KERR WOOD LEIDAL
consulting engineers

Section 10

Sewage Heat Recovery and District Energy

10. Sewage Heat Recovery and District Energy

10.1 Overview

District Energy Systems (DES) are a means of transporting thermal energy from a prime generating plant through a pipe network to end consumers. Heat is transported by circulating water or steam, usually through a closed-loop piping system. Heat exchangers or other devices on the consumer end of the system transfer heat from the DES to the buildings. A DES may provide hot water, ambient-temperature water, chilled water or steam to consumers. For this study, sewer heat recovery is considered as the primary energy source for potential DES.

DES generally consist of four ‘macro’ components:

- Energy Centre to provide primary energy to the system;
- Distribution Piping System to transport the energy;
- Energy Transfer Stations to transfer energy from the DES to the consumer buildings; and
- Hydronic or other HVAC systems to distribute heat throughout the buildings (must be compatible with DES).

These components can be provided in a number of arrangements, including centralized and distributed arrangements as shown in Figure 10-1.

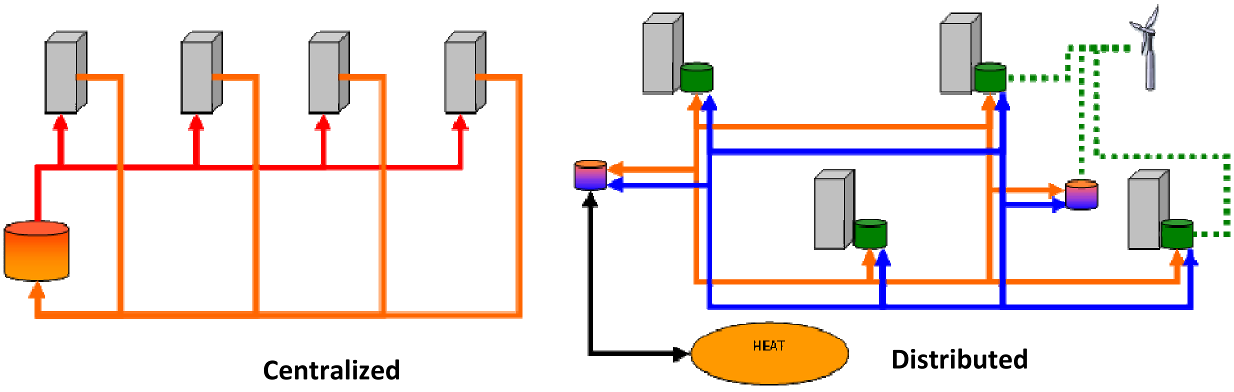


Figure 10-1: Schematics of District Energy Systems

A DES requires some kind of primary energy source or sink to provide heating and/or cooling. Energy sources can be described as high-grade or low-grade, which refers to temperature and energy content.

For instance, natural gas is a high-grade energy source because once combusted, can produce very high temperatures, and has a high energy content of 40 megajoules per cubic metre (MJ/m^3). It can also be transported long distances in pipelines. Other high-grade sources include biomass, biogas, electricity, liquid fuels, waste heat, etc.

By contrast, air is one of the lowest-grade energy sources, and in Colwood may be as cold as -8ºC with an energy content of 0.01 MJ/m^3. Low-grade energy sources need to be in abundance, and usually require heat pumps to boost the temperature of the low-grade energy up to the required heating temperature. Low-grade sources that are cool enough can potentially be used for ‘free’ cooling, where electricity is not required to run a cooling unit. Water-based heat sources such as sewage and geoexchange are generally considered low-grade.

District Energy System Components

Energy Centre

An Energy Centre houses the primary energy generation within a DES. The Energy Centre contains mechanical heating and cooling devices and piping to control the temperature and water flow through the system. An energy centre will usually house gas boilers, water pumps and possibly other renewable energy systems such as heat pumps, biomass combustors or gasifiers.

Distribution Piping System

DES require pipes to deliver thermal energy with a heated or chilled fluid, usually water. Closed-loop piping systems are typical, in which one pipe sends energy and the other returns the energy. This is referred to as a ‘two-pipe’ system. A system may have more than one pair of pipes if transporting hot and chilled water, i.e. a ‘four-pipe’ system. Depending upon the fluid temperature, different piping materials are required. Hot water requires specialized insulated piping, which can be significantly more expensive than uninsulated piping, which can be used for cooler temperatures.

Energy Transfer Stations

An energy transfer station transfers energy between the DES and the client buildings and creates a hydraulic separation. This is also a convenient limit of responsibility for a utility. In a hot water DES, this usually consists of a heat exchanger, control assembly and energy meter. An ambient-temperature (10-15ºC) DES will use heat pumps to transfer heat to or from the DES.

Renewable Energy Sources

There are many options for supplying renewable energy to a DES, and most are present in Colwood. All DES will generally use natural gas boilers for peaking and backup purposes.

Geoexchange

Geoexchange (GHX) is the process of extracting or depositing thermal energy in the earth. This can be accomplished in a number of ways, including closed-loop and open-loop arrangements. Closed-loop systems transfer heat through the walls of a vertical or horizontal buried piping system and open-loop systems draw groundwater or surface water to directly exchange heat. Vertical closed-loop and groundwater systems are affected by drilling conditions and the presence of aquifers, while horizontal closed-loop systems generally require a large open space, such as playing fields. Size is a limiting factor for geoexchange, as larger applications either require a significant footprint (closed-loop), or a large volume of groundwater (open-loop).

In all cases where GHX is proposed, it is recommended that a site-specific review of hydrogeology is conducted to fully assess resource potential.

Temperatures typically range between 5ºC and 10ºC for open-loop systems. Closed-loop system temperatures may fluctuate seasonally depending upon the design and loading on the field. Typical design values for field temperatures are 0-5ºC for heating and 20-30ºC for cooling. A heat pump running on a geoexchange system will typically have a coefficient of performance (COP) between 3 and 3.5, depending upon input and output.

Waste Heat

Waste heat to support district energy may be available from large refrigeration loads (e.g. ice arenas, supermarkets, cold-storage, etc.) or industrial processes.

Colwood's only ice surfaces are the two ice rinks and curling facility at the Juan de Fuca Recreation Centre. We understand that there is already a heat exchange between the upper ice facilities and the swimming pool.

Colwood otherwise has few if any industries that could yield significant sources of waste heat.

Sewage Heat Exchange

Sewage may provide an abundant source of energy where large trunk sewer facilities are available. The most cost-effective opportunities for sewage heat recovery exist when there are major sewer upgrades, and the heat recovery component can be integrated into a larger project. Otherwise, existing sewer facilities must be accessed by excavating the sewer and building an underground structure to access the sewage.

The amount of sewer heat available is determined from the flow and temperature of the sewage flow. Sewer flows are affected by rainfall, and in older systems, flows during wet weather may increase by up to 10 times compared with dry weather. The temperature of the sewage may drop significantly during large wet weather events, which can temporarily reduce the amount of recoverable heat. Average sewer temperatures range from approximately 12ºC in the winter to over 20ºC in the summer. Heat pump COP expected between 3.5 and 4.5.

Air Source Heat Pumps

Air-source heat pumps can be installed on almost any building, and can be used to provide hot or chilled water. A conventional air conditioning unit is a form of air-source heat pump. Air-source heat pumps have a lower COP (2.0 - 2.5) than geoexchange or sewage heat recovery because air has a lower energy content than water.

Solar

Solar energy can be captured and used in a district energy system, but due to the coastal BC climate, is generally not suitable as a base load supply. This is because solar energy is at its greatest availability in summer, when demand is low, and may be scarce in winter, when demand is highest. It can be used as a supplemental heat source, and may be paired with geoexchange to assist in recharging field capacity.

Biomass

Biomass thermal involves the combustion or gasification of a biomass fuel source to produce heat. Suitable biomass sources include wood residues (construction waste, sawmill residues or yard waste), wood chips, wood briquettes, and pellet fuels. The City's park waste, yard waste, and construction waste represent potential opportunities to leverage a local biomass fuel supply suitable for energy production. Potentially viable biomass fuel alternatives could be sourced from regional suppliers or other areas in British Columbia.

Municipal Solid Waste

Municipal solid waste (MSW) is handled by the CRD, and disposed in the Hartland Landfill. The landfill is slated to reach full capacity in several years, at which time the CRD will need to determine an alternate disposal location. There have been discussions of the possibility of waste-to-energy at the regional level, with Hartland Landfill being a potential location. The landfill is located too far from urban areas to be a realistic option for district energy, but if greenhouses were constructed on the surrounding agricultural land, heat from a waste-to-energy facility could be utilized. The CRD currently has a landfill gas power generation facility at Hartland that produces approximately 1.6 MW of electricity.

Renewable energy sources do not need to provide 100% of the peak heating requirements of a DES, and in fact can provide most of the annual energy at only 1/3 of the peak load on the system.

10.2 Demand Analysis

District energy must generally be first approached from a demand-side standpoint, which means that there must be demand for the type of thermal energy offered by a prospective DES. As discussed, this usually means that potential customers have existing or plan to have hydronic heating and cooling systems.

Existing hydronic systems are often indicated by the presence of boilers. The B.C. Safety Authority maintains a database of existing boilers registered under the *Power Engineers, Boiler, Pressure Vessel and Refrigeration Regulation* of the *Safety Standards Act*. KWL has mapped this information in GIS according to the addresses of the boilers contained in the database. The database denotes the size of the heat exchanger in each registered boiler, from which the heating capacity of the boiler can be determined. Also known is the type of use of the boiler installations, which provides an indication of boiler utilization, also known as “equivalent full load hours” (EFLH), based on typical energy use observed in the southern B.C. region. Boiler plants are often oversized for redundancy, which needs to be accounted for in estimate energy demand.

Energy use for assessing district energy potential is considered in two ways. The potential peak demand for thermal energy determines the sizing of the system, and is measured in units of power (kW, MW or Btu/hr). The annual thermal energy consumed by the system (kWh, GJ or Btu) determines what amount of fuel and recovered energy is required to feed the system, and also the amount sold to consumers. The annual energy is the key determinant of unit energy pricing (i.e. $/kWh or $/GJ), and for the boilers, is determined by multiplying the estimated EFLH against the peak demand of the system.

To conduct the demand analysis, two scenarios were developed: an existing scenario based on the presence of boilers, and a future scenario that includes the existing boilers plus new development proposed in Colwood, based on the same future population projections used in the estimation of future sewage flows.

The following table summarizes the existing boiler capacity identified from the BC Safety Authority Database. Some boilers at Royal Roads were excluded because they produce steam, which is not compatible with recovered sewage heat. These boilers could be integrated with a higher temperature thermal system such as biomass or combined heat and power.

Table 10-1: Existing Boiler Capacity and Annual Energy Demand

Address	Site Description	Estimated Boiler Capacity (kW)	Estimated Annual Energy Demand (MWh)
1767 Island Highway	JDF Rec Centre	1,260	1,575
2005 Sooke Road	Royal Roads	4,221	6,405
2139 Sooke Road	School	147	147
3010 Wishart Road	School	378	378
3310 Wishart Road	School	210	105
3341 Painter Road	School	840	420
Total		**7,056**	**9,030**

Future energy demands were determined based on projected floor area for medium and high density residential, and ICI properties. Single family and townhouse residential were not considered to be suitable candidates for district energy, as the densities for these land use types are generally not high enough to support an economic case for district energy. Floor areas were projected for residential based on the number of units provided in planning data from the City, while ICI floor areas were estimated based on assumed floor area ratios. The following table shows the estimated floor areas and corresponding energy demands for the future scenario.

Table 10-2: Estimated Energy Demands for Future Development

Land Use	Floor Area (m^2)	Energy Use Intensity		Peak Demand (kW)	Annual Demand (MWh/yr)
		Peak (W/m^2)	Annual (Wh/m^2)		
Lowrise Residential	157,000	47	99	7,000	16,000
Highrise Residential	774,000	47	99	36,000	77,000
Industrial	44,000	55	66	2,000	3,000
Commercial	550,000	55	66	30,000	36,000
Institutional	121,000	55	66	7,000	8,000
Total	**1,646,000**	**50**	**85**	**82,000**	**140,000**

As indicated, there is a significant amount of growth proposed for Colwood, and correspondingly, a large increase in the potential for uptake of district energy. Section 10.4 further discusses the potential for district energy with respect to available sewage heat.

10.3 Supply Analysis

Energy recoverable from sanitary sewers is dependent upon the flow and temperature of the sewage stream. For planning purposes, the average dry weather flow (ADWF) is the key flow parameter of greatest interest in assessing the sewage heat resource. Recoverable sewage heat is determined from the 'sensible heat' in the sewage flow, and is described by the following equation:

$Q = m\ c\ \Delta T$, where

Q = energy recoverable (kW or kJ)

m = mass (kg) or mass flow (kg/s)

c = 4.186 kJ/kg-ºC

ΔT = sewage temperature drop or 'delta T' (ºC)

The mass of sewage is related to the sewage flow rate according to the fluid density, which is approximately 1 kg per litre. Hence, the mass flow in kg/s can simply be swapped with sewage flow in L/s. The delta T ranges from 3ºC to 5ºC depending upon the proposed heat recovery technology.

Having modelled the average dry weather flow condition for each pipe in the system, it is possible to estimate the available recoverable sewage heat on a pipe-by-pipe basis. The amount of recoverable heat will vary hourly over the course of the day, and the temperature will tend to fluctuate. For this level of planning, it is acceptable to simply consider the average flow over the course of the day, though the daily diurnal variation in sewage heat needs to be considered at the feasibility stage of a project.

The amount of sewage heat available in Colwood is discussed in Section 10.4.

Heat Recovery Process

In order to recover heat from sewage, the heat needs to be extracted through a heat exchanger to another closed piping loop for distribution of heat to customers. Once in the separate loop, the temperature of the system needs to be elevated to a serviceable temperature for space and hot water heating. This is done using a heat pump, which is analogous to a refrigerator working in reverse. The heat pump extracts the heat using a refrigerant and boosts the temperature of the refrigerant by compressing it. The hot refrigerant is then used to heat water for customer use, and cycled back through the heat pump.

There are a number of sewage heat recovery technologies available commercially, some of which have local installations. In general, raw sewage heat recovery requires some kind of screening to remove larger solids, down to 75 mm to 2 mm depending upon the technology. In most cases, a separate screening and heat exchanger process is required to feed heat to the heat pump, though the Southeast False Creek Neighbourhood Energy Utility uses a specially-designed heat pump to extract heat directly from a screened sewage supply.

At this stage of analysis it is not necessary to select a heat recovery technology, however in all cases, a heat recovery system will generally consist of a tap into a sewer, sewage pumps to move the sewage through the heat recovery process, the screening and heat exchanger, and a heat pump to extract the heat.

A final consideration for raw sewage heat recovery is that the 'leaving sewage temperature' from a heat recovery process is limited in cases where secondary biological wastewater treatment is in place or planned. Most biological treatment processes require a minimum sewage temperature of 11ºC, which means that if the entire raw sewage stream is to be utilized, this temperature is a limit on the delta T. After treatment, the treated effluent may be further utilized for heat recovery, down to a temperature of roughly 6ºC, beyond which there is potential for freezing the effluent in the heat recovery process.

10.4 Assessment of Heat Recovery Potential

The basic exercise in determining heat recovery potential is to match the potential heat demand with projected available heat supply. This was completed for both the existing and future development cases, and consisted of comparing the estimated demands against the available sewage supply within a 500 m distance of a given development.

Figures 10-2 and 10-3 show the existing and future potential for heat recovery in terms of the available sewage supply in each line, represented in terms of the size of system that can potentially be supported. Potential demand is represented in terms of energy density (MWh/ha), noting that areas with higher density will require less piping infrastructure per unit of heat delivered, which reduces the overall cost of the DES service.

Business Case Development

For any heat recovery project to proceed past a conceptual stage, it is of key importance to conduct a technical and financial feasibility study and prepare a business case. These studies require significant resources to properly assess, so it is important to determine the overall priority for heat recovery opportunities. Further, the primary driver behind district energy is to reduce greenhouse gas emissions, so projects that have higher potential to successfully reduce GHGs should be given priority. In general, a larger system will have a better economy -of-scale than a smaller system, so priority should be given to a single larger system, as compared to an equivalent number of smaller systems, for instance.

Another important factor to understand with DES is that these systems are capital-intensive, and decision-making requires evaluation of the value of the project over its life cycle, typically 30 years. This places greater emphasis on future growth than existing opportunities from a planning perspective.

In order to facilitate a prioritization of sewage heat recovery opportunities, an indexed scale was developed to prioritize the potential opportunities. In each of the existing and future scenarios, both the available heat demand and supply were normalized from 0 to 1 based on the ratio of a given area to that of the area with the largest supply and/or demand. The optimization for both supply and demand involves maximizing both, so the normalized demand and supply were multiplied to come up with an overall priority index. Figure 10-4 shows the calculated supply demand index for both the existing and future scenarios, which provides a ranked priority for the City to consider the available opportunities.

As shown on Figure 10-4, Colwood Corners has the highest indexed potential of 1.0, as it abuts the CRD Northwest Trunk Sewer – West Section (NWT-W), which has the highest concentration of sewage flow in the City. It also has the highest demand potential in the City. This suggests Colwood Corners should have the highest priority for sewer heat recovery of all the potential opportunities. As shown on Figure 10-5, the projected future sewage supply also matches very closely to the potential demand, which further suggests this is the best opportunity to achieve significant avoidance of GHG emissions from future development.

Also indicated on Figure 10-4 is that Royal Roads University has the highest existing potential at an index of 0.96. This presents a potential conflict of interests in tapping into the sewage heat resource. However, as Figure 10-5 shows, the potential sewage heat demand at Royal Roads is only about 10% of Colwood Corners. It is therefore recommended that Colwood Corners be considered the leading opportunity for raw sewage heat recovery.

Wastewater Treatment Plant Heat Recovery

As part of the Core Area Liquid Waste Management Plan, one or more wastewater treatment plants (WWTPs) in the Western Communities are likely, with Colwood being a likely location due to its availability of ocean discharge. Potential plant opportunities have been identified throughout Colwood as discussed in Section 9.

As discussed above, there is potential to recover heat from the treated sewage effluent. This can occur regardless of whether raw sewage heat recovery is implemented upstream. It will be important for the

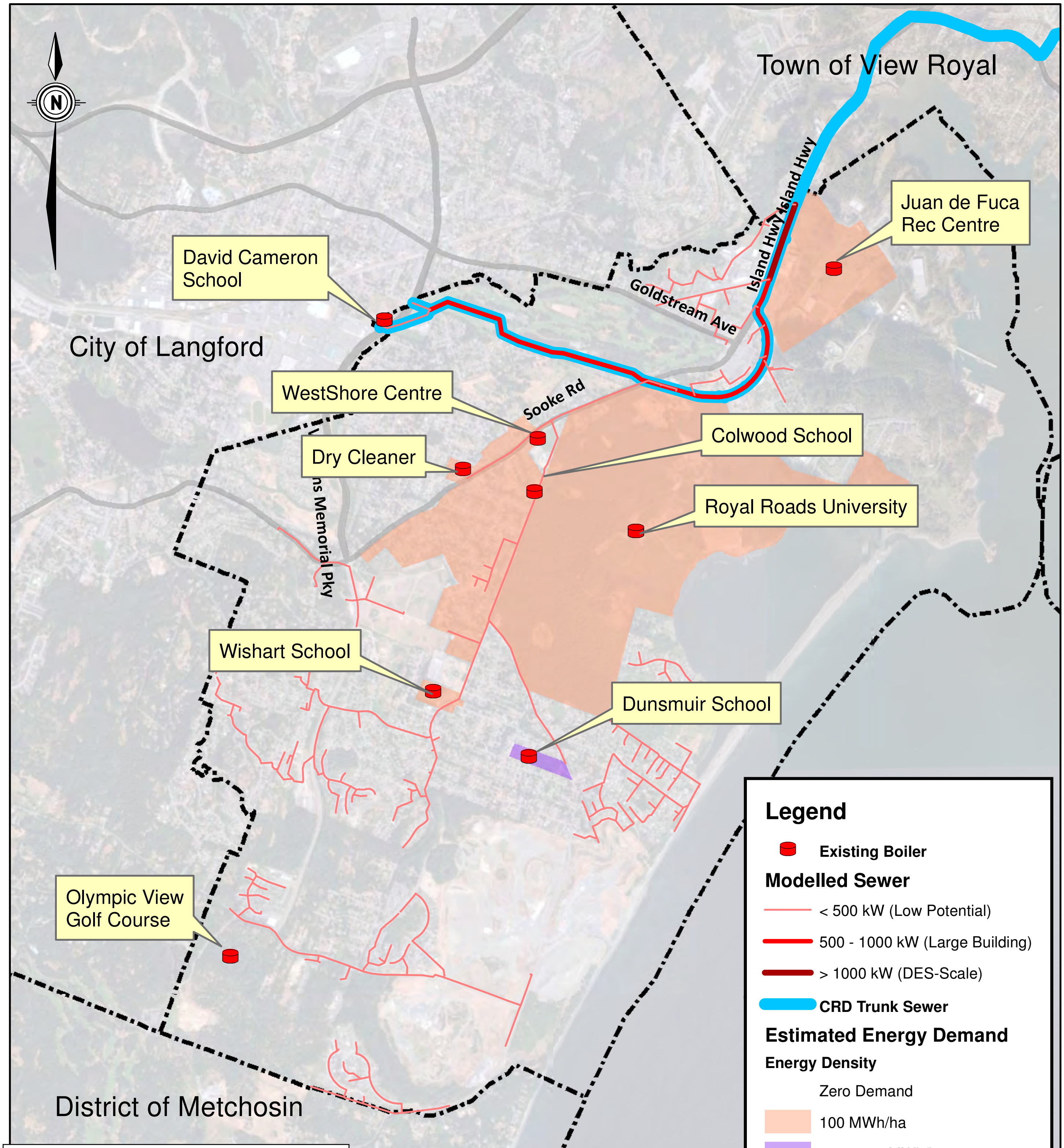
City to work with the Capital Regional District in allocating sewage heat amongst potential opportunities, particularly where projects associated with the Core Area Sewage Treatment program are concerned.

One of the potentially promising opportunities identified through previous studies is the siting of a WWTP in Royal Bay, which would allow the Royal Bay development to access treated effluent as a heat source. Royal Bay has the second-highest potential demand of the opportunities evaluated, but has minimal potential to access a raw sewage heat supply.

Recommended Approach

At this stage, it is recommended that the City engage with the CRD and the Capital City Centre developer to facilitate a heat recovery opportunity at Colwood Corners, as this opportunity has the highest potential to move forward. If this is not successful, the City should look to the next-most promising opportunities. A secondary strategy will be to identify opportunities for heat recovery from treated effluent. In all cases, the CRD will be a key partner for the City, as the CRD NWT sewer has the largest available heat resource. Since this sewer mostly carries flows from Langford, liaison with the City of Langford and Corix Water Utilities may be advisable.

Aside from sewage heat recovery, there are numerous other technologies available. For any opportunity it is recommended the City consider the range of available renewable heat resources, including biomass, geoexchange, solar, etc. A lack of sewer heat availability should not be considered as an impediment to the development of DES.



Reference: Orthophoto from Bing aerial image map. Boiler locations geocoded based on data from BC Safety Authority. Positions are approximate.

KERR WOOD LEIDAL
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City of Colwood
Sewer Master Plan

Project No.	Date
2417-003	June 2012

330 0 1,320 (m)
1:35,000

District Energy from Sewer Heat
Existing Potential

Figure 10-2

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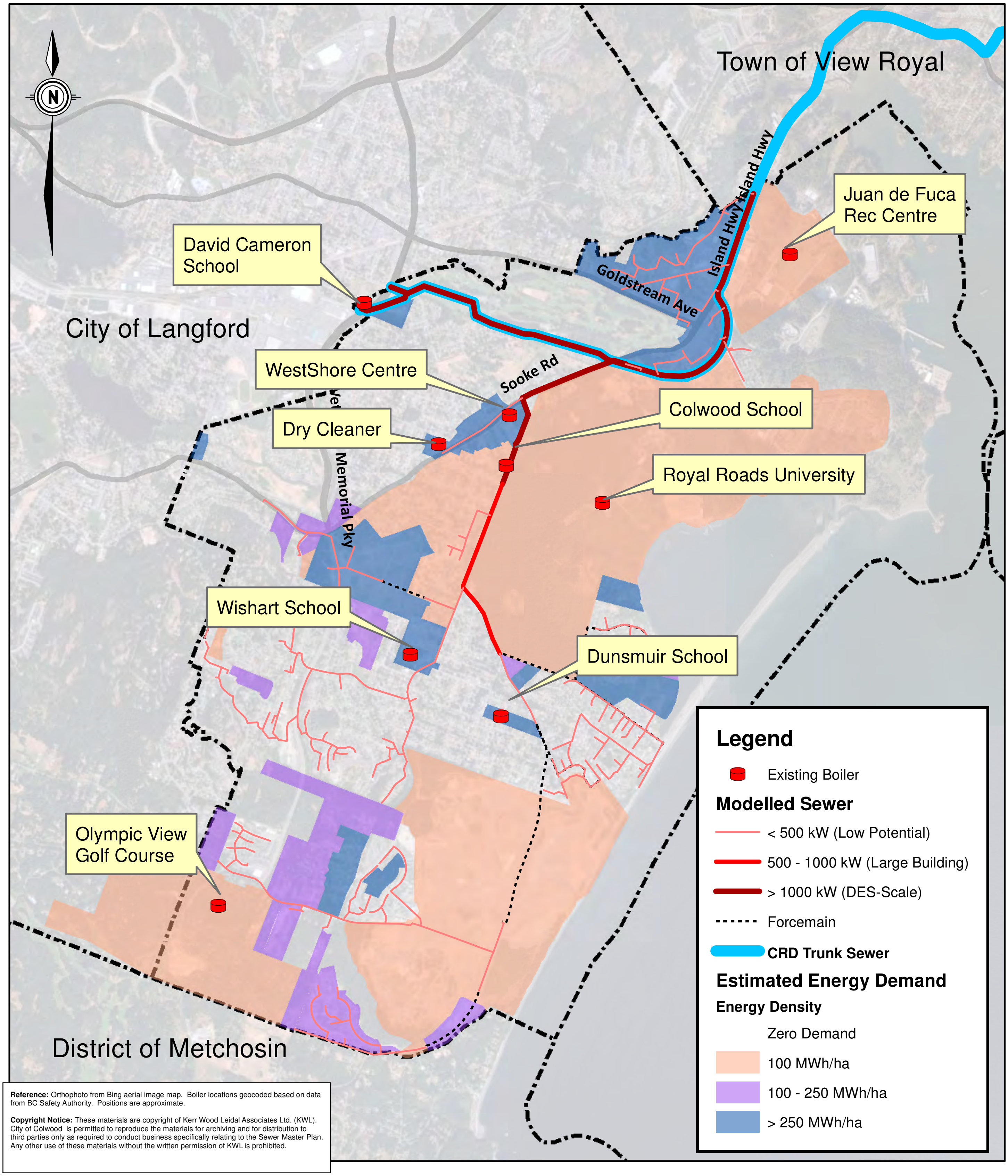
Author: MHomenuke



Reference: Orthophoto from Bing aerial image map. Boiler locations geocoded based on data from BC Safety Authority. Positions are approximate.

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(m)
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District Energy from Sewer Heat
Future Potential

Figure 10-3

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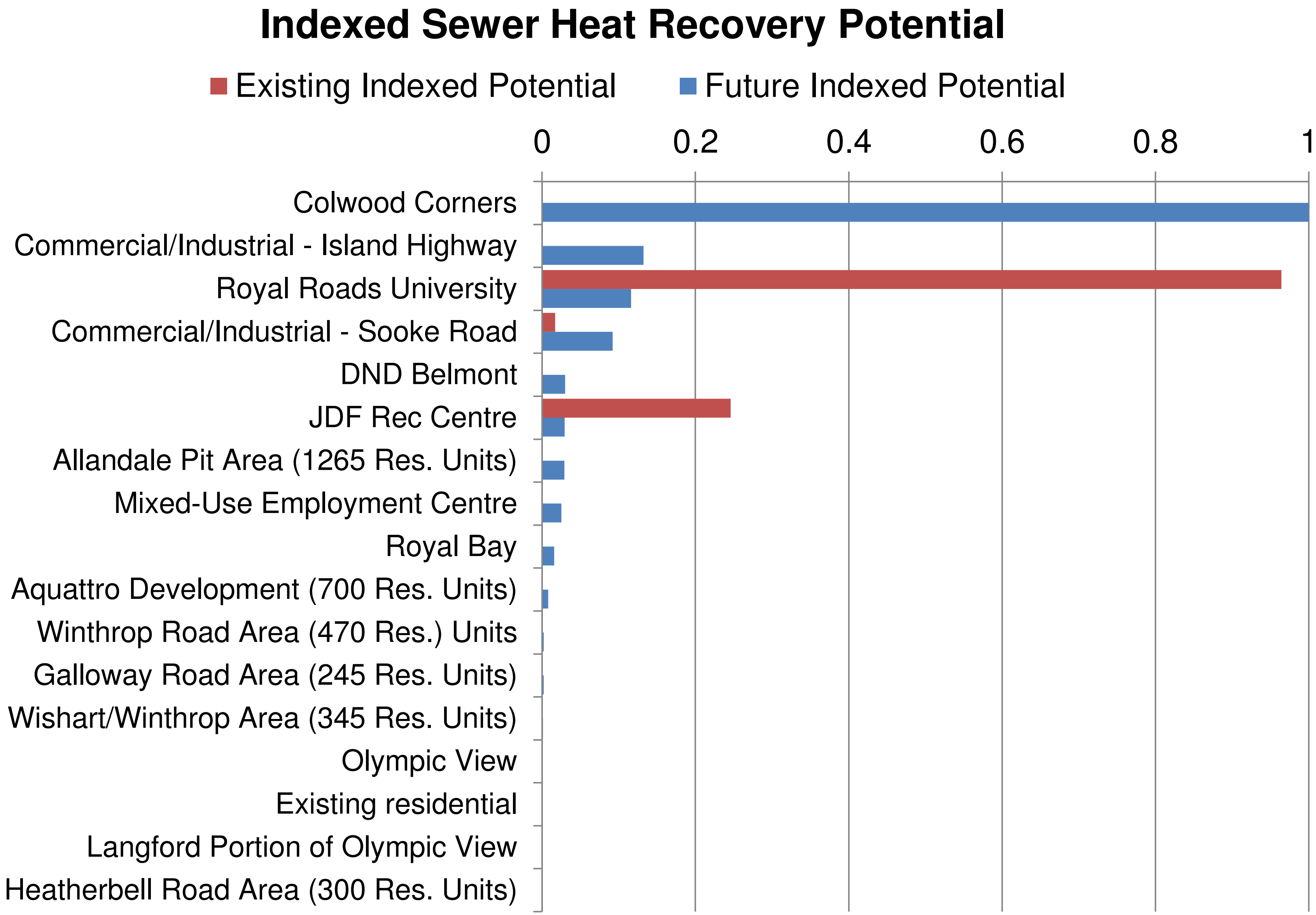
Indexed Sewer Heat Recovery Potential
🟥 Existing Indexed Potential
🟦 Future Indexed Potential
0
0.2
0.4
0.6
0.8
1
Colwood Corners
Commercial/Industrial - Island Highway
Royal Roads University
Commercial/Industrial - Sooke Road
DND Belmont
JDF Rec Centre
Allandale Pit Area (1265 Res. Units)
Mixed-Use Employment Centre
Royal Bay
Aquattro Development (700 Res. Units)
Winthrop Road Area (470 Res.) Units
Galloway Road Area (245 Res. Units)
Wishart/Winthrop Area (345 Res. Units)
Olympic View
Existing residential
Langford Portion of Olympic View
Heatherbell Road Area (300 Res. Units)

Figure 10-4

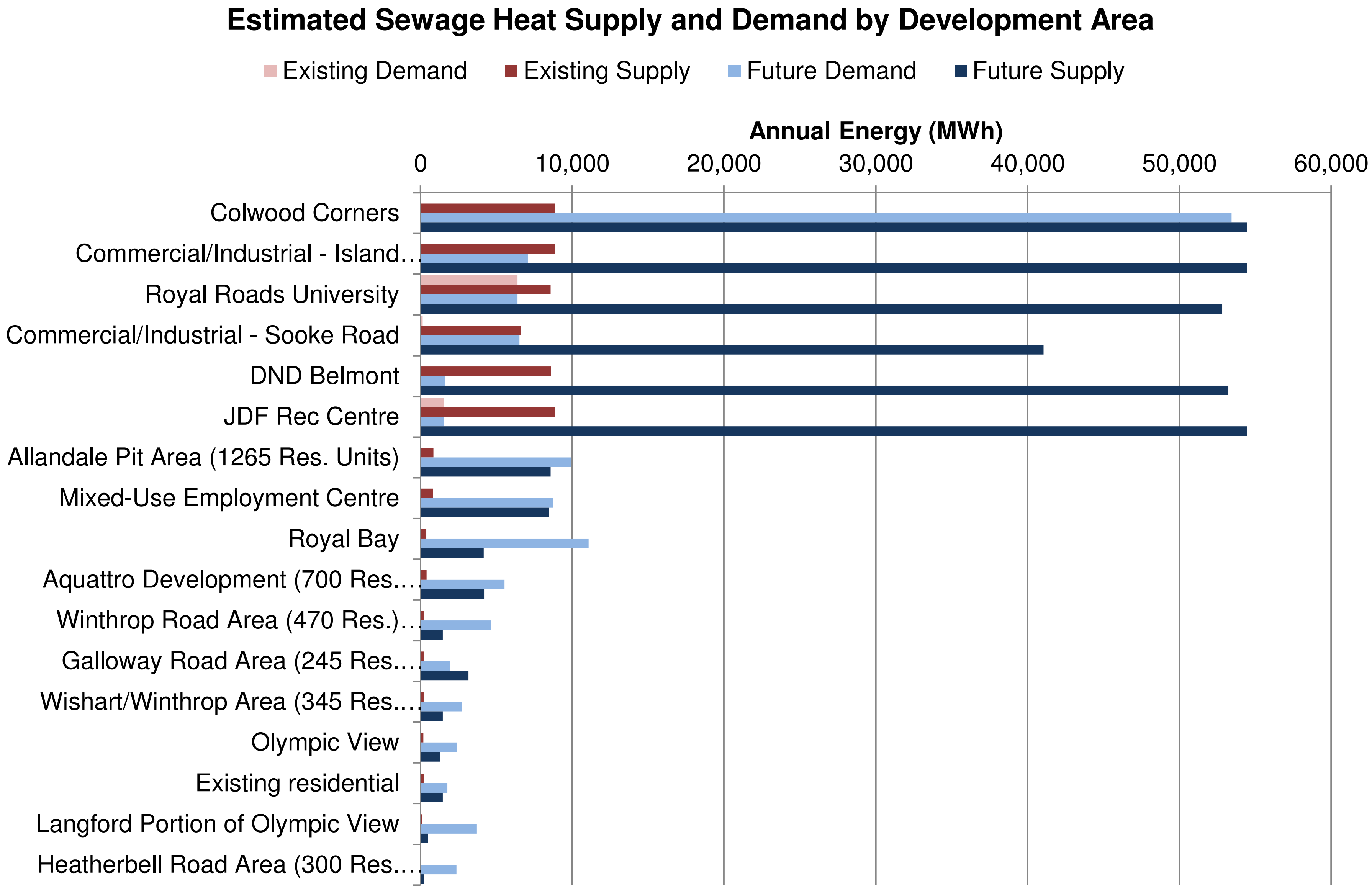
Estimated Sewage Heat Supply and Demand by Development Area
Existing Demand
Existing Supply
Future Demand
Future Supply
Annual Energy (MWh)
0
10,000
20,000
30,000
40,000
50,000
60,000
Colwood Corners
Commercial/Industrial - Island…
Royal Roads University
Commercial/Industrial - Sooke Road
DND Belmont
JDF Rec Centre
Allandale Pit Area (1265 Res. Units)
Mixed-Use Employment Centre
Royal Bay
Aquattro Development (700 Res.…
Winthrop Road Area (470 Res.)…
Galloway Road Area (245 Res.…
Wishart/Winthrop Area (345 Res.…
Olympic View
Existing residential
Langford Portion of Olympic View
Heatherbell Road Area (300 Res.…

Figure 10-5