University of British Columbia
District Energy Pre-Feasibility Study for Wesbrook Place (South Campus)

Final Report

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SUMMARY

Overview

The University of British Columbia (UBC), with support from BC Hydro, is conducting a pre-feasibility study to evaluate the general feasibility of implementing a District Energy (DE) system for Wesbrook Place. The study aligns with UBC's sustainability goals and greenhouse gas (GHG) emissions reduction targets for the Vancouver Campus and provides:

- A quantitative and qualitative description of the study area;
- A phased service plan for the core area, which includes a renewable energy phase;
- An estimate of the GHG and electrical load reduction compared to business-as-usual;
- An economic, environmental and social analysis for the full build-out of the system;
- Analysis of the governance options, and;
- A summary of the major obstacles to successful implementation.

Study Area and Development Scenarios

The core study area, known as Wesbrook Place, is a 39 hectare portion of South Campus bounded by Pacific Spirit Regional Park, a number of research facilities (including TRIUMF, Canada's national laboratory for particle and nuclear physics), UBC Farm, and 16th Avenue West.

The existing or committed construction is approximately 136,000 square metres of floor space. These areas are not considered to provide reasonable opportunities for connection to a DE system. As such, the study evaluates the potential for DE under two future land development scenarios, including:

- A <u>base</u> scenario, which projects development to occur in accordance with what is currently outlined in the South Campus Neighbourhood Plan (SCNP). The build out of this scenario will add an additional 154,000 square meters of floor area. This scenario includes a mix of additional town home, low-rise and high rise units.
- An <u>alternate</u> scenario, which projects a higher density development footprint than the base scenario. The build out of this scenario will add an additional 392,000 square metres of floor area. Key features of the alternate scenario are: (i) a shift to higher density development, and (ii) additional land for development; most of it at the southern edge of the community.

Business-as-Usual Energy Use Scenario

For each scenario, a business-as-usual (BAU) forecast was developed (see Table S-1). The thermal energy use (space heat and hot water) is estimated from "energy use intensity" factors which define the energy use per square foot of floor space. These factors are different for each type of building (low-rise, high-rise, etc).

A BAU forecast estimates annual consumption at 9,660 MWh thermal (for the base scenario) and 33,000 MWh thermal (for the alternate scenario).

The BAU scenario assumes that heating systems will continue as currently installed. Specifically:

- Hot water heating is provided by natural gas boilers serving the entire building (not individual suite water heaters)
- Hallway and common area space heating is provided by natural gas through air heating units. This source also provides about half of the suite heating through air leakage.
- Individual suite space heating is provided by electric resistance heaters.

Overall, the BAU shows the total heating energy delivered to be about 75% from natural gas and 25% from electricity.

Table S-1: Business as Usual (BAU) Forecast at Build Out

	Units	Base Scenario	Alternate Scenario
Total energy requirements at build out	(MWh / yr)	9,660	33,000
Heating Electricity Consumption	MWh / year	2,480	9,060
Natural Gas Consumption	GJ / year	35,050	116,000
GHG emissions	tonnes of CO_2e / year	1,700	5,640

Note:
The total load at build out is the same for both the BAU and the DE options (though different for each development scenario). The BAU and DE scenarios simply define different energy sources to meet that heating load.

District Energy (DE) Sizing Parameters

From the floor space and energy use intensity factors, the DE requirements are estimated (Table S-2). Important parameters to consider when sizing the DE system are:

- Annual energy load (i.e. consumption). This is the energy that must be delivered and defines the sales revenue of the DE utility, and;
- Peak demand (i.e. the greatest rate at which energy must be delivered). This parameter affects how much infrastructure must be developed to meet the demand, which is not called upon for the majority of the heating season.

For the DE scenarios, the buildings must have a different heating system than in the BAU scenario. A DE connected building uses heat exchangers to draw heat from the DE system rather than having boilers in the buildings. More importantly, the suite space heat is provided by a hydronic (i.e. water) system circulating hot water to radiators in the building, and not from electric baseboards.

Table S-2: District Energy Requirements at Build Out

	Units	Base Scenario	Alternate Scenario
Total Load (consumption) at build out	(MWh / yr)	9,660	33,000
Peak Demand at build out	(MW)	4.5	13.0

Note:
The total load at build out is the same for both the BAU and the DE options (though different for each development scenario). The BAU and DE scenarios simply define different energy sources to meet the heating load.
The DE system parameters assume that only new buildings are connected and that the existing and committed buildings are not connected to the DE system.

Energy Supply Options

A number of energy sources were considered and a screening was done to define the most viable options for evaluation. Based on this screening, the following four energy supply options were evaluated:

- Connection to the future campus medium temperature hot water system;
- Heat capture from the TRIUMF cooling facilities;
- Biomass combustion from a facility located on South Campus;
- Sewer heat capture from South Campus sewer lines.

The development cost of a DE system for the entire Wesbrook development would be approximately $8 million to $11 million under the base scenario and $13 million to $20 million under the alternate scenario. These costs are a small part of the entire community development, which amounts to 1.66 million square feet of building area (in the base scenario) to 4.22 million square feet of building area (in the alternate scenario).

Resource and GHG Benefits

A DE system would provide a number of resource and environmental benefits. Of specific interest are energy consumption and GHG emissions. In the alternate scenario, implementation of a DE system would result in estimated reductions (compared to the BAU) of:

- 2,400 to 8,000 MWh annually of electricity consumption;
- 30,000 to 80,000 GJ of natural gas consumption;
- 1,750 to 4,200 tonnes of CO_2 emissions annually.[1]

District Energy Costs

There are three cost factors to account for in the installation and operation of a DE system, including:

- Building Construction Costs: The capital costs for constructing a DE connected building adds \$2.50 to \$3.00 per square foot to construction costs (on top of an estimated \$4 per square foot for the BAU heating system)[2]. This premium is less than 2% of building costs.
- Building Operating Costs: Long term building operating and maintenance costs are modestly lower for a DE connected building. This is primarily because heat exchangers require less maintenance and replacement than boilers.
- Energy Purchase Costs: Energy purchase costs are typically higher for new DE systems as the energy purchased must pay for the infrastructure developed. As well, current natural gas prices are at low levels compared to recent years (thus making the BAU scenario a lower cost option for the present).

Long Term Cost of Ownership (Life Cycle Cost)

The total costs of building construction, ownership, and fuel purchases is normalized to the amount of energy provided as the 'levelized' cost of energy (see Figure S-1). This represents the full life cycle costs per unit of energy purchased (not per square foot of floor space). For all cases the DE supplied heat is more expensive than for the corresponding BAU. Note however that:

- For the base scenario, DE options are not competitive with the BAU (life cycle costs are 50% to 75% greater than the BAU).

- For the alternate scenario, DE options are more similar (life cycle costs are 20% to 30% greater than the corresponding BAU scenario).[3]

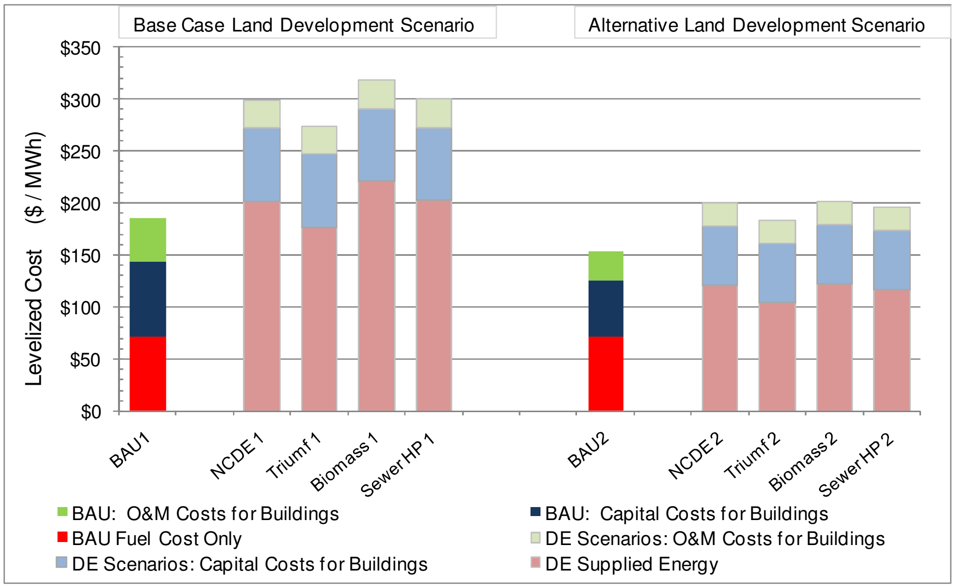
- Comparing the base scenario BAU costs to the alternate scenario district energy costs indicates that the life cycle energy costs are about equal. This comparison indicates that a change from the base to the alternate scenario could be accompanied by a change to a DE system without an overall increase in the cost of a unit of heating.

[1] These are the ranges resulting from the four energy supply options evaluated.

[2] Capital costs are estimated from research conducted by the City of Vancouver.

[3] Other DE systems in the region typically have energy costs comparable to or greater than a BAU scenario (though there are differences in pricing structure). For a benchmark comparison, (i) the Lonsdale Energy Corp charges are comparable to the BAU (a mixture of natural gas and electric heating), (ii) the Southeast False Creek energy costs are similar to the cost of electric heating, and (iii) the SFU UniverCity DE system has proposed rates that are about 30% higher than the cost of electric heating.

Figure S-1: Full Ownership Levelized Costs (25 years)



Note:
BAU = business as usual; NCDE = north campus district energy connection; Triumf= heat capture from TRIUMF; biomass = biomass boilers; Sewer HP = sewer heat capture. Suffix "1" refers to the base scenario and Suffix "2" refers to the alternate scenario.

Ownership Options and Project Viability

A simplified sensitivity was evaluated to compare UBC ownership against a third party owner. The essential difference is that it was assumed that there are efficiencies in staffing and savings in other operating costs that would accrue to a UBC owned system. As a result, the third party ownership scenarios are less attractive financially.

Simple metrics used to define the financial viability for operating a DE system are the Net Present Value (for UBC ownership all debt financing) and the Return on Equity (RoE) for a third party operator (debt and equity financing). Findings are that:

- For a UBC ownership model the breakeven point is achieved when the DE provided energy is priced at the same level as electricity (+/- 10%)[4]
- For a third party operator a suitable return is achieved when the DE supplied energy is priced at 24% to 49% above the cost of electricity[5].

Reducing the Cost of District Energy Heating

To make DE heating more attractive a number of strategies may be employed, including:

- <u>Charge a premium rate for energy compared to the BAU:</u> The BAU cost is a mixture of natural gas and electricity purchase costs. Several DE systems benchmark against the cost of electrically provided heating (Southeast False Creek) or greater (SFU)[6].

[4] Breakeven here is defined as a 25 year NPV just becoming positive at 25 years.

5 A suitable metric is utility allowed return on equity of 9.67%

[6] For example the Southeast False Creek system charges rates comparable with electric heating, and the SFU system is proposing to charge rates 31% above electric heating. Both of these are higher than the current BAU (a mixture of electric and natural gas heat).

- Obtain grant and incentive funding: The Lonsdale Energy Corp and Southeast False Creek DE systems were able to access grant funding from higher levels of government, as well as through the Federation of Canadian Municipalities Green Municipal Fund.
- Charge a development cost fee: The SFU UniverCity system will be partially funded by a $1 / square foot capital grant from the developer to the DE utility.
- Provide density bonuses: Developments at SFU UniverCity are eligible for additional density if they incorporate alternative energy systems. This provides additional saleable floor space to offset the building capital costs.

Triple Bottom Line Comparison

A triple bottom line comparison was made of the four energy supply options. Categories of attributes evaluated are: (i) financial, (ii) technical and operations, (iii) resource use, (iv) environmental (emissions), (v) social, and (vi) sustainability features. This review identified the most promising options as: (i) heat capture from the TRIUMF facility and (ii) connection to the North Campus DE system.

Conclusions

Key conclusions from the study are that:

- There are several technically viable ways to provide energy to a medium temperature DE system. Heat capture from the TRIUMF facility and connection to the North Campus DE systems are the most promising options.
- District energy does not appear attractive under the base scenario, but has reasonably competitive life cycle costs for the alternate scenario.
- There are incremental capital costs to the builder; on the order of 2% of the building costs.
- There are modest long term operational savings to the building owner due to reduced operations and maintenance (O&M) costs.
- Costs to supply DE heat are at a premium compared to the BAU energy (electricity and natural gas).
- Energy charges for the alternate scenario priced in the same range as electricity (+/-10%) will achieve long term breakeven for a UBC owned system. A third party operator would require a premium of at least 24% to achieve a standard utility return.

Recommendations

Key recommendations are that:

- A full feasibility study is warranted with a focus on heat capture from the TRIUMF facility and connection to the North Campus DE system.
- UBC should explore opportunities to make DE more attractive to builders and residents through pricing and incentives.

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Acronyms and Abbreviations

ASHRAE	American Society of Heating Refrigeration and Air Conditioning Engineers
BAU	Business as usual
BEPI	Building energy performance indicator (same as EUI)
Btu	British thermal unit: a measure of energy
CHP	Combined heat and power
DE	District energy
DH	District heating
DHW	Domestic hot water
DPS	Distribution piping system: Piping to circulate hot water through a neighbourhood
ETS	Energy transfer station: A heat exchanger to take heat from the DPS and provide it to the building energy systems
EUI	Energy use intensity
GHG	Greenhouse gas
GJ	Gigajoule (unit of energy)
HP	Heat pump
HX	Heat exchanger
kW	Kilowatt (rate of energy delivery)
kWh	Kilowatt hour: A measure of energy (typically electricity)
LEC	Lonsdale Energy Corporation
MBH	1000s of Btus per hour: a measure of rate of boiler energy size
MW	Megawatt: a unit of power (rate of energy delivery)
MWh	Megawatt hour: a unit of energy (typically electricity)
MWh thermal	MWh of thermal (heat) energy (1 MWh = 3.6 GJ)
NEU	Neighbourhood Energy Utility
SEFC	Southeast False Creek
SH	Space heating
TRIUMF	National Particle and Nuclear Physics laboratory located on South Campus
WTE	Waste-to-energy

1 INTRODUCTION

1.1 Context

The University of British Columbia (UBC) is a recognized leader in advancing sustainability practices on campus. Sustainability at UBC incorporates a balanced focus on people, place and process. Sustainability decisions are informed and guided by equal measures of ecology, economy and expectations of society.

In 2010, UBC completed a Climate Action Plan for the Vancouver Campus, which set ambitious targets for reducing greenhouse gas (GHG) emissions, including:

- 33% below 2007 levels by 2015;
- 67% below 2007 levels by 2020;
- 100% below 2007 levels by 2050.

Wesbrook Place is a new residential development. Over 1 million square feet has been developed or committed and current planning indicates at least 2 million more square feet of development potential. UBC, with support from BC Hydro, is conducting a pre-feasibility study to evaluate the general feasibility of implementing a District Energy (DE) system for Wesbrook Place that will align with UBC's sustainability goals and GHG reduction targets for the Vancouver Campus.

1.2 Objectives

The viability of DE is related to energy density, the scale and rate of development, and the availability of low-cost energy sources. This study will evaluate the potential for a renewable DE system by assessing the energy density and levelized costs of renewable energy alternatives for Wesbrook Place under two scenarios at full build-out.

The study will provide:

- A quantitative and qualitative description of the study area, including the core service area and opportunities for connectivity and expansion;
- A phased service plan for the core area, which shall include a renewable energy phase;
- An estimate of the potential GHG and electrical load reduction resulting from a DE system, as compared to business-as-usual (BAU);
- An economic, environmental and social analysis of the renewable energy supply alternatives for the full build-out of the system and comparison to the BAU;
- An analysis of the governance options for a potential system and a summary of the key trade-offs between public and private ownership and operations;
- A summary of the major obstacles to successful implementation of a DE system for the study area and a recommended mitigation strategy.

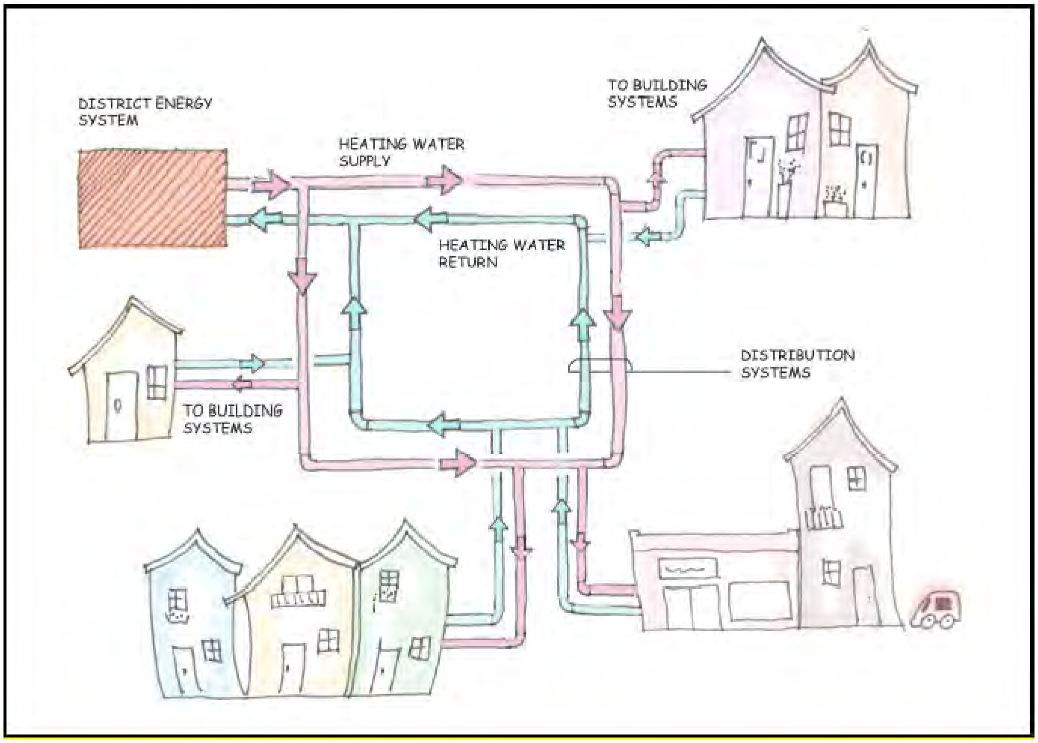
1.3 District Energy Systems Background

1.3.1 Key Components

District energy is a means to distribute thermal energy (both heating and cooling) to a number of buildings connected to a common heating or cooling plant. Key components of a DE system are outlined below and shown in Figure 1.

- **Energy source** / **heating plant.** Heat is either captured from, or generated at a facility. The heat could be waste heat from another process (e.g., heat capture from a cooling tower or the condensate return line), or generated in a standalone heat plant (e.g., a biomass plant, a heat pump facility, etc). The heat source provides hot water to the distribution system. Older systems use steam; however, the inefficiency of these systems impacts cost and environmental performance.
- **Distribution system.** A network of insulated pipes that circulate the heated water. Typically these are two pipe systems installed side by side in a trench. These pipes are relatively large (e.g., 8" to 12" for the scale of capacity in this project). One pipe carries the heated water to the buildings, and the return line brings the cooled water back to the heat plant.
- **Building connections.** Each building is connected to both the supply and return side of the distribution network. Relatively smaller (e.g., 2" to 4") pipes carry the hot water into the building from the supply line and return the cooled water from the building to the return line.
- **Energy Transfer Stations.** These are heat exchangers located within the building. Heat from the circulating distribution piping system (DPS) fluid is transferred to the water systems that feed radiators in the buildings and the hot water tank.

Figure 1. Schematic of a district energy (heating) system



1.3.2 Temperature Regimes of District Energy Systems

The nomenclature for DE systems is not completely standardized. However, there are some general system types often referred to as high temperature systems, medium temperature systems, and ambient systems. These three systems are described in Table 1.

Table 1: Types of district energy systems

Type	Description	Considerations
High Temperature System	High temperature water (> 100 deg C under pressure) or steam is generated and distributed through the DPS. In steam systems the steam is sometimes circulated around the building heating system, and sometimes a heat exchanger is used to transfer the heat to a building water system.	• Almost always requires a form of combustion as the source of heat - this may limit the range of energy sources used. • Steam systems traditionally have substantial system losses through the DPS. • System that is currently in place at UBC
Medium Temperature Systems	Distribution system supply water can be from 65 deg C (low load) to 110 or 120 deg C (upper). Modern systems vary the temperature to reduce water pumping costs (i.e. at high load, rather than pump more water, the system pumps higher temperature water (which carries more heat). Each building connects to the DPS by a heat exchanger.	• System can accommodate non-combustion energy sources more easily. • System can scale back to provide lower temperature water when the load is low (e.g., summer time heating is often only hot water). • System that is being implemented at UBC and most other new projects

Type	Description	Considerations
Ambient Systems	Low temperature water (5 deg C to about 25 deg C) is circulated through the DPS. Each building has its own heat pump that either 'pulls' heat from the DPS fluid (for heating) or 'pushes' heat into the fluid for building cooling. The DPS fluid circulates back to a source where the temperature is equalized (i.e. re-warmed, or re-cooled). The equalization of the DPS fluid can be a geo-exchange field, or an ocean loop.	• Circulation piping can be simple HDPE ("plastic") and is more affordable. • Limited track record of these systems in operation, with concerns over pump energy, pipe connection reliability and increased maintenance as ongoing concerns • Applications when buildings require cooling and heating. • Requires installation of heat pump in each building served,

The choice of system is defined by the types of loads being met. Considerations include:

- Steam based systems are most appropriate where there are large humidification and sterilisation loads, as well as other process steam loads. Note that even in hospitals, only 10% of the load actually requires steam.
- Medium temperature systems are the most common installation approach adopted throughout North America and Europe.
- Ambient temperature systems are appropriate for installations where heating and cooling loads are concurrent and are matched in magnitude. This approach is consistent with distributed heat pumps in building applied to a much larger scale

In the case of Wesbrook, either a medium temperature or ambient system makes most sense as there is no requirement for process steam that would justify a higher temperature system. The choice of medium temperature versus ambient systems is driven by the cooling load. An analysis of this is provided in Section 4.

1.3.3 District Energy Systems: A Long Term Investment

District energy systems require a long term investment by the system operator. Utility systems typically require a large investment in capital infrastructure in the early years. The operating, financing, depreciation and other costs result in high expenses in the early years. As well, the early portion of a utility project is a period when there are few customers and a limited revenue stream. This means that the full cost of operating the system cannot be recovered each year.

To address this, DE systems are frequently financed through a levelized costing basis in which the pricing is set such that the entire costs are paid over a long period (e.g., 20 or 30 years). This avoids an unreasonable burden on the early customers and achieves cost recovery to the operator.

Examples include:

- The Lonsdale Energy Corporation (LEC) (Figure 2) has been in operation since 2003. To the end of 2008 it had accumulated losses of about $700,000. In 2009 it achieved an operating profit and was beginning to reduce the accumulated debts. The establishment of the LEC included an investment by the City of North Vancouver of $2,000,000 to capitalize the company (as well as significant grants from the federal government).

- The Southeast False Creek (SEFC) Neighbourhood Energy Utility (NEU) began commercial operation in 2010. A forecast of its operating financials (Figure 3) indicates that it is expected to incur losses until about 2018 and then incur profits after that (Note: the small loss in 2019 is due to a capital expansion). Cumulative losses are expected to be recovered by 2028. The NEU was capitalized by an allowance to draw from the City of Vancouver's reserve funds and received significant grants from utilities, the federal government and through the International Olympic Commission (IOC).
- The Corix British Columbic Utilities Commission (BCUC) application for a DE utility system for the UniverCity development at the Simon Fraser University (SFU) campus indicates a 20-year cost recovery period.

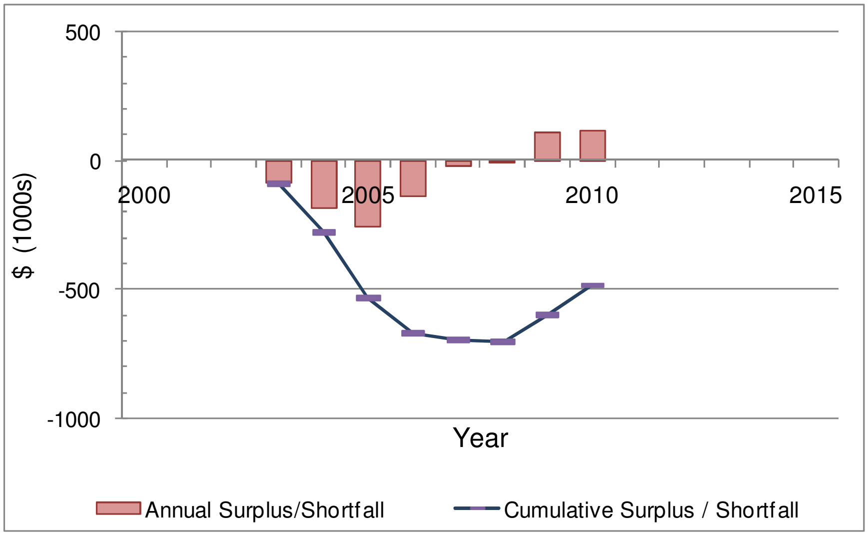
This financial performance is common in utility investments. This allows for the capital burden to be spread over many years, and is captured by the full customer base. To be profitable in the first year would place an excessive burden on the early customers. However, over the longer term, the DE operator recovers their investment. If the operator is a private sector company, the cost recovery includes an allowance for an acceptable return on investment. This is the basis upon which private sector utilities are regulated by the BCUC.

The implications are that the owners of a DE system have to be committed to a long term investment in being a utility operator. As a result, traditional operators of DE systems have been local governments, large institutions, and utility companies – all of which have a long term perspective, a guaranteed client base, and sometimes have access to unique funding sources (i.e. grants, etc.).

More recently the property development community has explored DE system ownership. Examples include Dockside Green (Victoria), the Pier Hotel (Sidney)[7], the Upper Gibsons Development (Sunshine Coast) and Parklane homes development of the East Fraser lands development (Vancouver). Experience with these ownership models is limited and it is premature to comment on the merits of the evolving ownership models or their potential application to UBC Wesbrook.

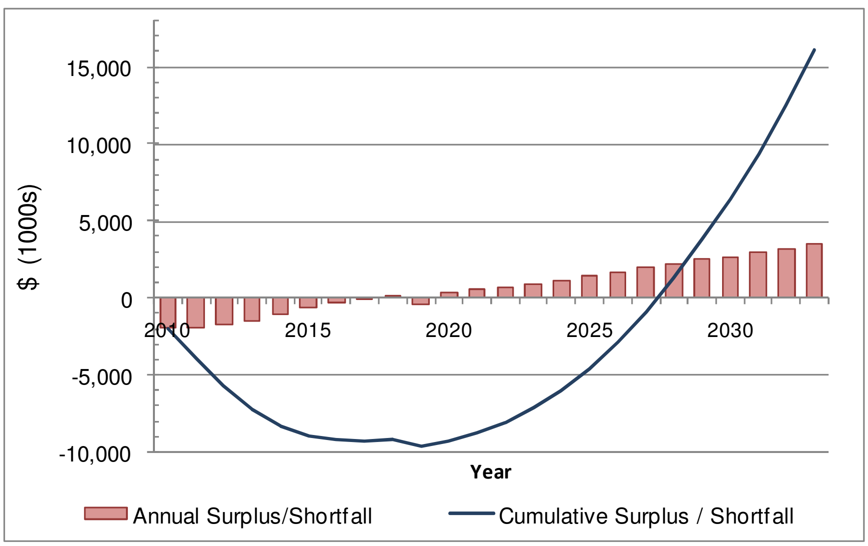
[7] The Pier Hotel is not a true "district" energy system. Rather it is an attached hotel and condominium complex. The hotel operator has an ocean loop heating/cooling system and provides these services to the attached condominiums. The owner is exploring whether the system can be extended to an adjacent property being considered for development.

Figure 2: Historical Financial Performance of the Lonsdale Energy Corporation



Note:
Figures are on an accrual basis and not a cash flow basis.
Source: City of North Vancouver financial statements.

Figure 3: Forecasted Financial Performance of the SEFC NEU



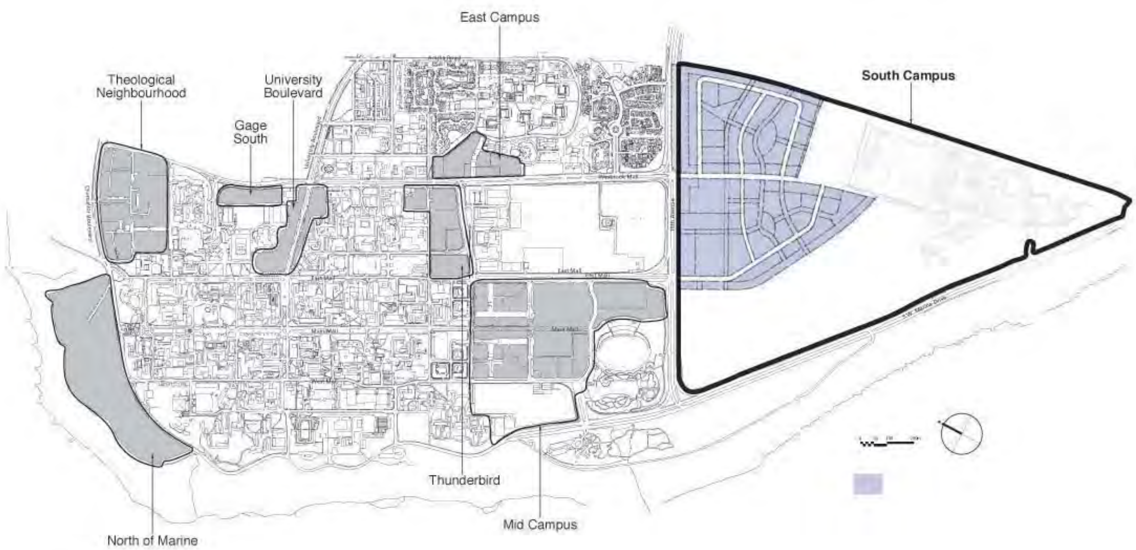
Note:
Figures are on an accrual basis and not a cash flow basis.
Source: City of Vancouver SEFC NEU 2011 Customer Rates (City of Vancouver council report December 2, 2010).

2 STUDY AREA OVERVIEW

2.1 Neighbourhood Profile

The core study area, known as Wesbrook Place, is a 39 hectare portion of UBC's south campus bounded by Pacific Spirit Regional Park, a number of research facilities (including TRIUMF, UBC farm, and 16th Avenue West) (Figure 4). The study considers the existing and planned developments at Wesbrook Place, as well as areas outside of the core study area that may present opportunities for energy supply.

Figure 4: Campus Map indicating the location of the South Campus



The South Campus Northeast Sub-Area Neighbourhood Plan (January 2005) defines the land use, design guidelines, development controls, transportation and servicing strategies for the area, consistent with the Official Community Plan (OCP) and the Campus Community Plan (CCP). The development scenarios used in this study stem from the South Campus Neighbourhood Plan (SCNP).

2.2 Development Scenarios

To help understand the potential load from future development within the study area, two development scenarios are evaluated:

- A **base** scenario projects development to occur in accordance with what is currently outlined in the SCNP.
- An **alternate** scenario projects a higher density development footprint than the base scenario.

The scenarios were created by planning staff at UBC Properties Trust using the SCNP[8] as a guide to estimate the development yield and timing of new residential floor space. In both scenarios, the pace of development is phased into five-year increments, including: existing buildings (either completed or under construction); Phase 1, 2011 – 2015; Phase 2, 2016 – 2020; Phase 3, 2021 – 2025.

The development scenarios are to be interpreted as a reasonable estimate of the build out scenario rather than as a precise forecast of what will occur. They represent the current plans based on the experience of planning staff at UBC Properties Trust, their impressions of developer interest in the Wesbrook Place neighbourhood, and the pace of past development on the UBC Vancouver campus.

These two scenarios represent the lower and upper bounds of the likely development, providing a worst case and best case scenario of the load forecast. Clearly there will be a range of factors which affect the rate at which new development occurs, but for the scale of this study, these development scenarios provide a defensible set of boundaries.

2.2.1 Base Scenario

The existing or committed construction is approximately 136,000 square metres. The existing buildings extend along each side of Wesbrook Boulevard and up to one lot further away. The majority of the existing stock includes row house and low rise apartment detachment styles.

The base scenario build-out will add an additional 154,000 square metres of floor area (Table 2). This scenario includes a mix of additional town home, low-rise and high rise units. Phase 2 develops each side of the area away from the existing buildings and Phase 3 fills in some dispersed lots (Figure 5).

Table 2. Development Footprint of Base Scenario

	Development Footprint (m^2)				
Phase	**Town Home**	**Low Rise**	**Mid Rise**	**High Rise**	**Total**
Existing	11,617	83,072	15,744	25,716	136,149
Phase 1 (2011 – 2015)	41,789	39,009	-	25,634	106,431
Phase 2 (2016 – 2020)	12,593	20,965	-	14,383	47,942
Phase 3 (2021 – 2025)	--	--	--	--	--
Total at build-out	65,999	143,046	15,744	65,733	290,522

Note:
Existing floor space is not included in the subsequent district energy evaluation.

[8] South Campus(Wesbrook Place) Neighbourhood Plan (2005): http://www.planning.ubc.ca/vancouver_home/plans_and_policies/forms_and_documents/documents/libraries177.php

Figure 5: Build Out Phasing under Base Development Scenario

Legend: Existing Buildings Phase 1 Buildings Phase 2 Buildings

2.2.2 Alternative Scenario

The existing or committed construction is approximately 136,000 square metres. As above, the existing buildings extend along each side of Wesbrook Boulevard and up to one lot further away.

The build out of this scenario will add an additional 392,000 square metres of floor area. Key features of the alternative scenario are:

- A shift to higher density development. This scenario does not include any further town home developments and increases the amount of higher density development. (Table 3).
- Additional land for development (Figure 6). Most of this occurs at the southern edge of the community and is shown in Phase 3.

Table 3. Development Footprint of Alternate Development Scenario

	Development Footprint (m^2)				
Phase	**Town Home**	**Low Rise**	**Mid Rise**	**High Rise**	**Total**
Existing	11,617	83,087	15,744	25,716	136,164
Phase 1 (2011 – 2015)	0	65,862	19,887	95,473	181,222
Phase 2 (2016 – 2020)	0	52,761	0	63,572	116,333
Phase 3 (2021 – 2025)	0	94,841	0	0	94,841
Total at build-out	11,617	296,551	35,631	184,760	528,559

Note:
Existing floor space is not included in the subsequent district energy evaluation.

Figure 6: Build Out Phasing under Alternative Scenario

Existing Buildings Phase 1 Buildings Phase 2 Buildings Phase 3 Buildings

2.3 Related Activities on Campus

In addition to the Wesbrook development, a number of initiatives are underway on campus that would impact the development of a DE system. These include:

- **Steam to hot water conversion:** The campus is currently served by a steam-based DE system. This is being converted to a medium temperature hot water system. A concept plan has been prepared for a conversion in about 8 phases over several years. For the first phase design is now underway and Phase 1 construction will commence this year.

  This conversion will provide UBC with a new approach to operating a DE system that can accommodate a diverse range of energy sources for campus heating. As well, such a heating system could connect to a system for the Wesbrook development easily if that system was a compatible temperature regime.

- **Nexterra:** UBC is proceeding with a biomass gasification and combined heat and power (CHP) facility on campus. This is the first biomass power project on campus and is the first diversification away from natural gas heating on campus. This project will allow for many operational issues to be understood including: transportation, material handling, supply pricing and contracting, etc. These are all new activities for UBC staff. This experience could help UBC better understand the implications of increased use of biomass on campus, which may impact heating options under consideration for the Wesbrook development.

- **TRIUMF:** There is a substantial cooling load from this facility. In addition, the expansion over the next few years of the ARIEL facility will increase this load. The capture of this energy is well aligned with campus objectives to become a more integrated energy system and a 'net producer' of energy. It could also allow TRIUMF to highlight a sustainability feature and community benefit of its operations.

- **Wesbrook Rental Accommodation – market and non-market:** The Wesbrook development includes rental accommodation; both market and non-market housing. Renters typically pay directly for operating costs.[9] These tenants might be price sensitive to the monthly energy charges and less interested in the long term life cycle cost savings that a DE system could offer.[10]

[9] Market renters pay for capital costs through their rents, but the costs are somewhat hidden. Non-market renters pay a lower rent and would not be covering the full cost of the capital costs of their facilities.

[10] It is acknowledged that owners frequently do not take a long term of life cycle approach to costs either. They might be sensitive to the capital cost and not appreciate if there are long term operating savings.

3 LOAD PROFILE AND DEMAND FORECAST

This section provides an estimate of the energy loads that can be expected from the Wesbrook development. This information is used to develop revenue forecasts in subsequent sections.

3.1 Energy Use Intensity

Floor areas are combined with energy use intensity (EUI) factors to determine the annual heating loads as well as the peak demand. In developing a revenue model, two factors are critical, including the load and the demand:

- **Load** is the amount of heat delivered, and much of the of the DE revenue stream is charged as a cost per unit of heat delivered. Measured in kWh or MWh. This is analogous to a commodity charge for other utilities.

- **Demand** (or capacity) is the peak rate at which energy must be supplied in order to meet all the customer demands at a time when the load is peaking (e.g., a cold winter day). The DE utility must provide enough capacity to meet this condition. Capacity in the system requires capital investment and for many periods of the year this capacity is not fully utilized.

The EUI and demand requirements for each type of building are shown in Table 4. Also included here are the estimates of the cooling load (to be discussed subsequently). The EUI factors used at the pre-feasibility stage are specified in the BC Hydro District Energy program requirements.[11]

Table 4. Energy Use Intensities for New Buildings

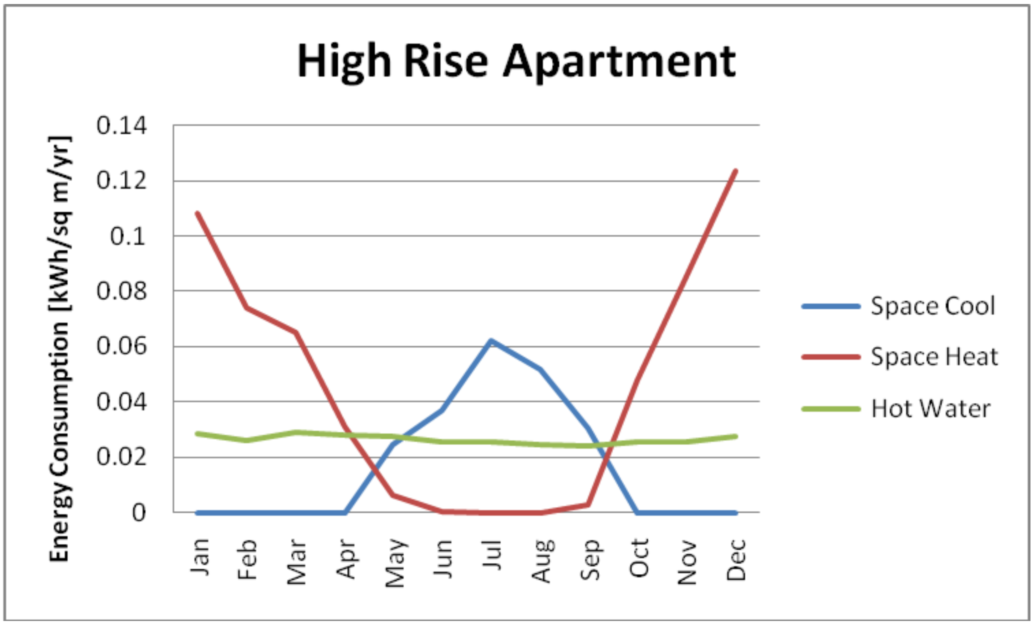
	Town Home	Low-rise	Mid-rise	High-rise
DEMAND (W / m^2)				
Peak Space Heat Demand	24	28	50	50
Peak DHW Demand	4	4	4	4
Peak Space Cooling Demand	16	20	40	40
Annual LOAD (kWh / m^2)				
Annual Space Heat Loads	12	44	80	80
Annual DHW Loads	16	18	30	30
Annual Space Cooling Loads	18	20	50	50

Source:
Demand Factors and EUIs for townhomes from team experience based on DOE modeling.
Load Factors for low-rise and high rise buildings from the BC Hydro District Energy Program Assumptions List. These are based on energy modeling assuming a code compliant building meeting the energy standard of ASHRAE 90.1 – 2004. No substantive difference is expected from these values to ASHRAE 90.1 - 2010 as there are no prescriptive changes to the building envelope.

[11] These values are in reasonable agreement with other estimates previously used by Stantec.

Based on typical energy use characteristics, a seasonal load profile for a high-rise apartment unit is presented in Figure 7.

Figure 7. Typical Suite Heating and Cooling Profile for Apartment Unit



3.2 Business-as-Usual Forecast

The business as usual (BAU) forecast is created by assuming current practices for heating systems will continue in further developments. The estimates are based on:

- Domestic hot water (DHW) is provided by boilers within each building and provide to suites. Heating is by natural gas at 69% efficiency[12]
- Make up air (MUA) for hallways and common areas is provided by natural gas fuelled air handling units (at 78% efficiency). Common area heating also provides a substantial portion of the heat for suites through air leakage and hallway pressurization.
- Suite heating is provided by electric baseboard heaters (100% conversion efficiency).

For a typical building the common areas are 15% of the floor space. For the remaining 85% (the suites) approximately 55% of the suite heating is provided by the common area heating system (natural gas) and 45% by the in-suite baseboard heaters (electric). Factoring in the hot water heating, approximately 25% of the total thermal load is provided by electricity and 75% is provided by natural gas.[13]

The BAU forecast is developed using the development floor space estimates, multiplied by EUI factors for each building type (i.e. how much energy per square metre).

[12] Efficiencies for DHW and common area space heat are from BC Hydro DE Program Criteria Assumptions.

[13] These values are based on BC Hydro recommended assumptions and team member expertise.

The BAU scenario at build out is provided in Table 5 and plotted over time for the base scenario (Figure 8), and the alternate scenario (Figure 9). The development is assumed to occur more or less evenly over the five year period of each phase. As such, straight line estimates of the annual growth are used through each phase. Upon full build-out, the annual energy consumption is assumed to remain constant.

Table 5: BAU Forecast at Build Out

	Units	Base Scenario [1]	Alternative Scenario [1]
Total Thermal Load [2]	MWh / year	9,660	33,000
Estimated Cooling Load [3]	MWh / year	320	1,322
Heating Electricity Consumption	MWh / year	2,480	9,060
Natural Gas Consumption	GJ / year	35.050	116,000
GHG emissions [4]	tonnes of CO2e / year	1,703	5,640

Note:
[1] Values are at full build out which is 2020 for the Base and 2025 for the Alternate scenario.
[2] The total thermal load is the amount of useful heating that is required. However, different fuel types provide this heat with different efficiencies. The total thermal load is the same for both the BAU and DE scenarios as it assumes that other building components that would affect heating energy are not materially different.
[3] Cooling loads assume only 10% saturation. Base on highest uptake levels in recent projects.
[4] GHG emissions are from natural gas only and assume that electricity has zero carbon content. This is a defined assumption for the BC Hydro District Energy program and is intended to reflect the current policy commitment of zero carbon electricity in BC by 2016.

Figure 8: BAU Forecast for Base Scenario

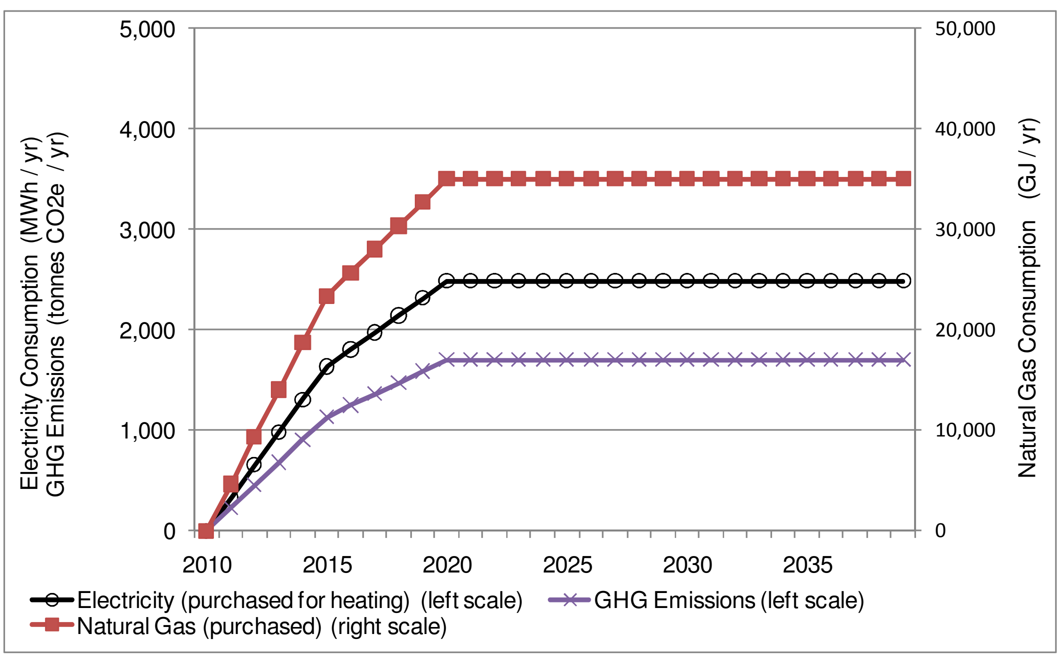
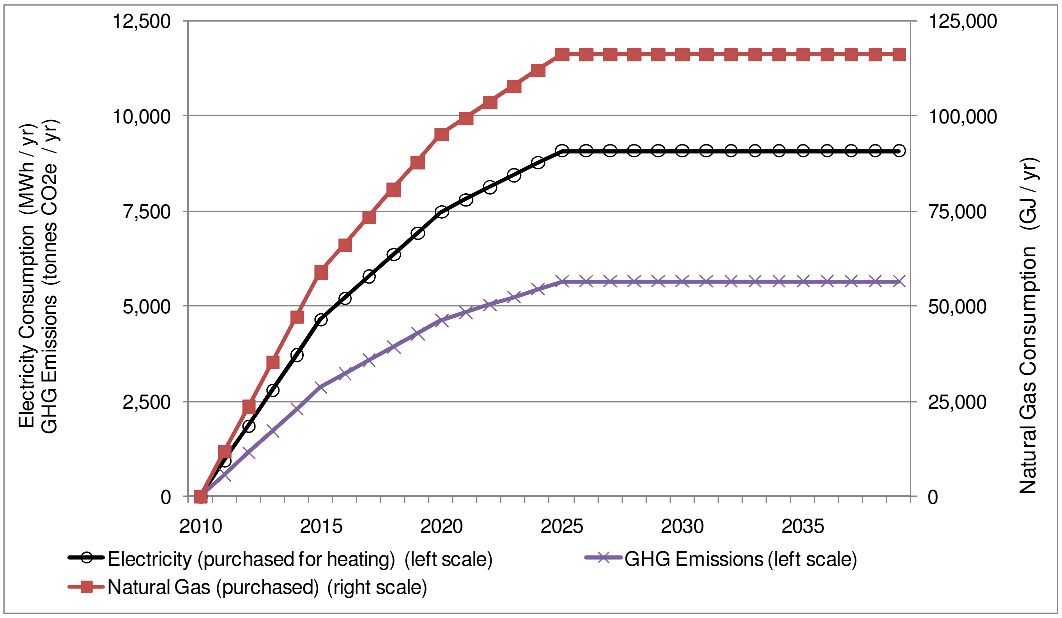


Figure 9: BAU Forecast for Alternate Scenario



3.3 District Energy System

Load duration curves for the base (Figure 10) and the alternate (Figure 11) scenarios provide the amount of heating required as each phase is completed.

Key assumptions in the load duration curve are that:

- Only new buildings are considered for connection to the DE system. Existing and under-construction buildings are not included as DE load.
- All future floor space was included in the load estimate. In practice, there may be some floor space that is not feasible to connect due to low revenues (e.g., town homes in the base scenario).
- The peak demand is based on a diversified space heating demand only, while DHW loads are captured by the total load requirement. The peak demand does not include DHW.

The total load requirements are estimated at 9,660 MWh and 33,000 MWh annually for the base and alternate scenarios, respectively.

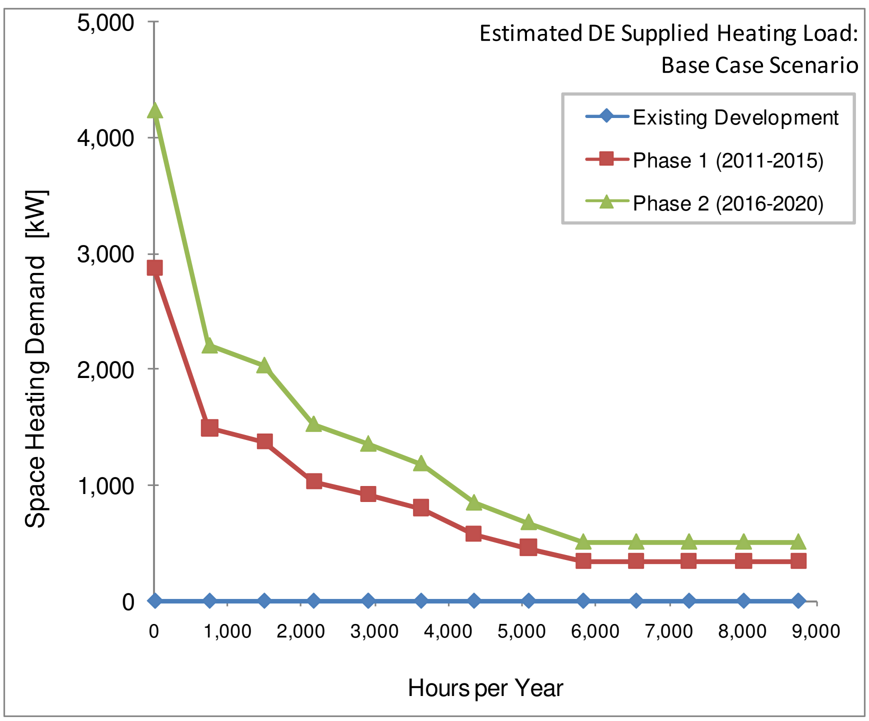
This analysis assumes that buildings connected to the DE system will use DE supplied heat for all their thermal loads (DWH, make-up air, suite heating). It does not attempt to evaluate any type of hybrid system of partial DE and partial BAU heating systems.

Table 6: Load and Capacity Requirements by Scenario

Phase	Component and Units	Base Scenario	Alternative Scenario
LOAD			
Phase1: (to 2015)	Space Heat (MWh / yr) DHW (MWh / yr)	4,265 2,155	12,120 4,673
Phase2: (2016 - 2020)	Space Heat (MWh / yr) DHW (MWh / yr)	2,222 1,019	7,402 2,878
Phase3: (2021 – 2025) [2]	Space Heat (MWh / yr) DHW (MWh / yr)	-- --	4,163 1,745
Total Load at Build Out	(MWh / yr)	9,660	33,000
Capacity Requirement			
Peak Demand at Full Build-out [3], [4]	(MW)	4.5	13.0

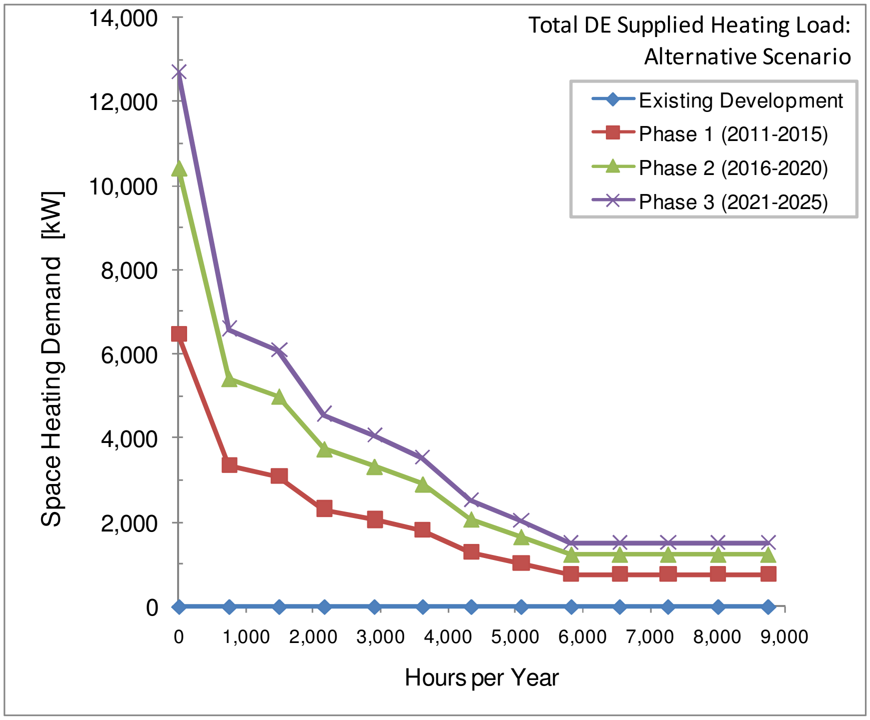
Note:
[1] Values may not add precisely due to rounding
[2] The base scenario is complete after 2 phases.
[3] Peak demand is estimated for space heating only and assumes a diversification factor of 85%. Diversification accounts for the fact that not all the loads will peak at the same time.
[4] Values rounded up to next 0.5 MW

Figure 10: Load Duration Curve for DE System: Base Scenario



Note:
Existing buildings are deliberately shown in the figure as having zero DE load. However, if a DE system was developed then some of these buildings could conceivably have conversions made to their DHW or MUA units to connect to a DE system. This would only occur many years in the future as these systems require replacement. For this analysis, there is no DE load assumed to arise from existing buildings.

Figure 11: Load Duration Curve for DE System: Alternate Scenario



Note:
Existing buildings are deliberately shown in the figure as having zero DE load. However, if a DE system was developed then some of these buildings could conceivably have conversions made to their DHW or MUA units to connect to a DE system. This would only occur many years in the future as these systems require replacement. For this analysis, there is no DE load assumed to arise from existing buildings.

4 ENERGY SYSTEM AND ENERGY SUPPLY SCREENING

4.1 District Energy System Screening

This section provides a screening review of four types of district energy systems, including:

- an ambient system;
- a medium temperature water system;
- a high temperature system;
- a dedicated heating and cooling (i.e. 4 pipe) system).

4.1.1 Provision of Cooling

To date, most DE systems in Canada and certainly in BC have been developed for the provision of heating energy only. Local examples include: the Lonsdale Energy Corporation in North Vancouver, Revelstoke District Heating, Dockside Green and the Neighbourhood Energy Utility on Southeast False Creek in Vancouver.

While building scale cooling may be provided at the suite or building scale (such as the Neighbourhood Energy Utility), centralized cooling energy can be provided either through: (i) a second set of distribution pipes (supply and return) which provide cooling water, or (ii) an ambient system, which can allow for building scale cooling.

UBC Properties Trust does not prescribe whether a building should have cooling; rather this decision is left to the developer. To date none of the Wesbrook buildings have included cooling. As well, it is expected that low rise buildings would not require cooling, due to their better insulation (less glazing) and better wall insulation.

Research calls were made to a number of local developers active at UBC to assess their perspectives on cooling. Comments received include:

- Adera offers a split cooling system (condenser on deck) as an optional component. Uptake on these units has been relatively low for recent projects including:
    - Legacy – 5 units or 9%
    - Pathways – 10 units or 9%
    - Pacific – Not on Options List
    - Spirit – Not on Options List
    - Ultima – 1 unit or 2.5%
- Polygon only offers cooling on select high-rise projects and when they do it is generally a split system in each suite (and common area cooling).
- Discussions with the construction manager at Intracorp confirmed they do not offer cooling on any of their projects, including tower developments.
- In discussion with Oris Development it was learned that cooling is provided only on projects where noise and security are issues that prevent use of operable windows. Otherwise window ventilation is assumed for suite cooling during the summer.

These notes do not address the question of ‘who would use cooling if they had it?” but rather “who is willing to pay the costs for cooling as an add-on at the time of purchase?”. This low uptake suggests that it is not a highly valued add-on. Then it may also be true that buyers would not see the value of a district cooling system if factored into their purchase price.

Modeling of a typical new high rise apartment was completed to estimate the relative importance of heating versus cooling. Based on that analysis, cooling represents 20% of the annual thermal load –indicating a system should be optimized for space heat and domestic hot water service. A scoping analysis of the costs of a central versus suite level cooling concept indicates that suite level cooling could be provided for $1,500 to $1,800 per unit, while a centralized unit would cost approximately $3,200 per unit. In addition to this incremental capital cost, the revenue stream available from cooling is limited. With typical co-efficient of performances, and current electricity rates, the revenue from cooling would be less than $100 per year per suite.

Table 7 provides a screening review of the different DE systems. Based on this review, the expected interest in cooling as discussed above, and on conversations with UBC staff, cooling is not recommended to be provided through a DE system.

The implications for DE are that:

- The saturation of cooling will likely be low. As a result, suite level units are likely a more cost effective option than centralized cooling equipment.
- This removes the driving factors for either a four- pipe heating and cooling system.
- This weakens the drivers for an ambient system.

Given this, a medium temperature system is recommended and will be assumed in the evaluation of energy supply sources.

4.1.2 Implications of not providing District Cooling

By not providing district cooling (i.e. no ambient temperature system) there are some implications for building construction that can be deployed to minimize any ‘lost opportunity’ that this presents. These include:

- Cooling requirements for buildings should be minimized. This can be achieved by enhancing the passive design of the developments to reduce cooling loads and maximizing the opportunity for operable windows.
- Maximizing any waste heat captured at the building level. One of the cited advantages of an ambient system is to allow for heat capture and re-use. Capturing this heat at the building level (e.g., heat recovery ventilators, etc.) makes the most of this resource within each building.

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Table 7: Screening Review of District Energy Systems for Wesbrook Area

	Ambient	Medium Temperature Hot Water	High Temperature Hot Water / Steam	Hot & Cold Water (4 pipe)
Description	Low temperature water (5 deg C to about 25 deg C) is circulated through the DPS. Each building has its own heat pump that either extracts heat from the DPS fluid (for heating) or rejects heat into the fluid for building cooling. The DPS fluid circulates back to a source where the temperature is equalized (i.e. re-warmed, or re-cooled). The equalization of the DPS fluid can be a geo-exchange field, or another large heat reservoir (e.g. an ocean loop).	The DPS supplies water at temperatures varying from 65 deg C (low load) to 110 or 120 deg C (upper). Modern systems vary the temperature to reduce water pumping costs (i.e. at high load, rather than pump more water, the system pumps higher temperature water (which carries more heat). Each building connects to the DPS through an energy Transfer Station (ETS)	High temperature water (> 100 deg C under pressure) or steam is generated and distributed through the DPS.	A heating system (medium or high temperature) is paired with a dedicated set of cooling pipes. The result is a four pipe district energy system. The heating and cooling systems must both have a source of the heating or cooling. With the four pipe system, the cooling supply and return pipes are installed parallel to the heating supply and return pipes.
Service Provided	Both heating and cooling.	Heating only.	Heating only.	Heating and Cooling.
Scale of Application	Systems have been implemented ranging from individual dwellings, to larger, multi-units.	Typically many buildings. Common in Europe for systems that serve a range of municipal tenants - e.g. residents, businesses etc.	Steam systems more common in campus settings (e.g. UBC, or VGH) or systems serving large building loads (e.g. CHDL, or Seattle steam).	Typically for areas with high loads and for areas where both cooling and heating load are substantial.
Connectivity with the new campus hot water DE system.	Ambient systems generally do not connect to hot water systems though examples likely exist.	Compatible with the hot water system that UBC is constructing.	Not compatible – the campus is converting to a medium temperature system.	Heating side could be compatible if it was medium temperature.

	Ambient	Medium Temperature Hot Water	High Temperature Hot Water / Steam	Hot & Cold Water (4 pipe)
Building Compatibility Issues (Wesbrook specific)	Installation of heat pumps is required in each building. Hydronic system with radiators or structural radiant system is often used.	Requires and Energy transfer station (ETS) in each building. Each ETS includes a Heat exchanger for space heating and hot water heating. New in-building systems can be designed for a minimum DE supply temperature of 65 to 70 deg C.	None at Wesbrook for new design. In steam systems the steam is sometimes circulated around the building heating system, and sometimes a heat exchanger is used to transfer the heat from the steam to a building water system.	Heating systems – same as med or high temp. Building cooling system must be designed for centralized cooling system.
Sources of Energy	Geo-exchange. Ocean loop. Could be designed to capture some rejected heat from other buildings. Note this is expected to be minimal at Wesbrook as most buildings are residential and there is limited	Range of energy sources including heat pumps, biomass combustion, solar thermal, gasification, biogas, waste heat recovery.	High temperature systems almost always require a form of combustion as the source of heat. Limits energy supply to fossil fuels, biomass, and biogas.	Heating (same as for med and high temp) Cooling system requires either a source of cooling (lake water or ocean water exchange) or mechanical or absorption chillers.
Key Advantages	Circulation piping can be simple HDPE (“plastic”) and is more affordable than insulated steel pipe. Allows for DE system to provide heating and cooling. Can provide for concurrent heating and cooling during shoulder seasons as well as waste heat recovery. NB Waste heat recovery opportunities are expected to be minimal due to homogeneous development (i.e. limited mixed use).	Allows for a variety of heating sources compared to high temp or hot water system. Distribution losses are very small in modern systems.	Hot water and steam systems provide a very compact and dense form of energy - smaller pipe sizes and building radiators etc.	Provides dedicated heating and cooling.

	Ambient	Medium Temperature Hot Water	High Temperature Hot Water / Steam	Hot & Cold Water (4 pipe)
Key Disadvantages	Requires heat pumps in every building (sometimes each suite). Electricity savings may be minimal compared to the BAU due to HP energy requirements. Electricity consumption may increase as the DE system replaces natural gas energy and replaces it with electrically driven heat pump energy. Would make more difficult connection to a campus hot water system.	Does not allow for district cooling.	Does not allow for district cooling. Limits the renewable energy sources to combustion related. Steam systems traditionally have substantial system losses through the DPS.	Requires a lot of capital for infrastructure. Requires more trench space - potential for utility conflicts. Requires separate sources of cooling (e.g. a geo field or an ocean loop) and heating.
Notes	Limited track record of these systems in operation in BC for multiple buildings - no long history to assess pipe reliability, pumping costs, etc.	Campus is transitioning to a medium temperature system.	Steam system is being decommissioned on campus.	Cooling requirement is low within the development.
Recommendation and Key Rationale	Do not pursue: • Low cooling demand. • Low cooling uptake in buildings. • Limited waste heat recovery options.	RECOMMENDED: • Maximum flexibility of energy supply. • Compatibility with Campus DE system	Do not pursue. • Limited energy sources • High losses • Low compatibility with campus system.	Do not pursue: • District cooling is not being recommended.

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4.2 Energy Supply Screening

For a medium temperature option, there are a number of possible energy sources. Table 8 presents a matrix screening of the various supply options. The objective of this screening is to arrive at a reasonable number of energy supply options for evaluation.

This screening draws from: (i) recent investigations of alternative energy by UBC staff, (ii) the recently completed alternative energy study for UBC which evaluated a number of energy supply options, and (iii) team experience.

Based on the screening table, there are four options which seem suitable for evaluation. These are:

- Connection to the future campus hot water system;
- Heat capture from the TRIUMF cooling facilities;
- Biomass combustion from a facility located on south campus;
- Sewer heat capture from south campus sewer.

These energy supply options will be evaluated for both the base and alternate scenarios.

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Table 8: Screening of Energy Supply Options

Supply Options	Description	Strengths / Benefits	Challenges / Limitations	Screening Recommendations
BAU	Buildings use natural gas for hot water and common area heating and electric baseboards for suite heating.	• Low capital cost • Known technologies – low performance risk	• Increases electricity use • Does not reduce GHG emissions. • No renewable source. • No advancement of sustainability initiatives	Comparator for DE options
Connection to campus DE system	Connection to the new medium temperature water system being developed on campus. Connection point at or near peaking boiler plant – about 950 m from the Wesbrook community.	• High reliability – system will be designed for campus reliability • Includes renewable energy component as a portion of the energy will be provided from biomass (Nexterra).	• Extra load may cause campus system to increase natural gas use earlier than otherwise expected.	**Evaluate**
TRIUMF	Capturing waste heat from TRIUMF, which currently rejects approx 1MW in winter and 3-4 MW in summer.	• High temperature (>20 deg C) cooling tower flows make for efficient HP system (high COP). • Heat recovery systems are established technology. • Integrates TRIUMF into the south campus 'community' • Sustainability benefit for TRIUMF. • Reductions of Wesbrook GHG emissions could be offsets against TRIUMF's Bill 44 requirements • Energy source will be available for the foreseeable future. • Energy would be free or at low cost. • Supports campus as a 'net producer' initiative.	• Uncertain if electrical capacity exists at TRIUMF transformer to power heat pumps. (Note that in the BAU an even greater electrical capacity must be provided to the buildings). • Uncertainty whether there is enough heat load • Not able to capture all loads	**Evaluate**

Supply Options	Description	Strengths / Benefits	Challenges / Limitations	Screening Recommendations
Ocean Loop	Heat pumps pull heat from the ocean and provide heat to a medium temperature system	• "Endless" supply of temperature regulation in ocean.	• High capital costs • Issues with ocean access – slope stability, construction, public acceptance of a facility on the beach front. • Low temperatures in winter (range of 6-9 deg C) result in poor heat pump performance.	No further evaluation
Geothermal (GSHP)	Generates heating & cooling for new buildings. Low temperature system that must be paired with compatible low temperature in-building systems	• Allows for heating and cooling when used with an ambient system.	• Requires large area for geoexchange field. • Soil conductivity may be a limiting factor. • Most commonly used with ambient systems as a temperature regulator. • Heating supply temps are usually in the range of 50 deg C so requires buildings designed for this temperature regime.	No further evaluation
Biomass Combustion	On-site biomass combustion reduces combustion of NG for DHW and SH.	• Biomass is considered a zero GHG emission source • Well established technology. • Flexible systems with high turndown ratios.	• New technologies within residential areas - unknown acceptance by residents. • Future of biomass market and future prices is unclear.	**Evaluate**
Biomass Gasification	Biomass (wood waste) is gasified and burned to make heat, or heat plus electricity.	• New and innovative technology. • May be perceived as 'more green' than direct biomass combustion.	• Emerging technology – costs and operations not well understood.	No further evaluation
Sewer Heat Recovery	Heat pumps extract heat from sewer system as in the case of Southeast False Creek.	• Substantial GHG emissions reduction. • Low public impact (traffic noise etc.)	• Systems are new in Canada. • High performance risk – fouling, contamination, maintenance, etc.	**Evaluate**
Natural gas boilers	Conventional (though highly efficient) boilers provide heat for hot water. Will be required for back up on renewable options.	• Low performance risk – well established technology.	• No reduction in GHG emissions • No green features.	Evaluate as peaking and back-up

Supply Options	Description	Strengths / Benefits	Challenges / Limitations	Screening Recommendations
Waste-to-energy	Waste is combusted or gasified. Heat is recovered from the process and used to heat hot water.	• High energy content of waste. • Additional revenue stream through tipping fees.	• Unlikely to be acceptable to public. • Limited GHG reductions (about half of carbon in the waste is fossil fuels) • High capital cost - particularly for a small system. • Insufficient waste on campus to support an economically sized system – might result in importation of waste to campus.	No further evaluation
Anaerobic Digesters and Biogas	Organic material (food scraps, plus manures, etc.) is digested to produce	• Manages waste stream at same time.	• UBC has an on campus composter and Metro Vancouver is initiating region-wide organics diversion.	No further evaluation
Solar Thermal	Solar panels capture heat energy	• No fuel cost (sun is free). • Substantial GHG reductions.	• Mismatch with load requirements – low energy availability during the winter. • Not reliable enough as core renewable component.	Not a core energy supply.

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4.3 Combined Heat and Power (CHP)

Combined heat and power (CHP) systems generate electricity and capture heat from an energy source. These are of interest in that they can create distributed electricity generation, which can reduce the demand for transmission and distribution infrastructure. To encourage this, BC Hydro offers a premium price for distributed electricity generation which includes some substantial mark-ups for peak day and peak hour production.

Several CHP options and their suitability to the Wesbrook DE system are described below (Table 9). CHP options are essentially limited to additional heat capture on the biomass combustion option. Given the small amount of generation it is suggested that CHP would not be an economic application. Efforts would be better focused to capture stack exhaust from the biomass boiler into the DE system through economisers and condenser additions.

Table 9: CHP Options

Natural Gas CHP (turbine)	A natural gas turbine is used to generate electricity. Heat exchangers on the exhaust stream capture heat for stream or hot water. Typically 30% - 40% of the input energy is converted to electricity and a similar amount of heat is captured. This is typically done for larger installations (e.g. 100 + MW electricity production). Natural gas cogeneration is not considered as it results in higher GHG intensity electricity, and does not help to meet UBC or provincial government goals to reduce GHG emissions.
Biogas or Natural Gas Internal Combustion"	Natural gas or more preferably a biogas source is burned in a larger internal combustion engine to generate electricity. Heat is captured from the exhaust stream. Examples include landfill gas, anaerobic digester biogas, and syngas from gasification systems (e.g. Nexterra). These systems come in smaller units – typically starting in the 500 kW capacity range. Using natural gas in an internal combustion engine is not an economic nor GHG friendly way to generate electricity. There are no known sources of biogas in the Wesbrook development area.
Biomass combustion	A biomass boiler can create steam for electricity generation. Heat is captured from the exhaust stream. Typical installations are at sawmills to consume saw dust and wood chips.
Biomass gasification	The Nexterra facility being developed on campus will gasify biomass and generate a syngas to be burned in an internal combustion engine.
Organic Rankine Cycle (ORC)	ORC systems are similar to steam turbine systems except that they use special refrigerants instead of water as the circulating fluid. This allows them to work with lower temperature heat sources (150 – 190 deg C with a minimum of 90 deg C) compared to water boilers with combustion temperatures of several hundred degrees. These systems have relatively low efficiency – converting on the order of 15% of the input heat to useful electricity. For the biomass boilers considered in this DE scenarios about 85% of the input energy is consumed (65% is transferred into DE system and 20% is used to effectively dry the biomass during combustion). For the size considered (up to about 3.0 MW), the maximum output then is on the order of a few hundred kW or less.

5 DISTRICT ENERGY OPTIONS AND COMPONENTS

Based on the screening presented in Section 4.2, four energy supply options are evaluated. These are shown in Table 10. The first option is a system connected to the hot water system being developed on campus. The other three are stand alone systems. Each of these options is described below. Note that there are several variations on each option that could be considered, such as routing of DPS, precise locations of facilities, etc. The approach here is to define the key features and the order of magnitude costs for each option.

Table 10: Energy Supply Options for Evaluation

Energy Supply Option	Option Acronym for Base Scenario	Option Acronym for Alternate Scenario
Connection to the future campus hot water system – serving the main campus but 'north of 16th Ave'	NCDE-1	NCDE-2
Heat capture from the TRIUMF cooling facilities	Triumf-1	Triumf-2
Conventional biomass combustion from a facility located on south campus	Biomass-1	Biomass-2
Sewer heat capture from south campus sewer	Sewer-1	Sewer-2

5.1 Costing Methodology

This study is a 'pre-feasibility' study under the terms of the BC Hydro program funding. The primary objectives are to understand the magnitude of the thermal load and screen whether there are any suitable energy sources available.

Costs are assumed to be "Class "D" cost estimates – as defined by Public Works Canada as "indicative" estimates. Such estimates are frequently based on gross unit cost estimates. We have used this approach for several components of these estimates (see Table 11).

Where information is available, costs have been cross checked against other cited sources that are locally relevant. This includes the UBC Concept Study for hot water conversion, the Corix BCUC application for a DE system at UniverCity on the SFU campus, personal communication from LEC and NEU staff, Hanscomb Yardsticks for Costing, and team member expertise. The estimate methodology is highlighted in the each of the sections below.

For simplicity, it is assumed that the system comes on line (project year 1) in 2012 and the renewable energy supply is built to the full capacity required for build-out. The DPS is built at the start of each 5-year phase to cover all the service area of that phase. In practice, some components of the heat plants might be deferred until later in the development. At the pre-feasibility stage, this is not expected to affect the results. As well, a sensitivity analysis to deferred capital is made.

The cost estimates do not include land costs. Many factors would affect the cost of land for DE facilities. For example a UBC owned facility might not incur a direct cost for land, though there could be an opportunity cost when a DE facility occupies land that would otherwise be developable. In contrast, a third party owner might be expected to purchase a pre-paid land lease for any land consumed. Land values range from $1 million per acre for institutional land uses to $20 million per acre for residential land uses.

Table 11: Costing Methodology

Component	Method	Examples
Specialized major equipment	Supplier estimates or quotes	Heat pump costs and performance specs, Biomass boilers
Unit costs	Unit Costs	Buildings ($ / m^2) Distribution piping ($ / trench meter) Energy transfer stations ($ / kW) Building Costs ($ / m^2)
Overheads	Percentages of capital costs	Engineering design and construction management (10%-15%) Contingency (10%)

5.2 Peaking and Back up Natural Gas Capacity

For the three stand alone DE systems, natural gas boilers will be required to provide back-up and peaking capacity – equivalent to the peak load. Boiler capacity installation is staggered to provide the peak requirement for each phase at the beginning of each phase. The required increments are shown in Table 12. These increments are drawn from the load duration curves of Figure 10 and Figure 11.

Costs are estimated at $62,500 per MW of boiler capacity (installed) plus an allowance for construction of a basic building (320 m^2 at $2000 / m^2) (for first installation only), and service connections and metres for the plant ($ 100k), engineering (15%) and contingency (10%).

This estimate assumes that a standalone facility is constructed for the natural gas boilers. In practice there could be efficiencies if this boiler capacity was located at the energy plant, or closer to the Wesbrook community. This total capacity could be dispersed amongst several locations and possibly incorporated into new buildings or site development features.

Table 12: Natural Gas Boiler Capacity Requirements

	Base Scenario		Alternate Scenario	
Installed	Capacity (MW)	Cost ($)	Capacity (MW)	Cost ($)
2012	3	1,160,000	6.5	1,430,000
2016	1.5	120,000	4	310,000
2021	-		2.5	200,000
Total	4.5	1,280,000	13.0	1,940,000

Note:
[1] Natural gas boilers are not required for the scenario NCDE1 and NCDE2 which connect to the campus hot water DE system which is currently under development.

5.3 Connection to the North Campus DE System

Description

UBC has begun the process to transition from a steam-based district energy system, to a hot water system. This process is at the design stage and a phased implementation over several years is likely. Part of this retrofit will include the installation of Nexterra's biomass gasification and cogeneration facility, as well as a new peaking boiler plant.

This option connects the Wesbrook district energy system to this new campus system near the new peaking boiler plant proposed near the intersection of East Mall and Thunderbird Boulevard. The distance from the new boiler plant along East Mall to the Wesbrook development boundary at 16th Avenue is approximately 950 m. A heat exchanger at or near the new peaking boiler plant could take heat from the campus system to the Wesbrook development area. The Wesbrook DE system would essentially start at the connection to the campus system.

Some variations could be developed for this option including: [14]

- UBC could provide a line from its campus system to 16th Ave and provide a heat exchanger near the Wesbrook boundary. Thus the line along East Mall would be part of UBC's system. Currently there are sports fields and limited customers but this might be desirable for future development options.
- The systems could be completely connected with the same circulating fluid and no heat exchanger.

Operating features are compiled in Table 13, and a simplified schematic is shown in Figure 12. A layout of a possible distribution pipe network is shown for the base scenario (Figure 18) and the alternate scenario (Figure 19).

Cost estimates for the four DE energy supply options are summarized in Table 21.

Discussion

This option has a low operational risk. The technology required is a heat exchanger to remove heat from the main campus system and this is a common technology. Given that this is a connection between two DE systems – each with a conditioned circulating fluid – issues such as fouling or contamination would not be expected.

One operational issue may be that temperature drops across the heat exchanger (likely 2-3 deg C), and line losses in transit to the Wesbrook neighbourhood (one or two deg C perhaps) might result in supply temperatures slightly below a desired set point at some moments of the year. This could be resolved with a small top-up boiler to add a few degrees back to the supply line.

Fuel price certainty is the same as for the UBC campus system. Natural gas (and the biomass from the Nexterra system) are the main sources of heat. The assumed pricing model was that heat would be purchased at a fixed premium (percentage increase) above the forecasted cost of natural gas. The campus is a large consumer and so has the option of commanding low cost prices.

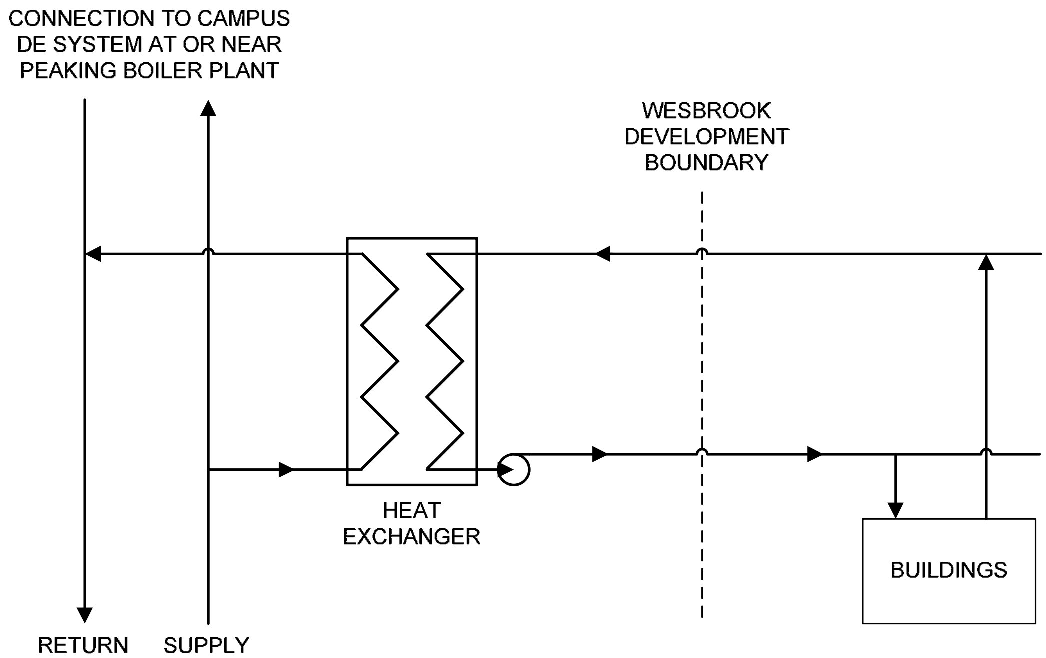
[14] These variations are identified but not explored in this work.

Table 13: Operating Features: North Campus DE Connection

Component	Units	Base Scenario	Alternate Scenario	Comments / Notes
Capacity Installed via Heat Exchangers	MW	4.5	13.0	
Distance from HX to DE service area	m	950	950	[1]
DPS Length (within Wesbrook development)	m	1600	1980	[2]
Assumed Staff:	# FTEs			
Operators		0.5	0.5	
Engineering		0.25	0.25	
Administrative		0.25	0.25	See note [3]

Note:
[1] Distance from proposed site of new peaking boiler plant to connection on south side of 16th Ave.
[2] Estimated distribution system distance within the development area.
[3] Staffing requirement for evaluation assumes that UBC is the operator. It is assumed that some functions (monitoring, call outs etc) could be completed by existing staff (for example the Nexterra facility will require hiring some new staff yet some activities will be absorbed by current staff). This estimate is for incremental FTE's required to operate the system above the existing staff complement.

Figure 12: System Schematic for Connection to the Campus DE System



Note:
Schematic is not to scale

5.4 TRIUMF Heat Capture

Description

The TRIUMF facility uses several cooling towers to cool its facilities. This heat is currently discharged to the atmosphere using a cooling tower. In this scenario, waste heat is captured from the facility, and using heat pumps, this heat is input to a medium temperature DE system.

The current cooling fluid could be circulated to the edge of the TRIUMF property line (and outside the controlled access area). There is a utility right of way running east-west just south of the building.

Performance assumptions used in the evaluation are shown in Table 14. Price and performance information was used for McQuay "Templifier" heat recovery heat pumps as an example of modular (each unit is 675 kW) heat pumps specifically designed to extract heat from water flows in the 7 deg to 30 deg C temperature range (see example in Figure 13).

Cost estimates for the four DE energy supply options are summarized in Table 21.

Discussion

The technology to capture waste heat using heat exchangers such as these is well established. Because the current cooling fluid circulates to the atmosphere in the cooling towers, there is the potential for contamination. This could result in fouling of the evaporator side of the heat pump. This might requires some additional screening of the cooling water.

For the Wesbrook development, BC Hydro provides electrical power to the new development independently of UBC's supply. Electricity supply to the campus is reaching capacity and at the TRIUMF facility there may be capacity limitations. This heat pump option will reduce the overall electrical demand but will increase it at the location of the heat pumps. Further review is required to determine if the location of power needs are mismatched.

Table 14: Operating Features: TRIUMF Heat Capture

Component	Units	Base Scenario	Alternate Scenario	Comments
Heat Pump (Discharge Capacity) Installed	MW	1.5	4.0	
COP	--	3.5	3.5	COP may be higher during higher temperature periods.
Return Temp	Deg C	20	20	Temperature of flow returning to facility

Component	Units	Base Scenario	Alternate Scenario	Comments
Discharge Temp	Deg C	70	70	Assume that for higher demand, then NG boilers will be required in series. Supplier also indicates that these units can also deliver to 85 deg, though COP will decline to about 2.
Capacity	kW	675 ea	675 ea	Modular units allow for installation in modules.
Share of DE system energy provided by HPs	Annual average	60%	60 %	See notes [1], [3]
Incremental Staffing Operators Engineering Administrative	# FTEs	 0.5 0.25 0.25	 0.5 0.25 0.25	See note [2]

Notes:
[1] Remainder of heat is assumed to be provided by stand alone natural gas boilers.
[2] Staffing requirement for evaluation assumes that UBC is the operator. It is assumed that some functions (monitoring, call outs etc) could be completed by existing staff (for example the Nexterra facility will require hiring some new staff yet some activities will be absorbed by current staff). This estimate is for incremental FTE's required to operate the system above the existing staff complement.
[3] This does not include heat recovery from the new Ariel facility. Currently, it is planned to place a cooling tower on the roof of the facility. Connecting this flow to the main cooling towers on the south side of the TRIUMF building is not an option, but this cooling tower could be relocated to the north (current staff parking lot area).

Figure 13: Example of a Package Size Heat Recovery Heat Pump

Source: Templifier (R) Heat Recovery Water Heaters Catalogue McQuay Air Conditioning

Background

The TRIUMF research facility on campus requires cooling for its equipment. There is the possibility that this heating could be captured and used to provide heat to a campus DE system. Considerations include:

- The facility has process and cooling loads year round. However, the main operational period, which requires the most cooling, is from April 1 to December 22. Potential heat capture during this period is in the range of 4 MW.
- During facility shut downs, the cooling loads are reduced and the potential heat capture in this period is about 1 MW. The TRIUMF facility is shut down for 2 to 3 months annually (usually from January to March).
- The new ARIEL facility is planned to be operational 11 months per year.
- During experimental operations, there are activity interruptions (switch trips, etc.). These do not immediately stop the cooling requirements as much of the equipment remains energized.
- Electricity consumption ranges from 80% to 95% of peak capacity (8-10MW electrical).
- Main cooling tower has feed (from equipment) of approximately 22 deg when non - operational (e.g., February) and 25 - 28 deg C when operational (e.g., June). A heat pump would be required to transfer this heat to a hot water system.
- From main cooling towers, it would likely require any heat capture facility be located off of the TRIUMF site to allow for future TRIUMF activities. Routing to the South (or West) is most viable (East is possible, but facility adjoins Pacific Spirit Regional Park and would require land).
- TRIUMF are not considering any charge associated with capturing the waste heat. All costs associated with capturing the waste heat would be borne by the project.
- TRIUMF is currently undergoing a major expansion with the development of the ARIEL facility. While any public or research facility would be challenged to guarantee its operating status 10 or 20 years in the future, the risk of TRIUIMF not functioning is no different than for any waste heat source.

Table 15: Summary of Cooling Facilities at TRIUMF

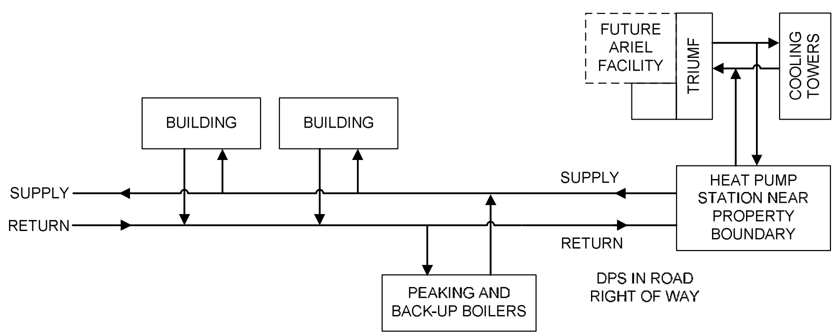
Cooling Unit	Location	Description	Capacity	Accessibility
Main Cooling Tower	Directly South of Main Accelerator building	Open circuit (wet) cooling tower with make-up water, and variable speed fans for control. Assembly has 7 banks of towers - each rated ~400 tons capacity (~1.4 MW) in 2 rows - one with three and one with four. Total name plate capacity is about 9.8 MW. Suggested by staff that operational capacity is closer to 6 MW. Slot is available for one more 400 ton unit.	Name plate = 9.8MW Suggested operational capacity = 6 MW Required peak capacity = 7MW (additional capacity will be implemented in the near future).	Water flows from building, underground to the tower assembly. Twin header pipes (~10 inch dia) surface at the north side of the towers.
ISAC	Roof of ISAC building	Package units on rooftop.	2.2 MW total capacity.	Difficult: Challenging to connect
Nordion	Rooftop units at Nordion facility	Private isotope manufacturer. Rooftop mounted units. Use unknown.	1MW (approximate)	Difficult. Rooftop and across the main building from the main cooling tower. Would need road excavation to bring to East fence then to TRIUMF parking lot
ARIEL e-linac & 4AN		ARIEL is located directly north of the main Cyclotron building. The addition of the e-linac accelerator and 4AN beam line is estimated to require ~1.4 MW of cooling by 2014 and further ~1 MW by 2020 (depends of next five year funding approval)	Expect a load requirement of 2.0 to 2.2 MW. Present thinking is to have CT as rooftop unit. Some cooling may be accessed via the main cooling tower.	Rooftop unit: Difficult to access from the roof. Planning of the additional capacity is underway. Location TBD, but likely near the present South CT Not an option to send cooling water to the south to the main cooling towers (shielding, trenching, pumping). It may be possible to route this cooling line to the North to a ground level heat pump location or cooling tower – likely near the current car park.

Figure 14: TRIUMF Cooling Towers

(b) 

Note:
(a) Main Cooling Tower
(b) Rooftop Cooling Tower

Figure 15: System Schematic for Heat Capture From the TRIUMF Facility



Note:
Schematic is not to scale

5.5 Biomass Combustion

Description

A conventional biomass boiler burns wood waste to produce hot water. This is circulated through the DE system. A biomass boiler could easily achieve the desired peak discharge temperature (max of around 95 deg C).

Wellons and other makers provide package units complete with all material handling components. Discussions with sales representatives have provided a quote of $5 million for a 5MW system ($1 million per MW) but also indicate that some economies of scale are lost for smaller systems. A unit cost of $1.25 million per MW capacity is used here.

Biomass would typically be 50% moisture content (MC) hog fuel or similar, though opportunities to capture construction waste could provide high energy content biomass with low moisture content.

Biomass boilers have turn down rates on the order of 5:1, so the system could be operated below the boiler rated capacity. This would allow for use during the low demand summer months, thus enabling the biomass source to provide a large share of the total energy requirements.

Cost estimates for the four DE energy supply options are summarized in Table 21.

Discussion

This technology is well established in practice, but is most often deployed at an existing forest products facility. Capital and funding risks might include any BC Safety Authority requirements for oversight which might require greater staffing than assumed here.

Operational risks are primarily the cost and reliability of future biomass supply. This is an area of great uncertainty. The biomass market is not open and transparent, but rather defined by a number of individual arrangements - reducing market transparency. The price forecasts used here are based on interviews and other research (particularly the expectations of UBC and SFU DE systems). Regardless, these estimates can become dated. As such, forecasts of biomass pricing should be considered as less accurate than electricity prices.

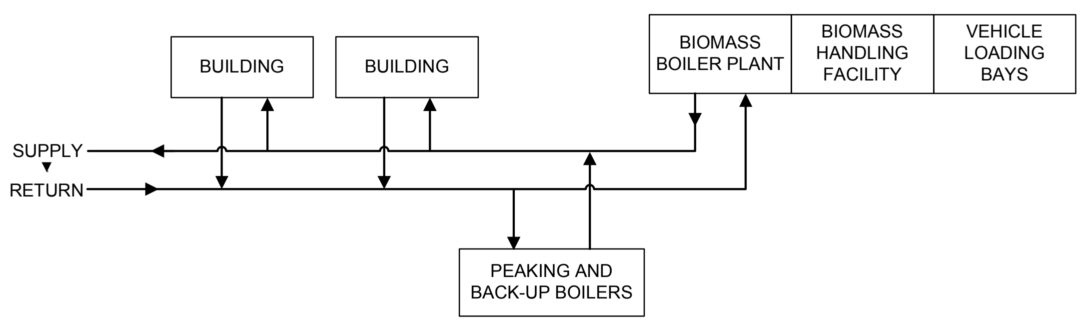
Resident or neighbourhood concerns about truck traffic and on-campus traffic congestion might be cited as a consideration. However, there are already hundreds of commercial vehicles arriving on campus daily, including many to the South Campus area. Given that vehicle routing would likely be via South West Marine Drive to a location south of the Wesbrook neighbourhood, resident concerns are expected to be limited.

Table 16: Operating Features: Biomass Combustion

Component	Units	Base Scenario	Alternate Scenario	Comments
Biomass Boiler Capacity	MW	1.5	4.0	
Estimated biomass requirement annually	tonnes	2,190 (MC=20%)	8,010 (MC=20%)	Tonnage based on 20% moisture content energy and price estimate. Actual biomass purchased is expected to be typically 50% MC hog fuel.
Share of DE system energy provided by biomass boiler	Annual average	70 %	75 %	
Incremental Staffing Operators Engineering Administrative	# FTEs	 2 0.25 0.25	 2 0.25 0.25	See notes [2], [3]

Notes:
[1] Remainder of heat is assumed to be provided by stand alone natural gas boilers.
[2] Staffing requirement for evaluation assumes that UBC is the operator. It is assumed that some functions (monitoring, alarm call outs etc) could be completed by existing staff. As a comparative example the Nexterra facility will require hiring some new staff yet some activities are expected to be absorbed by current staff or transferred from the existing steam plant. This estimate is for assumed 'incremental' FTE's required to operate the system above the existing staff complement. Note that these are indicative estimates. The authority for defining operational and staffing requirements resides with the BC safety authority.
[3] The other options have estimated 0.5 incremental FTEs for operation. For the biomass option 2 FTEs are estimated as the minimum. This is because of the material handling and delivery requirements that are not present with other options.

Figure 16: System Schematic for Biomass Combustion



Note:
Schematic is not to scale

earthvoice strategies

5.6 Sewer Heat Pumps

Description

The sewage from the south end of campus flows north to south past the Wesbrook development approximately along the property line with Pacific Spirit Regional Park. Several lines converge on South Campus about where the current composting facility is located, south of the TRIUMF facility. From the junction sewage flows in two lines; a 12" concrete gravity line from manhole US7-S004a and a 525 mm PVC gravity drain from manhole US7-S047a.

To access the heat, a constructed diversion basin or storage tank (e.g., a wet well) will be required. Sewage will flow through a heat exchanger assembly and transfer heat to an intermediate loop that will circulate between the heat exchanger and the heat pump. Sewage would be returned to the sewer line after heat extraction.

The intermediate loop is a manufacturer's recommendation to prevent fouling of the heat pump. This is for the specific heat pump reviewed as an example. It is expected that other equipment of a similar size would have the same requirement.[15] Heat would be transferred from the sewage, via a heat exchanger to the heat pump evaporators. The heat pumps used would be similar to those described above for the TRIUMF heat capture scenario.

Cost estimates for the four DE energy supply options are summarized in Table 21.

Discussion

This option is limited in the amount of heat that is available to be drawn from the sewage. Current estimates are for an average of 30 L/s which may increase to 35 L/s (base scenario) or 42 L/s (alternate scenario). There is a limit to the amount of heat that can be extracted from this flow. As a result, in the alternate scenario there is only expected to be enough heat in the sewer flow to provide about 40% of the required thermal load. The remainder would be provided by natural gas.

Sewer heat pump technology is a new application in Canada. The SEFC NEU has about a year of operating experience and uses a large (3 MW) heat pump. The proposed system uses smaller heat pumps in a more modular design. There are some unknowns regarding the sewage flow rates that would be required for accurate system design. For example, the sewage flow is expected to be warm at present but this might be due to the amount of steam condensate discharged to the sewer. As well, the performance of the system with the variable diurnal flows of wastewater needs to be considered.

For the Wesbrook development, BC Hydro provides electrical power to the new development independently of UBC's supply. Electricity supply to the campus is reaching capacity and for the South Campus there may be capacity limitations. This heat pump option will reduce the overall electrical demand but will increase it at the location of the heat pumps. Further review is required to determine if the location of power needs are mismatched in their location or whether the power that would have been dedicated to the new buildings can be used at the sewer heat pump locations.

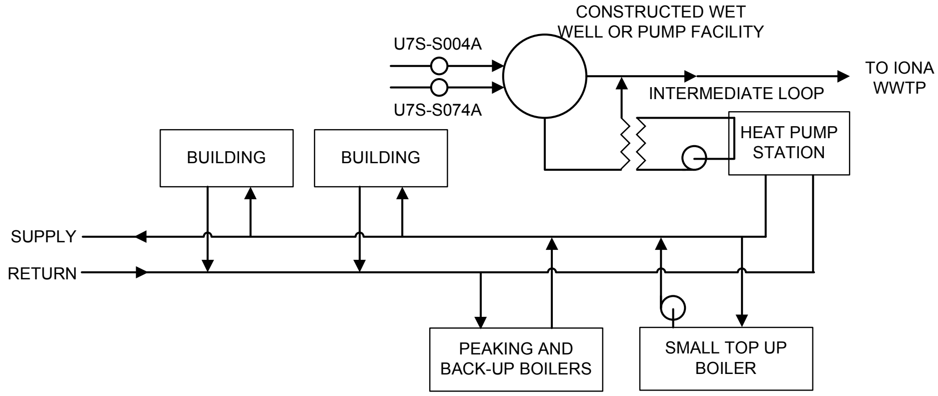
[15] This system uses smaller heat pumps than the SEFC NEU. That system has large 3 MW heat pumps. A system of four way valves is used to reverse the flow direction and prevent fouling.

Table 17: Operating Features: Sewer Heat Pumps

Component	Units	Base Scenario	Alternate Scenario	Comments
HP Capacity Installed	MW	1.7	2.0	HP capacity is limited by the estimated flow in the sewer lines. Even at full build out, there is a limited amount of sewage available to draw heat from (NB: Based on preliminary flow monitoring provided by UBC.)
COP	--	Summer = 2.55 Winter = 2.3	Summer = 2.55 Winter = 2.3	See Note [3]
Average Sewage Flows Current: At build out :	L / s	30 35	30 42	Build out values include estimate of flow from completed residential development estimated at 150 L/capita/day.
Sewage temperature in	Deg C	Summer = 18 Winter = 11	Summer = 18 Winter = 11	See note [3]
Sewage temperature out	Deg C	Summer = 9 Winter = 5	Summer = 9 Winter = 5	See note [3]
HP Discharge Temp to DE System	Deg C	70	70	Assume that for higher demand, then NG boilers will be required in series. Supplier also indicates that these units can also deliver to 85 deg, though COP will decline to about 2.
Share of DE system energy provided by HPs	Annual average	70 %	40 %	See note [1]
Incremental Staffing Operators Engineering Administrative	# FTEs	0.5 0.25 0.25	0.5 0.25 0.25	See note [2]

Note:
[1] Remainder of heat is assumed to be provided by stand alone natural gas boilers.
[2] Staffing requirement for evaluation assumes that UBC is the operator. It is assumed that some functions (monitoring, call outs etc) could be completed by existing staff (for example the Nexterra facility will require hiring some new staff yet some activities will be absorbed by current staff). This estimate is for incremental FTE's required to operate the system above the existing staff complement.
[3] Seasonal sewage temperatures estimated. At present, temperatures may be higher on campus due to condensate discharge. This will be eliminated with the transition from a steam to hot water system on campus. As well an intermediary HX is used to prevent sewage contact with the HPs (manufacturer's recommendation) with an assumed loss of 2 deg C.

Figure 17: System Schematic for Sewer Heat Capture



Note:
Schematic is not to scale

5.7 Distribution Piping System (DPS)

Schematic DPS layouts were made to estimate the total length of the DPS required. Each line of the DPS includes both the supply and return line. For the stand alone options (TRIUMF heat capture, sewer heat, and biomass heat) the DPS within the Wesbrook area is the same. A slightly different layout is devised for the connection to the North Campus.

The layouts are:

- Base scenario – connection to the campus DE system (Figure 18).
- Alternate scenario – connection to the campus DE system (Figure 19).
- Base scenario – stand alone heat plant (Figure 20)
- Alternate scenario – stand alone heat plant (Figure 21).

Cost estimates for the DPS are summarized in Table 21.

Figure 18: Base Scenario: DPS Layout for Connection to the Campus DE System

Existing Buildings Phase 1 Buildings Phase 2 Buildings
Phase 1 Piping Phase 2 Piping

Figure 19: Alternate Scenario: DPS Layout for Connection to the Campus DE System

Existing Buildings Phase 1 Buildings Phase 2 Buildings Phase 3 Buildings
Phase 1 Piping Phase 2 Piping Phase 3 Piping

Figure 20: Base Scenario: DPS Layout for Connection to stand alone Heat Plant (to the South)

Existing Buildings Phase 1 Buildings Phase 2 Buildings
Phase 1 Piping Phase 2 Piping

Figure 21: Alternate Scenario: DPS Layout for Connection to stand alone Heat Plant (to the South)

The length of each component of the distribution piping system was estimated from maps of the service area and the location of the heat source. Costs are estimated from approximate unit costs per trench metre. Costs used are:

- Connection from the new campus peaking boiler plant (scenario North Campus DE connection) at $1750 per trench metre. Value is based on the average DPS cost estimated in the Hot Water concept development study (indicated range from $1900 (100 mm pipe) to $2500 (250 mm pipe).[16]. For this segment the cost has been reduced by about 20% because the expected path is a wide roadway and with minimal utility conflicts.

- DPS within the Wesbrook development area at $1500 per trench metre[17]. This represents a 25% discount from the average of the estimated cost from the FVB study[18]. This discount is used because much of the site is a green field site and there would be cost efficiencies involved in the design and installation as other utilities and roads are constructed.

[16] "Concept Development Feasibility Study for a Hot Water District Energy System at the University of British Columbia" prepared by FVB Energy Inc., December 2010.

[17] This value is the average of costs cited in Corix Energy's BCUC application for a DE system at UniverCity at SFU (Nov 2010). That development includes a reasonably similar thermal load as the Wesbrook forecast.

18 The UBC Hot Water conversion study estimated DPS costs at: Pipes, installation, etc. Range from $450 to $740 per trench m, Civil and Excavation $600 / tm (all sizes), Contractor overheads: Admin 20%, Construction mgmt 20% Scope changes 3%, HST 12%; Owner / UBC overheads: Eng design and support 10%, Contingency 10% . total costs estimated ranged from $1950 (100 mm)to $2550 (250 mm pipe) per trench meter.

5.8 Building Connections and Energy Transfer Stations

Connecting each building to the DPS requires a smaller diameter building connection. It is assumed that this would require 30m of connection at a cost of $ 900 / trench meter. This unit cost is from the City of Vancouver connectivity study and equates to $27,000 per building.

Each building requires an ETS to take heat from the DPS circulating fluid into the building hydronic system (see example in Figure 22). Costs were estimated based on a unit costing derived of $350 per kW of capacity[19]. This is the average value cited for residential developments at UniverCity, and is consistent with unit costing estimates for the City of Vancouver connectivity study. This is about $100,000 per ETS.

Figure 22: Examples ETS

Photo Courtesy Lonsdale Energy Corporation

[19] $350 per kW of capacity is about equivalent to the unit cost of a 400 kW ETS. This would provide heat for about a 100,000 ft^2 of residential floor space.

5.9 In-Building systems

A building must be "DE compatible" in order for it to capture energy from the DE system and to ensure the best operation of the DE network. The building must include hydronic heating systems, and the building will require circulation pumps and controls. This is not new technology as hydronic systems have been used for many years.

There are some benefits cited for a DE compatible building. One is that there can be space savings within the building. While true, these space savings are usually small. Other benefits may be more intangible such as strata preference for an ETS rather than a boiler.

5.9.1 Building Construction Costs

Higher capital costs for hydronic and DE heating systems can be a barrier to DE implementation. To assess this impact, estimates of the capital cost for the building heating systems are included in the business-as-usual, and the DE scenarios.

Estimates of capital costs for BAU systems as well as DE systems are derived from work for the City of Vancouver connectivity study. [20] The baseline scenario in that work is similar to the BAU scenario in this report; electric space heating and gas-fired DHW heating.

Anecdotally, estimates have been provided to the project team indicating that the incremental cost of constructing a DE connected building could range as high as $70 per m^2 ($7,000 for a 1,000 square foot suite). Documentation of these estimates is difficult to obtain and it is uncertain if these refer to in-slab or radiator systems. It is recognized that incremental capital costs are a concern to developers. For the pre-feasibility analysis it is felt that the City of Vancouver estimates are a useful benchmark. This analysis did not price specific suppliers or components (e.g., metres, valves, etc.), though it did include qualified quantity surveyor estimates for general technologies.

Table 18: Capital Cost Assumptions for Heating Systems

	BAU Scenarios ($ / square metre)	District Energy Scenarios (all) [2] ($ / square metre)	Incremental Costs ($ / square metre)
Town homes [1]	$ 38	$ 62	$ 24
Low-rise and Mid-rise [1]	$ 38	$ 62	$ 24
High-rise	$ 46	$ 80	$ 34

Source: Adapted from City of Vancouver DE Connectivity Study: MURB Hydronic Upgrade and district energy Compatibility Analysis, by Compass Resource Management and Associates 2009
Notes:
[1] The connectivity study modeled lows rise and high rise buildings. For this analysis medium rise buildings were modeled as low rise buildings. Town homes were also modeled with costs of low rise buildings.
[2] The district energy scenario used the average of a 'typical' and a 'upscale' installation.

[20] City of Vancouver District Energy Connectivity Study: MURB Hydronic Upgrade and district energy Compatibility Analysis, prepared for the City of Vancouver, prepared by Compass Resource Management in association with Enersys Analytics, Advicas Quantity Surveyors, and FVB energy Inc. December 2009

5.9.2 Building Operating Costs

Operating costs are similarly estimated from the connectivity study. A summary comparison of the costs used is shown in Table 19.

Table 19: Operating Cost Assumptions for Heating Systems

	Units	BAU Scenarios		District Energy Scenarios	
		Cost ($)	Frequency (every x years)	Cost ($)	Frequency (every x years)
Low Rise [1]					
Mte: DHW	$ / bldg	1000	3	0	-
Mte: MUA	$ / bldg	500	3	500	3
Replace: suite ventilation	$ / suite	1500	15	1500	15
Replace DHW tanks	$ / bldg	35000	10	0	-
Replace: MUA	$ / bldg	120000	15	86000	15
High Rise					
Mte: DHW	$ / bldg	1000	3	0	-
Mte: MUA	$ / bldg	500	2	500	3
Replace: suite ventilation	$ / suite	1500	15	1500	15
Replace DHW tanks	$ / bldg	35000	10	0	-
Replace: MUA	$ / bldg	120000	15	86000	15

Source: City of Vancouver DE Connectivity Study: MURB Hydronic Upgrade and district energy Compatibility Analysis, by Compass Resource Management and Associates 2009
Notes:
[1] Low rise values are used for mid-rise and town home units

5.10 Discussion of Costs

The costs cited here should be placed within the context of the broader development. Some points to note include:

- The incremental costs to build buildings suitable for a DE system compared to the BAU is estimated (from previous work) in the range of $2.50 to $3.00 per square foot (see Table 18 and Table 21) [21] Within the context of construction costs (excluding land) this is potentially in the range of $ 500 per square foot. This represents a premium of less than 0.5% to 1.2% of construction costs (excluding land costs).
- The development costs of a DE system are not immaterial. From Table 21, the estimates range from $ 8 million to $ 11 million for the base scenario and $13 million to $ 20 million for the alternate scenario. However, these occur through the development of 1.66 (base) or 4.22 (alternate) million square feet of building area. The capital cost of the DE system is about 1.2% (base) or 0.4 % (alternative) of the total construction costs (see Table 20).

[21] The cost estimates used here are based on the work of the City of Vancouver connectivity study. Compass Resource Management in association with Enersys Analytics, Advicas Quantity Surveyors, and FVB energy Inc. December 2009

Table 20: DE Capital Compared to Total Building Systems

	Base Scenario	Alternate Scenario
Developable Floor Space (thousands of m^2))	154	392
DE System Capital Costs (S millions)	8.5 - 11	13.5 - 20.0
Construction Cost to Build out ($ millions) [a]	830	2,110
DE System Capital as percentage of total Development Costs (construction + land lease).	~ 1.2 %	~ 0.4 %

Notes:
[a] Assumes a simple estimate of total development costs including building construction and land lease costs are in the range of $500 per square foot.

Table 21: DE Scenario Cost Summary

	Base Case Development Sceanrio					Alternative Development Sceanrio					
	BAU1	NCDE1	TRIUMF1	Biomass1	SewerHP1	BAU2	NCDE2	TRIUMF2	Biomass2	SewerHP2	Notes:
General											
Total Developed Floor Space (ft^2)	1,660,804	1,660,804	1,660,804	1,660,804	1,660,804	4,221,543	4,221,543	4,221,543	4,221,543	4,221,543	
Building Costs (Construction)											
Building Capital Costs (Total - undiscounted)	$ 6,186,299	$ 10,291,415	$ 10,291,415	$ 10,291,415	$ 10,291,415	$ 16,183,369	$ 27,191,295	$ 27,191,295	$ 27,191,295	$ 27,191,295	1a,2, 25
Building Capital Costs (NPV)	$ 5,087,341	$ 8,461,137	$ 8,461,137	$ 8,461,137	$ 8,461,137	$ 11,918,287	$ 20,077,314	$ 20,077,314	$ 20,077,314	$ 20,077,314	1, 25
Building Construction Costs ($ / sq ft) (undiscou	$ 3.72	$ 6.20	$ 6.20	$ 6.20	$ 6.20	$ 3.83	$ 6.44	$ 6.44	$ 6.44	$ 6.44	3, 25
Incremental Costs Compared to BAU ($ / sq ft)	--	$ 2.47	$ 2.47	$ 2.47	$ 2.47	--	$ 2.61	$ 2.61	$ 2.61	$ 2.61	4, 25
Building Operational Costs (O&M, replqcements, excl fuel)											
Building O&M Costs (25 Year Total)	$ 8,588,133	$ 5,538,900	$ 5,538,900	$ 5,538,900	$ 5,538,900	$ 17,684,917	$ 14,005,500	$ 14,005,500	$ 14,005,500	$ 14,005,500	1a, 25
Building O&M Costs (25 Year NPV)	$ 4,289,717	$ 2,704,655	$ 2,704,655	$ 2,704,655	$ 2,704,655	$ 8,502,059	$ 6,557,765	$ 6,557,765	$ 6,557,765	$ 6,557,765	1, 25
Total O&M Costs per year (at full buildout)	$ 396,850	$ 256,300	$ 256,300	$ 256,300	$ 256,300	$ 893,417	$ 709,500	$ 709,500	$ 709,500	$ 709,500	6
Average Annual Operating Costs ($ / sq ft / yr)	$ 0.24	$ 0.15	$ 0.15	$ 0.15	$ 0.15	$ 0.21	$ 0.17	$ 0.17	$ 0.17	$ 0.17	7
Incremental Costs Compared to BAU ($ / sq ft)	--	-$ 0.08	-$ 0.08	-$ 0.08	-$ 0.08	--	-$ 0.04	-$ 0.04	-$ 0.04	-$ 0.04	8
District Energy System Costs											
A) DE System - Scenario specific											
Heat exchanger to Campus system	$ -	$ 400,000	$ -	$ -	$ -	$ -	$ 500,000	$ -	$ -	$ -	9
Connection to Campus DE System	$ -	$ 1,662,500	$ -	$ -	$ -	$ -	$ 1,662,500	$ -	$ -	$ -	10
Heat Pumps purchase and install	$ -	$ -	$ 324,000	$ -	$ -	$ -	$ -	$ 972,000	$ -	$ -	11
Piping to Triumf WEST boundary	$ -	$ -	$ 45,000	$ -	$ -	$ -	$ -	$ 45,000	$ -	$ -	12
Biomass Plant	$ -	$ -	$ -	$ 1,875,000	$ -	$ -	$ -	$ -	$ 5,000,000	$ -	13
Sewer HPs	$ -	$ -	$ -	$ -	$ 550,000	$ -	$ -	$ -	$ -	$ 660,000	14
HX / screens / secondary loop	$ -	$ -	$ -	$ -	$ 250,000	$ -	$ -	$ -	$ -	$ 250,000	15
B) DE System - Common to Some Scenarios											
Building	$ -	$ -	$ 375,000	$ -	$ 375,000	$ -	0	$ 562,500	$ -	$ 562,500	16
Pumps Vessel, Controls	$ -	$ 500,000	$ 500,000	$ 500,000	$ 500,000	$ -	$ 500,000	$ 500,000	$ 500,000	$ 500,000	17
NG Boilers (includes eng and contingency)	$ -	$ -	$ 1,280,000	$ 1,280,000	$ 1,280,000	$ -	$ -	$ 1,940,000	$ 1,940,000	$ 1,940,000	18
Engineering & construction mgmt	$ -	$ 384,375	$ 186,600	$ 356,250	$ 258,750	$ -	$ 399,375	$ 311,925	$ 825,000	$ 303,375	19
Contingency	$ -	$ 256,250	$ 124,400	$ 237,500	$ 172,500	$ -	$ 266,250	$ 207,950	$ 550,000	$ 202,250	20
C) Distribution Piping System (DPS)											
Phase 1 (2012)	$ -	$ 1,995,000	$ 2,617,500	$ 3,292,500	$ 3,292,500	$ -	$ 2,145,000	$ 2,617,500	$ 3,067,500	$ 3,067,500	21
Phase 2 (2016)	$ -	$ 450,000	$ 450,000	$ 450,000	$ 450,000	$ -	$ 450,000	$ 675,000	$ 675,000	$ 675,000	21
Phase 3 (2021)	$ -	$ -	$ -	$ -	$ -	$ -	$ 375,000	$ 375,000	$ 375,000	$ 375,000	21
D) Building Connections											
Phase 1 (2012)	$ -	$ 459,000	$ 459,000	$ 459,000	$ 459,000	$ -	$ 459,000	$ 459,000	$ 459,000	$ 459,000	22
Phase 2 (2016)	$ -	$ 162,000	$ 162,000	$ 162,000	$ 162,000	$ -	$ 216,000	$ 216,000	$ 216,000	$ 216,000	22
Phase 3 (2021)	$ -	$ -	$ -	$ -	$ -	$ -	$ 135,000	$ 135,000	$ 135,000	$ 135,000	22
E) Energy Transfer Stations (ETS)											
Phase 1 (2012)	$ -	$ 1,617,003	$ 1,617,003	$ 1,617,003	$ 1,617,003	$ -	$ 3,004,292	$ 3,004,292	$ 3,004,292	$ 3,004,292	23
Phase 2 (2016)	$ -	$ 738,305	$ 738,305	$ 738,305	$ 738,305	$ -	$ 1,891,877	$ 1,891,877	$ 1,891,877	$ 1,891,877	23
Phase 3 (2021)	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,360,961	$ 1,360,961	$ 1,360,961	$ 1,360,961	23
District Energy System Summary (subtotals)											
A) DE System - Scenario specific	$ -	$ 2,062,500	$ 369,000	$ 1,875,000	$ 800,000	$ -	$ 2,162,500	$ 1,017,000	$ 5,000,000	$ 910,000	24
B) DE System - Common to Some Scenarios	$ -	$ 1,140,625	$ 2,466,000	$ 2,373,750	$ 2,586,250	$ -	$ 1,165,625	$ 3,522,375	$ 3,815,000	$ 3,508,125	24
C) Distribution Piping System (DPS)	$ -	$ 2,445,000	$ 3,067,500	$ 3,742,500	$ 3,742,500	$ -	$ 2,970,000	$ 3,667,500	$ 4,117,500	$ 4,117,500	24
D) Building Connections	$ -	$ 621,000	$ 621,000	$ 621,000	$ 621,000	$ -	$ 810,000	$ 810,000	$ 810,000	$ 810,000	24
E) Energy Transfer Stations (ETS)	$ -	$ 2,355,308	$ 2,355,308	$ 2,355,308	$ 2,355,308	$ -	$ 6,257,130	$ 6,257,130	$ 6,257,130	$ 6,257,130	24
TOTAL		$ 8,624,433	$ 8,878,808	$ 10,967,558	$ 10,105,058	$ -	$ 13,365,255	$ 15,274,005	$ 19,999,630	$ 15,602,755	

Notes to Table 21:

1. NPV discounted at 6%

1a Total is undiscounted

2. Capital costs estimated from values in Table 18
3. Values are total undiscounted capital divided by gross building area.
4. Difference from BAU - Positive = an increase
5. NPV based on all building costs over 25 years, discounted at 6%
6. Annual costs at build out (total of all buildings)
7. Annual costs divided by total floor space.
8. Difference from BAU. Negative = a decrease.
9. Estimated from scaling of estimate for a similar ETS
10. 950 m at $1,750 / trench metre
11. Each HP is $81 k$; * 2 for installation
12. Cooling water pipe estimated at $300 per trench metre
13. $1,250,000 per MW installed capacity
14. Estimated for same heat pumps as TRIUMF options
15. Ball park estimate
16. $2500 / m^2 industrial type buildings
17. Ball park estimate
18. Estimate based on boiler quote + building + engineering
19. 15 % of cost for engineering and construction management
20. 10% of costs for contingency
21. $1500 per trench metre
22. 30 m estimated at $900 per trench metre - $27k $ per building. (City of Vancouver Connectivity Study)
23. $350 / kW
24. Subtotal
25. Some values in this row slightly revised July 29, 2011
26. For all rows, including totals: Un-rounded values shown to allow for summation cross checks. The number of significant digits displayed does not indicate a level of accuracy. All costs estimates are expected to be in the range of class “D” estimates.

6 OPTIONS ANALYSIS

6.1 Financial Analysis

A number of financial indicators can be used to define the viability of a DE system. Three metrics are used here which are relevant to energy systems and utility operations. These are the levelized cost of energy, the net present value of the project, and the return on equity (for a third party operator).

- **Levelized cost** is a measure of the long term average cost of providing energy. As highlighted in section 1.3.3, the capital costs of a utility system cannot be recovered from the small number of early customers. In the early years the system operates at a loss and then recaptures these losses in later years. The time period to just recapture the costs is the levelization period. For this analysis we have examined the 25-year levelized cost. The levelized energy cost is the present day value of the investments and operating expenses over the study period divided by the present day value of the energy delivered over the study period. It is a common comparator in energy utility investments. All levelized costs are expressed in real 2011 $.
- **Net Present Value (NPV)** is the present day value of all the revenues and expense of the project, discounted to today's dollars. This analysis captures the NPV from the start of the project to 25 years.
- **Return on Equity (RoE)** is a measure of the return that an investor would make for investing in the project. The analysis assumes that the project is funded 40% by investor money and 60% by debt. The RoE can be calculated each year (we have used the average RoE over 25 years). The RoE is used for analyzing a third party operator. UBC as an operator would finance by debt and not equity, so the RoE is not a suitable indicator.

6.1.1 Levelized Energy Costs

The levelized costs of providing the heating energy are shown in Figure 23 for both development scenarios. The BAU fuel cost is the 25-year levelized cost for the entire development area to purchase electricity and natural gas. The DE options levelized cost is the cost for those DE options to provide the same amount of heating energy to the development.

The DE costs have been broken out into (i) the portion that is fuel purchases by the DE system operator, (ii) the portion that is required to recover capital investment (assumes 100% debt funded as UBC is the assumed operator), and (iii) the O&M costs (including staff and administration).[22]

The BAU fuel cost can be viewed as the average cost for a unit of heat energy purchased by the resident. The total DE cost is an indicator of the minimum price that the DE system would have to charge in order to break even.

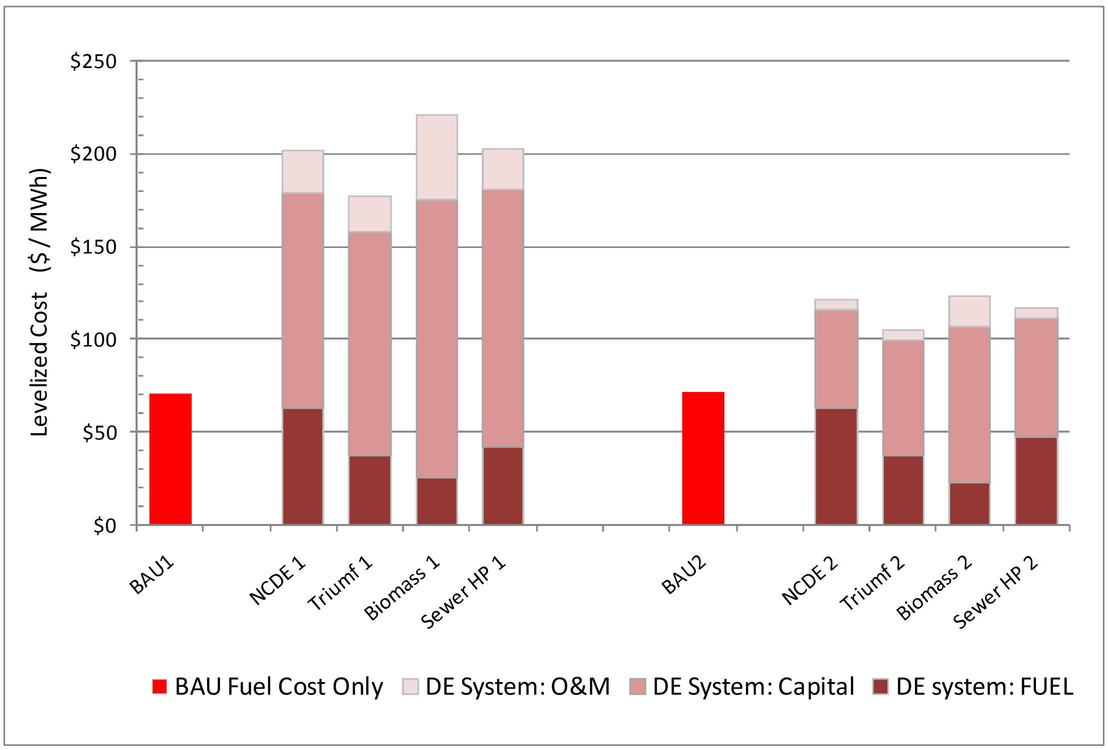
[22] As a comparison check, Corix's BCUC application for a system at University (of a similar size to the Base Case development scenario here) estimates a 20 year levelized cost of $149 to 156 per MWh

Some observations to note from the figure include:[23]

- Levelized fuel costs for the BAU scenarios are about $71 per MWh and are not affected by the density of the development.
- Energy supply costs for the base scenario are higher than the BAU scenario. This is because of the high capital costs being supported by a relatively small amount of annual heat sales. Levelized costs of energy range from $175 to $225 per MWh.
- Energy supply costs for the alternate scenario are lower than the base scenario as the capital costs are supported by a much larger amount of energy sales. Levelized costs are in the range of $105 to $123 per MWh. This is still greater than the BAU at $71. .

It is important to note that this comparison of the energy costs alone is an incomplete presentation. This presentation does not account for the building and other costs that are relevant to the developers and the owners of buildings (this is addressed in Section 6.1.3).

Figure 23: Levelized Costs of Energy Only



Note:
The BAU energy costs are a blend between natural gas and electricity prices and reflect the expected mixture of heating sources for the buildings. For solely electric heating the BAU energy costs would be in the range of $100 per MWh.

[23] Some of the differences mentioned here may be too small to observe from the graphic.

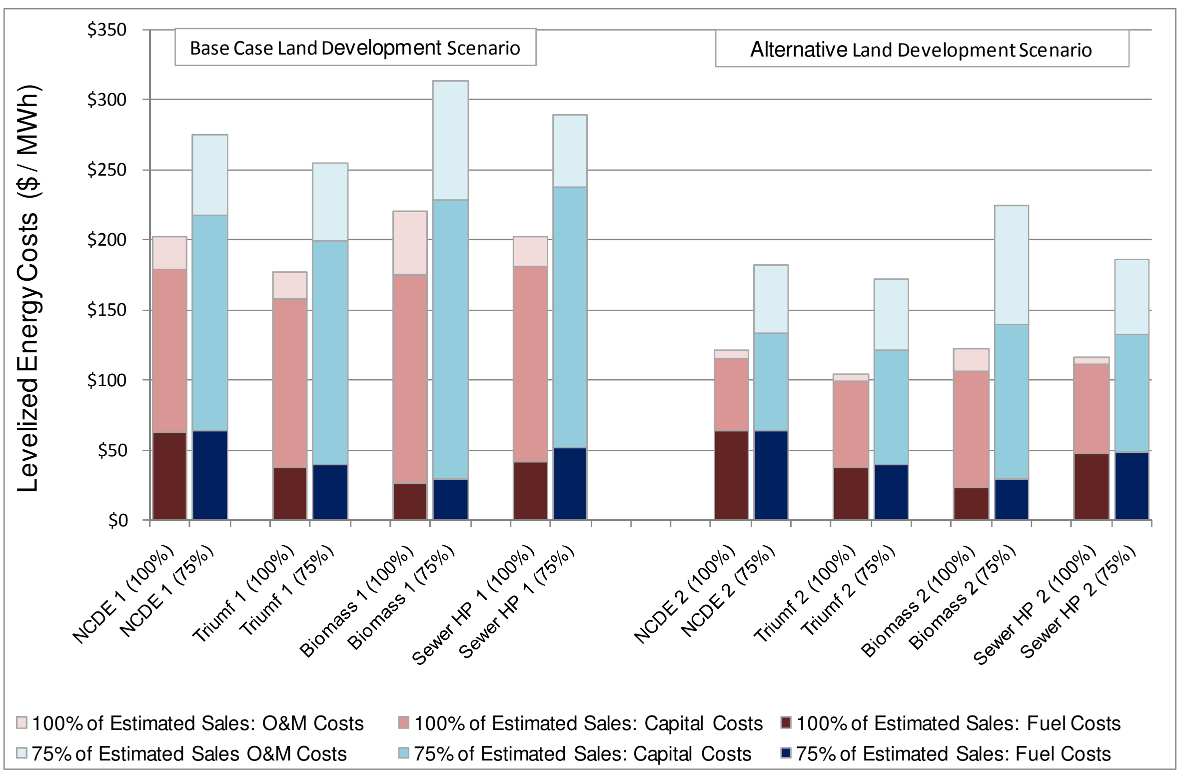
6.1.2 Sensitivity of Energy Costs to Uptake

A sensitivity analysis is carried out to account for potential lower energy sales of the DE system. This could occur for a number of reasons, such as the development plan slows, or the residents use less energy than expected, or future buildings become substantially more energy efficient.

A sensitivity run is made to estimate the impact of a 25% decrease in energy consumption[24]. In this scenario all the capital is still invested, but the sales are 25% less, and the fuel inputs to the DE system are similarly reduced. The result is shown in Figure 26. Observations from this figure include:

- There is an increase in levelized costs due to the same capital and fixed O&M funds being supported by a smaller amount of sales. That is constant capital and fixed O&M account for the change in levelized costs. Fuels costs scale in proportion to the sales of heat energy.
- Overall, the levelized costs increase for all energy supply options for both development scenarios. Increases are 23% to 29% for the base scenario options, and 16% to 27% for the alternate options. The difference between energy supply options is due to the relative amounts of capital and O&M costs for each energy supply option.

Figure 24: Comparison of DE Levelized Costs for a 25% Reduction in Load



Notes:
[1] Each pairing represents a combination of an energy supply option and a development scenario. The pairings compare the estimated costs for a 100% of estimated sales (left bar) with a sensitivity of 75% of sales (right bar of the pair).
[2] These costs are only the DE system operator's costs. The red bars (left side of each pairing) are the same data as presented in Figure 23.

24 75% reduction is a BC Hydro required sensitivity level.

6.1.3 Full Ownership and Operational Costs

The previous section examined only the energy costs. This section looks at the full cost of ownership and operation. There are different costs (and different cost payers) for a building's energy system. These include:

- The "**builder costs**" are capital costs incurred at the time of construction (shown as the bottom bars in each bar chart stack: dark blue for the BAU, light blue for the DE scenarios). These costs are greater for the DE scenarios than the BAU scenarios[25]. While called builder costs, these costs will eventually be paid by the building owners through the cost of the residences, or by UBC through a lower margin on the sales.
- The "**owner costs**" are ongoing maintenance and replacement of equipments, allocated across the life of the buildings (shown as the middle bars in the stack: dark green for BAU, and light green for DE scenarios). These costs are lower under a DE scenario because the owners do not have to maintain and replace boilers and hot water heaters.
- "**BAU fuel purchases**": This is the natural gas and electricity purchased to pay for heating in the BAU scenario.
- **DE Energy Supply**: This is the cost of the DE system to deliver heat to the customer. This includes the capital, operating, and fuel costs that the DE system operator must bear. This value is the total of the three DE components just presented in Figure 23.

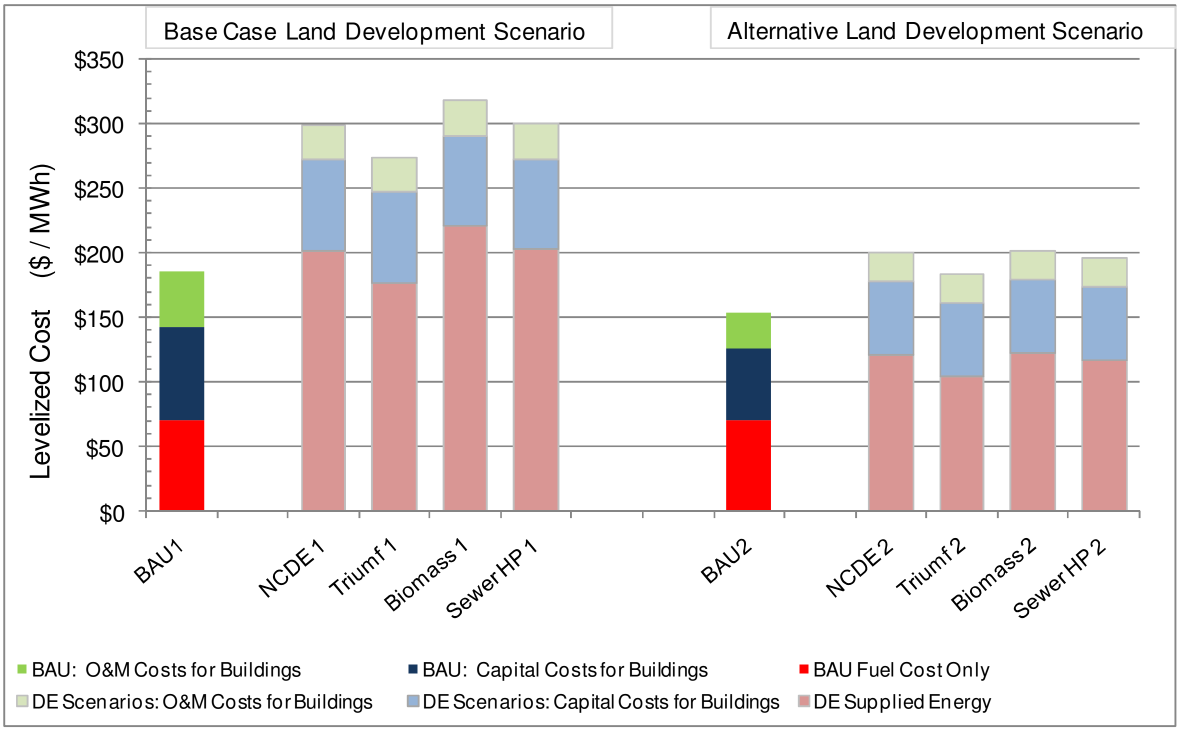
The "full ownership" levelized costs are shown in Figure 25. Some observations to note from this figure include:

- DE energy has lower costs for the non-energy components (building capital and O&M combined) compared with the BAU: 15% lower for the base scenario and 5% lower for the alternate scenario. This difference in savings between the land development scenarios is due to the changing building type.
- For the base land development scenario the full ownership costs of DE energy are 50% to 70% higher than for the BAU.
- For the alternate land development scenario the full ownership costs of DE energy are 20% to 30% higher than for the BAU.

These higher costs must somehow be incentivized if a DE system is to be implemented. A discussion of options is provided in Section 7.

[25] This result is consistent with the CoV District Energy Connectivity study findings.

Figure 25: Full Ownership Levelized Costs



Note:
The "full ownership" scenarios include the capital costs paid by builders (and presumably passed on to purchasers) and the O&M costs paid by strata councils and residents. These are stacked on top of the pure energy costs previously presented.

6.1.4 Levelized Cost Sensitivity

For a pre-feasibility study, costing is expected at the scoping level or unit cost basis. We have endeavoured to define key components more accurately based on our other experiences. As a benchmarking exercise a calculation has been made of the impact of a number of possible changes to the cost estimates (Table 22). For example, a million dollar change to the capital cost alters the levelized energy cost by $5 to $6. Deferral of capital spending reduces the levelized cost by an even smaller amount.

Table 22: Sensitivity of 25-year Levelized Energy Cost

Parameter	Base Scenario	Alternate Scenario
Change in capital cost of $1 million (+ or -)	(+ or -) $ 9.93	(+ or -) $ 3.26
Defer $1 million of capital investment for 5 years	(-) $2.51	(-) $0.82
Defer $1 million of capital investment for 10 years	(-) $4.29	(-) $1.44
Change in operating costs of $100,000 per year (e.g. 1 FTE)	(+ or -) $12.70	(+ or -) $4.17

6.2 Ownership Structure Sensitivity

Different ownership structures may have different benefits to a DE system operator. In the evaluation of the four DE options we have assumed UBC ownership of the system. This is believed to be the lowest cost operating model primarily because staffing could conceivably be shared with other UBC operations and UBC wouldn't have to pay itself an access fee. As well, UBC finances its capital by debt, whereas a third party might use a combination of debt and equity.

This sensitivity analysis approximates the operation of the system by a third party operator. Primarily there is an assumption that staffing costs would be higher because activities would not be shared with UBC staff. In addition, there is a slight difference in borrowing rate, and a third party operator would be required to pay access fees and property taxes. These assumptions are described in Table 23.[26]

The result is shown in Figure 26. Observations from this figure, include:

- Fuel costs are the same for either ownership model.
- Capital costs are lower for the private ownership model because some of the capital is funded through equity and not debt.
- Operating costs are higher for the private ownership model because of the assumptions of staffing and other cost increases. It is worth noting that these have not been rigorously evaluated; rather, some simplified assumptions have been made.

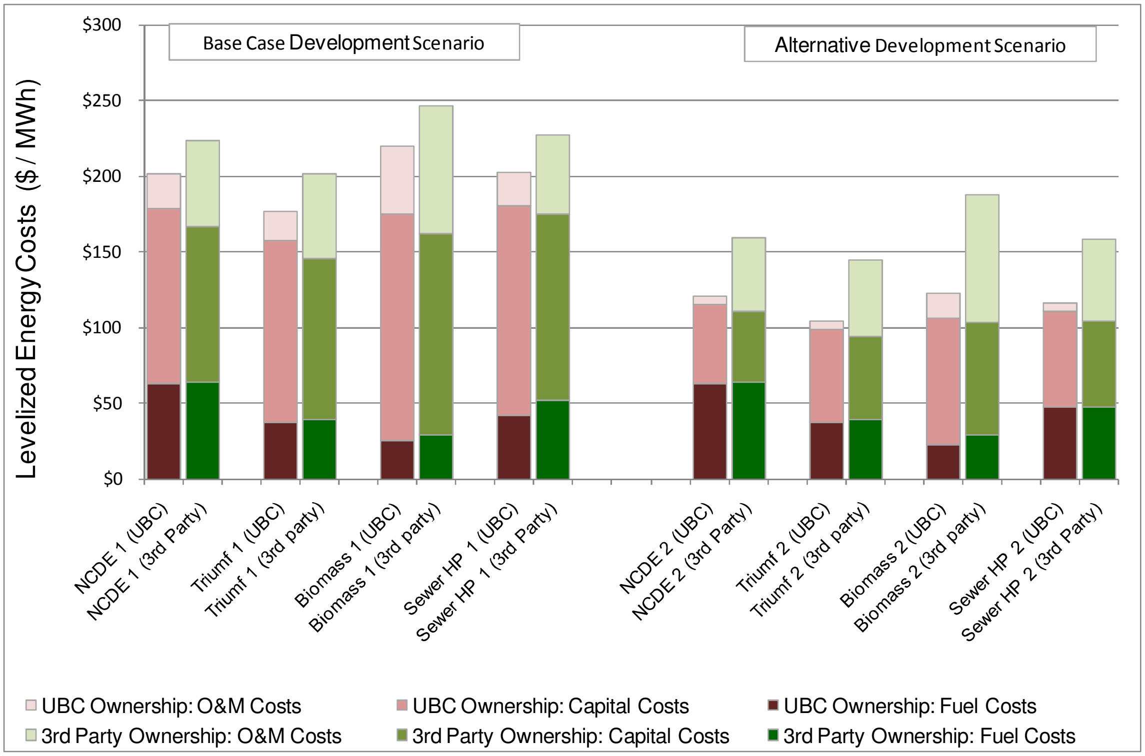
The weighted average cost of capital is not substantially different. For UBC, it is 5.75% nominal and for the private operator it is 6.00% nominal.

Table 23: Assumptions for Comparing UBC Ownership to Third Party Ownership

	UBC Ownership	Third Party Ownership	Implication
Financing	100 % debt	60% debt, 40% equity	Lower debt service costs
Borrowing Rate	5.75%	6.0 %	Slightly increased debt costs
Operators	2 FTE for biomass option 0.5 operator FTE for other options	4 FTE for biomass option 2 FTE operators for other options.	Increased operating costs
Access fees	0	0.78 % of gross revenue (CoV rate)	Increased O&M costs
Property Taxes	0	$52.50 per thousand (CoV tax rates)	Increased O&M costs

[26] Note that these assumptions are included to define the general magnitude of the impact of different ownership models. There may be many factors that could be identified upon review that would affect the cost of service. These estimates are to highlight the issues and not to make precise predictions of the magnitude of these costs.

Figure 26: Comparison of DE Levelized Costs for UBC or Third Party Ownership



Notes:
[1] Each pairing represents a combination of an energy supply option and a development scenario. The pairings compare the estimated costs for an identical system with the different ownership assumptions – UBC ownership on the left stack of each pair and private ownership on the right stack of each pair.
[2] These costs are only the DE system operator's costs. The red bars (left side of each pairing) are the same data as presented in Figure 23.

6.3 The System Operator's Perspective

This section offers screening level financial metrics from the perspective of a system operator.

6.3.1 UBC Ownership Metric: 25-Year Net Present Value

For an assumed UBC operator - funding activities by debt and not equity - the 25-year NPV is used as a metric of "value" of the project (Table 24). All of the base scenario energy supply options have a negative NPV. For the alternate scenarios, the TRIUMF energy source has a positive NPV, and the three other energy supply options have a negative NPV, but of smaller magnitude than for the base scenario.

Also shown in Table 24 is the price premium that would have to be charged in order for the NPV to just become positive after 25 years. For the base scenario, the DE energy supply options require substantial price premiums (45% to 83%) over electricity in order to achieve break even.

The energy supply options under the alternate scenario are competitive with electric heating. Price premiums required to achieve break even are 2% to 11%. For the TRIUMF option, the premium is *negative* 10%, indicating that this option has a break even below the price of electricity.[27]

Table 24: NPV and Breakeven Point for UBC Ownership Model Energy Supply

Base Scenario			Alternative Scenario		
Energy Supply Option	**NPV** (to 25 years)	**Breakeven Sales Price Premium Required** (% greater than electricity)	**Energy Supply Option**	**NPV** (to 25 years)	**Breakeven Sales Price Premium Required** (% greater than electricity)
NCDE 1	-$ 7,150,000	75%	NCDE 2	-$ 3,150,000	11 %
TRIUMF 1	-$ 4,382,000	46 %	TRIUMF 2	**$ 3,210,000**	**-10 %**
Biomass 1	-$ 7,914,000	83 %	Biomass 2	-$ 470,000	**2 %**
Sewer HP 1	-$ 6,351,000	67 %	Sewer HP 2	-$ 321,000	**2 %**

Note:
A price premium of X % means that energy priced X% above the cost of electric heat will achieve a 25 year NPV of zero. The option TRIUMF-2 has a premium of -10%. This means that the energy could be priced 10% below the cost of electricity and still achieve a 25 year NPV of 0.

6.3.2 Private Operator Metrics: Return on Equity (RoE) and NPV

For the private sector operator, the return on equity (RoE) is an important evaluation metric, as well as the net present value (NPV) of the project (Table 25). The RoE and NPV are dependent on the revenue charged for the DE supplied heat.

In this analysis, it has been assumed that DE thermal energy is sold at the same price as residential electricity[28]. Based on this assumption, it is impossible for the DE utility to be profitable and to achieve a desired RoE for a utility (9.67% is a common benchmark RoE that would be applicable to this utility[29].)

This result is to be expected since it has been previously identified (Section 6.1.1) that the levelized cost of the DE energy supply options is greater than the assumed charge rate (which is based on the cost of electric heating). Selling heat at the price of electricity (at a price of about $80 to $112 over time) will not fully recover the costs of the energy.

A number of strategies to overcome these cost barriers are described in Section 7.

[27] In the BCUC application submitted for the SFU UniverCity development, prices are expected to be 31% greater than electric heat.

[28] Typically utility rates are set based on the cost of providing the service - based on the levelized cost and ROE expectations. In this analysis we are evaluating the business case for a potential operator - under the assumption that a competitive sales price must be achieved. Sensitivity analysis is also made to define the required rates for profitability for a DE system operator.

[29] It is stipulated by the BC Hydro Powersmart DE Guidelines and is based on the 2009 Low Risk Benchmark Utility ROE established by the BCUC plus 100 basis points.

Table 25: Financial Metrics for Third Party Ownership

Development Scenario	Energy Supply Option	RoE (average over 25 year)	NPV (to 25 years)
Base Scenario	NCDE 1	-29.84%	-$ 13,555,000
	Triumf 1	-21.25%	-$ 10,886,000
	Biomass 1	-27.25%	-$ 16,663,000
	Sewer HP 1	-23.72%	-$ 13,797,000
Alternate Scenario	NCDE 2	-13.98%	-$ 10,166,000
	Triumf 2	-1.73%	-$ 4,673,000
	Biomass 2	-8.04%	-$ 12,545,000
	Sewer HP 2	-7.57%	-$ 8,484,000

6.3.3 Utility Return on Equity: Required Rate Premium

For a private sector operator – assuming regulation under the BCUC – the billing rates are set in order to achieve a reasonable rate of return (defined here as 9.67%, a common benchmark RoE that would be applicable to this utility).

The financial performance for a third party operator (Table 25) assumes that the DE thermal energy is sold at the same price as residential electricity. This sensitivity examines: *"What level of price premium that would be required to make a DE system attractive to private sector investors and therefore financeable?"* The results are shown in Table 26. Not surprising, the base scenario energy supply options require extremely high rate premiums. The alternate scenario energy supply options require much more modest rate premiums.[30] In practice, the rate setting is more complex, including components that recover capital and those that pay for variable costs. As well there may be different rate structures for different classes of customers.

Table 26: Price premium required to achieve target RoE (Third Party Ownership)

Base Scenario		Alternate Scenario	
Energy Supply Option	Sales Price Premium (% greater than electricity)	Energy Supply Option	Sales Price Premium (% greater than electricity)
NCDE-1	155 %	NCDE-2	40 %
Triumf-1	130 %	Triumf-2	24 %
Biomass-1	190 %	Biomass-2	49 %
Sewer-1	165 %	Sewer-2	38 %

Note:
A value of X% means that the DE supplied energy would have to be priced X% above the cost of electricity for the operator to achieve the benchmark RoE of 9.67%.

[30] For comparison, the Corrix BCUC application for a DE system at SFU UniverCity, anticipates a rate premium of 31% above electricity will be required,.

6.4 Environmental and Social Considerations

Key environmental drivers for the consideration of district energy are:

- GHG emissions reductions. These are defined in provincial initiatives (e.g., Greenhouse Gas Reductions Target Act, GHGRTA or Bill 44), and in local government requirements (e.g., Local Government (Green Communities) Statutes Amendment Act, Climate Action Charter). [31]
- Electricity demand reductions. BC Hydro is mandated to achieve the majority of its load growth through conservation activities.

Key social drivers are:

- Construction jobs created
- Permanent operating jobs created (operating FTEs).

6.5 Multiple Account Summary Matrix

A summary matrix of the technical, financial, and environmental considerations was compiled (Table 27). This matrix qualitatively and quantitatively compiles the various considerations of the energy supply options. In the far right column a relative ranking ("A better than B") is provided.

In a more comprehensive decision analysis or triple bottom line analysis, these attributes would be weighted according to the different stakeholder concerns and objectives. That would allow the importance of different rows to be properly represented. Frequently then, these attributes are numerically scored to express the combined effect of the ranking, and the importance of the attribute.

For this analysis, a less 'numerically' precise approach was taken. Each category is given a qualitative assessment of its importance (high–medium–low). These are based on project team judgment but are not dissimilar to the weightings developed for the UBC Alternative Energy Study.

Based on this, the following preferred options are in order:

(a) Heat capture from TRIUMF

(b) Connection to the campus DE system

(c) Biomass or sewer heat recovery

[31] Bill 44 (2007), the *Greenhouse Gas Reduction Targets Act* sets targets for the province-wide reduction of GHG emissions and requires a carbon neutral public sector beginning in 2010 (which includes UBC); Bill 27 (the Local Government (Green Communities) Statutes Amendment Act requires local governments to establish community-wide reduction GHG targets within their OCP documents; the Climate Action Charter is a voluntary agreement between the Province and Local Governments to create low carbon communities.

Table 27: Summary Comparison of DE Options

		Base Scenario					Alternative Scenario					Relative Ranking
	Units	BAU1	NCDE 1	Triumf 1	Biomass1	Sewer1	BAU2	NCDE 2	Triumf 2	Biomass2	Sewer	Less is better unless otherwise indicated. Left alignment is better, right side is less desirable
Financial (importance = high)												
Capital Cost (DE system)	$ millions (un discounted)	--	8.6	8.9	11.0	10.2	--	13.4	15.3	20.0	15.7	NCDE or Triumf or Sewer < Biomass
Annual O&M Costs (at build out)	$ thousands per year	--	220	188	392	207	--	250	240	512	242	Triumf<NCDE<Sewer<<Biomass
Levelized Cost of Energy Only	$ / MWh	71	202	177	221	203	71	121	105	123	117	Triumf < NCDE or Sewer<Biomass
Levelized Cost of ownership and operation	$ / MWh	185	299	274	318	300	154	200	183	202	195	Triumf < NCDE ≈ Sewer < Biomass
Technical and Operations (importance = moderate)												
Capital Cost Risk	Qualitative	--	Low	Med	Med	High	--	Low	Med	Med	High	NCDE < Triumf or Biomass < Sewer
Operations Cost Risk	Qualitative	--	Low	Med	High	Med	--	Low	Med	High	Med	NCDE < Triumf or Sewer < Biomass
Fuel Price Risk	Qualitative	--	Med	Low	Med	Low	--	Med	Low	Med	Low	Triumf = Sewer < NCDE or Biomass
Performance Risk	Qualitative	--	Low	Med	Med	High	--	Low	Med	Med	High	NCDE < Triumf or Biomass = < Sewer
Resource (importance = moderate to high)												
Natural Gas Consumption	GJ / year	35,048	21,911	16,873	12,655	12,655	116,003	74,803	57,602	36,001	86,403	ALL are < < BAU Biomass < Triumf < NCDE or Sewer
Electricity Consumption	MWh / yr	2,481	299	1,962	676	3,156	9,060	1,020	6,698	2,309	6,393	All but (sewer_1) are < BAU NCDE <Biomass < Triumf < Sewer
Electricity Savings (pos = reduction)	MWh / yr	‘--	2,182	519	1,805	-675		8,040	2,362	6,751	2,666	All but (sewer_1) are < BAU NCDE <Biomass < Triumf < Sewer
Environmental (importance = high)												
GHG emissions	tonnes CO2 / yr	1,703	1,065	820	615	615	5,638	3,635	2,799	1,750	4,199	All are < BAU Biomass < Triumf < Sewer or Sewer
Social (Importance = low to moderate)												
Construction Jobs Created	person years	20	34	36	44	41	48	53	61	80	63	Biomass > Sewer > Triumf or NCDE (NB greater is better)
Operating Jobs	FTE	0	1.0	1.0	2.5	1.0	0	1.0	1.0	2.5	1.0	Biomass > NCDE or Triumf or Sewer (NB greater is better)
Sustainability (importance = moderate)												
Advances Campus Sustainability Initiatives	Qualitative		Low	High	Med	Med		Low	High	Med	Med	Triumf > biomass = Sewer > NCDE (NB greater is better)
Advances Campus Climate Action Initiatives	Qualitative		Low	Med	High	Med		Low	Med	High	Med	Biomass > Triumf = Sewer > NCDE (NB greater is better)
Advances Provincial and BC Hydro Initiatives	Qualitative		High	Med	Med	Low		High	Med	Med	Low	NCDE > Triumf = Biomass > NCDE (NB greater is better)

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7 DISCUSSION

7.1 Impact of Different Energy Supply Options

The analysis has indicated that all the DE systems have a similar levelized cost. Factors that account for this include:

- The different energy supply options do not have dramatically different capital costs. Where there are some substantial differences, these are fortuitously offset with lower fuel costs.
- Operating costs were generally assumed to be the same for each option (i.e. same assumption such as O&M is X % of capital). An exception is staffing wherein we assumed the biomass option would require more staffing.
- The capital cost for the energy supply itself represents only 25% to 35% of the capital cost of the DE system. The remainder is for the costs of the DPS and energy transfer stations. Within each of the two development scenarios, the cost of the DPS only varies a small amount, and the cost of the ETS is the same.

The implication is that the focus of a subsequent feasibility study should not be to extensively review energy supply options, but rather to reconfirm these conclusions. Efforts should then be focused on determining if there are different financing scenarios or operational considerations that can be used to create a more financially attractive project.

7.2 Barriers to District Energy Implementation

The financial analysis has highlighted that DE supplied thermal energy – at current forecasts of electricity and natural gas prices – could not be provided at a lower cost than the BAU thermal energy. The 'flip side' to this is that if energy is priced at a rate comparable to electric heating, then a DE system would not be viable.[32]

This section explores the activities that can be implemented to encourage DE development.

Issue: Building Capital Costs

Construction costs are higher for DE compatible buildings. This may not be recognized by purchasers (or tenants) and so this cost is absorbed by the builder (and reduces the contribution to UBC).

Options include:

- A floor space premium. At SFU's UniverCity development, builders that use alternative energy systems are eligible for a density bonus of up to 10% floor area ratio (FAR). This extra density becomes saleable property which can be used to offset the extra capital cost.
- A development charge. SFU's agreement with Corix provides $1 per square foot to help offset the cost of the DE system. A similar charge at the Wesbrook development would result in $1.5 to $4 million in capital.

[32] Note that utility pricing by the BCUC is based on the on the cost to deliver the service and is not based on comparisons to other energy sources. Benchmarking of the DE supplied energy and other sources is presented to provide a comparison benchmark.

Issue: DE Supplied Energy is more expensive than Conventional Energy

The levelized cost of providing DE energy is not competitive with conventional electricity and natural gas. Options include:

- Regulate connection. The SEFC NEU has a service area defined by a City Council bylaw. Buildings within this area are required to connect to the system. Rates charged by the DE system are greater than the BAU scenario. Similarly the rates at UniverCity will be greater than the BAU alternative.
- Obtain capital grants. All the municipal systems developed recently (e.g., Revelstoke, Whistler, LEC, NEU) have received capital grants to offset these costs. The UniverCity development is exploring the options for I.C.E., or PSECA funding if they can service part of the main campus. BC Hydro has also developed a capital grant program.
- Property tax incentives. An option available (though not known to have been implemented yet) is Revitalization Tax Exemptions. These can provide property tax relief to the building owner. This would be an effort to equalize the cost barrier to the resident.
- Market the benefits: Increase awareness of the sustainability benefits of the DE system. This may result in a greater willingness to pay amongst residents.

This section highlights some key considerations in moving forward with a DE system. These are the impact of the different energy supply systems, and the key barriers to implementation.

As part of the draft review and meetings, comments have been received that highlight a number of considerations beyond the scope of this study, or that reinforce a desire for more detailed analysis of the assumptions and values used in this study. These are summarized in Attachment A.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

Based on the analysis performed for this pre-feasibility study, the following conclusions can be made:

- There are several technically viable ways to provide energy to a medium temperature DE system. Heat capture from the TRIUMF facility and connection to the North Campus systems are the most promising options.
- District energy does not appear attractive under the base scenario, but has similar reasonably competitive life cycle costs for the alternate scenario.
- There are incremental capital costs to the builder on the order of 2% of the total building costs.
- There are modest long term operational savings to the building owner due to reduced operations and maintenance (O&M) costs.
- Costs to supply district energy heat are at a premium compared to the BAU energy (electricity and natural gas).
- Energy charges for the alternate scenario priced in the same range as electricity (+/-10%) will achieve long term break even for a UBC owned system. A third party operator would require a premium of 24% above electricity rates to achieve a standard utility return.

8.2 Recommendations

Based on the analysis conducted for this pre-feasibility study the following recommendations are offered:

8.2.1 Technical Recommendations

Cooling should not be considered to be provided through a District Energy System

Cooling loads are low in this region. At present, many developers offer cooling as a suite level add-on and uptake is currently 10% of units or less.

Cooling should be addressed at the building level. Efforts should be made through building design to reduce the need for cooling, or to incorporate them most efficiently into the building.

A medium temperature hot water system is recommended

A screening level review of district energy system types indicates that a high temperature system is not warranted because there are no loads specifically requiring steam; a four-pipe heating and cooling system is not required due to the absence of centralized cooling, and; an ambient system is less favoured because of the expected lack of cooling loads. A medium temperature system provides the greatest flexibility with respect to energy supply options.

8.2.2 Next Step Recommendations

Refinement of the TRIUMF heat capture (Triumf-2) and the North Campus DE connection (NCDE-2) should be made in a full feasibility study.

A pre-feasibility study provides a scoping level review of the options and the issues. Based on this review, the two options which seem to best satisfy the greatest number of objectives are capturing heat from the TRIUMF facility and connecting to the new North Campus hot water DE system being developed.

UBC should explore opportunities to make DE more attractive to builders and residents.

This study identified a number of measures that can be used to overcome some of the hurdles to district energy implementation; primarily incremental building costs to be DE-ready and capital costs for building a DE system.

ATTACHMENT A: REVIEW CONSIDERATIONS FOR FUTURE PHASES

As a pre-feasibility study, this work is focused primarily on a screening level evaluation to determine whether there are suitable energy supply options, and sufficient thermal loads to support a viable DE system.

Through the review a number of suggestions were made for areas of study that could be pursued subsequent to this work (either separately or within future DE evaluations). These are summarized in Table A-1. It is important to note that many of the statements here are offered informally and so represent opinions that have not been clearly documented. The text here is intended to display the range of discussion points that have been received, and acknowledges that there may be differences of opinion that cannot be resolved in this study.

Table A-1: Review Considerations

Area	Review Comment	Discussion Points	Recommendations
Building Construction			
Capital Costs for DE Buildings	DE heating systems have a higher capital cost than a BAU system.	• This point is acknowledged in the study. Estimates used in this work were from the CoV Connectivity Study (Compass RM, FVB, and Advicas) which indicated premiums of $25 to $35 per square meter. • UBC PT feels costs could be higher - they have cited values in the range of $ 70 per square meter (cost breakdown not provided). • Perimeter vs. in-floor hydronic system costs may vary depending on the market conditions and there may or may not be a price differential. Any price advantage for one may reverse under different conditions. • UBC PT feels that higher capital costs will result in lower land bids. • There are likely a number of factors which affect a developer's land bid. (NB CoV sustainability office staff involved in DE have not received feedback that DE issues affect land values in the CoV - though the UBC land lease situation may be unique). • There are many DE developments proceeding and so developers are managing to find a way to develop DE connected properties in many locations in the lower mainland. • Consumers may not place a value on a hydronically heated building. UBC PT feels cost premium will not be recovered through a higher market value	• Evaluate options with a financial sensitivity to capital costs. • Survey developers involved in current DE connected projects to define concerns. (Specifically at SFU UniverCity). • Survey developers and real estate agents within the LEC, or SEFC service area to determine if hydronic heating is recognized in pricing.
Building Operations			
Strata Administration	Strata may not be interested to do suite-level billing. Administration burden might be too great.	• Meter data might not be used. • Might have to contract for third party metering and billing. • Flat rate billing may reduce the incentive for conservation.	Compile a summary of what other DE buildings in the lower mainland are doing.

Area	Review Comment	Discussion Points	Recommendations
DE System Operations			
System Operator	It has not yet been defined what party would own or operate the system.	Residents, stratas or the UNA might have preferences, or objections, to specific companies or agencies as the owners or operators. Operations of a DE system might pose some operational risk to UBC (currently not defined whether this is a financial liability or a reputational risk, etc.). However, UBC operates utilities (including a DE utility) routinely. The components of this "risk" might need to be explored through consultation with stakeholders.	• Review the assumptions of the ownership structure analysis for validity. • Revise the financial assessment with respect to ownership models. • Review with the UNA and other stakeholders for their feedback.
Load Certainty	Risk that a DE ready building, built prior to the DE system being built might not connect.	Any DE ready buildings built now until the DE system is in-place should be connected to the De system, once available. It might be that a reasonable time period id allowed. The DE operator will likely have to commit to this retrofit expense.	• Make as a requirement in the development permit.
DE System Pricing			
Premium for DE Supplied Energy.	DE system energy typically costs more that the BAU once a renewable energy supply has been incorporated.	• Not clear if consumers would value De benefits and be willing to pay a premium. • Typically energy costs in multi-family buildings are a small budget item so residents may not have a preference. • LEC and SEFC have pricing that is competitive with electricity - though greater than natural gas heating.	• Define premium and long term benefits. • Define capital grant opportunities to reduce system cost.
Utility Rate Setting.	Is there uncertainty over sales revenue and impact on DE pricing?	• Sales revenue could be lower than forecast for a number of reasons including behavior, occupancy, development timing, and future advancements in the building code (NB While the energy code has become more stringent in recent years the energy use in MF buildings has remained relatively constant - RDH study). • Utility energy is supplied based on the cost of providing the service plus a suitable return on equity for the owner. If sales are lower than forecast, then the utility can request a rate increase from the BCUC. • Energy price uncertainty exists for the BAU option as well.	• Include a financial sensitivity to see the effect of lower sales revenue. (NB This pre-feasibility included a sensitivity to a 25% reduction in energy demand - i.e. sales revenue).
Other			
Multiple Systems	Do buildings with different systems (existing BAU) and future DE, affect the market or resale value?	• Not know whether the De system would present a market advantage or not compared to a neighbouring unit with a BAU heating system.	• Discuss with developers or reseller agents.