also citing environmental benefits.

In conclusion, there is little problem for the industrial waste heat option supplying the temperature needs of the identified customer base in Saint John, by polishing with LP steam and peaking boilers. But the uptown located heat pump options, without the benefit of top up with LP steam, would need significant supplementation with fossil fired peaking boilers and that would provide less economic and environmental advantage versus BAU.

We recognize that the client will still strive for temperatures as low as possible for as many hours as possible in order to minimize burning natural gas and thereby fulfill the vision of the GTU.
5. Energy Source Options

The scope of this study required evaluation of the following energy source options, which had been suggested in previous studies (references 5 and 6).

Option A – Industrial Waste Heat

Option B – Raw Sewage

Option C – Saint John Harbour Water

Option D – Waste Heat from Buildings

Option E – Cold and Hot Underground Thermal Energy Storage (UTES)

5.1. Industrial Waste Heat

*Precedents and Preliminary Comments*

Industrial waste heat has been successfully used on a large scale in European district heating systems for many years. For example, FVB has been involved in at least half a dozen projects of this type in Sweden (see reference list, Appendix 3).

When the available heat is truly a waste product, the incremental cost to use it for district heating is mainly a capital investment in long-life assets such as heat exchangers, pumps and pipes, with very little on-going operating and maintenance cost. Displacement of fossil fuel and/or electricity that would otherwise be consumed results in a lower carbon footprint for the community.

Some of the technical issues to be examined when considering this option are:

1) Distance from the source to the customers

2) Capacity of the energy source in relation to demand

3) Temperature of the resource in relation to the required supply and return temperatures used in the DES, and,

4) Availability; i.e. is it constant or intermittent or cyclic, e.g. daily or seasonal.

*Evaluation of Opportunities in Saint John*

Representatives of two major local industrial facilities have confirmed the potential availability of waste heat.
1) Irving Pulp and Paper Limited mill (4 kilo-metres west of uptown)

2) Irving Oil Refinery (6 kilo-metres east of uptown)

Discussions have been held with representatives of Irving Pulp and Paper Limited to the extent that a concept for supply from this Mill is included as part of the CES design recommendation, as outlined below.

Less extensive discussions have been held with representatives of Irving Oil. From those discussions, it is believed that the refinery probably has waste heat that would be useful for district heating, but this has not been confirmed and defined as well as the Mill option.

Moreover, it is expected that access to waste heat at the refinery would be more expensive than from the Mill due to both the longer distance from uptown and to the more spread-out character of refinery operations. For example, condensate from heat tracing of outdoor equipment (pipes, tanks and such like) was mentioned as one possible source of waste heat because it is not all returned to the steam plant.

Since the Mill, by itself, has suitable and sufficient waste heat for the size of CES currently foreseen in Saint John per Section 3, pursuit of supply from the refinery is not a priority. But the refinery should be kept in mind as a potential alternative source.

_Irving Pulp and Paper Limited_

There are 3 possible sources of waste heat at the Irving Pulp and Paper (IPP) mill:

1) Process Heat Recovery

2) Boiler Exhaust

3) Plant Effluent

_Process Heat Recovery_

The Mill recovers process heat off various coolers for internal re-use, but it has excess that cannot be used within the Mill and is discharged. The stream that is discharged has an estimated flow of approximately 320 L/s that is currently at a temperature of
71°C (160°F). This flow is constant year-round, except during the plant shutdown for maintenance of 1 week that occurs in the spring or fall every 18 months.

Heat energy could be extracted from the wasted process heat recovery stream by means of simple plate and frame heat exchangers and supplied to a district heating system at temperatures up to 70°C. The heat exchangers would be sized in phases to match the required peak demand flow rates, with design temperatures of 71°C entering the hot-side and 65°C to 70°C on the cold side.

The portion of the total district heating thermal energy requirement in Saint John that can be supplied from this low temperature resource (similar in temperature to the output of a heat pump) is a function of the primary supply temperature set-back schedule and was determined by analysis discussed in Section 4 to be approximately 30% for a maximum 98°C district heating supply temperature.

Fortunately, there is another suitable and sufficient energy source at the Mill, namely LP (10 psig) steam that can be extracted from steam turbines, that can supply the remaining 70% of the energy required above 70°C.

Extraction of LP steam to use in a steam to hot water converter is not a high capital cost retrofit. Furthermore, we may reasonably assume this will enhance the energy efficiency of the Mill operation.

If there is any net incremental variable cost to the Mill, it should be, at most, a small cost. A fuller description of this process is as follows.

The boilers generate high pressure steam to drive two power turbines, a 14 MWe extraction condensing turbine and a 17 MWe extraction back-pressure turbine. LP steam is extracted from each turbine and supplemented with flow from the exhaust of the back pressure turbine for use in the Mill. This is a classic steam turbine CHP train such as found in many industrial facilities, especially pulp and paper mills and sugar refineries.

The LP steam is an economic source of heat energy because part of the cost of the fuel required to raise the steam is recovered in the value of electricity generated as the steam expands from its high pressure out of the boiler to a lower pressure near the back end of an extraction turbine or exhausting from a back-pressure turbine.
Also, in this case, the main fuels are waste products from the mill process itself, i.e. black liquor, bark and waste wood. Like many pulp and paper mills and sugar refineries, IPP has optimized its CHP and mill process to the point where it co-fires natural gas at times. Therefore, steam that is extracted, e.g. for district heating, may require the input of more co-fired natural gas. This would be the incremental cost of the heat energy thereby produced. So there may be some fossil fuel cost and some incremental greenhouse gas emissions, but much less than the alternative of generating the same amount of heat energy in a typical in-building natural gas boiler. The exact pricing of heat energy from the Mill will require attention, but is expected to be favourable for both parties.

As a condition of providing heat for district heating, IPP stipulated that they be responsible for designing, building, owning and operating the heat extraction systems and hot water piping inside the mill. This would be a practical approach and acceptable provided the GTU had the right to review and approve the conceptual design to ensure its suitability to provide the required level of reliability, efficiency and capacity, which is not expected to be an issue. FVB's preliminary concept of the district heating process flow, incorporating the IPP Mill heat source is sketched in Figure 10 (SK-9291-01) and more process concept details are shown in Figure 11 (SK-9291-03).

Approval of Common Council to award contracts for supply of materials and construction of the major portion of the DPS between the Mill and uptown should be conditional upon completion of at least a Memorandum of Understanding leading to a suitable Energy Supply Agreement, and this should be undertaken in the next stage of project development.

In order to access this source of heat energy the other major project element required (in addition to the Energy Centre, uptown DPS and ETS that are common to all heating options) would be a hot water transmission loop from the Mill to the Energy Centre. Approvals will be required to carry the pipes across the Railway Bridge now under the ownership of NB Southern Railway (another division of the Irving business holdings). This will require a special study and design for the bridge crossing, involving assistance from a structural engineer.
According to preliminary consideration, the portion of the hot water transmission loop that would be incremental for supply from the Mill (as opposed to other energy sources that would be located uptown) would be approximately 4,200 trench metres in length.

The complete DPS would comprise an estimated 5,700 trench metres in Phase 1, expanding to 7,800 trench metres at full build-out. The optimal pipe size of the trunk main between the Mill and the Energy Centre has been determined from preliminary analysis to be 250 mm (10 inch NPS), with an outside diameter, including insulation of 400 mm (16 inches). Branch lines, supply and return, would be smaller diameter as indicated on Figure 4, System Overview Pipe Sizing. All of these preliminary calculations are subject to more detailed study at the preliminary and detailed design stages.

Operating at a peak $\Delta T$ of 30°C (95°C supply, 65°C return), the 250 mm nominal pipe size will conservatively deliver up to 18 MWt. The peak diversified load identified to-date is 15 MWt and the potential identified to date including non-hydronic buildings close to the DPS is 20 MWt.

It is expected that some of the non-hydronic load would be connected in the long run, as well as others that may have been missed in the survey and future new development, and the $\Delta T$ may drift down for various reasons so it possible that the total system peak load of the Saint John CES may eventually exceed the capacity of the pipeline from the Mill to uptown.

But, as indicated in Figures 12 and 13, the Heating Load Duration Curve and Heat Energy versus Load Chart for Saint John, the transmission loop would be capable of supplying the base load (e.g. at least 90% of the energy) for a peak demand as large as it might be reasonably imagined that the Saint John CES would grow to in the foreseeable future, e.g. it could easily supply most of the energy to meet the City’s goal as expressed in the RFP of eventually connecting 6 million square feet, in the order of 30-40 MWt of diversified load.

The capital cost of this energy option has been determined to be approximately $3.4 million inside the Mill (including $1.2 million for piping) and a DPS increment of approximately $10.3 million for the hot water transmission loop between the Mill.
and uptown. All options based on the Mill would bear this DPS increment. This would be the additional capital cost of sourcing energy from the Mill versus uptown and would be justified by the operating savings in fuel, electricity and maintenance of this simple, direct heat recovery method as opposed to a combination of heat pumps supplemented by more extensive firing of the Energy Centre.

All supply alternatives from the Mill would consume approximately the same quantity of electricity for pumping, up to approximately 1% of the thermal energy delivered.

*Waste Heat Boiler Exhaust*

The Irving Pulp and Paper mill has two boilers:

1) a Recovery Boiler is fired with various Mill waste streams and generates 500 mlb/hour of steam (approximately 147 MWt)

2) the Bark boiler generates 220 mlb/hours of steam (approximately 65 MWt)

The boiler exhaust is at a temperature of 218°C (425°F) and would account for possibly 10% or more of the thermal input. Therefore, waste heat boilers could theoretically be a source of low cost energy for district heating.

This resource has not been considered in detail because it has the disadvantage of being intrusive to Mill operations, with technical issues relating to possible condensation of flue gases, which leads to corrosion in a high temperature environment, raising questions regarding long-term maintainability and reliability. Staying below the condensation temperature could limit the output temperature.

*Plant Effluent*

The Mill effluent, which includes the process heat recovery discharged discussed above, has a large flow that could be a potential source of heat energy for district heating using heat pumps. The temperature of the Mill effluent would be higher than raw sewage leading to higher COP and higher output temperature possibilities and the output temperature could be still topped to 95°C with LP steam as described above.
However, this option would have significantly higher capital costs than the heat pump options located uptown and higher capital costs than the simple heat exchanger option at the IPP Mill, together with higher electricity costs from running the heat pumps.

5.2. Raw Sewage Energy Source

Precedents and Preliminary Comments

Since the City of Saint John is in the process of upgrading its wastewater system, there is interest in raw sewage as an energy source for district heating.

Most large scale sewer heat projects use treated wastewater rather than raw sewage; e.g. in projects FVB has been involved with in Sweden in Stockholm (approximately 100 MWt) and Vasteras (approximately 15 MWt). Treated wastewater may have higher flow-rate, higher temperature (especially from a plant with digesters), more constancy of temperature and cleaner water. Its sole disadvantage versus raw sewage is generally distance from customers. This disadvantage is decisive in Saint John where the main wastewater treatment plant (which is being expanded) is approximately 6 kilo-metres by road east of uptown. Also this plant does not use digesters and its effluent temperature is only 6 to 8°C in winter.

As compared with treated wastewater, raw sewage has the sole advantage that it can be found closer to the customers. However, this advantage is offset by disadvantages of lower and more uncertain flow and temperature and dirtier water.

The most recent and closest precedent is the 2.7 MWt heat pump recently installed by the City of Vancouver's Southeast False Creek (SFC) Neighbourhood Energy Utility at the Cambie Street lift station in SCF as part of the Olympic Athlete’s Village development. This lift station handles a combination of untreated sewage and storm water. The heat pump was commissioned recently and is currently in the early stages of operation.

The City of Vancouver decided to use this option following an assessment of potential heat sources by FVB similar to this study for Saint John. One of the first points learned in the Vancouver study is that whereas the client's original concept of raw sewage heat recovery was from flow in the sewage mains, as is practiced in a
few places in Switzerland and Germany, a critical assessment of the associated technical issues and economics, including a tour of some of those installations, led to the conclusion that in-line sewer systems could not be relied upon to provide sufficient capacity to serve a significant portion of foreseen demand.

After that conclusion was reached, the focus of the Vancouver study shifted to installing a heat pump of 2.7 MWt at the lift station, which was going to be built anyway. The new design for the lift station gave particular consideration to incorporating the heat pump. One of the main issues, which would be an issue also in Saint John, is to ensure sufficient constant flow for the heat pump. The manufacturer's indicated the minimum should be 600 m3/h or 167 L/s. They did not favour the solution of achieving this by recirculation, citing risks with build-up of contaminants and freezing. The solution adopted in Vancouver was to up-size the wet-well to buffer variations of in-flow and to provide back-up in-flow via a force-main from another lift station.

The input flow to the heat pump evaporator has to be screened to <2 mm passing. The screens must be cleaned, and the over-size augured back into the wet well.

All of the above measures to use heat pumps for raw sewage require careful design by sewage experts.

Even screened raw sewage presents evaporator tube cleaning challenges. Specialist sewage heat pump manufacturers' expertise is essential. To FVB's knowledge there are essentially only two suitable manufacturers. In the case of SFC, it was decided to procure the heat pump from Tecson, a vendor in Mexico. This was Tecson's first raw sewage application, but they at least have a representative in Vancouver. The almost monopoly sewage heat pump supplier in Europe is Swiss based, Friotherm, who can provide limited technical support to North America.

Heat pumps have poor turndown, which means they lose efficiency at low heat load. Friotherm recommended the heat pump not be operated lower than 40% of peak load, whereas Tecson allowed operation down to 25% of peak load. For SFC, this limitation was addressed by configuring the facility with two units that operate in parallel for base load and one can be shutdown for low loads. The two units can also be operated in series to produce output of 80°C if desired, but at reduced
efficiency. It should be noted that the Tecsol unit is a custom designed system that is yet to be proven in long-term operation.

Temperature fluctuations are clearly problematic for combined sewer systems such as in SFC (and Saint John). For example, a FVB engineer recently visiting the heat pump in SFC witnessed a temperature change of 6°C, between 15°C and 9°C over less than 1 hour due to the effects of rain. Tecsol’s representative, also attending, expressed concern as to the consequential compressor loading changes on long-term maintenance and performance.

Evaluation of Opportunities in Saint John

It has been determined above that a low temperature (<70°C) resource supplying the recommended customers in Saint John would generate approximately 2-4 MWT. As discussed below, comparing the conditions for the heat pump in Vancouver casts doubt as to whether that capacity could be reliably provided by raw sewage in Saint John. Any shortfall in output from the heat pump plant would have to be made up by burning more fuel in the Energy Centre and this would be a major economic and environmental risk for this option.

As was concluded in the study for the City of Vancouver, it is recommended that evaluation of the potential for energy recovery from raw sewage in Saint John be focused on the larger flows available at large lift stations.

A new large lift station (LS 10) is planned for construction in the near future close to uptown (Figure 14, from reference 7). The approximate in-service date is 2011, which jives with the CES schedule.

The referenced report notes that LS 10 will have a Wet Well/Dry Well Configuration (which means the pumps are situated in a separate dry well) with a permanent diesel generator for back up in the event of a power interruption and will have a total foot-print of approximately 30 metres by 30 metres, so it will be quite large.

If it were decided to pursue this option, it would be important to provide input to the Harbour Clean-up team on the key lift station design features that would be required to incorporate a heat pump, as mentioned generally above, concerning water flow and quality, to be confirmed by detailed engineering.
The conceptual design capacity of LS 10 is stated to be (reference 7) 220 L/s, the Measured Dry Weather Flow is report to be 43 L/s and the Peak Measured Dry Weather Flow is reported to be 220 L/s. In addition the Wet Well is designed to handle a maximum wet weather flow of 4,800 L/S by allowing overflow to the Harbour.

The variation in flow is similar to that observed for the Cambie street lift station in Vancouver. As in Vancouver, it would appear additional municipal works are likely to be required to ensure sufficient flow, including provision of sufficient wet well flow buffering capacity and possibly additional force mains from other lift stations.

It is too hard on motors to cycle on-off and neither do heat pumps perform well under varying flows through the evaporator tubes. As mentioned earlier, recirculation is not recommended.

The main challenges with this option relate to: (1) raw sewage temperatures, as impacting efficiency and reliability, and, more decisively, (2) output temperature capability in relation to the requirements of a district heating system intended to serve existing older buildings (as opposed to the SCF customer base, which will be all new construction with low temperature systems).

The temperatures in LS 10 are expected (reference 13) to vary seasonally between 5°C and 15°C. But it seems uncertain whether combined sewer temperatures in Saint John winter wet weather can be counted on to be even be as high as 5°C at all times, considering that wet weather flows greatly overwhelm dry weather flows. Based on previous advice from heat pump manufacturers, the low end of the range quoted, i.e. towards 5°C, and anything below that, could be problematic for efficiency and reliability. See COP versus evaporation temperature chart, Figure 15.

For the purpose of a comparative economic evaluation of this option versus others, we have assumed a COP of 3 for the heat recovery system (including auxiliary pumps, augers etc). This may be optimistic, so we have assigned a high relative risk factor that should also be taken into consideration.

The limited output temperature capability is a serious cost consideration in relation to the winter needs of a district heating system as envisaged in Saint John. If the heat pumps can supply only 30% of the annual energy and the rest must be raised in
fossil fuel boilers, then clearly the economic and environmental benefits of this option are not as good as the recommended option, and this is shown in the financial and environmental analysis sections of this report.

5.3. Saint John Harbour Water  
*Precedents and Preliminary Comments*

Previous studies (references 5 and 6) identified Saint John Harbour Water as a potential source of heating and cooling. The notion was that the same seawater installation consisting of intake, heat exchanger, chiller/heat pumps and outfall could supply cooling in summer and heating in winter.

The RFP scope of work requested evaluation only of seawater cooling not heating so that is what will be mainly reported here. Some high level calculations were also made for seawater heating that showed it was less favourable than the industrial waste heat option, even combined with cooling (i.e. assuming the seawater intake/outfall and chiller/heat pump plant were charged to cooling). The reasons were mainly related to the temperature limitations (as discussed above for raw sewage) with associated consumption of electricity and peaking fuel far in excess of that required for the industrial waste heat option. In this context, combining seawater heating with cooling would not improve the economics of seawater cooling.

The conceptual potential for this energy source should not be confused with Deep Water Cooling (DWC). DWC exploits the fact that water can be found at 4°C (the temperature of its maximum density) year-round below a certain depth, e.g. approximately 80 metres in the case of Lake Ontario. To access this source of cooling energy usually requires a very long intake pipe and very thorough knowledge of site specific seasonal temperature profiles at depth.

DWC has been applied by Enwave Energy Corporation (Enwave) in Toronto, by Cornell University on Lake Cayuga in New York State, in Sweden and is being implemented in Hawaii. We have no information to support the idea that it might be cost effectively applied in Saint John, especially in view of the relatively limited demand for cooling.
Information available in reference 5, the Saint John Harbour Temperature Profile Final Report, is consistent with conclusions reached in a similar study by FVB with respect to lake water (not DWC) cooling in Ontario, and is reflected in the following analysis.

Unlike DWC, the concept being evaluated in this study is to use seawater for direct cooling when possible or at other times for pre-cooling or as condenser cooling. See process schematic, Figure 16.

The annual near surface (i.e. to a depth down to the order of 10 metres) temperature profiles according to these studies can provide direct cooling in the 5 or 6 coldest months of the year and pre-cooling for another few months. But chillers would normally still be needed to take the full peak load in the 2 or 3 warmest months of the year. Therefore, the projected annual savings in electricity are in the range of only 20-30%.

It would certainly be desirable to eliminate cooling towers and their associated consumption of not only electricity but also city water, chemicals, operation, maintenance and periodic refurbishment cost, public health concerns, occupation of space and industrial appearance, but the economic payback from operating cost savings versus incremental capital cost is not necessarily compelling.

In the case of Saint John, a district cooling project based only on Phase 1 cooling prospects as defined in subsection 3.3 would have a long payback and seawater cooling does not improve that very much, e.g. the payback would still in the order of 50 years. If the additional potential cooling customers could be captured, the payback has been theoretically calculated to be shorter (but still about 20 years). Capturing these existing customers is a very tenuous assumption, unless capital avoidance is possible, and is therefore assigned a high relative risk factor.

FVB has been involved in seawater cooling projects in Sweden and the Middle East. The following sidebar (condensed from reference 5) puts the Stockholm and Purdy’s Wharf experiences into perspective.

The sea water district cooling system in Stockholm has the benefit of a fortuitous sub-surface thermocline (change in temperature between warm water and deeper cold water) and current that transports water that has been cooled during the winter in the Baltic sea, taking a couple of months to reach the
intakes just in time for the cooling season. This reduces requirements for supplementary chiller operation.

The Stockholm system also makes use of major infrastructure, including heat pumps that were already in place for district heating and existing tunnels for distribution. And it must be recognized that the proponent is Stockholm Energie, which was already a large, well-established electricity and district heating utility. This history illustrates a commonly seen pattern of development of district energy systems in which use of renewable energy sources builds upon existing infrastructure, rather than being part of a start-up.

Other seawater projects such as Purdy’s Wharf in Halifax are reported to have more favourable annual temperature profiles than Saint John and are designed to meet a much lower demand from the more tightly defined needs of a single new development, with no distribution infrastructure and no ΔT’s required between primary and secondary loops, such as would be needed to serve multiple buildings in a district cooling system through indirect connections, i.e. heat exchangers, which is the recommended method of connection.

Seawater systems need heat exchangers to separate the cooling system from the seawater. The material must cope with salt water corrosion, which requires either titanium or cupro-nickel alloy. The seawater pipes to and from the heat exchanger, can use plastics of various types, for example polyethylene.

When direct cooling, the COP is approximately 5. In other words, electricity consumption (needed only for pumping) is approximately 2% of the cooling energy output, a big improvement on a conventional district cooling system COP of around 4, where the electricity consumption for pumps, cooling towers and compressors is 25% of the cooling energy output. Even when using the chillers in summer, with indirect seawater condensing, the COP will increase to about 5, dropping electricity consumption to approximately 20% of cooling energy output for the summer months. (For clarity, the decrement is 25 – 20 = 5/25 or a 20% saving versus district cooling without seawater in the summer). During the shoulder seasons, pre-cooling is possible yielding somewhat higher savings than in summer.

Unfortunately, by far the largest portion of cooling energy is required in summer when seawater cooling provides the least benefit. As a result, the overall average annual savings in electricity from using seawater cooling (without UTES), as opposed to district cooling without seawater, would be in the range of 20-30% and this has been confirmed by some preliminary calculations for this study.
Evaluation of Opportunities in Saint John

A good suggestion was made in reference 5 that seawater cooling projects on a smaller scale, similar to Purdy's Wharf, might be custom built over time, as new developments are committed along the waterfront. These would not necessarily be district cooling projects. But a small district cooling system based on seawater might eventually be developed if several potential viable customers could be identified as needing service starting within a reasonably close window of time and significant capital avoidance can be achieved as a decisive added benefit.

The seawater temperatures logged as part of the temperature profile study (reference 5) showed great variations during the same month. Normally, variations occur between different years, but FVB's experience (from Sweden) has been that there are not usually such high differences from day to day. Variations usually depend on weather conditions over longer periods, not from day to day. Momentary variations are caused by wind, but these usually settle down quickly to the average daily values.

In the case of Saint John, tidal influences may be causing the high differences from day to day. This could impact design considerations such as optimal length, depth and position of the intake and the complementary use of thermal energy storage.

Some preliminary calculations have been made on the amount of cooling energy that could be obtained from direct cooling and pre-cooling chillers, based on the temperature records reported in reference 5 and a standard district cooling primary supply temperature setback profile of 4°C in summer, 6°C during the autumn/spring and 8°C in winter.

The results in Figure 17 show about 30% overall annual savings in electricity for the mean temperatures, which is roughly consistent with an estimate made in reference 5 and the Lake Ontario study by FVB.

Another case was run based on the lowest temperatures reported in reference 5 and as expected this appeared to show a much greater portion of direct cooling, Figure 18. It seemed that colder temperatures might be available on certain days even in the late spring and early summer and thereby allow some direct cooling to be achieved in the cooling season. The results of this run should be viewed with a lot
of caution and should be verified before any design was based on this idea. But it highlights the importance to optimization of system design of a detailed understanding of the seawater temperature profiles. Therefore, if the City remains interested in pursuing the seawater cooling option, we recommend a further seawater temperature study be undertaken aimed at confirming variations during the cooling season and finding ways to exploit them.

The cooling load duration curve and load versus energy curve for Saint John are shown in Figures 19 and 20. Clearly with a typical cooling EFLH of only 525 in Saint John, a district cooling project, whether using seawater or not, is likely going to have a long payback period. In order to optimize project economics, FVB suggests that an eventual seawater cooling project be targeted to serving buildings where capital can be avoided for new or replacement chillers and are close to the Harbour. It would be ideal to have a large tranche of cooling load from new development supplemented with some chiller replacements.

To an extent that opportunity exists today, taking into account Market Square, the Police HQ, the Law Court and the Coast Guard Site. But the actual loads of these 4 prospects are either small or uncertain. There is currently uncertainty about the true cooling load in Market Square, which will be hopefully clarified after it uses district heating instead of heat recovery from its chillers.

The aggregate estimated cooling demand is rather small for the Police HQ and Law Court. The Police HQ, at 90 tons, is particularly small. Using the pipe route as originally given to FVB for the Peel Plaza renewal project to reach the Law Court (itself not that large at 230 tons) would have required a considerable number of trench metres of pipe, approximately 800 metres, with, so far, no other committed loads along the route. A shorter pipe route identified during this study improves prospects to supply cooling to the Law Court, but the overall feasibility of district cooling is still so doubtful that it is recommended to proceed cautiously.

The timing of the Coast Guard Site development is still not confirmed and includes mostly mid-rise condos, which typically have low cooling demand.

It is understood the City wishes to take the opportunity to lay down district cooling pipes along Union Street at part of the Peel Plaza Infrastructure Renewal project.
A further suggestion was made in previous studies to combine seawater cooling with cold UTES, and this is evaluated below in subsection 5.5.

5.4. Building Waste Heat

_Precedents and Preliminary Comments_

Previous studies have suggested using the heat rejected from building cooling systems to provide district heating. This would be essentially a district version of what is already accomplished by the Market Square complex, including the Hilton Hotel.

The most obvious limitation of this source of heat energy for district heating is that heat recovered from chillers is available mostly in the summer, whereas district heating needs energy mostly in the winter. Previous studies have suggested overcoming the latter limitation with hot UTES, and this suggestion is evaluated in subsection 5.5 below.

The second limitation is that, whereas chillers reject heat at around 30°C, district heating requires much higher temperatures, as previously discussed, to effectively serve a range of building ages and types. Therefore, some form of temperature supplementation would be required as part of this option (whether in direct supply or discharge from storage mode).

Temperature supplementation could be achieved with fossil fuel; however, that would result in the majority of the total heat energy requirement being sourced from fossil fuel, undermining the whole point of the GTU. For the purpose of this study, we have performed a preliminary evaluation assuming that temperature supplementation would be first by heat pumps and then topped up as necessary with fossil fuel using the same Energy Centre as assumed to be required for the other options.

_Evaluation of Opportunities in Saint John_

Without UTES, this option can provide only that small fraction of total heat demand that occurs in the summer. Even if the option worked perfectly with UTES, the heat potential is limited by the heat rejection of the contributing buildings, which will be assumed to be all the potential cooling customers listed above in Tables 7 and 8,
which, collectively, would reject approximately 14,600 MWht annually or 43% of the total heating demand of the 25 target heating customers.

The other limitation is that a low temperature resource can supply only a portion of the annual energy of the contemplated system anyway, as determined in Section 4. The building waste heat option does enjoy the advantage of a higher source temperature than, say, raw sewage or seawater. This would allow a higher output temperature from heat pumps, e.g. possibly 80°C instead of 70°C, which would reduce the consumption of fossil fuel to top up the temperature.

On the other hand, whereas raw sewage and seawater are available year round, building waste heat is available for a limited period, mostly June through August, and its usefulness to meet demand during the colder seasons when heat is most needed are mediated by the effectiveness of UTES for this specific application, which introduces uncertainties in both temperature of output and % recovery of the quantity of heat that is stored.

In summary, there are so many uncertainties affecting the fraction of total heat supply that could technically be supplied from this source, that some gross assumptions will have to be made for the purpose of evaluation and a very high risk factor applied.

Since this option can be meaningfully assessed only in combination with UTES, further comments are deferred until that subsection, 5.5.2 below.

5.5. Underground Thermal Energy Storage (UTES)

5.5.1 Cold UTES

Precedents and Preliminary Comments

Cold UTES was suggested in a previous study (reference 6) as a way to overcome the seasonal mis-match between the annual seawater temperature profile and annual district cooling load profile, which is illustrated in Figures 17 and 18.

Since there is no indication of a suitable aquifer in Saint John, the type of UTES contemplated is Borehole Thermal Energy Storage (BTES), not Aquifer Thermal Energy Storage (ATES). The principal issue with BTES is high capital cost in relation to the value of capacity and energy stored. The capital cost is high because a large
number of deep boreholes must be drilled through rock and long lengths of Borehole Heat Exchanger (BHE) U-tubes inserted, together with connecting piping, pumps, valves and controls, but the main expense is simply drilling through so many metres of hard rock.

A practitioner of this technology quoted a rule of thumb for the capacity of cold UTES of 200 feet per ton, equivalent to 0.06 kWt per metre (m), but case studies report a wide variance on that. For example, a BTES in Germany (reference 9) reports 154 boreholes each 70 metres (m) deep to provide 340 kWt of cooling capacity. This amounts to 0.03 kWt/m of borehole. A system in Norway cited by another report (reference 10) reports 180 holes each 200 metres deep to produce 3.2 MWT of cooling, which is 0.09 kWt/m. The range from low to high in these examples is 300%, which would directly impact the installed capital cost.

As a related issue, the optimal business model for district cooling is to avoid the cost of chiller plants for new development. This implies that a CES must be very reliable. This means that proven technology, i.e. chillers, must be available, for backup, e.g. in case the UTES became depleted before the end of the cooling season. Therefore, the cold UTES would not avoid chiller plant capital. The only savings would be electricity, water and chemicals. And it is likely that the cold energy from UTES would be use for pre-cooling, not for direct cooling because chillers would be operating to meet summer peaks anyway. It can be seen, summarily, that the payback would be extremely long.

The following are some additional notes on FVB's experience of successful cold UTES projects in Sweden. It is illuminating to understand the local context in which such projects have succeeded. The main point is that the UTES projects that we know have been successful have been based on ATES not BTES.

ATES has been employed for over 6 years at a location known as Sollentuna in Sweden. The keys to its success were the coincidental presence of 1) a deep cold lake and (2) an aquifer, both close to a demand for district cooling.

The project in Sollentuna was able to overcome the economy of scale challenge of DWC by exploiting the fortuitous presence of an aquifer suitable for cold UTES. The aquifer provided the ability to store cold energy so that a relatively small diameter
DWC intake pipe and smaller pumps can operate at 100% capacity factor year-round to continuously charge the aquifer with cold water from deep in the lake.

The aquifer storage is 400,000 m³, which annually stores 2,000 MWh of cooling energy.

In assessing the relevance of the successful Sollentuna project to possibilities in Saint John, we must recognize the fortuitous presence of both the deep lake and a suitable aquifer that do not exist in Saint John.

FVB was involved in another cold UTES, in Stockholm, also ATES. However, that cold ATES is a daily not seasonal storage with a thermal capacity of just 25 MWh. We are aware of another cold ATES at Arlanda Airport in Stockholm.

Aquifers are valuable assets for UTES, in both energy intensity and discharge capacity. With respect to energy intensity, water has more than twice the energy density of granite (4,186 kJ/m³°C versus 1,896 for granite) (reference 8). Consequently, for any given ΔT, more than twice the energy can be stored within a given volume of water than the same volume of granite.

Even more importantly, with respect to the discharge capacity in MWt achievable when extracting the stored energy, the energy stored in an aquifer can be recovered relatively rapidly by pumping out the cold (or hot) water.

In contrast, the capacity, or thermal power, that can be extracted from a borehole field depends on heat transfer to a recovery loop through BHE, which in turn depends on the rate of migration of heat through rock either to or from the boreholes under the force of the prevailing ΔT. UTES proponents generally run tests to determine thermal conductivity of the site host rock before committing the projects.

Whereas, most cold BTES examples seem to be serving a single customer, it must be remembered that district cooling involves another heat exchange step, between the primary loop and customers’ internal HVAC systems. District cooling systems aim for a peak primary supply temperature in summer ideally down to 4°C. Although Enwave’s DWC system in Toronto takes in approximately 4°C water from the lake, that still needs to be polished (i.e. reduced by a degree or two with mechanical
refrigeration) to optimally meet the peak needs of the district cooling system, after taking into account an approach temperature of at least 1°C for the heat exchangers between the lake water and the district cooling loop.

Incorporation of cold BTES would increase the number of heat transfer steps by two, i.e. (1) from the district cooling loop to the UTES and (2) from the UTES back to the district cooling loop. Polishing could well be needed, depending on the exact seawater temperatures. Therefore, if cold UTES were to be contemplated, it would be prudent to first spend some effort in gaining a very good understanding of (1) seawater temperature profiles (especially given evidence they are cyclic in Saint John Harbour) and (2) thermal conductivity of the host rock.

*Evaluation of Opportunities in Saint John*

Using cold UTES with seawater could at the limit theoretically save 90% of the electricity consumed for cooling, as opposed to possibly 30% for seawater without UTES. But for reasons explained above, we would not recommend dispensing with chillers to rely on cold UTES for capacity. Therefore, the cold BTES really supplies only energy not capacity and the optimal size would not be the full system peak load.

For illustrative purposes, we have evaluated a configuration sized for 40% of the cooling capacity from cold UTES (theoretically 80% of the cooling energy per the Cooling Energy Versus Load curve for Saint John, Figure 19), which would result in a maximum overall electricity saving of approximately 72% (90% of 80%), an increment of 42% over seawater without UTES.

Since we cannot assume connection of the additional uptown prospective cooling customers per Table 8, the UTES in this evaluation is sized to supply 40% of the peak cooling capacity required by the Phase 1 customers, i.e. approximately 1.5 MWt.

Using the mid value of the range of unit capacities of 0.06 kW/m, this would imply 27,000 metres of BHE. Using a practical depth of 100 metres, 270 holes would be required, recommended to be on 4.5 metre centres, thereby occupying approximately half a hectare (5,000 m²), which might fit in currently unoccupied space close to the waterfront. It is recommended to be in a circular multi-pass configuration, similar to the pattern used in Okotoks (discussed briefly in 5.5.2
below), as was illustrated in reference 6. All of this would be subject to detailed
verification by UTES experts prior to project commitment.

At a typical borehole drilling cost of $100/m (reference 11), the estimated borehole
drilling cost to provide the 1.5 MWt of cooling UTES capacity, according to the
above parameters would be approximately $2.7 million. But since there is range of
300% between the reported kW per metre and a lot of uncertainty in other
associated costs, this option has a wide range of risk. In view of this wide range, we
have not even attempted to estimate the balance of UTES project costs (in addition
to drilling) but have simply added an allowance of 20%.

The UTES cost would be incremental to the overall Phase 1 district cooling. If it
worked at a technical level, in accordance with the assumptions in this very
preliminary evaluation, cold UTES would shorten the predicted payback of the
district cooling system, but the latter is so long that it would still not bring it into a
commercially attractive range.

These calculations are outlined quantitatively in the financial analysis section.

5.5.2 Hot UTES

Precedents and Preliminary Comments

The following are some comments on the state of the art of hot BTES. As with cold
UTES, in the absence of an aquifer, the type of UTES that would be employed in
Saint John would be BTES, not ATES. Examples of hot BTES can be found in the US,
Germany, Norway and Canada.

In addition to the other examples described in references 9, 10 and 12, there is a
recent project in Canada that FVB peer reviewed at the Drake Landing Solar
Community in Okotoks, Alberta and which is described in reference 12. It supplies
52 houses with a total capacity far less than the district heating system envisaged in
Saint John and was highly subsidized. When fully in-service, it is intended that 90% of
the heat energy for these homes will be provided by the sun, using solar
collectors connected to a hot BTES, consisting of 144 boreholes, each 37m deep.

Solar heated water is pumped into the ground at a maximum of 90 °C. During the
winter, the hot water flows from the BTES field to the houses through a distribution
network. Once inside the house, it flows through fan coil units, over which air is blown. The hot air then heats the house. Each house also has an independent solar thermal system installed on its sloped roof to provide domestic hot water.

Three differences with the requirements for Saint John stand-out from review of this case history and others.

The first is that the scale of successful hot BTES projects to date is a fraction of what is required to meet the potential district heating demand in Saint John. Specifically, they are generally well below 1 MWt in capacity.

The second is that solar energy has been the source for hot BTES projects to date. Solar thermal has been used on a large scale for district heating in only a few places to date and is not contemplated in Saint John.

The third is that the small-scale solar UTES projects are designed to recover heat directly, not with heat pumps, from relatively hot (not just warm) storage fields that have been charged by relatively hot water (up to 90 °C) produced in solar collectors. Those projects that recover heat from the ground using heat pumps are more aptly and commonly described as geo-exchange, which was not contemplated as part of this scope of work.

The cost of hot UTES capacity per kWt is of a similar order of magnitude as cold UTES discussed earlier, a little less, due to higher ΔT.

**Opportunity in Saint John**

The application of hot UTES in a specific location must be considered in the context of the potential customer demand and the energy source. In Saint John, the recommended energy source is industrial waste heat from the IPP mill. This energy source can, by itself, meet the full peak winter demand that is anticipated from a district heating system in Saint John for many years to come.

Although the lowest grade of waste heat available at the Mill will not meet the higher temperature requirements of the district heating system in winter by itself, the Mill has a supplementary resource in the form of LP steam that will meet the temperature requirements cost effectively.
In any case, hot UTES would not be an effective option to meet the required peaking duty, because the challenge is lack of temperature not lack of energy availability.

Therefore, there is no immediate role seen for hot UTES in the envisioned Saint John CES in the recommended design configuration. Hot UTES was suggested in a previous study (reference 6) because its focus was on heat energy resources that are seasonal in output, the most obvious example being waste heat from buildings. Raw sewage, treated wastewater and seawater were also suggested as heat sources in that previous study and they have some seasonal character to the extent that, whereas heat pumps may be able to extract heat from these sources year-round, the operation would be more efficient in the summer when these resources could support higher evaporation temperatures (see Figure 15).

The RFP for this study did not call for evaluation of treated wastewater or seawater heat sources, although some comments have been made on these in this report. It is uncertain whether raw sewage could be used to generate sufficient excess heat in summer to be worthwhile storing and, even if it could, this would certainly not be “free” heat in the same sense as waste heat from buildings or solar thermal.

Therefore, this study evaluates hot UTES only as an adjunct to the evaluation of waste building heat, which was mandated by the scope of work of the RFP. However, while using the term “hot UTES”, we are aware that this application is really a version of geo-exchange, not pure UTES, because the output of the UTES would be too low in temperature to be directly useful.

Waste heat from buildings would need UTES to supply more than the relatively low fraction of the total heat demand that occurs in summer. This concept would require construction of (1) a heat rejection loop that would tie into the condenser water loop supply and return of each contributing building’s cooling system, (2) a UTES which would be “warmed” by this heat rejection loop in summer and discharged by it in winter, (3) a heat pump plant, downstream of the UTES, that would extract heat from the heat rejection loop, with the only expected significant source of energy in winter being the UTES (which would include the annual solar gain collected by the ground itself) and (4) the balance of district heating system
essentially the same as for the other options with standby/peaking boilers, DPS and ETS.

Alternative configurations might be envisaged, but without a net benefit. E.g., the heat pump plant could be omitted and total polishing performed with boilers. But this would result in direct combustion locally of a large volume of natural gas, counter to the intent of the GTU.

Alternately, the Energy Centre, DPS and ETS could all be dispensed with by connecting all the customers directly to the heat rejection loop and using local temperature boosting through distributed heat pumps. This configuration was envisioned in reference 6, but was not recommended as optimal in that report and FVB would agree because the cost of extending the low ΔT heat rejection loop to connect all the participants would be extremely high and uncertain. Multiple on-site heat generation equipment would be collectively costly and have high maintenance and replacement costs. They would consume a lot of electricity and thereby indirectly generate high greenhouse gas emissions. Benefits to customers offered by CE of convenient, reliable off-site sourcing of thermal energy would be lost.

The difference between this concept and a typical geo-exchange project is mainly in having multiple energy sources and the CE business configuration (i.e. multiple customers). Geo-exchange projects typically use UTES to heat and cool a single customer. Although that may be a campus composed of several buildings like Durham College in Oshawa, Ontario (which has one of the largest geo-exchange systems in the world), it still has a single owner/operator.

Challenging business and technical issues would be created by sourcing heat from chillers owned and operated by multiple parties, not necessarily the same as would benefit from use of the heat. These would include multi-source pumping pressure, flow and control design issues that are beyond this preliminary comparative study. The potential practical, human, business and legal issues involved in using so many different source of supply could lead to numerous delays and cost overruns, which are among the reasons why the highest risk factor is assigned to this option in the financial analysis.
As with cold UTES there is a range of possibility for the capacity attainable in terms of kW/m of borehole, so the cost and performance risk of the UTES itself is very high.

For the purpose of this evaluation, we assumed the intent would be to provide UTES capacity equivalent to 40% of the peak winter load. The quantity of energy that could be supplied with this option using heat pumps is subject to numerous uncertainties. To make a fair comparison with the other options, we have assumed that it would supply 30% of the annual heat energy for district heating. This may be optimistic in relation to the total heat energy available from the identified chillers being only 43% of the heat energy demand projected for district heating, but any variance is intended to be reflected by the risk factor.

As outlined in the financial analysis section, this study calculated the capital and operating costs assuming this system worked perfectly according to simple and probably optimistic assumptions and found the payback to be still very long with a high risk factor in sharp contrast to much shorter payback and lower risk for the recommended option.

In order to evaluate this option, several assumption have to be made that FVB has little confidence in such as: (1) the willingness and practically of building operators to tie into a district wide heat rejection system with low potential economic compensation for them, (2) the cost and constructability of such a system, (3) cost of a “warm” UTES and (4) extent of recovery of heat energy and temperature from a “warm” UTES. This lack of confidence is reflected in a relatively high risk factor in the financial analysis.
6. Financial Analysis
6.1 Comparative Financial Analysis of Energy Sources
The following financial analysis was developed to compare various energy source options on a consistent basis, using reasonable assumptions for energy pricing. This analysis should not be used broadly as a definitive representation of projected results of the proposed CES. Those results will be determined after finalization of a number of issues, including:

1. Final capital costs
2. Agreement on price of purchased energy
3. Rate structure for customers

Key results of the financial analysis to compare the relative economic benefit of the energy source options are listed in Table 8, specifically total capital investment required in thousands of current dollars, net of the $9.8 million FGIF grant, margin (= annual revenue – annual expenses) in thousands of current dollars at build-out and payback (= capital/margin).

Relative risk factors are also assigned indicating a subjective assessment of the relative chances that results could be very much worse than projected. The definition of “very much worse” is a little fuzzy, but meant to imply something like a 50% variance in payback.

For example, using Heat Pumps to recover Industrial Waste Heat is deemed to involve 1.5 times the risk of using Heat Exchangers due to greater complexity of technology with more uncertain technical parameters involved in the calculations, e.g. COP. Similarly, using Hot UTES with Waste Heat from Buildings is deemed to have 10 times the risk of using Heat Exchangers to recover Industrial Waste Heat, again because of numerous technical complexities and uncertainties.

---

4 Note estimates in this financial comparison are Class D estimate, with an accuracy -25% to +75%. The recommended option is regarded as a Class C estimate used for preliminary discussion of feasibility. The greater precision of -15% to +25% is justified by FVB’s experience with the proposed concept.
The capital and margin estimates were derived by first developing projected cash flows for the recommended heating option (A-1), as well as for the cooling options (C-1 and C-2). Data for these projections are outlined in more detail in subsections 6.2 and 6.3 below. Then differences in capital and expenses from A-1 were estimated and applied for each of the heating options, and between C-1 and E-1.

Table 8 CES Capital Cost Estimate Summaries

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Capital</th>
<th>Margin</th>
<th>Payback</th>
<th>Risk Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1</td>
<td>Industrial Waste Heat: Heat Exchangers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A-2</td>
<td>Industrial Waste Heat: Heat Pumps</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Raw Sewage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-1</td>
<td>Harbour Water: Phase 1 Cooling</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-2</td>
<td>Harbour Water: Phase 2 Cooling</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Waste Heat from Buildings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-1</td>
<td>Option C-1 with Cold UTES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-2</td>
<td>Option D with Hot UTES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments on Capital and Margin Differences

The following differences for heating options are relative to option A-1.

Option A-2 would have higher capital of approximately $3.9 million due to using 4 MWt of heat pumps instead of heat exchangers. Its expenses would be higher as a result of additional electricity to run the heat pumps, and slightly higher maintenance.

Option B, would save on the capital cost of connection to the IPP Mill, i.e. approximately $3.4 million for works within the mill plus $10.3 million for the hot water loop between the Mill and the Energy Centre. But it would incur approximately $5.6 million for a 4 MWt raw sewage heat pump plant, including associated process equipment. The expenses would be increased mainly by additional natural gas required to supply approximately 70% of the annual energy and by electricity for the heat pumps.

Option E-2 would similarly save on connection to the IPP Mill, but incur capital for the heat rejection loop, heat pumps and the UTES. Expenses would be increased as per Option B, except the additional electricity cost would be slightly less due to the assumption of a COP of 4 from the warm UTES, as compared with 3 from raw sewage in Option B.
Capital and margin for the cooling options (C-1 and C-2) were derived from the data as outlined below in subsection 6.3. C-1 would represent the Original Phase 1 customers whereas C-2 includes the additional potential cooling customers that have been identified among existing uptown buildings.

Option E-1 differs from C-1 due to additional capital for the UTES, but slightly lower expenses due to saving an estimated 72% of electricity by using seawater as opposed to saving only 30% using seawater without UTES. Although the projected increased saving is only $125,000 per year, the payback of the seawater cooling system was so poor to begin with that it does appear to be slightly improved by using cold UTES, but with an increased risk factor.

6.2 Financial Projection for District Heating
Appendix 4 contains more details of conceptual capital cost estimates for the proposed district heating system (Option A-1).

A summary breakdown by major component for A-1 is presented in Table 9.

Table 9 District Heating System Capital Break-down

<table>
<thead>
<tr>
<th>Component</th>
<th>Phase 1</th>
<th>Phases 1-7</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPP Connection</td>
<td>3,017</td>
<td>3,420</td>
</tr>
<tr>
<td>Energy Centre</td>
<td>5,597</td>
<td>7,384</td>
</tr>
<tr>
<td>DPS</td>
<td>12,882</td>
<td>16,777</td>
</tr>
<tr>
<td>ETS</td>
<td>3,307</td>
<td>6,063</td>
</tr>
<tr>
<td>Total</td>
<td>24,803</td>
<td>33,644</td>
</tr>
</tbody>
</table>

A projection of the above capital expenditure in un-escalated dollars, consistent with the load connection schedules projects in Tables 4 and 5, is given in Table 10.

Table 10 Capital Expenditure Projection

<table>
<thead>
<tr>
<th>Year</th>
<th>Mill</th>
<th>Standby</th>
<th>DPS</th>
<th>ETS</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>2,576</td>
<td>2,576</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>5,597</td>
<td>5,153</td>
<td>396</td>
<td>11,146</td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>3,017</td>
<td>5,153</td>
<td>1,922</td>
<td>10,091</td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td></td>
<td>989</td>
<td></td>
<td>989</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>403</td>
<td>1,787</td>
<td>974</td>
<td>838</td>
<td>4,002</td>
</tr>
<tr>
<td>2015</td>
<td></td>
<td></td>
<td>974</td>
<td>1,129</td>
<td>2,103</td>
</tr>
<tr>
<td>2016</td>
<td></td>
<td></td>
<td>974</td>
<td>370</td>
<td>1,344</td>
</tr>
<tr>
<td>2017</td>
<td></td>
<td></td>
<td>974</td>
<td>419</td>
<td>1,393</td>
</tr>
<tr>
<td>Totals</td>
<td>3,420</td>
<td>7,384</td>
<td>16,777</td>
<td>6,063</td>
<td>33,644</td>
</tr>
</tbody>
</table>
A preliminary cash flow projection is shown in Table 11, in escalated dollars (assuming 2% escalation in all revenue and costs) through 2018, after which it would essentially escalate at 2%.

**Table 11 District Heating Cash Flow Projection**

<table>
<thead>
<tr>
<th>Year</th>
<th>Revenue</th>
<th>Expenses</th>
<th>Margin</th>
<th>Capital</th>
<th>Project</th>
<th>Grant</th>
<th>Net</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The revenue projection assumes pricing at displaced fuel cost only, which is only 66% of the estimated total customer's avoided cost. District heating service is often sold at a price equivalent to the customer's full avoided cost, including fuel, non-fuel operating and maintenance (O&M) cost and annualized cost of replacing equipment. It is recognized that a discount may be appropriate to promote fast sign-up of customers. Final pricing will be developed in the Business Plan. The unique sales proposition that can be offered is de-coupling price escalation from natural gas, oil or electricity.

A break-down of estimated customer avoidance cost is tabulated in Table 12. The avoided fuel costs are based in part on consumption information from the building surveys and in part on estimated consumption of thermal energy from FVB’s experience for the size and use, all using current local fuel costs.

Most prospective district heating customers in Saint John use natural gas for heating. Only 300 Union (the Irving Oil HQ) still uses fuel oil. Market Square and the Custom's Building use electricity. The Police HQ is designed to use electricity and gas. The Law Court is designed to use gas. The Coast Guard Site development has no definite plan, but it is assumed it would use gas.

The avoided O&M and annualized capital estimates in Table 12 are based on general rules of thumb as used for other DE projects. They may be a little high for Saint John and are shown here more for illustrative purposes than to suggest definitive pricing, which would be premature.
Table 12 Heating Customer Estimated Avoided Costs

<table>
<thead>
<tr>
<th>Customer</th>
<th>Fuel</th>
<th>O&amp;M</th>
<th>Annualized Capital</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Police HQ</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Law Court</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Market Square/Hilton Hotel</td>
<td></td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>City Hall</td>
<td></td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CGAC</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Centrebeam</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brunswick House</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coast Guard Site</td>
<td>4</td>
<td></td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Harbor view High</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NB Museum</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lord Beaverbrooke arena</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Fort Howe Hotel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hillyard Place</td>
<td>2</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>300 Union</td>
<td>2</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Prince Edward Square Mall</td>
<td>1</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Prince Edward Square Apts</td>
<td>1</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>St Joseph's Hospital</td>
<td>3</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Cathedral</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saint Vincent's School</td>
<td>2</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Customs Building</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saint John High</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>City Market</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imperial Theatre</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St Malachy's High</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Sydney Arms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td></td>
<td>9</td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

The projection also assumes 100% sign up of the 25 recommended CES customers staged per Tables 4 and 5. A few may not be connected for whatever reason. But it is expected those would be at least compensated by connection of other, as yet unidentified, customers, including future new development.

The expenses projection shown in Table 11 was developed from a projection of heat production from each of the various sources (waste heat, LP steam and standby boilers) taking into account: the suggested build-out schedule as shown in Tables 4 and 5, the split between energy sources as discussed in Section 4, interim supply to the new developments, anticipated Coast Guard Site build out over 5 years, connection of heating customers generally by the 4\textsuperscript{th} quarter of their first year in-service and projected DPS heat loss.

Well over 90% of the heat energy would be supplied by the Mill, the balance being generated in the standby boilers for peaking when required and when the Mill is on...
shutdown, which occurs every 18 months for one week in the spring or fall. The price and other terms will be negotiated with IPP in the next stage of project development. A reasonable assumption was made for the price of heat from the Mill.

Energy input prices are a major determinant of expenses. Current Saint John Energy and proposed Enbridge New Brunswick rates are used and it is assumed that the Energy Centre will use natural gas, even though light fuel oil is estimated to be cheaper for this low load factor duty (but would require higher capital and have higher emissions).

Non-fuel CES O&M expenses projections were developed from general CE industry rules of thumb. It is assumed that 1 Full-Time-Equivalent will be sufficient to operate this system, bearing in mind almost all the run time of production equipment will be at the Mill, and operated/maintained by IPP. Other non-fuel expenses include consumables, maintenance, administration and insurance.

The Project Cash Flow projection in Table 11 yields an internal rate of return from which a rate of return on capital is calculated, excluding the grant. This is an acceptable rate of return for this type of project, considering the revenue stream would be locked in through customer contracts.

6.3 Financial Projection for District Cooling
Appendix 4 contains more details of conceptual capital cost estimates for the potential district cooling systems (Phases 1 and 2 which refer to serving, respectively, the original Phase 1 customers per Table 6, and the additional uptown existing potential cooling customers per Table 7).

A summary breakdown by major system component is presented in Table 13.

<table>
<thead>
<tr>
<th>Component</th>
<th>Phase 1</th>
<th>Phase 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling Plant</td>
<td>8,652</td>
<td>14,314</td>
</tr>
<tr>
<td>DPS</td>
<td>4,401</td>
<td>4,654</td>
</tr>
<tr>
<td>ETS</td>
<td>1,076</td>
<td>3,008</td>
</tr>
<tr>
<td>Total</td>
<td>14,129</td>
<td>21,976</td>
</tr>
</tbody>
</table>

Cash flows for district cooling are projected to be as shown in Table 14.
Table 14 District Cooling Cash Flow

<table>
<thead>
<tr>
<th>Phase 1</th>
<th>Revenue</th>
<th>Expenses</th>
<th>Margin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>-7</td>
</tr>
<tr>
<td>Phase 2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The revenues for district cooling are based on pricing the service at the full avoided cost (fuel + O&M + annualized capital) per Table 15.

Table 15 Cooling Customer Avoided Costs

<table>
<thead>
<tr>
<th>Phase 1</th>
<th>Fuel</th>
<th>O&amp;M</th>
<th>Annualized Capital</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Police Headquarters</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Law Court</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Market Square/Hilton</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coast Guard Site</td>
<td></td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phase 2</th>
<th>Fuel</th>
<th>O&amp;M</th>
<th>Annualized Capital</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>City Hall</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brunswick House</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mercantile Building</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ailant Dial</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Brunswick Square</td>
<td>4</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Sub-total</td>
<td>7</td>
<td>2</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Total Phase 2 + Phase 1</td>
<td>2</td>
<td></td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

The expenses projection for district cooling was developed in a similar fashion as for district heating, with one of the key assumptions being that use of seawater for direct cooling in cold months, pre-cooling in shoulder months and condenser water in warm weather would save on average approximately 30% of the electricity otherwise consumed in a district cooling central plant.

In the case of district cooling, the higher risk for Phase 2 is related to uncertain connection of existing buildings as customers, at least with the assumed level of pricing, since there may not be a sufficient level of capital cost avoidance.

The capital for a seawater cooling system to Market Square only was developed separately and estimated to be approximately the complete Phase 1 Cooling per Table 13. A breakdown of this estimate is also included in Appendix 4. It includes no new chillers. The revenue stream for this project is represented by the estimated 30% savings in electricity that would be
achieved for Market Square. This would be 30% of $265,000 per year, as listed in Table 15, i.e. $79,500 per year.
7. Environmental Impacts

7.1 Environmental Approvals

Since this project is being supported with a grant from the federal government, a Canadian Environmental Assessment must be completed, which may take from 6 to 12 months.

If and when the seawater cooling project proceeds, numerous marine related approvals must be obtained, as outlined in detail in reference 5. These would be expected to take in the order of 18 to 24 months.

The above are the main approvals required in this case, other than the standard approvals for use of certain equipment, boiler and pressure vessels, city planning approvals and construction approvals, none of which are expected to have a significant timing impact.

7.2 Greenhouse Gas Emission Reductions

By reducing consumption of fossil fuels and electricity, the CES will reduce the carbon foot-print of the community to a degree that can be estimated from the reduction in volume of energy inputs and emission factors.

Results of calculations for each energy source option are summarized in Tables 16 and 17. The GJ and MWhe columns list the annual volumes of energy inputs for each option. Greenhouse Gas (GHG) emissions and reductions are shown in tonnes of CO₂ per year.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>GJ</th>
<th>MWhe</th>
<th>GHG</th>
<th>Reduction</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>A-1</td>
<td>Business-as-Usual – Heating (1)</td>
<td>148,679</td>
<td>2,876</td>
<td>11,200</td>
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<tr>
<td>A-2</td>
<td>Industrial Waste Heat: Heat Exchangers</td>
<td>15,905</td>
<td>730</td>
<td>1,562</td>
<td>9,618</td>
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<td>Raw Sewage</td>
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<td>E-2</td>
<td>Option D with Hot UTES</td>
<td>114,970</td>
<td>3,487</td>
<td>9,448</td>
<td>1,752</td>
<td>16%</td>
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</table>

(1) the BAU scenario for heating also uses 247,000 litres/year of light fuel oil.

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>MWhe</th>
<th>GHG</th>
<th>Reduction</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-1</td>
<td>Harbour Water: Phase 1 Cooling</td>
<td>717</td>
<td>799</td>
<td>714</td>
<td>48%</td>
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<tr>
<td>C-2</td>
<td>Harbour Water: Phase 2 Cooling</td>
<td>2,137</td>
<td>2,350</td>
<td>2,127</td>
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<tr>
<td>E-1</td>
<td>Option C-1 with Cold UTES</td>
<td>287</td>
<td>142</td>
<td>1,360</td>
<td>91%</td>
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</table>
8. References

2. Market Square Energy Audit, October 26, 2007 MCW Maricor
8. EngineeringToolBox.com Heat Storage in Materials
12. Wikipedia, Seasonal Thermal Storage
13. Email communication, CBCL
Appendix 1 Illustrations and Lists

Figure 1 List of Buildings Surveyed
Figure 2 Data on Buildings Surveyed
Figure 3 Locations of Buildings Surveyed and Energy Sources
Figure 4 CES Overview DPS Route and Sizing
Figure 5 Map of Potential District Cooling Customers
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Figure 19 Saint John Cooling Load Duration Curve
Figure 20 Cooling Energy versus Load Chart for Saint John
# Figure 1 List of Buildings Surveyed

<table>
<thead>
<tr>
<th>Building</th>
<th>Address</th>
<th>Site visit</th>
<th>Report</th>
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</thead>
<tbody>
<tr>
<td>Centrebeam</td>
<td>14 King Street</td>
<td>Full</td>
<td>Yes</td>
</tr>
<tr>
<td>Brunswick House</td>
<td>44 Chipman Hill</td>
<td>Full</td>
<td>Yes</td>
</tr>
<tr>
<td>Hilton</td>
<td></td>
<td>Full</td>
<td>Yes</td>
</tr>
<tr>
<td>City Hall</td>
<td>15 Market Square</td>
<td>Full</td>
<td>Yes</td>
</tr>
<tr>
<td>CGAC</td>
<td>50 Union Street</td>
<td>Full</td>
<td>Yes</td>
</tr>
<tr>
<td>Market Square</td>
<td>1 Market Square</td>
<td>Full</td>
<td>Yes</td>
</tr>
<tr>
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<td>170-200 Prince William Street</td>
<td>Full</td>
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</tr>
<tr>
<td>300 Union</td>
<td>300 Union Street</td>
<td>Full</td>
<td>Yes</td>
</tr>
<tr>
<td>St Malachy's High</td>
<td>2-20 Leinster Street</td>
<td>Full</td>
<td>Yes</td>
</tr>
<tr>
<td>Harbor View High</td>
<td>305 Douglas Avenue</td>
<td>Full</td>
<td>Yes</td>
</tr>
<tr>
<td>St Joseph's Hospital</td>
<td>130 Bayard Drive</td>
<td>Full</td>
<td>Yes</td>
</tr>
<tr>
<td>Brunswic Square</td>
<td>39 King Street</td>
<td>Full</td>
<td>Yes</td>
</tr>
<tr>
<td>Alant tower</td>
<td>Germain Street</td>
<td></td>
<td></td>
</tr>
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<td></td>
<td></td>
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<td>47 Charlotte Street</td>
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<tr>
<td>Red Rose Tea</td>
<td>12 Smythe Street</td>
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<tr>
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<td>Building sizing only</td>
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<tr>
<td>Prince Edward Square Apartments</td>
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<tr>
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<td>Cathedral</td>
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<td>Sydney Arms</td>
<td>111 Sydney Street</td>
<td>Basic</td>
<td>Building sizing only</td>
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<td>400 Main Street</td>
<td>Basic</td>
<td>Building sizing only</td>
</tr>
<tr>
<td>Lord Beaverbrook arena</td>
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<td>Basic</td>
<td>Building sizing only</td>
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<td>10 Sydney Street</td>
<td>Full</td>
<td>Yes</td>
</tr>
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<td>Carleton Towers</td>
<td>15 Macklenburg Street</td>
<td>Basic</td>
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</tr>
<tr>
<td>Customs Building</td>
<td>189 Prince William Street</td>
<td>Basic</td>
<td>Building sizing only</td>
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<tr>
<td>Masonic Temple</td>
<td>92 Germain Street</td>
<td>Basic</td>
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<tr>
<td>Fort Howe Hotel</td>
<td>10 Portland Street</td>
<td>Basic</td>
<td>Building sizing only</td>
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<tr>
<td>Hillyard Place</td>
<td>800 Main Street</td>
<td>Basic</td>
<td>Building sizing only</td>
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<tr>
<td>Saint Vinents School</td>
<td>Corner Cliff St and Coburg St</td>
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<td>Rothesay Ave. PO Building</td>
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<tr>
<td>Simms</td>
<td>33 Bridge Road</td>
<td>None</td>
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### Figure 2 Data on Buildings Surveyed

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<th>Address</th>
<th>Use</th>
<th>Floor Area m²</th>
<th>Floor Area sq ft</th>
<th>Peak Demand kWt</th>
<th>Annual Energy MWh</th>
<th>Fuel for Heating</th>
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<td>750</td>
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<td>347,858</td>
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<td>2,500</td>
<td>Electricity</td>
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<td>Dock Street</td>
<td>Office</td>
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<td>214,668</td>
<td>1,400</td>
<td>2,800</td>
<td>Natural Gas</td>
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<td>5</td>
<td>Police HQ</td>
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<td>Institution</td>
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<td>750</td>
<td>1,500</td>
<td>Natural Gas</td>
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<td>118,708</td>
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<td>1,080</td>
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<td>Institution</td>
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<td>91,689</td>
<td>500</td>
<td>1,236</td>
<td>Natural Gas</td>
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<td>365 Douglas Avenue</td>
<td>Institution</td>
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<td>Hilliard Place</td>
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<td>Office</td>
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<td>Office</td>
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<td>Institution</td>
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<td>0</td>
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<td>900</td>
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<td>Office</td>
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<td>Office</td>
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<td>400</td>
<td>900</td>
<td>Oil</td>
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<tr>
<td>38</td>
<td>P.D. Building</td>
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<td>800</td>
<td>1,880</td>
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<td>39</td>
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<td>100</td>
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<td>43</td>
<td>Captain's Towers</td>
<td>16 Macaulay Street</td>
<td>Accommodation</td>
<td>4,543</td>
<td>49,344</td>
<td>300</td>
<td>700</td>
<td>Electricity</td>
</tr>
<tr>
<td>44</td>
<td>Rothesay Ave- PO Building</td>
<td>155 Rothesay Avenue</td>
<td>Office</td>
<td>6,976</td>
<td>75,000</td>
<td>400</td>
<td>900</td>
<td>Oil</td>
</tr>
<tr>
<td>45</td>
<td>Hotel Courtenay Bay</td>
<td>350 Haymarket Square</td>
<td>Accommodation</td>
<td>2,068</td>
<td>22,000</td>
<td>200</td>
<td>468</td>
<td>Oil</td>
</tr>
</tbody>
</table>

**Legend**

- **Hydronic**
- **Steam Radiators**
- **Distributed Heat Pump**

---

[Energy Inc. Logo]

3/24/2010
Figure 3 Locations of Buildings Surveyed and Energy Sources
Saint John Community Energy System Design Recommendation

Figure 4 CES Overview DPS Route and Sizing
Figure 5 Map of Potential District Cooling Customers
Figure 6 Portion of Load Served by Low Temperature Resource

Figure 7 Proposed Heat Supply Primary Temperature Set-back Schedule
Figure 8 Hours versus Outside Air Temperature in Saint John

Figure 9 Hours vs Primary Supply Temperature for Proposed Set-back in Saint John
Figure 10 District Heating Flow Schematic
Saint John Community Energy System Design Recommendation
Figure 11 IPP Mill Heating Connection Schematic
Figure 12 Saint John Heating Load Duration Curve

Figure 13 Heating Energy vs Load for Saint John
Saint John Community Energy System Design Recommendation

Figure 14 Planned Sewage Lift Stations in Saint John
Figure 15 Sewage Heat vs Evaporation Temperature

COP at different evaporation temperatures

- Heat pump
- Heat recovery system (Heat pump + auxiliary system)

COP of the heat pump

Evaporation temperature

5 10 15 20 25
Figure 16 Seawater Cooling Schematic
Figure 17 Cooling with Seawater vs Chillers at Mean Harbour Water Temperatures
Figure 18 Cooling with Seawater vs Chillers at Minimum Saint John Harbour Water Temperatures
Figure 19 Saint John Cooling Load Duration Curve

Figure 20 Saint John Cooling Load vs Energy Curve
Appendix 2 Notes from Building Surveys

*Market Square*

The Market Square Building has been built in various stages although the most recent major renovation was carried out in 1983. The facility was originally constructed in 1984 to host the 1985 Canada Summer Games. The building houses various shops, several restaurants and fast food establishments, The New Brunswick Museum and the Saint John Trade and Convention Centre. The building is also home to several service providers such as dentists, employment agencies and the Saint John Public Library. Much of the lower level of the building contains an underground parking garage. There are a total of three floors above ground. The building also has a floor below ground which houses the parking garage. The building has a total building square footage of 540,000 ft² (50,167 m²).

The building HVAC system is split into various areas as shown in Table 1. There are four CAM industries electric boilers that are being used as heating backup within the facility. Two boilers have a capacity of 990 KW each and the other two boilers have a capacity of 360 KW each. All the boiler has been de-rate to 50% of its original capacity. The main source for the heating system are two 400 ton Trane heat pump chillers and 7 thermal storage tanks. 4 tanks each with a volume of 200,000 liters are used to storage hot water and 3 tanks each with a volume of 150,000 liters are used to storage cold water.

Table 1 - Major Ventilation Systems Summaries

<table>
<thead>
<tr>
<th>System</th>
<th>Area Served</th>
<th>Air Volume (cfm)</th>
<th>Motor load (HP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC # 1</td>
<td>T&amp;CC Marco Polo 1, 2, 3 rooms and Call Centre</td>
<td>36,300</td>
<td>50</td>
</tr>
<tr>
<td>AC # 2</td>
<td>Museum, retail and food court area</td>
<td>45,960</td>
<td>50</td>
</tr>
<tr>
<td>AC # 3</td>
<td>T&amp;CC Marco Polo and Loyalist rooms</td>
<td>30,640</td>
<td>35</td>
</tr>
<tr>
<td>AC # 4</td>
<td>Atrium</td>
<td>45,960</td>
<td>65</td>
</tr>
<tr>
<td>AC # 5</td>
<td>Library and adjacent retail spaces</td>
<td>43,955</td>
<td>78</td>
</tr>
<tr>
<td>AC # 6</td>
<td>T&amp;CC kitchen</td>
<td>3,850</td>
<td>5</td>
</tr>
<tr>
<td>AC # 7, 7a</td>
<td>Museum</td>
<td>7,700</td>
<td>10</td>
</tr>
<tr>
<td>AC # 8</td>
<td>Main Entrance</td>
<td>8,750</td>
<td>7.5</td>
</tr>
<tr>
<td>AC # 9</td>
<td>Mechanical Room</td>
<td>N/A</td>
<td>3</td>
</tr>
<tr>
<td>North Market Wharf</td>
<td>North Market Wharf businesses</td>
<td>N/A</td>
<td>6</td>
</tr>
</tbody>
</table>
Canada Games Aquatic Centre

The Canada Games Aquatic Centre Building is 25 years old. The facility was originally constructed in 1984 to host the 1985 Canada Summer Games. The building houses a 50 meter competition pool and a 25 meter leisure pool complex complete with water slides and tots pool. Poolside sauna, steam room and hot tubs are used for pre and post exercise relaxation. The facility also features a weight room and fitness area. The building is generally used for recreation and is open to the general public. It has a total of three floors above ground, one floor covers the entire footprint of the building, one of which is approximately ½ the footprint of the facility while the third floor is a penthouse which houses the mechanical equipment. The building also has a partial sub-basement. The building has a total building square footage of 62,904 ft² (5,844 m²).

The building HVAC system is split into various areas as shown in Table 1. There are two, 2132MBH, natural gas boilers that are being used as primary heating source within the facility. Only one boiler is used at a time and they alternate on a weekly basis. When not in service, the secondary boiler serves as a back-up. The existing non condensing boilers supply heating to all air handling units, domestic hot water heaters, pool heaters, and hydronic baseboard heaters for perimeter heating. The majority of the heating load is met with the ventilation system. The boilers were converted to Natural Gas in 2002.

Table 1 - Major Ventilation Systems Summaries

<table>
<thead>
<tr>
<th>System</th>
<th>Location</th>
<th>Air Volume (l/s)</th>
<th>Motor Load HP</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHU-1 Competition Pool</td>
<td>Mech Penthouse</td>
<td>9,500</td>
<td>15 HP / 7.5 HP</td>
</tr>
<tr>
<td>AHU-2 Leisure Pool</td>
<td>Mech Penthouse</td>
<td>4,750</td>
<td>12 HP / 4 HP</td>
</tr>
<tr>
<td>AHU-3 Administration and</td>
<td>Located on Roof</td>
<td>3,750</td>
<td>7.5 HP / 1 HP</td>
</tr>
<tr>
<td>Multipurpose room (New Rooftop)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AHU-4 General Change Rooms</td>
<td>Mech Penthouse</td>
<td>2,100</td>
<td>4 HP / 3/4 HP</td>
</tr>
<tr>
<td>AHU-5 Staff Change Rooms</td>
<td>Basement Workshop</td>
<td>1,600</td>
<td>3 HP / 1 HP</td>
</tr>
<tr>
<td>AC Offices underneath Pedway</td>
<td>Office Mech Closet</td>
<td>1,600</td>
<td>3 HP</td>
</tr>
<tr>
<td>AC New Fitness Room</td>
<td>Fitness Area Mech Closet</td>
<td>2,100</td>
<td>3 HP</td>
</tr>
</tbody>
</table>
Saint John Police HQ
The Saint John Police Headquarters building forms part of the Peel Plaza development and is proposed to begin construction in the near future. The building is designed to accommodate the existing police station which are currently housed in the Saint John City Hall building and also meet the accommodation needs of several satellite police stations throughout Saint John. The facility has a floor area of approximately 72,000 ft² (6,689m²).

Heating and air conditioning is provided by a heat pump loop system.

The mechanical room will house:

- Two Viessmann Vitocrossal 300 CT3-28 hot water boilers c/w Weishaupt burners
- One Viessmann Vitocell V 300 indirect fired domestic hot water tank.
- Various circulating pumps including the 2 main Armstrong 4300 vertical in-line pumps

Saint John Law Courts
The Saint John Law Courts building is part of the Peel Plaza project which is proposed to begin construction in the near future. The building is designed to accommodate the existing law courts which are currently housed in three buildings spread out throughout Saint John. The facility has a floor area of approximately 129,500 ft² (12,030m²).

Heating and air conditioning is provided by a heat pump loop system.

The mechanical room will house:

- Two Viessmann Vitocrossal 300 CT3-72 hot water boilers c/w Weishaupt burners
- One Fulton ICX-30 steam boiler system c/w Riello RS-50/m burner to provide steam to the humidification system
- One Bradford White EF-100T-199E gas fired domestic hot water heater.
- Various circulating pumps including the 2 main Armstrong 4302 vertical in-line pumps
City Hall

The City Hall building houses the offices and council chambers for the City of Saint John along with several shops and eateries and the main Saint John Police station. There are a total of fifteen floors above ground plus a penthouse and two floors below ground level. The building has a total building square footage of 220,078 ft² (20,446 m²).

The building is heated by hot water coils in the air handling equipment and by baseboard heating around the perimeter of the building. The heated water is supplied by two, 200 HP, natural gas boilers located in the penthouse mechanical room. Only one boiler is used at a time and they alternate on a weekly basis. When not in service, the secondary boiler serves as a back-up. The majority of the heating load is met with the ventilation system.

The building is cooled by chilled water coils in the air handling equipment. Chilled water is supplied by a 300 Ton chiller located in the penthouse mechanical room.

The penthouse mechanical room houses:

- Two Powermaster 200HP natural gas fired boilers.
- Two Armstrong 4030 horizontal base mounted hot water circulation pumps.
- Trane 300 Ton centrifugal chiller.
- Two Armstrong 6x5x10 4030 horizontal base mounted chilled water circulation pumps.

Fresh air into the building is controlled by CO₂ Sensors.

300 Union Street (JD Irving)

300 Union Street houses the offices for various divisions of JD Irving. There are a total of twelve floors above ground plus a penthouse. The building has a total building square footage of 220,078 ft² (20,446 m²).

The building is heated by hot water coils in the air handling equipment, the heated water is supplied by two, 8,369 Mbh, fuel oil boilers. Only one boiler is used at a time and they alternate on a weekly basis. When not in service, the secondary boiler serves as a back-up. The majority of the heating load is met with the ventilation system.

The building is cooled by chilled water coils in the air handling equipment. Chilled water is supplied by a 450 Ton chiller located in the ninth floor mechanical room.

The first floor mechanical room houses:

- Two Cleaver Brooks CB600-200 oil fired fire-tube boilers.
- One Calortecnica oil fired boiler for domestic hot water c/w four Amtrol Boilermate storage tanks.
- Four Bell and Gossett 1510 horizontal base mounted circulating pumps (two standby).

The ninth floor mechanical room houses:

- Trane CVHA-044J 450 Ton centrifugal chiller.

FVB ENERGY INC.
• Four Bell and Gossett 1531D horizontal base mounted chilled water circulating pumps (two standby).
• Two Bell and Gossett 1531D horizontal base mounted condenser water circulating pumps (one standby).

_Brunswick House_

The Brunswick House Building is 43 years old. The building was constructed in 1966 with steel frame and pre-cast concrete panel cladding. It is comprised of fourteen (14) floors of commercial office including a full basement. The floor area measures approximately 11,050 m² (118,950 ft²). The building exterior dimensions measure approximately 35m x 23m (115 ft x 76 ft) and stands approximately 52 m (168 ft) above the ground.

A rooftop penthouse houses the mechanical ventilation system equipment, cooling tower and the elevator equipment. Two boilers with natural gas fired burners and centrifugal chiller cooling plant are located in the basement, in addition to the related circulating pumps, water pump, condenser pump, domestic water pumps and domestic hot water heaters.

The basement mechanical room houses:

• Two B&W Steam Block SHW-70-5 Boilers C/W Power Flame CR3-G-20C natural gas burners.
• One Trane Central Vac Model PCV-2C-C1 water cooled centrifugal chiller

Fresh air into the building is limited to 10% when the outside temperature reaches a set point.

_Centrebeam_

The Centrebeam Building is a group of heritage buildings which have been modernized; the most recent major renovation was carried out in 2008. The building houses several shops and the offices of various companies. There are a total of three floors above ground. The building also has a floor below ground. The building has a total building square footage of 130,000 ft² (12,067 m²).

The building HVAC system is composed of several variable refrigerant heat pumps and a perimeter hot water heating system that acts as a back up for the heat pump systems. There are four boilers. Two of the boilers are Gasmaster, One 292 Kw, and the other is 586 kw. The other two boiler are Viessmann each one with a capacity of 164 kw. The boilers are set in lead/lag configuration to satisfy the building heating requirements. The hot water is circulated through two single speed centrifugal pumps.
The complex has two mechanical rooms located in the basement. One mechanical room is located off Prince William Street and the other is on Canterbury Street.

**Mechanical room at Prince William Street:**

- Two GasMaster Boilers C/W Weishaupt G5/1-D natural gas burners.
- Two Centrifugal pumps. (one is a backup).

**Mechanical room at Canterbury:**

- Two Viessmann boilers.
- Two centrifugal pumps.

Fresh air is provided by an air handle unit located at the roof and is equipped with a hot water coil to temper the out side air.

---

**Harbour View High School**

Harbour View High School was built in 1925 on Douglas Avenue and houses approximately 1,000 students. The school has a 610-seat auditorium, a lecture theatre, gym, and two cafeterias, woodworking, electrical and cooking labs, five computer labs, and a library.

The building is heated by two 2.4MBH De Dietrich hot water boilers fired by natural gas Riello RS70 burners. Heated water is circulated by 6 (3+3back-up) Grundfos vertical in line pumps.

Domestic hot water is provided by three Giant 1126C-3-18 electric, 100 gallon, 18kW hot water tanks

**The basement mechanical room houses:**

- Two De Dietrich GT-412 Boilers with Riello RS70 Natural Gas Burners.
- 6 Grundfos circulating pumps.
- 3 Giant 1126C-3-18 water heaters.

Fresh air into the building is controlled via the Delta control system by CO₂ Sensors.

---

**Saint Joseph Hospital**

Saint Joseph hospital is located at 130 Bayard Drive. The building has a total of 9 floors and an approximate area of 25,000 m² (269,000 ft²) some of the floors have been modernized; the most recent major renovation was carried out in 2007. The building houses several services from medical/surgical to a community health center.
The building HVAC system is composed of several heat pumps and perimeter hot water heating system that act as a back up for the heat pump systems. There are 3 gas fired boilers that supply steam at 85 psi. The steam is passed through a heat exchanger to heat water. The hot water is circulated by means of a centrifugal pump. One boiler is sufficient to supply the building heating requirements. The heating plant also supplies steam to the cathedral, a convent, Saint Vincent's High School and the rectory. This small heating district has been in operation for more that 20 years.

The heating plant is located at the street level on the back of the building.

Mechanical room houses:

- One Clever Brooks boiler model CLS 400, 300 HP, 12,563,000 Btu/h
- One Clever Brooks boiler model Ci-00X, 300 HP, 12,563,000 Btu/h
- One Clever Brooks CBI400-200LE, 8,164,600 Btu/h

Fresh air is provided for by an air handling unit located on the roof and is equipped with a hot water coil to temper the outside air.

Saint John High School

The Saint John High School facility opened in 1932 and houses approximately 1260 students. Two additions have been made to this building since its opening. The "New Wing" added in 1964 houses the science labs, a double gymnasium and a swimming pool. In 1986 the school experienced major renovations updating its electrical, windows computer labs and adding an enlarged library. The building overlooks the Saint John harbour in close proximity to the uptown centre.

The building operates Monday-Friday between 7am and 10pm and on Saturday and Sunday for an average of 8 hours per day when required.

The building is heated by three 2.2 MBH Cleaver Brooks gas fired hot water boilers.

The main floor Canterbury Street mechanical room houses:

- Three 2.2MBH Cleaver Brooks 50A gas fired boilers.
- 4 Bell and Gossett A5120 circulating pumps.
- 2 Bell and Gossett 1510 circulating pumps

Fresh air into the building is controlled via the Delta control system by CO₂ Sensors.
Saint John Community Energy System Design Recommendation

Saint Malachy’s High School

Saint Malachy’s High School was built in 1976 on Leinster Street and houses approximately 1,300 students. The school has an auditorium, a lecture theatre, gym, cafeteria, music labs, three science labs, four computer labs, a food lab and a library.

The building is heated by two 2.4MBH Weil McLean hot water boilers fired by natural gas Webster JB2G-10-RM7896C-H.25/.20-CSA-ULC burners. Heated water is circulated by 13 (7+6back-up) Grundfos vertical in line pumps and controlled by a combination of DDC and Pneumatic control systems.

The basement mechanical room houses:

- Two Weil McLean H8617.512346790 Boilers with Webster Natural Gas Burners.
- 4 Grundfos double circulating pumps.
- 1 Grundfos circulating pump.
- 2 ITT circulating pumps.

Fresh air into the building is controlled via the Delta control system by CO₂ Sensors.
Appendix 3 FVB Industrial Waste Heat Projects

**Stora Enso Skutskär**

Älvkarleby Fjärrvärme

Year 2003

Condensate from steam: 6 bar(g), 100°C
DH: 16 bar övertryck, 120°C
Max load: 13,5 MW

**Skutskär, Sweden**

Waste heat from StoraEnso (pulp and paper)Skutskär. Distribute to DH-system. The waste heat consists of both low steam and condensate.

FVB did:
- Pre-study
- System solution
- Design
- Purchase an negotiation
- Supervision during the project

**AB Fortum Värme**

Iggesund Paperboard

Year 2005

Waste energy: 70-74°C
DH: 16 bar 110°C
Steam for top load: 2,0 bar(g), 160°C
Load steam condensor: 4,5 MW
Load HEX: 2 MW

**Iggesund**

Waste heat recovery from the industry and distribution to the DH-system.
- System solutions
- Inquiry documents
- Purchase
- Project management

**AB Fortum Värme**

Hedins saw mill in Krylbo

Year 2004-2009

**Avesta**

Pre-study for waste heat to saw mill from waste incinerator as well as waste heat from Steal production. Heat distribution via existing DH-system

Pre-study complies:
- Princip solution
- System design
- Energy- and flowbalances
- Economic calculations
- Project management
- Automation system
- Commissioning

---

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3/24/2010
AssiDomän Frövi
< >
Linde Energi AB
Year 1996-1999
Load: 20 MW
Waste heat: 85°C hot water
Top load: steam 120°C (bark fired boiler)
Billerud Gruvöns Bruk
(pulp and paper)
< >
StoraEnso Gruvöns sågverk och Fortum Värme
2000-2001
Steam and black liquor
Max load saw mill: 20 MW, 120°C
Max load DH: 8.5 MW, 90°C

StoraEnso Nymölka
(pulp and paper)
< >
Ifö Sanitar och Bromölla fjärrvärme
Year 1999-2000
IFÖ: 6 MW, 120/90°C
Bromölla DH: 9 MW, 90/40°C
Steam supply: 3.9 bar(g), 150°C

Waste heat to Lindesberg, Frövi och Vedevåg, 95 GWh/år
• Pre-study
• System solution
• Design
• Control
• Negotiations, purchase

Grums
Waste heat from Billerud (pulp and paper) distribution to StoraEnso saw mill.
FVB did:
• Pre-study
• System solution
• Design
• Project management
• Control and commissioning

Bromölla (Fortum Värme)
Waste heat from StoraEnso Nymölka. Distribution of heat via DH-system
• Pre-study
• System solution
• Design
• Purchase
• Control
• Commissioning
Appendix 4 Capital Cost Estimates

<table>
<thead>
<tr>
<th>ITEM</th>
<th>Phase 1</th>
<th>Total Buildup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural equipment support</td>
<td>$17,000.00</td>
<td>$25,000.00</td>
</tr>
<tr>
<td>Water to water heat exchangers</td>
<td>$44,000.00</td>
<td>$87,000.00</td>
</tr>
<tr>
<td>Steam to water heat exchangers</td>
<td>$43,000.00</td>
<td>$66,000.00</td>
</tr>
<tr>
<td>Pumps and vdfs</td>
<td>$146,000.00</td>
<td>$225,000.00</td>
</tr>
<tr>
<td>Interface HW piping with IPP process</td>
<td>$100,000.00</td>
<td>$100,000.00</td>
</tr>
<tr>
<td>Interface steam piping</td>
<td>$100,000.00</td>
<td>$100,000.00</td>
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<tr>
<td>Hot water piping</td>
<td>$170,000.00</td>
<td>$200,000.00</td>
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<tr>
<td>Steam piping &amp; specialties</td>
<td>$99,000.00</td>
<td>$150,000.00</td>
</tr>
<tr>
<td>Control valves</td>
<td>$32,000.00</td>
<td>$40,000.00</td>
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<tr>
<td>HW underground piping</td>
<td>$1,200,000.00</td>
<td>$1,200,000.00</td>
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<tr>
<td>Metering</td>
<td>$50,000.00</td>
<td>$50,000.00</td>
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<tr>
<td>Electrical gear and cabling</td>
<td>$75,000.00</td>
<td>$100,000.00</td>
</tr>
<tr>
<td>Controls</td>
<td>$80,000.00</td>
<td>$100,000.00</td>
</tr>
<tr>
<td>Construction Soft Costs</td>
<td>$259,000</td>
<td>$293,000</td>
</tr>
<tr>
<td><strong>Subtotal Construction Costs</strong></td>
<td><strong>$2,415,000</strong></td>
<td><strong>$2,736,000</strong></td>
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<tr>
<td>Engineering and supervision</td>
<td>$360,000</td>
<td>$410,000</td>
</tr>
<tr>
<td>Contingency 10%</td>
<td>$241,500</td>
<td>$273,600</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$3,016,500.00</strong></td>
<td><strong>$3,419,600.00</strong></td>
</tr>
</tbody>
</table>

Notes
1) Construction costs are estimates for feasibility purposes only.
2) Soft costs include contractor's O&M, bonding and insurance, construction administration
3) Engineering includes design, specialty consultants and construction supervision
4) Cost of land acquisition, Easements, and Rights of way not included
5) Costs do not include provincial / federal taxes
6) Phase 1 sized to provide 8.6 MWt of capacity, Total Build out 15 MWt
## Saint John District Energy System

### Green Thermal Utility Facility - HEATING Only

### Cost Estimate

<table>
<thead>
<tr>
<th>Description</th>
<th>Phase 1</th>
<th>Total Buildout</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GTU Plant</strong><a href="#">1</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building &amp; Site</td>
<td>Arch &amp; Civil / Util / Structural</td>
<td>$900,000</td>
</tr>
<tr>
<td>Electrical Equip. &amp; Installation</td>
<td>Services and Process</td>
<td>$650,000</td>
</tr>
<tr>
<td>Mechanical Equipment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boilers</td>
<td>Gas Water Tube with Economizers</td>
<td>$480,000</td>
</tr>
<tr>
<td>Stacks</td>
<td></td>
<td>$200,000</td>
</tr>
<tr>
<td>Pumps</td>
<td>Circulation and Distribution</td>
<td>$250,000</td>
</tr>
<tr>
<td>Process Piping, etc</td>
<td>Heating Systems</td>
<td>$750,000</td>
</tr>
<tr>
<td>Controls</td>
<td>PLC based controls</td>
<td>$100,000</td>
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<tr>
<td>Mechanical Installation</td>
<td>Process and Building Services Systems</td>
<td>$750,000</td>
</tr>
<tr>
<td>Construction Soft Costs</td>
<td>see note (3)</td>
<td>$490,000</td>
</tr>
<tr>
<td><strong>Subtotal Construction Cost</strong></td>
<td></td>
<td>$4,570,000</td>
</tr>
<tr>
<td>Engineering and supervision</td>
<td>see note (4)</td>
<td></td>
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<tr>
<td>Contingency 10%</td>
<td></td>
<td>$570,000</td>
</tr>
<tr>
<td><strong>TOTAL HEATING</strong></td>
<td></td>
<td>$5,597,000</td>
</tr>
</tbody>
</table>

### Notes

1. Phase 1 is 8.7 MWt diversified and total buildout is 15 MWt diversified.
2. Construction costs are estimates for feasibility purposes only.
3. Soft costs include contractor’s OH&P, bonding and insurance, construction administration
4. Engineering includes design, specialty consultants and construction supervision
5. Cost of land acquisition, Easements, and Rights of way not included
6. Costs do not include provincial / federal taxes
### Saint John District Energy System

#### HEATING ETS and Building Conversions

<table>
<thead>
<tr>
<th>#</th>
<th>Building</th>
<th>GFA (m²)</th>
<th>Heating Load (kWt)</th>
<th>ETS Cost</th>
<th>Conversion cost</th>
<th>Subtotal</th>
<th>Construction Support (4%)</th>
<th>Engineering (13%)</th>
<th>Contingencies (15%)</th>
<th>Total ETS</th>
<th>Existing System Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL Phase 1</td>
<td>191,564</td>
<td>10,250</td>
<td>$2,330,000</td>
<td>$170,000</td>
<td>$2,500,000</td>
<td>$102,000</td>
<td>$327,000</td>
<td>$378,000</td>
<td>$3,307,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL Full Buildout (incl Phase 1)</td>
<td>322,836</td>
<td>17,350</td>
<td>$4,040,000</td>
<td>$545,000</td>
<td>$4,585,000</td>
<td>$187,000</td>
<td>$588,000</td>
<td>$683,000</td>
<td>$6,063,000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

1. ETS Costs reflect primary side only and are based on aggregate $/kW values from FVB database.
2. Conversion Costs assume minor pipe modification to HX connections, no removal of existing equipment and sufficient space for ETS equipment.
3. Estimate assumes ETS location in basement / main level mechanical room with sufficient space.
## Saint John District Energy System
### COOLING ETS and Building Conversions

<table>
<thead>
<tr>
<th>Building</th>
<th>Tons</th>
<th>Cooling Load (kWt)</th>
<th>ETS Cost</th>
<th>Conversion cost</th>
<th>Subtotal</th>
<th>Construction Support (4%)</th>
<th>Engineering (13%)</th>
<th>Contingencies (15%)</th>
<th>Total ETS</th>
<th>Existing System Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1 Total</td>
<td>1,200</td>
<td>4,400</td>
<td>$800,000</td>
<td>$15,000</td>
<td>$815,000</td>
<td>$32,000</td>
<td>$106,000</td>
<td>$123,000</td>
<td>$1,076,000</td>
<td></td>
</tr>
<tr>
<td>Total with additional</td>
<td>2,330</td>
<td>8,300</td>
<td>$1,470,000</td>
<td>$25,000</td>
<td>$1,495,000</td>
<td>$61,000</td>
<td>$224,000</td>
<td>$152,000</td>
<td>$3,008,000</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
1. ETS Costs reflects primary side only and are based on aggregate $/kW values from FVB database
2. Conversion Costs assume minor piping modification, no removal of existing equipment and sufficient space for ETS equipment
3. Estimate assumes ETS location in basement / main level mechanical room with sufficient space.
4. Brunswick Square system includes mall, Delta Hotel and Allant Office Tower
### Saint John DES Feasibility

#### Distribution Piping System - Capital Cost Summary

**Heating Pipes - Phase 1**

**Description:**
1) This cost estimate is based on running district heating pipes from Irving Paper Mill to Saint John Downtown and branches to Phase 1 customers.
2) The proposed hot water pipe size is 250 mm with a capacity of up to 18 MW at 30 deg. C Delta T.

<table>
<thead>
<tr>
<th>Line No.</th>
<th>Description</th>
<th>Heating (2009$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Phase 1: 5374 metres of trench</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Mechanical - Material &amp; Installation</td>
<td>5,374 m</td>
</tr>
<tr>
<td>3</td>
<td>Civil - Excavation, Backfill &amp; Reinstatement</td>
<td>5,374 m</td>
</tr>
<tr>
<td>4</td>
<td>Contractor Admin., Bonding, Insurance &amp; OH&amp;P</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Provincial Sales Tax</td>
<td>0.0%</td>
</tr>
<tr>
<td>6</td>
<td>Goods &amp; Services Tax</td>
<td>0.0%</td>
</tr>
<tr>
<td>7</td>
<td>Construction Management &amp; Supervision</td>
<td>4.0%</td>
</tr>
<tr>
<td>8</td>
<td>Construction Changes</td>
<td>3.0%</td>
</tr>
<tr>
<td>9</td>
<td>Phase 1 DPS Construction Subtotal</td>
<td>$10,734,000</td>
</tr>
<tr>
<td>10</td>
<td>Owner’s Costs</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Engineering (Design &amp; Construction Support)</td>
<td>10.0%</td>
</tr>
<tr>
<td>12</td>
<td>Contingency</td>
<td>10.0%</td>
</tr>
<tr>
<td>13</td>
<td>Phase 1 DPS Total</td>
<td>$12,882,000</td>
</tr>
</tbody>
</table>

**Notes:**
1) Shoring trench box allowance included for trenches deeper than 1.2 m.
2) Trench depth allows for 1200 mm cover to top of pipe.
3) Cost per meter includes material supply, mechanical installation and all civil works, including roadway reinstatement.
4) Price to include for pre-insulated heating supply and return lines.
5) Mechanical and civil costs include allowance for mobilization, subcontractors, bonding and insurance.
6) GST & PST are NOT included in the cost.
7) Costs are budgetary only and are to be confirmed during the preliminary design stage.
8) Cost does not include U-fill backfill and assumes 35% rock excavation.
9) No allowance has been made for fees, permitting, right of ways, easements, or removal of contaminated soils.
### Saint John DES feasibility

**Distribution Piping System - Capital Cost Summary**

**Heating Pipes - Total System Buildout**

**Description:**
1. This cost estimate is based on running district heating pipes from Irving Paper Mill to Saint John Downtown and branched to all 25 buildings envisaged in the Full Build-out.
2. The proposed hot water pipe size is 250 mm with a capacity of up to 18 MW at 30 deg. C Delta T.

<table>
<thead>
<tr>
<th>Line No.</th>
<th>Description</th>
<th>Heating (2009$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Phase 1: 7813 metres of trench</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Mechanical - Material &amp; Installation</td>
<td>7,813 m, $5,423,000</td>
</tr>
<tr>
<td>3</td>
<td>Civil - Excavation, Backfill &amp; Reinstatement</td>
<td>7,813 m, $6,034,000</td>
</tr>
<tr>
<td>4</td>
<td>Contractor Admin., Bonding, Insurance &amp; OH&amp;P</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Provincial Sales Tax</td>
<td>0.0%, $0</td>
</tr>
<tr>
<td>6</td>
<td>Goods &amp; Services Tax</td>
<td>0.0%, $0</td>
</tr>
<tr>
<td>7</td>
<td>Construction Management &amp; Supervision</td>
<td>4.0%, $523,000</td>
</tr>
<tr>
<td>8</td>
<td>Construction Changes</td>
<td>3.0%, $392,000</td>
</tr>
</tbody>
</table>

**Phase 1-7 DPS Construction Subtotal**

<table>
<thead>
<tr>
<th>Line No.</th>
<th>Description</th>
<th>Heating (2009$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Owner's Costs</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Engineering (Design &amp; Construction Support)</td>
<td>10.0%, $1,399,000</td>
</tr>
<tr>
<td>11</td>
<td>Contingency</td>
<td>10.0%, $1,399,000</td>
</tr>
</tbody>
</table>

**Phase 1-7 DPS Total**

<table>
<thead>
<tr>
<th>Line No.</th>
<th>Description</th>
<th>Heating (2009$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

1. Shoring trench box allowance included for trenches deeper than 1.2 m.
2. Trench depth allows for 1200 mm cover to top of pipe.
3. Cost per meter includes material supply, mechanical installation and all civil works, including roadway reinstatement.
4. Price to include for pre-insulated heating supply and return lines.
5. Mechanical and civil costs include allowance for mobilization, subcontractors, bonding and insurance.
6. GST & PST are NOT included in the cost.
7. Costs are budgetary only and are to be confirmed during the preliminary design stage.
8. Cost does not include U-fill backfill and assumes 35% rock excavation.
9. No allowance has been made for fees, permitting, right of ways, easements, or removal of contaminated soils.
## Saint John District Energy System
### Green Thermal Utility Facility - COOLING Only
#### Cost Estimate

<table>
<thead>
<tr>
<th>COOLING GTU Plant</th>
<th>Description</th>
<th>Phase 1</th>
<th>Total Built out</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building &amp; Site</td>
<td>Arch &amp; Civil / Utilities / Structural</td>
<td>$1,250,000</td>
<td>$1,250,000</td>
</tr>
<tr>
<td>Electrical Equip. &amp; installation</td>
<td>Services and Process</td>
<td>$1,950,000</td>
<td>$4,200,000</td>
</tr>
<tr>
<td>Mechanical Equipment</td>
<td>Centrifugal Sea Water Cooled</td>
<td>$650,000</td>
<td>$1,850,000</td>
</tr>
<tr>
<td></td>
<td>Sea Water (Titanium or Cu-Ni)</td>
<td>$240,000</td>
<td>$740,000</td>
</tr>
<tr>
<td></td>
<td>Pumps</td>
<td>Circulation and Distribution</td>
<td>$125,000</td>
</tr>
<tr>
<td></td>
<td>Process Piping, etc</td>
<td>Cooling Systems</td>
<td>$500,000</td>
</tr>
<tr>
<td></td>
<td>Sea Water Infrastructure</td>
<td>Structural, Pumps and Screens</td>
<td>$1,600,000</td>
</tr>
<tr>
<td></td>
<td>Sea Water Piping</td>
<td>$500,000</td>
<td>$500,000</td>
</tr>
<tr>
<td></td>
<td>Controls</td>
<td>PLC based controls</td>
<td>$100,000</td>
</tr>
<tr>
<td></td>
<td>Mechanical Installation</td>
<td>Process and Building Services Systems</td>
<td>$750,000</td>
</tr>
<tr>
<td></td>
<td>Construction Soft Costs</td>
<td>$848,000</td>
<td>$1,402,000</td>
</tr>
<tr>
<td><strong>Subtotal Construction Costs</strong></td>
<td></td>
<td><strong>Subtotal</strong></td>
<td><strong>7,065,000</strong></td>
</tr>
<tr>
<td>Engineering and supervision</td>
<td>see note (3)</td>
<td>$880,000</td>
<td>$1,460,000</td>
</tr>
<tr>
<td>Contingency 10%</td>
<td></td>
<td>$705,500</td>
<td>$1,189,500</td>
</tr>
<tr>
<td><strong>Total COOLING</strong></td>
<td></td>
<td><strong>$8,651,500</strong></td>
<td><strong>$14,313,500</strong></td>
</tr>
</tbody>
</table>

### Notes
1) Construction costs are estimates based on FVB experience which can be used for feasibility purposes only.
2) Soft costs include contractor's OH&P, bonding and insurance, construction administration
3) Engineering includes design, specialty consultants and construction supervision
4) Cost of land acquisition, Easements, and Rights of way not included
5) Costs do not include provincial / federal taxes

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*[FVB ENERGY INC.]*

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3/24/2010
## Saint John DES feasibility

### Distribution Piping System - Capital Cost Summary

#### Cooling

<table>
<thead>
<tr>
<th>Line No.</th>
<th>Description</th>
<th>Quantity</th>
<th>Cost 2009 ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Phase 1: 1043.5 metres of trench</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Mechanical - Material &amp; Installation</td>
<td>1,044 m</td>
<td>$932,000</td>
</tr>
<tr>
<td>3</td>
<td>Civil - Excavation, Backfill &amp; Reinstatement</td>
<td>1,044 m</td>
<td>$676,000</td>
</tr>
<tr>
<td>4</td>
<td>Contractor Admin., Bonding, Insurance &amp; OH&amp;P</td>
<td></td>
<td>$233,000</td>
</tr>
<tr>
<td>5</td>
<td>Provincial Sales Tax</td>
<td>0.0%</td>
<td>$0</td>
</tr>
<tr>
<td>6</td>
<td>Goods &amp; Services Tax</td>
<td>0.0%</td>
<td>$0</td>
</tr>
<tr>
<td>7</td>
<td>Construction Management &amp; Supervision</td>
<td>4.0%</td>
<td>$74,000</td>
</tr>
<tr>
<td>8</td>
<td>Construction Changes</td>
<td>3.0%</td>
<td>$55,000</td>
</tr>
<tr>
<td>9</td>
<td>Phase 1 DPS Construction Subtotal</td>
<td></td>
<td>$1,970,000</td>
</tr>
</tbody>
</table>

#### Owner's Costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Percentage</th>
<th>Cost 2009 ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 Engineering (Design &amp; Construction Support)</td>
<td>10.0%</td>
<td>$197,000</td>
</tr>
<tr>
<td>12 Contingency</td>
<td>10.0%</td>
<td>$197,000</td>
</tr>
<tr>
<td>13 Phase 1 DPS Total</td>
<td></td>
<td>$2,364,000</td>
</tr>
</tbody>
</table>

### Notes:

1. Shoring trench box allowance included for trenches deeper than 1.2 m.
2. Trench depth allows for 1200 mm cover to top of pipe.
3. Cost per meter includes material supply, mechanical installation and all civil works, including roadway reinstatement.
4. Price to include for pre-insulated heating supply and return lines.
5. Mechanical and civil costs include allowance for mobilization, subcontractors, bonding and insurance.
6. GST & PST are NOT included in the cost.
7. Costs are budgetary only and are to be confirmed during the preliminary design stage.
8. Cost does not include U-fill backfill and assumes 35% rock excavation.
9. No allowance has been made for fees, permitting, right of ways, easements, or removal of contaminated soils.
10. Chilled water pipe size of 350 mm has a capacity of upto 15 MWt (4300 TR) at 18 deg. F Delta T.
### Saint John DES feasibility

**Distribution Piping System - Capital Cost Summary**

**Cooling**

**Total System Buildout**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Phase 1: 2291.15 metres of trench</td>
<td>2,291 m</td>
<td>$1,773,000</td>
</tr>
<tr>
<td>2</td>
<td>Mechanical - Material &amp; Installation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Civil - Excavation, Backfill &amp; Reinstatement</td>
<td>2,291 m</td>
<td>$1,393,000</td>
</tr>
<tr>
<td>4</td>
<td>Contractor Admin., Bonding, Insurance &amp; OH&amp;P</td>
<td></td>
<td>$458,000</td>
</tr>
<tr>
<td>5</td>
<td>Provincial Sales Tax</td>
<td>0.0%</td>
<td>$0</td>
</tr>
<tr>
<td>6</td>
<td>Goods &amp; Services Tax</td>
<td>0.0%</td>
<td>$0</td>
</tr>
<tr>
<td>7</td>
<td>Construction Management &amp; Supervision</td>
<td>4.0%</td>
<td>$145,000</td>
</tr>
<tr>
<td>8</td>
<td>Construction Changes</td>
<td>3.0%</td>
<td>$109,000</td>
</tr>
<tr>
<td>9</td>
<td>Phase 1 DPS Construction Subtotal</td>
<td></td>
<td>$3,878,000</td>
</tr>
<tr>
<td>10</td>
<td>Owner's Costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Engineering (Design &amp; Construction Support)</td>
<td>10.0%</td>
<td>$388,000</td>
</tr>
<tr>
<td>12</td>
<td>Contingency</td>
<td>10.0%</td>
<td>$388,000</td>
</tr>
<tr>
<td>13</td>
<td>Phase 1 DPS Total</td>
<td></td>
<td>$4,654,000</td>
</tr>
</tbody>
</table>

**Notes:**

1. Shoring trench box allowance included for trenches deeper than 1.2 m.
2. Trench depth allows for 1200 mm cover to top of pipe.
3. Cost per meter includes material supply, mechanical installation and all civil works, including roadway reinstatement.
4. Price to include for pre-insulated heating supply and return lines.
5. Mechanical and civil costs include allowance for mobilization, subcontractors, bonding and insurance.
6. GST & PST are NOT included in the cost.
7. Costs are budgetary only and are to be confirmed during the preliminary design stage.
8. Cost does not include U-fill backfill and assumes 35% rock excavation.
9. No allowance has been made for fees, permitting, right of ways, easements, or removal of contaminated soils.
10. Chilled water pipe size of 350 mm has a capacity of upto 15 MWt (4300 TR) at 18 deg. F Delta T.
# Saint John District Energy System

## Green Thermal Utility Facility - COOLING Only

<table>
<thead>
<tr>
<th>Description</th>
<th>Phase 1</th>
<th>Total Built out</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GTU Plant</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building &amp; Site</td>
<td>Arch &amp; Civil / Utility / Structural</td>
<td>$1,250,000</td>
</tr>
<tr>
<td>Electrical Equip. &amp; Installation</td>
<td>Services and Process</td>
<td>$90,000</td>
</tr>
<tr>
<td>Mechanical Equipment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chillers</td>
<td>Centrifugal Sea Water Cooled</td>
<td>$-</td>
</tr>
<tr>
<td>Heat Exchangers</td>
<td>Sea Water (Titanium or Cu-Ni)</td>
<td>$240,000</td>
</tr>
<tr>
<td>Pumps</td>
<td>Circulation and Distribution</td>
<td>$65,000</td>
</tr>
<tr>
<td>Process Piping, etc</td>
<td>Cooling Systems</td>
<td>$250,000</td>
</tr>
<tr>
<td>Sea Water Infrastructure</td>
<td>Structural, Pumps and Screens</td>
<td>$1,000,000</td>
</tr>
<tr>
<td>Sea Water Piping</td>
<td>$500,000</td>
<td>$500,000</td>
</tr>
<tr>
<td>Controls</td>
<td>PLC based controls</td>
<td>$75,000</td>
</tr>
<tr>
<td>Mechanical Installation</td>
<td>Process and Building Services Systems</td>
<td>$500,000</td>
</tr>
<tr>
<td>Construction Soft Costs</td>
<td>$476,000</td>
<td>$1,399,000</td>
</tr>
<tr>
<td><strong>Subtotal Construction Costs</strong></td>
<td>$3,970,000</td>
<td>$11,655,000</td>
</tr>
<tr>
<td>Engineering and supervision</td>
<td>see note (3)</td>
<td>$500,000</td>
</tr>
<tr>
<td>Contingency 10%</td>
<td>$397,000</td>
<td>$1,165,500</td>
</tr>
<tr>
<td><strong>Total Cooling</strong></td>
<td>$4,867,000</td>
<td>$14,280,500</td>
</tr>
</tbody>
</table>

### Notes
1. Phase 1 consists of providing direct cooling via seawater heat exchangers to the distribution loop connecting 1200 MWP capacity only (Market Square) without mechanical refrigeration.
2. Construction costs are estimates based on FVB experience which can be used for feasibility purposes only.
3. Soft costs include contractor's OH&P, bonding and insurance, construction administration.
4. Engineering includes design, specialty consultants and construction supervision.
5. Cost of land acquisition, Easements, and Rights of way not included.
6. Costs do not include provincial / federal taxes.
Capital Cost Assumptions

Energy Centre Capital Assumptions:

Generally the energy centre capital has been estimated using the following;

- Budget quote from York for the chillers
- Budget Quote from Sterling Combustion for hot water boilers
- FVB in house data base from previous community energy projects

The building costs are made up of the following areas:

- Cooling Equipment; building footprint – 500 m²
- Heating Equipment; building footprint – 375 m²
- Sea Water Intake Equipment – 400 m³

The phase 1 building cost include space for the total build out capacity.

Heating phase 1 equipment capacity is 9 MWT and total build out capacity is 15 MWT.

Cooling phase 1 consists of providing cooling via sea water cooling heat exchangers to offset the Market Square cooling load of 1.2 MWT without the use of chillers. Total build out cooling capacity is 13 MWT with full capacity via chillers. No cooling towers and associated equipment / structural / permitting costs are allowed for.

Construction soft costs include for the following:

- 10% for Contractor’s OH&P and construction administration
- 2% for permitting, bonding, & insurance

Owner’s soft costs include for the following:

- Engineering and construction supervision costs – 12.5 %
- Contingency of 10%.

Distribution Piping Capital Assumptions:

Generally the distribution piping capital has been estimated using the FVB in house data base from previous community energy projects

The budgets do not include for easement procurement.

- Shoring trench box allowance included for trenches deeper than 1.2 m.
- Trench depth allows for 1200 mm cover to top of pipe.
- Cost per meter includes material supply, mechanical installation and all civil works, including roadway reinstatement.
- Price to include for pre-insulated heating supply and return lines.
- Mechanical and civil costs include allowance for mobilization, subcontractors, bonding and insurance.
- GST & PST are NOT included in the cost.
Costs are budgetary only and are to be confirmed during the preliminary design stage.
Cost does not include U-fill backfill and assumes 30% rock excavation.
No allowance has been made for fees, permitting, right of ways, easements, or removal of contaminated soils.
Chilled water pipe size of 350 mm has a capacity of upto 15 MWe (4300 TR) at 18 deg. F Delta T.

The piping costs are made up of mechanical (material & installation) and civil costs for both heating and cooling pipes. Cathodic protection has been included for the cooling system. The communication ducts and wiring are included for both heating and cooling. An allocation is made for manholes, mobilization and demobilization, road crossing planning and barricading, and x-ray testing.

Cooling DPS phase 1 cost includes cooling pipes to be installed in Union St. as part of the Municipal Infrastructure project construction which will start in Spring of 2010.

Construction soft costs include for the following:
- GC OH&P OF 10% is included as part of the mechanical & civil costs
- 5% for administration, permitting, bonding, & insurance
- 4% for construction management & supervision
- 3% for construction changes

Owner's soft costs include for the following:
- 10% for engineering costs
- 10% for contingency.

Energy Transfer Station Capital Assumptions:

Generally the ETS capital has been estimated using the FVB in house data base from previous community energy projects
The budgets do not include for permits or inspections.
For the existing buildings, secondary piping is included to the system tie-in points. All ETS's are considered to be indirect connections with only 20% extra installed capacity over the peak load estimates. The location of the ETS's is assumed to be within 10 metres of an exterior wall on the ground floor or basement levels of the buildings.

Construction soft costs include for the following:
- GC OH&P (including mobilization, administration, permitting, bonding, & insurance) is included as part of the costs
- No taxes are included in the estimate
- 4% for construction management & supervision
- 0% for construction changes
- ETS Costs reflects primary side only and are based on aggregate $/kW values from FVB database
- Conversion Costs assume minor pipe modification to HX connections, no removal of existing equipment and sufficient space for ETS equipment
Estimate assumes ETS location in basement / main level mechanical room with sufficient space.

Owner's soft costs include for the following:
  ➢ 13% for engineering costs
  ➢ 15% for contingency.

Connection to IPP:

Capital Cost Assumptions

1) Construction costs are estimates for feasibility purposes only.
2) Soft costs (12%) include contractor's OH&P, bonding and insurance, construction administration. Contingency 10%
3) Engineering (15%) includes design, specialty consultants and construction supervision
4) Cost of land acquisition, Easements, and Rights of way not included
5) Costs do not include provincial / federal taxes
6) Phase 1 sized to provide 8.6 MWt of capacity, Total Buildout 15 MWt