NEU FEASIBILITY STUDY

Strategy for Transitioning the Neighbourhood Energy Utility to 100% Renewable Energy

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This project was conducted under the mentorship of City staff. The opinions and recommendations in this report, and any errors, are those of the author, and do not necessarily reflect the views of the City of Vancouver or The University of British Columbia.

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Photo credits: the NEU team, Alex Chapman.

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Executive Summary

The Neighbourhood Energy Utility (NEU) has always been ambitious in its plans to decarbonize, having set a target of 100% renewable by 2050 under the Greenest City Action Plan in 2015. In April 2019, the City of Vancouver (the City) joined hundreds of other cities around the world in declaring a climate emergency, indicating the City's intention to increase its efforts to tackle climate change. As part of this response, the City produced six 'Big Moves' and 53 'Accelerated Actions' to build upon the City's existing work to tackle climate change. Acknowledging that one of the greatest causes of emissions in Vancouver is its heating supply, accelerated Action 8 specifically sets out the challenge of reaching 100% renewable energy for the NEU by 2030, twenty years faster than the previous target of 2050. This report presents a high-level feasibility study of options for the Neighbourhood Energy Utility to transition to 100% renewable energy by the accelerated target year of 2030.

The NEU is a flagship district heating network located in False Creek, Vancouver. District heating networks are centralized systems where thermal energy is distributed from a central location to multiple residential and/or commercial buildings in an area. The NEU currently aims for 70% renewable energy supply, from a mixture of its innovative sewage waste heat recovery system and RNG supplied by Fortis BC. Natural gas makes up the remainder of the energy. As articulated in this report, the NEU faces two main challenges in meeting 100% renewable supply:

1. Bringing on new renewable energy generation to meet the growing baseload demand as they system continues to expand
2. Identifying a technology or technologies which can replace natural gas boilers for meeting peak demand whilst remaining affordable to end users.

As demonstrated in Part 3 of this report, the technologies that are best suited to providing base load energy are usually not the same as those that are suited to providing peak load. Reasons for this vary by technology, but in general concentrate around affordability and ease of operation.

To respond to these challenges, the project began with a literature review of district energy systems around the world that are operating at or near 100% renewable energy. The point of this review was to investigate how other district heating systems have achieved low carbon integration and which technologies are proving effective in this area. Table 2 demonstrates a range of technologies that are being used in both European and North American systems.

The next stage of the project entailed carrying out interviews with leading district energy specialists. A call to industry experts was made through a district energy working group which consists of local municipalities and district energy utilities. Industry experts were also identified

from governing bodies such as NRCan, and industry associations such as IDEA and QUEST. Data from these interviews was used to rank renewable technologies based on their suitability for meeting the baseload and peak load of the system (as presented in Part 3).

In Part 4, data gathered was assessed from an NEU specific lens. From this, the author generated the following recommendations:

1. *Utilize waste heat opportunities available through the expansion of the system to meet growing baseload demands:*
    a. Conduct a detailed inventory of waste heat opportunities in the NEU service area
    b. Given the magnitude of waste heat available at the 8th avenue sewer interceptor, key in on this opportunity early for further analysis
    c. Bring the waste heat to the NEU service area by exploring City policy tools that could be used to attract waste heat producers like data centres to the area
2. *Prioritize RNG, electric boilers, and thermal storage for addressing peak demand:*
    a. The biggest barrier for RNG is around availability/security of supply. With upcoming City access to large volumes of RNG through the landfill gas project, securing this RNG for NEU use should be a priority
    b. Keep a close watch on the outcomes of the BC Hydro Phase 2 Review as this may enable more cost-effective use of electric boilers
    c. Explore the use of thermal storage to optimize utilization of baseload technology and to potentially pair with biomass or electric boilers to improve their effectiveness for meeting peak demands.
3. *Explore options for demand-side management*: Conduct a study of possible demand-side response approaches to determine if there are measures that can be taken to help reduce or shift the peak. This should include looking at existing system data to evaluate the effectiveness of in-building hot-water storage on reducing domestic hot-water peaks.
4. *Follow emerging trends:* Following the development of emerging trends (highlighted in this report) as studies are carried out for the NEU is the best way to ensure future proofing of the final choice.

The lessons learnt from undertaking the literature review and interviews with district heating experts will be valuable in the next stage of planning for the NEU. Taking the time to review emerging practices and to canvas opinion from experts in the field ensures that no stone is left unturned before the in-depth analysis begins. However, as with all elements of climate change, the results have proven that there is no 'silver bullet' in decarbonizing district heating. The optimum design for each system is dependent on many factors, including (but not limited to) existing technology, access to resource and location. As the NEU transitions to 100% renewable, it has the opportunity to maintain its status as a world-leading example of innovation in district heating, setting the path for other systems to follow in the fight against global warming.

Part 1: Background

Introduction

The False Creek Neighbourhood Energy Utility (NEU) is a district heating network located in the heart of Vancouver, with a service area that encompasses Southeast False Creek, Northeast False Creek, the False Creek Flats, and part of Mount Pleasant. The system consists of a centralized energy centre (the False Creek Energy Centre) where thermal energy is extracted from recycled sewage waste heat and combined with renewable natural gas (RNG) to provide low carbon heating and hot water to homes and buildings through a network of underground pipes. The NEU produces 3MW sewage heat recovery (soon to be expanded to 8-10MW) combined with 24MW gas boilers which are currently fed a mixture of conventional and renewable natural gas.

The NEU is owned and operated by the City of Vancouver. The primary aim of the NEU is to reduce GHG emissions through a "*financially self-sustaining, commercially operated utility that delivers competitively priced thermal energy services*".[1] Compared with traditional methods, the NEU delivers low carbon heating and hot water to buildings, resulting in a significant reduction of greenhouse gas emissions. Other benefits of the system include increased energy independence and rate stability for end users. The NEU currently aims to produce 70% of its energy from renewable sources. In line with the Climate Emergency Response report approved by the City of Vancouver Council (the Council) in 2019, the NEU is evaluating options for an accelerated transition to provide 100% of its energy from renewable sources. This means that all sources from which energy is produced will be near-zero emissions, which would result in a 20,000 tonne reduction of CO_2-equivalent each year at system buildout compared to gas fired heating.

[1] City of Vancouver, Administrative Report, November 19 2019

Goal:

The goal of this report is to identify, assess and evaluate options for increasing the NEU's renewable energy supply from 70% to 100% by 2030.

Key Actions:

1. To identify renewable energy options and strategies best suited for increasing the NEU's renewable energy target
2. Perform a technical and economic evaluation of the options identified for achieving 100% renewable energy
3. Prepare recommendations

Research Approach

The project methodology was primarily designed by Derek Pope, Senior Engineer, Neighbourhood Energy Utility, with oversight from Linda Parkinson, Branch Manager, Neighbourhood Energy Utility. The approach involved a literature review of innovative district heating networks around the world, coupled with qualitative interviews with leading Canadian district energy experts, as more particularly described below.

Literature Review methodology

Following an introduction to district energy and the NEU in Part 1, a literature review of leading district energy systems in North America and around the world was undertaken. The point of this review was to establish whether and how other systems around the world have integrated 100% (or close to) renewable energy technologies into their district heating networks. Each district energy system is specific to its own location and circumstances. An investigation of best practices allows for evaluation of options that have proved successful in other areas. It also indicates the direction of travel for future technologies and systems. The consolidated findings are presented in table format in Part 2 (Table 2). In total 14 systems are described and categorized by technology, size, % renewable energy, and other operating parameters to allow for ease of comparison.

Interview Methodology

A qualitative approach to interviewing was undertaken. A call to industry experts was made through a district energy working group which consists of local municipalities and district energy utilities. Industry experts were also identified from governing bodies such as NRCan, and industry associations such as IDEA and QUEST. Due to COVID-19, interviews were conducted via video calls with those who responded affirmatively. The 11 participants included operators, consultants, and industry leaders. The panel were asked six pre-planned questions which had been shared with participants in advance (refer to appendix A for a full list of interview questions). Roughly half of the questions pertained to their experience and knowledge of low carbon district energy systems in general, with the remaining half being more specific to their knowledge and understanding of the NEU system (as more fully described in Part 3). For the most part, interviews took 45 minutes to one hour and though the questions were pre-determined, there was space and time to discuss issues around the topics as appropriate. This approach proved particularly useful for pointing towards other technologies, studies or systems to explore. Interviews took place in June and July 2020. No recordings of interviews were taken, and the responses presented in the results are anonymized. Summaries of the responses to questions 1-3 and 5 are provided, followed by a graphic presentation of the data collected for the 4th question. Question 4 asked experts to rank the compatibility of renewable energy technology choices for base and peak based on their knowledge and understanding of the NEU.

Results and Recommendations

In Part 4, the top-ranking technologies for peak and baseload selected by the interviewees were assessed from an NEU specific lens, along with some evaluation based upon further research. Four recommendations are given, identifying key opportunities for baseload and peaking energy supply and providing suggestions for projects to watch and emerging trends. Limitations of this research project are addressed before the conclusion.

Context of Report

The project is a product of the Sustainability Scholars program (Greenest City Scholar initiative) between the University of British Columbia and the City of Vancouver. This project supports the Greenest City 2020 Action Plan.

The Risks of Climate Breakdown

There is now unequivocal scientific consensus that climate change is occurring and that it is being driven by human emissions. The threat this poses to human beings, wildlife and the world's ecosystems has been well documented by scientists.

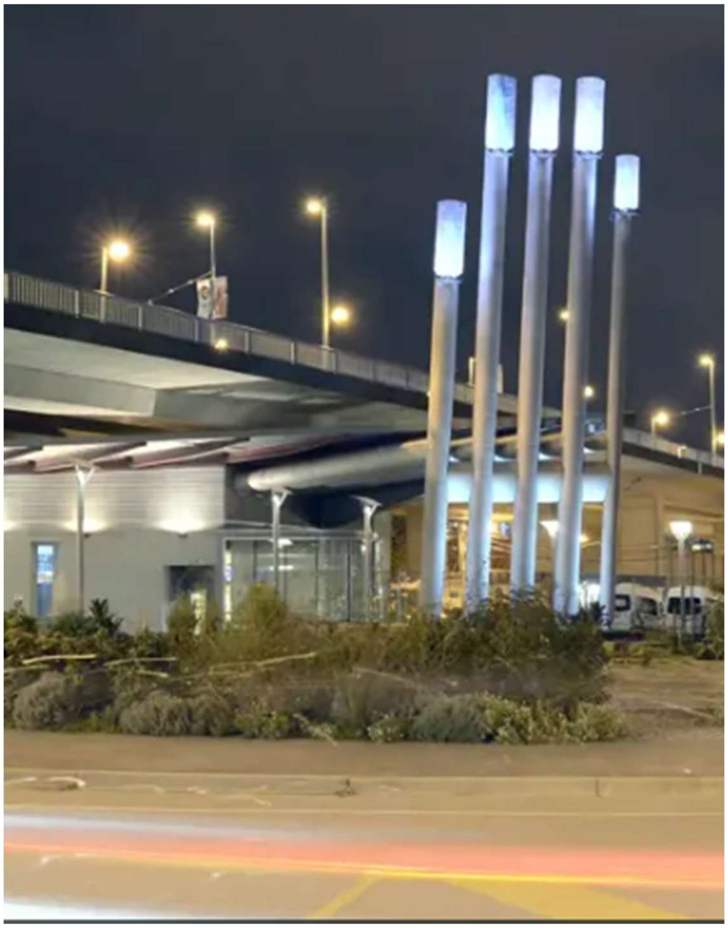
> *"Every degree of warming will increase those impacts and make it increasingly difficult, and eventually impossible, to adapt"*
>
> City of Vancouver, Administrative Report, April 2019

In 2015, 197 countries, including Canada, came together to sign the Paris Agreement, a worldwide commitment to keep the global temperature rise to below 2°C, and as close to 1.5°C as possible. In 2018, the Intergovernmental Panel on Climate Change (IPCC) released a special report highlighting the stark contrast between a world at 1.5°C and at 2°C, demonstrating that each increment of degree temperature rise leads to an increased risk of more extreme weather events and sea level rise.

Vancouver is already experiencing the impacts of 1°C of warming, as demonstrated by events such as the 2017/2018 BC forest fires. Other impacts include increased forest fire smoke, flooding and more severe storms.[2] Vancouver is also a coastal city and will therefore be on the frontline for sea level rise. Each increase in temperature makes the challenge of adaptation more acute.[3]

[2] City of Vancouver, "Climate Change Adaptation Strategy", 2018, accessed at https://vancouver.ca/files/cov/climate-change-adaptation-strategy.pdf

[3] City of Vancouver, "Administrative Report: Climate Emergency Response", April 16 2019, accessed at https://council.vancouver.ca/20190424/documents/cfsc1.pdf



Climate Emergency

Since 2016, a growing number of governments at regional and national level have recognized the need to react appropriately to the climate crisis by declaring a climate emergency. In making such declarations, governments acknowledge that the actions taken so far to combat global warming have not been sufficient. In 2019, Vancouver joined hundreds of cities around the world who have declared a Climate Emergency. In recognition of this declaration, in April 2019 the Council approved the Climate Emergency Response Report.[4]

The Climate Emergency Response Report includes six big moves and 53 Accelerated Actions that the Council has identified as critical in responding to climate change in Vancouver. Big Move Four, "zero emission space heating and hot water", (see infographic on the next page)[5] is most relevant for the purposes of this report, alongside Accelerated Action 6 (set out further at Appendix B). Accelerated Action 6 explicitly sets the goal of transitioning the NEU to 100% Renewable; however, it is subject to an evaluation using the NEU's existing investment decision framework and competitiveness with other low carbon energy option for buildings. This report will support the evaluation work required prior to adoption of the 100% renewable energy target.

ACCELERATED ACTION 6

Neighbourhood Energy: Transition the City-owned Neighbourhood Energy Utility to 100% renewable energy and expand the system.

[4] City of Vancouver *supra* note 3

[5] *Ibid.*

Big Move #4	Zero emissions space and water heating
	By 2025, all new and replacement heating and hot water systems will be zero emissions. *(Recommendation E)*
Carbon Reduction Potential	Ensuring that new and replacement space and water heating systems are zero emissions will reduce Vancouver's carbon pollution by 552,000 tonnes/year in 2030 (46% of the targeted reductions).
Description	Success for this Big Move will mean that by 2025, all space and water heating in new buildings and those replaced in existing buildings would be zero emissions. Heat pumps are expected to be an important solution is this transition. They are over 200% efficient at capturing heat from the air, ground or waste sources. They also cool buildings, which will be especially important as climate change causes hotter summers. The City's Neighbourhood Energy Utility will also need to get 100% of its energy from renewable sources by 2030 (currently 70%). For this Big Move to succeed, the Zero Emissions Building Plan for new construction will need to be sped up. New construction is critical because one quarter of the floor space in 2030 will be built over the next decade. Building that new floor space with zero emissions space and water heating starting as early as 2021 avoids the need to retrofit in the future. For existing buildings, the City will need to develop a Zero Emissions Retrofit Strategy to transition space and hot water heating to zero emissions. Furnaces and boilers last 15–25 years, while hot water heaters last closer to 10 years. Every time they are replaced is an opportunity to upgrade to zero emissions. A successful Retrofit Strategy will include sustained incentives (potentially through a Vancouver Climate Trust) and investments in industry capacity-building to support voluntary adoption of zero emissions space and water heating before 2025. Ultimately, there will need to be regulations that require zero emissions heating equipment when it is replaced (in the same way higher efficiency furnaces are already required when an old one is replaced). While 2025 is the key date to meaningfully bend the emissions reduction curve, moving this quickly will have implications on factors such as costs and business' ability to adapt to new opportunities. Success will depend on understanding where there are concerns and finding effective ways of addressing them. Also critical will be a jobs transition roadmap. In addition, careful consideration and analysis of the use of incentives is required in order to preserve affordability and avoid displacement of existing residents, particularly in aging rental buildings.
Links to Existing Work	Implementation of Zero Emissions Building Plan (2016) is ongoing. The City continues to require energy efficiency upgrades when a building is retrofitted, which help make the switch to zero emissions heating more affordable. The Neighborhood Energy Utility has been providing low-carbon heat and hot water to customer base in Southeast False Creek since 2010, and expansion is underway to parts of Mount Pleasant, North East False Creek and the False Creek Flats. The City has transitioned boilers to heat pumps at a growing number of its own facilities, including City Hall. This Big Move also supports the Vancouver Housing Strategy by ensuring homes are healthier and have lower energy costs.
Responsible Departments	• Led by Planning, Urban Design and Sustainability • Supported by Development, Buildings and Licensing; Engineering; and Real Estate and Facilities Management

Figure 1: Big Move 4

The Neighbourhood Energy Utility

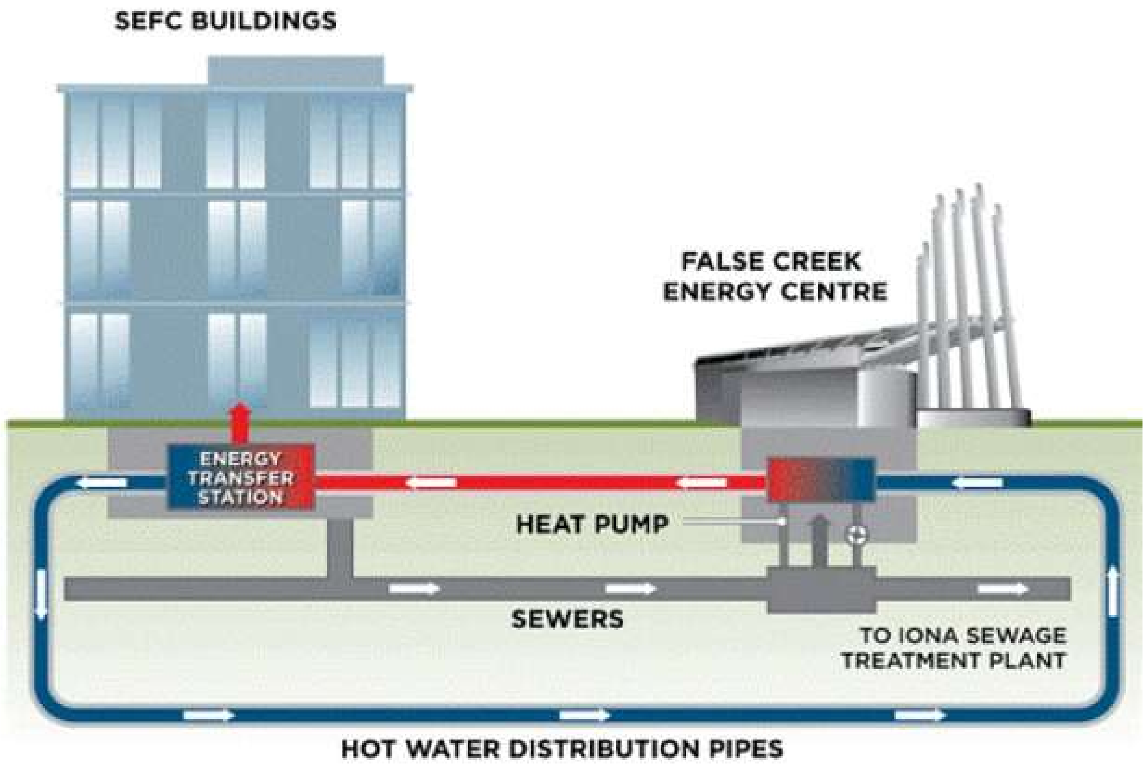


Figure 2: NEU System [6]

As shown in Figure 2, the NEU captures waste heat from sewage and wastewater, using innovative technology that enables the system to handle untreated urban wastewater. Sewage is pumped through a heat pump which transfers the thermal energy from the sewage to create system water as hot at 81°C. This process is described more fully in the Figure 3 below. Gas boilers (fed by conventional and renewable natural gas) are used for peaking and backup, and can lift the system water as high at 95°C as needed to meet the energy demand of the neighbourhood.

[6] Neighbourhood Energy Utility "Components of NEU System"

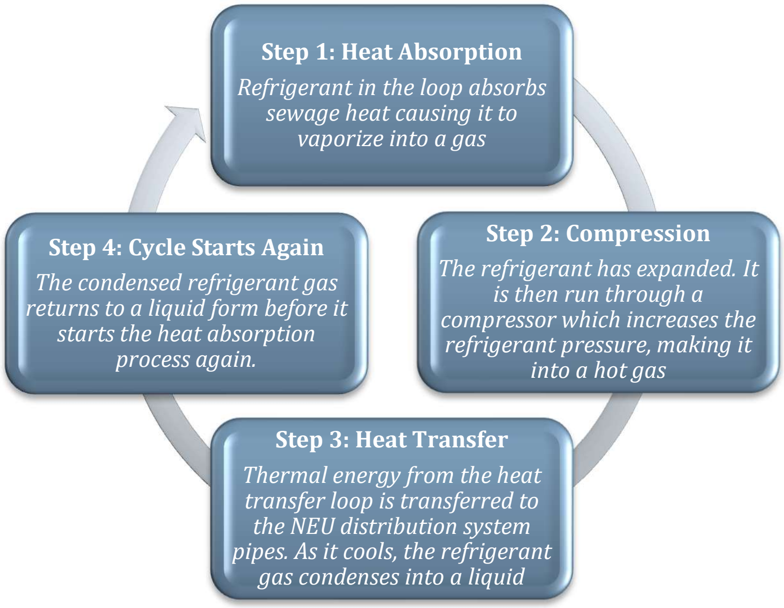


Figure 3: NEU Sewage Heat Recovery Process[7]

Project milestones

The NEU has undergone rapid expansion since it began operating in 2010. As of 2019, the utility served 534,000 m^2 (5,750,000 ft^2) of residential, commercial, and institutional space. In early 2018, the Council approved the expansion of the system to Mount Pleasant, Northeast False Creek, and the False Creek Flats areas. Once completed, the NEU will serve 2,100,000 m^2 (22,600,000 ft^2) and anticipates a 14,000 tonne reduction of CO2-equivalent per year. Figure 4 shows the existing service area and customers along with the proposed expansion of the NEU. The timeline in Figure 5 sets out some of the historical milestones in the NEU's expansion and journey towards 100% renewable energy.

[7] For text, see City of Vancouver, "Neighbourhood Energy Utility Heat Pump", accessed at https://vancouver.ca/files/cov/neighbourhood-energy-utility-heat-pump.pdf. Graphic otherwise created by the Author.

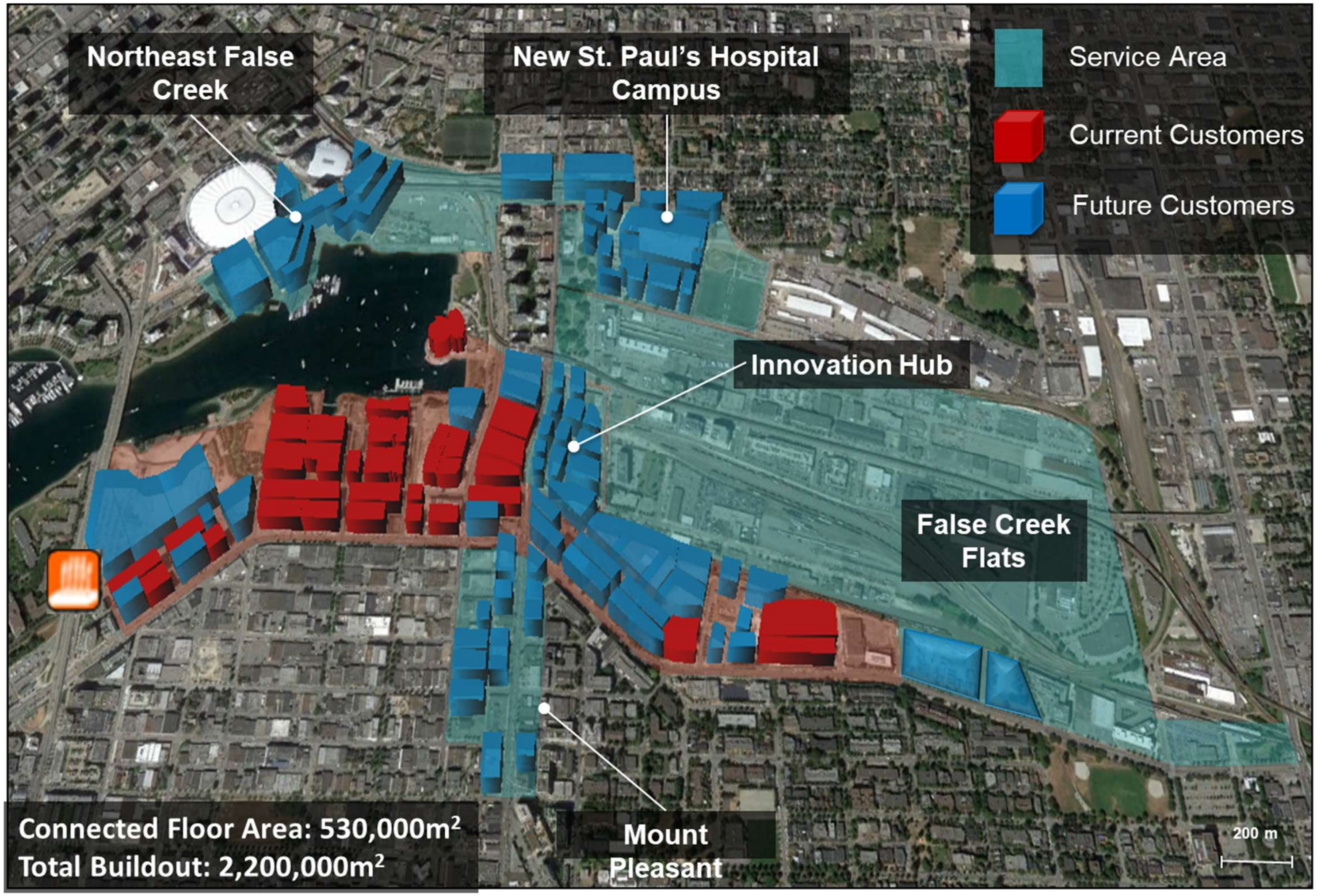


Figure 4: NEU System Expansion

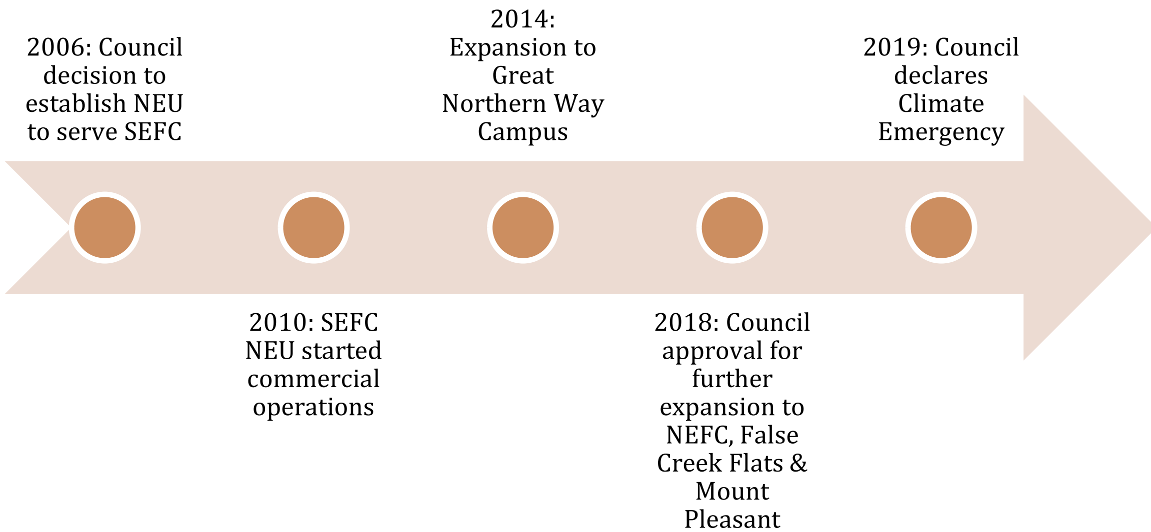


Figure 5: NEU milestones[8]

Environmental Performance

The NEU aims to supply an average of 70% of its energy from renewable sources. This has been achieved by utilizing sewage heat recovery as the primary source of renewable energy with RNG being blended in to top up the environmental performance as needed.

Two recent events have caused a temporary reduction in the NEU's environmental performance. The first, in October 2018, was as a result of flooding, "*triggered by an extreme rainfall event combined with high tide conditions and design/operational factors caused a prolonged outage of the sewage heat recovery system at the False Creek Energy Centre*".[9] The second, in August 2019, resulted from production shortages affecting the supply of RNG from Fortis (the natural gas supplier for BC). While repairs on the sewage heat recovery system are now complete, RNG curtailment continues. Procurement is now underway to expand the system's sewage heat recovery capacity by an additional 5-7 MW. This will enable the NEU to achieve its current GHG performance targets with reduced dependency on RNG. This investment is viewed as being well aligned with the larger objective of transitioning the NEU to 100% renewable energy.

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[8] See Neighbourhood Energy Utility, "Southeast False Creek NEU Timeline" for text, Graphic by Author.

[9] City of Vancouver, "Administrative Report: False Creek Neighbourhood Utility ("NEU") 2020 Customer Rates" November 19 2019. Accessed at https://council.vancouver.ca/20191203/documents/spec1e.pdf

The challenge of reaching peak demand with 100% renewable

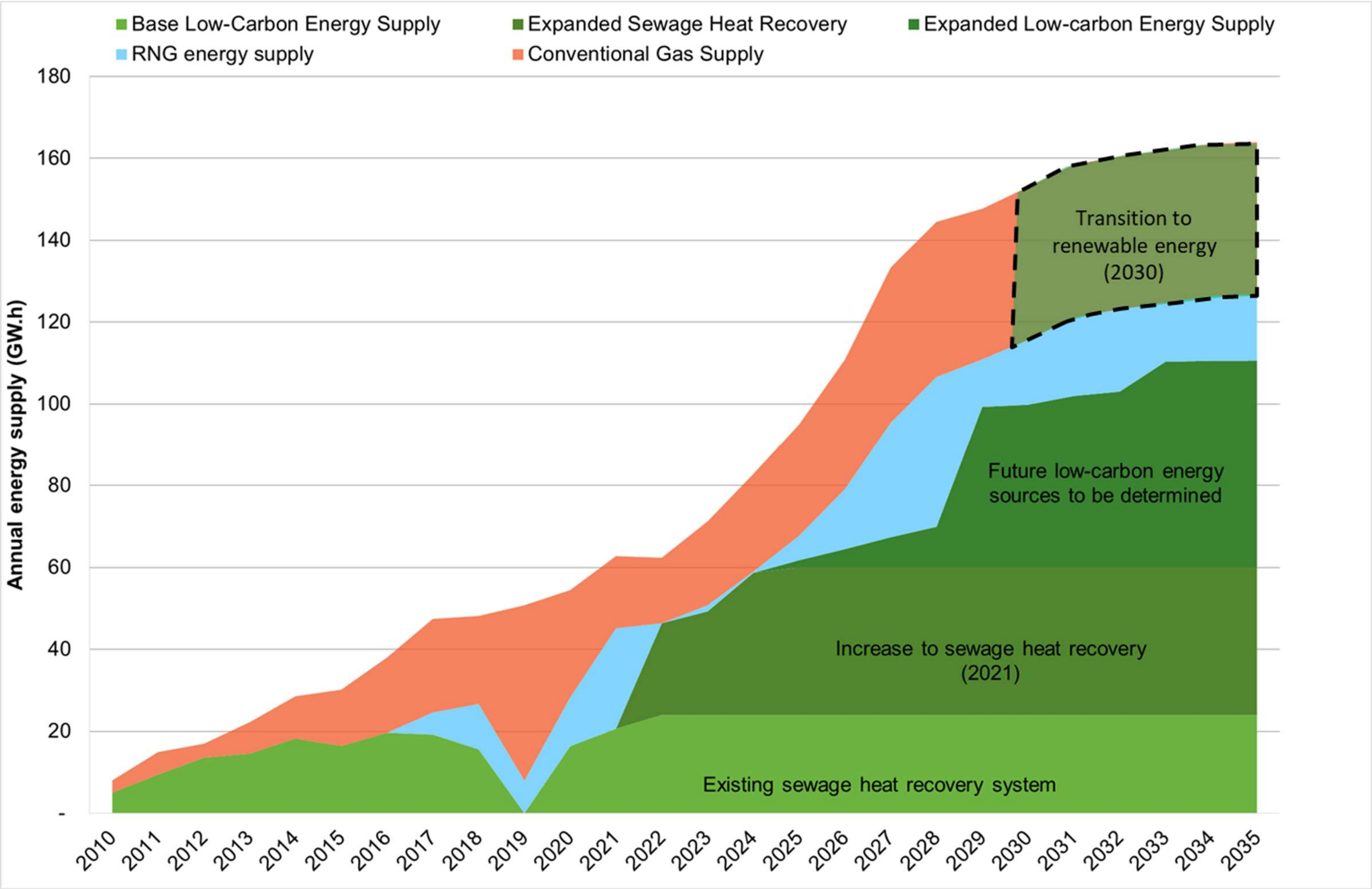


Figure 6: Projected NEU Supply Based on 70% Renewable Energy – 2030

Projected NEU Supply

The previous graph (Figure 6) shows the projected make-up of the annual energy supply for the NEU from 2010 – 2035. The graph represents modeling for 70% renewable energy, the current NEU target.

The Base Low-Carbon Energy shows the existing 3 MW of heat from sewage waste, which will soon be supplemented with an additional 5-7 MW of expanded sewage heat recovery (scheduled to come online at the end of 2021). Beyond that, additional low carbon energy supply (source currently unknown) will be added to meet the growing baseload as the system continues to expand. The curved line of RNG Supply is intended to fill the gaps between investments in low-carbon generation (as new generation is brought on incrementally), eventually becoming stable in supply load by around 2030.

The intended Conventional Gas Supply is represented by the red block. As this graph shows, in 2030 the NEU is forecast to supply around 130 GWh, with 37 GWh being supplied with conventional gas. With the accelerated target of 100% renewable by 2030, these 37 GWh must be replaced with a renewable energy source within the next ten years.

Forecast Daily and Seasonal Peak at NEU Buildout

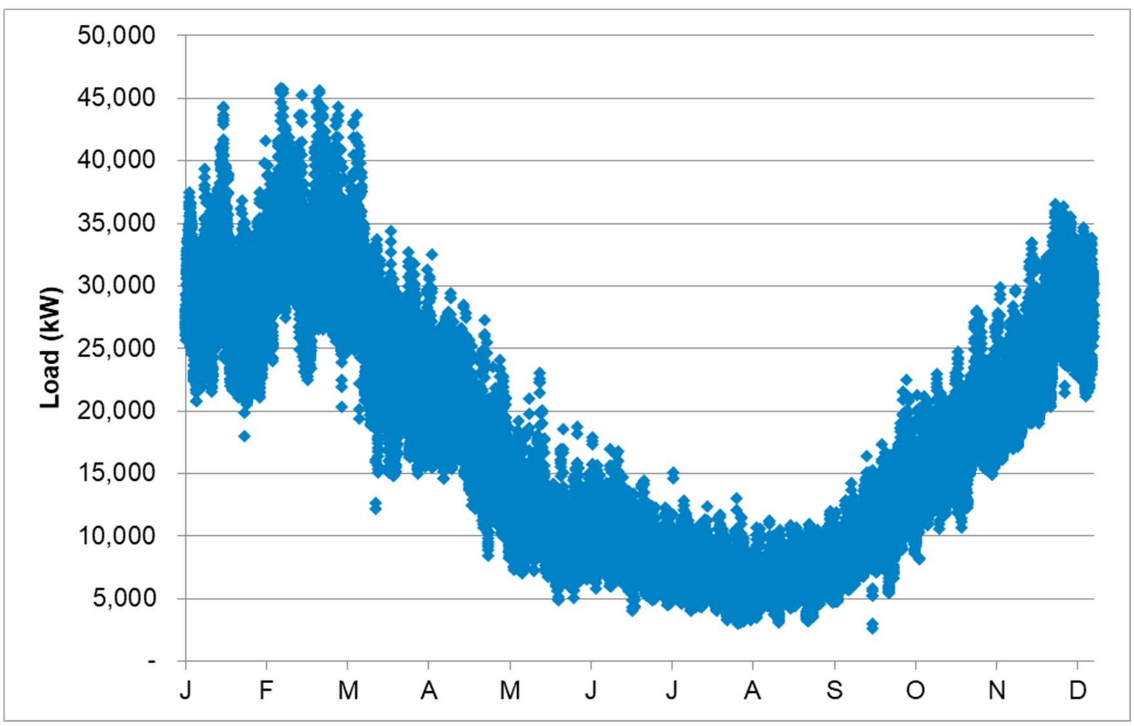


Figure 7: Forecast Daily and Seasonal Peak at NEU Buildout

One of the biggest challenges of operating a thermal utility is the large variations in system demand driven by daily and season peak demands. Peak demand refers to the window of time in which the most energy is needed in order to provide heat and hot water to the network. Figure 7 shows the forecast NEU load profile in year 2035 over the course of an average year in Vancouver. The NEU's daily peak is observed between 7-8.30am, coinciding with when people wake-up, turn-on their heating and take showers. As the temperature decreases in the winter months a seasonal peak is observed, driven by increased space heating demand.

Load duration curve

To illustrate the challenges of meeting the peak demand, Figure 8 shows the load duration curve observed for the NEU in 2019, in which a peak demand of 19 MW was observed. While the first 3 MW of energy generation equipment can be utilized continuously year-round, any additional capacity will operate at a lower utilization. For example, in 2019 the system only exceeded 10MW for a total of 44 days, and 15 MW for just 2 days. Currently, natural gas boilers are deployed as a way of conveniently meeting the system peaks as they benefit from the ability of being turned on/off readily. They are also low in capital cost, which is advantageous for a piece of equipment that will have a low utilization. The key question therefore, is which renewable technology(s) are best placed to meet these peak demands, whilst remaining affordable to end users.

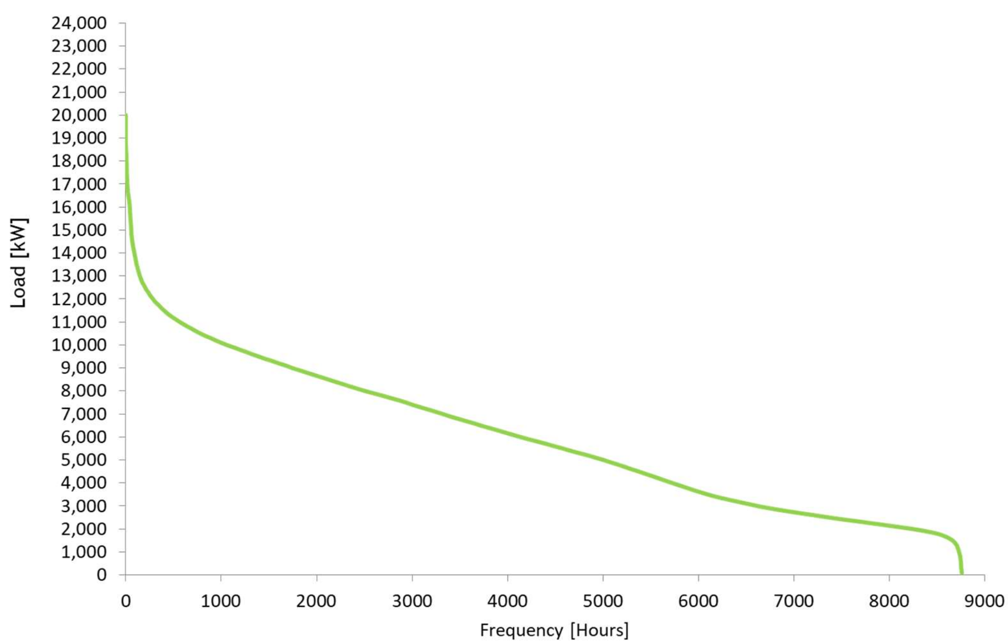


Figure 8: NEU 2019 Load Duration Curve

Scaling up technologies to reach peak demand, which only occurs for a limited number of hours on a limited number of days each year is can be prohibitively expensive. Hence this report separates out technologies that work best with peak and technologies that work best with base load in Part 3. There are many other challenges involved such as planning for a rapidly expanding system and changes in technology, but ultimately, it is essential that the cost of energy to the end-user is affordable.

Overview of Technologies

At the same time as the literature review was being carried out (see Part 2 below), an overview of existing and emerging renewable technologies was undertaken to inform the technologies to be included in Question 4 of the interview.

A brief description of each technology is provided in the Table 1 below.

Table 1: District Heating Technologies

System	Energy Source	Technology
Sewage Heat Recovery	Latent heat in sewage water	Heat pump Energy sewage filtration system.
Waste heat from data centres	Waste heat from cooling of data centres such as computer processing companies. May also be available from industrial processes (e.g. steelworks) and large refrigeration loads (e.g. ice rinks)	Captures heat lost from the process/activity undertaken in the building and recycles it using heat pump.
Air Source Heat Pumps (ASHP)	Heat from ambient air	An ASHP uses a refrigerant system to absorb heat from the air in one place and release it in another.
Ocean Heat Recovery	Heat from ocean water	Water-source heat pump. Heat transfer loops are located in the ocean.
Renewable Natural Gas	Methane generated from organic waste such as food or cow manure	Various. Power-to-gas techs capture methane released by rotting matter.
Electric Boilers	Heat from electric resistance	Similar to a kitchen kettle, EBs take in cool water from the house.
Biomass	Organic material (such as woodchip)	Material is combusted using a biomass boiler to produce energy.
Electrolysis	Electricity, splits water into hydrogen and oxygen	The reaction takes place in a unit called an electrolyser. This technology is not yet widely adopted, though trials in district heating are underway.
Thermal Storage	Any of the above.	Various, such as: • Solar energy storage

	Thermal storage stores energy for days or even months to help address seasonal variability in supply and demand	• Aquifers, or other forms of underground thermal storage • Heat storage in tanks/rock caverns • Heat storage in hot rocks • Battery
Geo- exchange	Earth's natural heat – thermal energy is either extracted (for heating) or deposited (for cooling) in the earth. Open loop: exchanges heat from ground or surface water Closed loop: transfer heat through buried pipes.	Ground-source heat pump Uses the ground as a 'storage battery' for energy.

A note on heat pumps

Heat pumps use electricity to transfer heat from surrounding heat sources to buildings. They can draw in heat in ambient air, water or the ground as primary source of energy (usually 66-80%) combined with a small auxiliary energy (around 20-33% directly from electricity).

Heat pumps are much more efficient than traditional fossil fuel boilers, at 200-400% efficiency, compared with 75-95% efficiency.

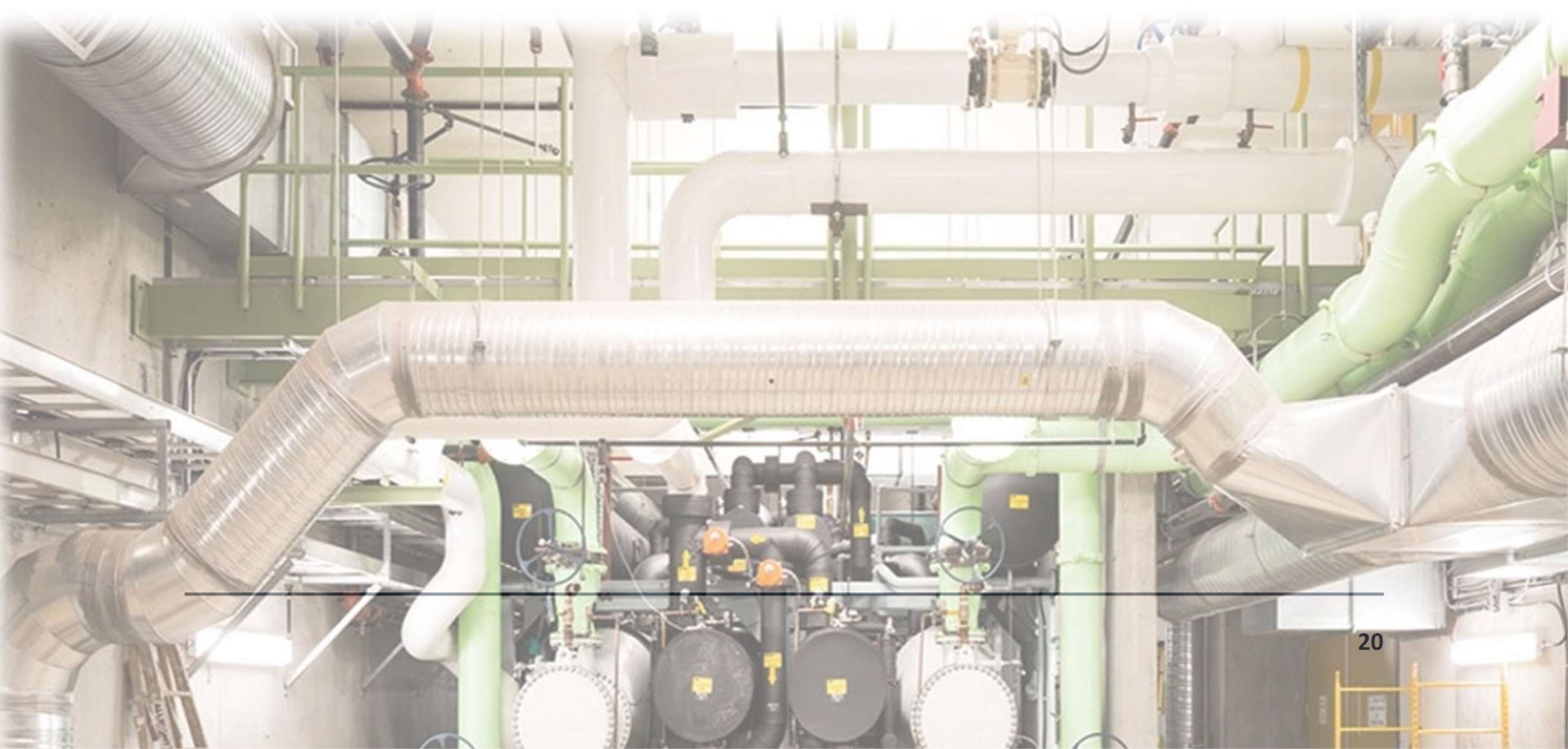
Part 2: Literature Review

Introduction

The origins of district heating can be traced back to the Roman Empire, in the form of hot water heated baths and greenhouses. However, the first real district heating system is considered to have been invented in France in the 14th Century – a system which used geothermal energy to provide heat to about 30 houses. In recent history, the first commercially successful district heating network began operation in New York in 1877.

Nowadays, Europe- in particular Scandinavian countries- are looked to as leaders in district heating networks and technology. Cities such as Copenhagen have been designed so that 90% of buildings within the city are connected to the district energy network. For the most part, European networks tend to be more well-established and much larger than their North American counterparts. However, interest in the technologies worldwide is growing due to benefits such as environmental; economy of scale; lifetime, safety and reliability of technology as well as ease of maintenance. Security of supply is also a key consideration, as many systems are still able to continue to run even if the main power network goes down.

A movement towards lower temperature district energy systems has also been observed. Traditionally district energy systems were designed as high temperature steam-based systems. Steam systems are challenged with higher thermal losses and are constrained on the heat generation technology due to the high temperatures required. Over time, a movement towards lower temperature water-based systems has allowed for greater system efficiency and opened the door to more technologies such as heat pumps. The NEU currently operates between a 3rd and 4th generation system, between 65-95°C depending on the outside air temperature.



Generations of District Heating

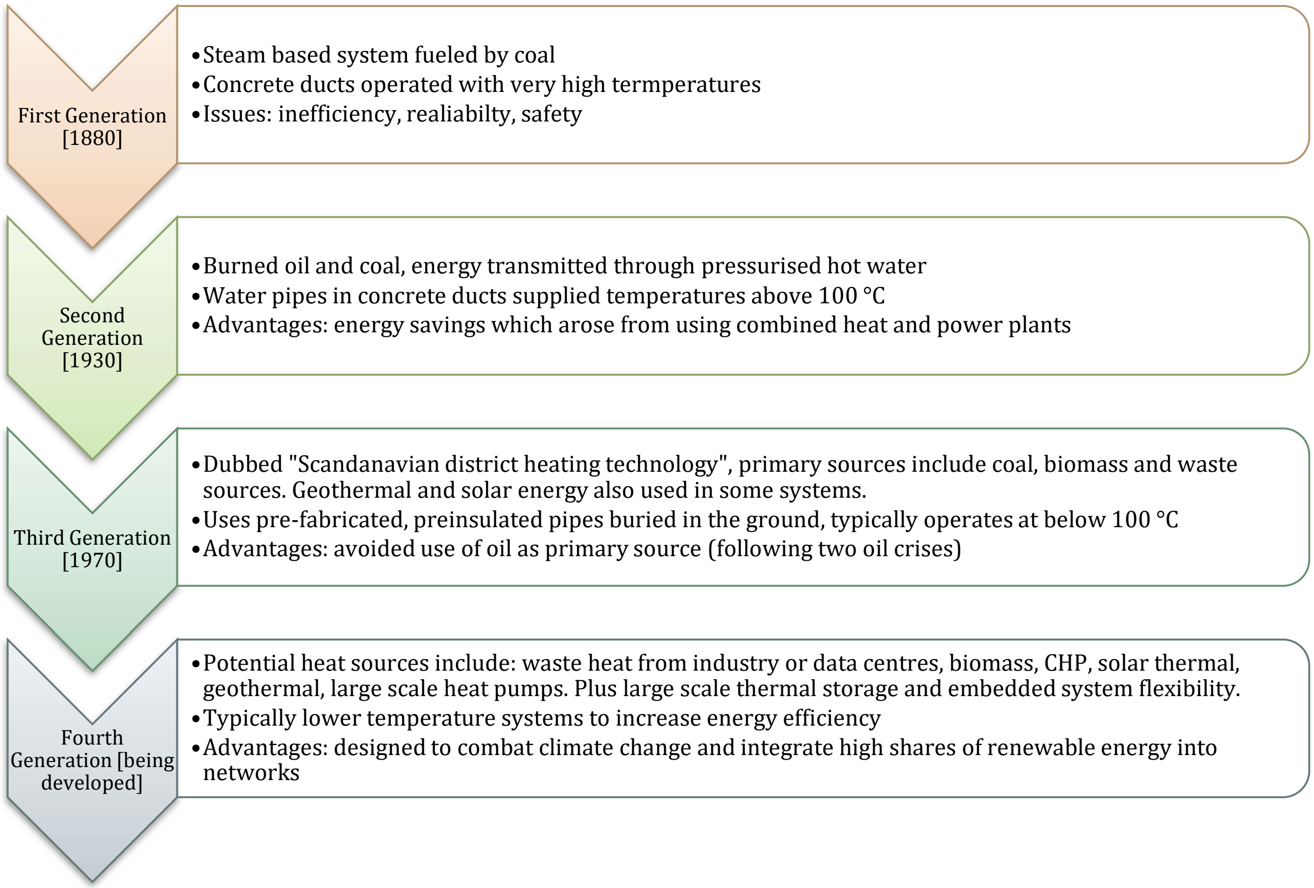


Figure 9: Generations of District Heating

The Literature Review (Table 2)

Table 2: Literature Review was produced to present information about district energy networks around the world that are operating at or near 100% renewable energy. The table is intended to demonstrate the range of technologies that are being used. As such, some projects that are included are at the pilot stage, as opposed to commercially operational.

Due to the historical development of the systems outlined above, the table is split between North American examples, European examples and examples from elsewhere. This enables more approximate comparisons to be made between systems relative to size, advancement etc.

The table is also categorized by location (specific), technology, system size, environmental performance, and any other comments/links.

Table 2: Literature Review

Location	Technology	System Size	Environmental Performance	Comments (links)
Neighbourhood Energy Utility Vancouver	3MW sewage heat recovery (soon to be expanded to 8-10 MW) 24 MW gas boilers using renewable natural gas for peaking.	Connected floor area: 5M ft2 35 buildings Peak demand: 20 MW	Targets 70% renewable energy	
Academic District Energy System, UBC, Vancouver	6MWt biomass gasification system2WMe cogeneration unit Gas for peaking	Connected floor area: 10M ft2 160+ buildings Peak demand: 45 MWt 25% of campus' heating and hot water needs	Targets tripling in size 2020 ADES targets 70% renewable 34% GHG reduction (in 2016 from 2007 levels)	[10] [11]
The Burnaby Mountain DEU, UniverCity	Biomass wood waste (extension) Gas for peaking	4000 residents (in 2015) (up to 10,000 residential units)	80% reduction in GHGs	[12]

[10] City of Vancouver, supra note 9

[11] "Looking ahead to 2020, UBC will be tripling the capacity of its biomass plant, energizing two thirds of the ADES with renewable fuel sources. This increase in capacity will further diminish UBC's reliance on fossil fuels and lead to the reduction of an additional 13,000 to 15,000 tonnes of carbon dioxide (tCO2) annually." See UBC, "UBC Academic District Energy System" 2018/19 accessed at: http://energy.sites.olt.ubc.ca/files/2019/06/2019-UBC_EWS_DES.pdf

[12] SFU, "Six ways AFU is reducing its carbon footprint" April 20 2018. SFU online: https://www.sfu.ca/sfunews/stories/2018/04/six-ways-sfu-is-reducing-its-carbon-footprint.html

SFU, Vancouver				
Drake Landing Solar Communit y Okotoks, Alta	800-panel garage mounted array Solar thermal energy/ borehole thermal (144 boreholes, each 35 m deep and radially plumbed in 24 parallel circuits) Seasonal and short-term thermal storage Gas for peaking	52 detached homes Solar PV = +18KW in 2011	90% of homes' heating needs 5 tonnes less GHG/house/year	[13] [14]
Alexandra District Energy Utility, City of Richmond	Ground heat as an energy source: • Geo-exchange fields (1st field = 385 boreholes, 2nd = 700) • Natural gas boilers (for peak) • Cooling towers	Connected floor area: 3.1 M ft2 3,100 residential and commercial units 13 MW heating 5.8MW cooling	33% reduction in GHG from 2007 levels by 2020	[15]
Blatchford District	Solar	Blatchford is expected to be home to 30,000 people	100% renewable	[16]

[13] Chung, Emily "Solar? Geothermal? Garbage? 6 climate-friendly ways to heat and cool buildings" December 3 2019. CBC online: https://www.cbc.ca/news/technology/district-energy-examples-1.5379125

[14] Drake Landing Solar Community online. Accessed at: https://www.dlsc.ca/

[15] Kerr Wood Leidal, "Alexandra District Energy Utility" accessed at: https://www.kwl.ca/project/alexandra-district-energy-utility/

[16] Lorinc, John "Oil Town building carbon neutral community powered by 100% renewables" December 4 2019 Corporate Knights online: https://www.corporateknights.com/channels/built-environment/edmonton-builds-carbon-neutral-neighbourhood-15754428/

Energy Sharing System, City of Edmonton	Geo-exchange (570 boreholes, depth 150m) [In later phases, Blatchford will also include sewer heat exchange.]			
Stanford Energy System Innovation (SESI) Stanford, university, California	Fuel= electricity & natural gas (for peaking) Water volume = 6M gal (including thermal energy storage) Large scale hot water and cold-water thermal energy storage 93% of campus' heating and hot water needs able to be met by recovering 57% of the waste heat from the chilled-water system	Connected floor area 12 M ft2 300 buildings	68% less GHG emissions	17
Large Scale District Heating,	Sea water (8 or 9° C, depth = 18m) Heat pump uses ammonia (75%) biomass (15%) – peak (seasonal) gas/oil (10%)-peak (daily)	200 large buildings 65,000 residents 67GWh/year	1.5m tonnes of carbon emissions a year or 1.5 mtCO2	18

[17] Stagner, Joseph "Stanford University's "fourth generation" district energy system" 2016 SFU accessed at: https://sustainable.stanford.edu/sites/default/files/IDEA_Stagner_Stanford_fourth_Gen_DistrictEnergy.pdf

[18] Case Studies by 100% Renewable Energy Districts: 2050 Vision, "100% RE District- Drammen, Norway" August 1 2019, Euroheat & Power. Accessed at: https://www.euroheat.org/knowledge-hub/case-studies/100-re-district-drammen-norway/

City of Drammen, Norway				
Grenoble Metropolis, France	Biomass Waste heat from incineration plant combined with rooftop solar thermal plant storage CO_2 capture smart control (under development)	Entire city 900 GWh	Currently 66.5%. Aims: 75 % RE in 2020 85 % RE in 2022 100% RE in 2033	[19]
Gotland Municipality Sweden	Biofuels from local forestry Biogas from a former landfill site and from a wastewater treatment plant Bio oils that replace fossil fuels District heating, solar and wind power	58 595 inhabitants Heats 90% of the city's apartment blocks and 12,000 detached homes.	2019: over 80% renewable Aim: 100% renewable by 2025	[20]
Brandenburg town,	Waste heat from the local steelworks solar thermal heat production	100 buildings 120 GWh/year	80 % climate neutral by 2022,	[21]

[19] Case Studies by 100% Renewable Energy Districts: 2050 Vision, "100% RE District- Grenoble Metropolis. France" 1 August 1 2019, Euroheat & Power. Accessed at: https://www.euroheat.org/knowledge-hub/case-studies/100-re-district-grenoble-metropolis-france/

[20] Andersson, Helena, "Local biofuel for district heating and transportation" accessed at: https://www.renewables-networking.eu/documents/SE-Gotland.pdf

[21] Case Studies by 100% Renewable Energy Districts: 2050 Vision, "100% RE District- Hennigsdorf, Germany" August 1 2019, Euroheat & Power. Accessed at: https://www.euroheat.org/knowledge-hub/case-studies/100-re-district-hennigsdorf-germany/

The municipal utility company of Hennigsdorf, Germany	power-to-heat from renewable surplus electricity Efficiency optimisation 22000 m3 multifunctional heat storage + buffer tank (1000 m^3) smart system (to assist with peak)		CO2 neutral by 2025	
Marstal District Heating, Denmark	Sun Conversion, Solar collectors (50-55%) Wood chips (40%) CHP heat pump (2-3%) – wind energy or combustion of bio-based oil Underground pit storage (summer to winter) 85,000 m3	Existing: 194000 ft2 solar collectors [soon to be increased by 161000 ft2.] 2,300 inhabitants	100% renewable energy	[22] [23]
Fortum Värme & Bahnhof Data Center,	Cooling system from the Baltic Sea Open District Heating™- business model to use heat from data centres	When fully operational = 112 GWh of heat recovered /year entire heating supply of a town of 20,000 inhabitants.	District heating in Stockholm = 100% renewable/ recovered energy by 2030.	[24] [25]

[22] Busch, Henner, "Marstal Fjernvarme – a solar district heating plant on the island of Ærø, Denmark" March 6 2019 interreg, European Regional Development Fund. Accessed at: https://cleanenergysolutions.org/sites/default/files/documents/June%205%20Per%20Alex%20Sorenson_MARSTAL_CHP%20DHC_05062014.pdf

[23] This is the world's largest thermal solar installation.

[24] According to Stockholm Data Parks, a load of 10MW can heat close to 20,000 residential flats.

[25] Open District Heating "Green data centres make Stockholm unique in the world" July 2 2015, Open District Heating online: https://www.smart-energy.com/industry-sectors/smart-energy/solar-driven-hydrogen-electrolysis-facility-a-first-for-middle-east/

Stockholm, Sweden	(e.g. Internet Company Bahnhof houses over 8000 servers.)			
Arabian Peninsula, Dubai	Solar power Electrolysis Hydrogen CHP Power-to-Gas or Power-to-X is a key technology for storing electricity generated from renewable energies both seasonally and long-term.	The project utilizes electricity from one of the largest solar parks in the world (800MW by the end of 2020) Pilot The actual size of the solar-hydrogen electrolysis plant is described as "MW-scale"	100% renewable energy	[26] [27]

[26] Smart Energy International "solar-dirven hydrogen electrolysis facility, a first for Middle East" February 5 2019, Smart Energy International online: https://www.smart-energy.com/industry-sectors/smart-energy/solar-driven-hydrogen-electrolysis-facility-a-first-for-middle-east/

[27] Note: This is a pilot project to test how the produced gas can be stored and converted back into electricity, or how it can be utilized for transportation purposes or other industrial applications.

Part 3: Interviews with Industry Experts

Introduction

Part 3 entailed conducting interviews with industry experts. Participants were identified from governing bodies (NRCan), industry associations (IDEA, QUEST) and a district energy working group which consists of local municipalities and district energy utilities. Following a call for expression of interest in mid-May 2020, interviews took place throughout June and July 2020. The interview questions followed a standard format and each participant was asked the same six questions. Participants were given a copy of the questions in advance of the interviews, a copy of the email sent to participants is included at Appendix A. Some participants chose to abstain from answering questions that did not pertain to their knowledge and experience, particularly with regards question 4. The results of the data collection reflect this, as described further in the results for question 4. Three respondents chose to refrain from ranking technologies in question 4 altogether, but their responses are otherwise integrated into the summaries for the first three questions

Experience

There is an impressive and extensive range of involvement in district energy systems from the 11 interviewees, between them reaching over 100 years' worth of experience. Participants ranged from consultants, who have advised on projects all over the world through to project managers, who have an unmatched in-depth understanding of specific district energy systems based in Canada such as the Alexandra District Energy Utility and the Blatchford District Energy Sharing System. Respondents have worked on projects using a wide range of different technologies and have first-hand experience of the ever-changing nature of the technological landscape of district energy.

Question 1

1. What is your experience with district energy systems?

Question 2

What technologies have you found to be most effective in decarbonizing district energy, and why?

a) How did cost considerations influence the selection of technology?
b) How did access to the energy source influence the selection of technology?

One of the key messages that came from the respondents in answer to Q2 is that there is no one technology that is most effective at decarbonizing district energy. As one respondent commented, "there is no bad technology, just bad applications". However, despite this observation, there were common themes within participants' responses.

With respect to part (a) of Q2, many respondents noted that capital cost is one of the greater challenges when considering district energy. The importance of ensuring that the cost of energy produced is acceptable to end users of the system was emphasized. One respondent noted that it is important to take into account CAPEX and OPEX considerations when making this calculation, as the life cycle fuel cost may be quite significant relative to CAPEX. Another interviewee noted that, although economy is always important, it is not necessarily critical. For example, the cheapest and easiest solution may not always be the most politically feasible.

With regards to part (b), the benefit of using local resources was emphasized as a big driver for decision making for multiple reasons; such as, access to the resource and security of its supply. It was noted that in the event of unforeseen disruptions to energy supply, local resources are most likely to remain accessible. More than one participant mentioned an increasing societal recognition of the importance of ideas such as the "circular economy" (elimination of waste and continual use of resources) and the likelihood of these ideas becoming even more important as the climate changes. It was noted that the location of the system will determine the load profile, access to resource (for example, proximity to a water resource to receive fuel) and also the more technical considerations such as the temperature of the system and surrounding resources.

One respondent noted the importance of looking at the smaller scale changes that can be made before "thinking big", noting particularly the impact that demand-side changes can have on load profile.

Technology specific responses

Waste heat

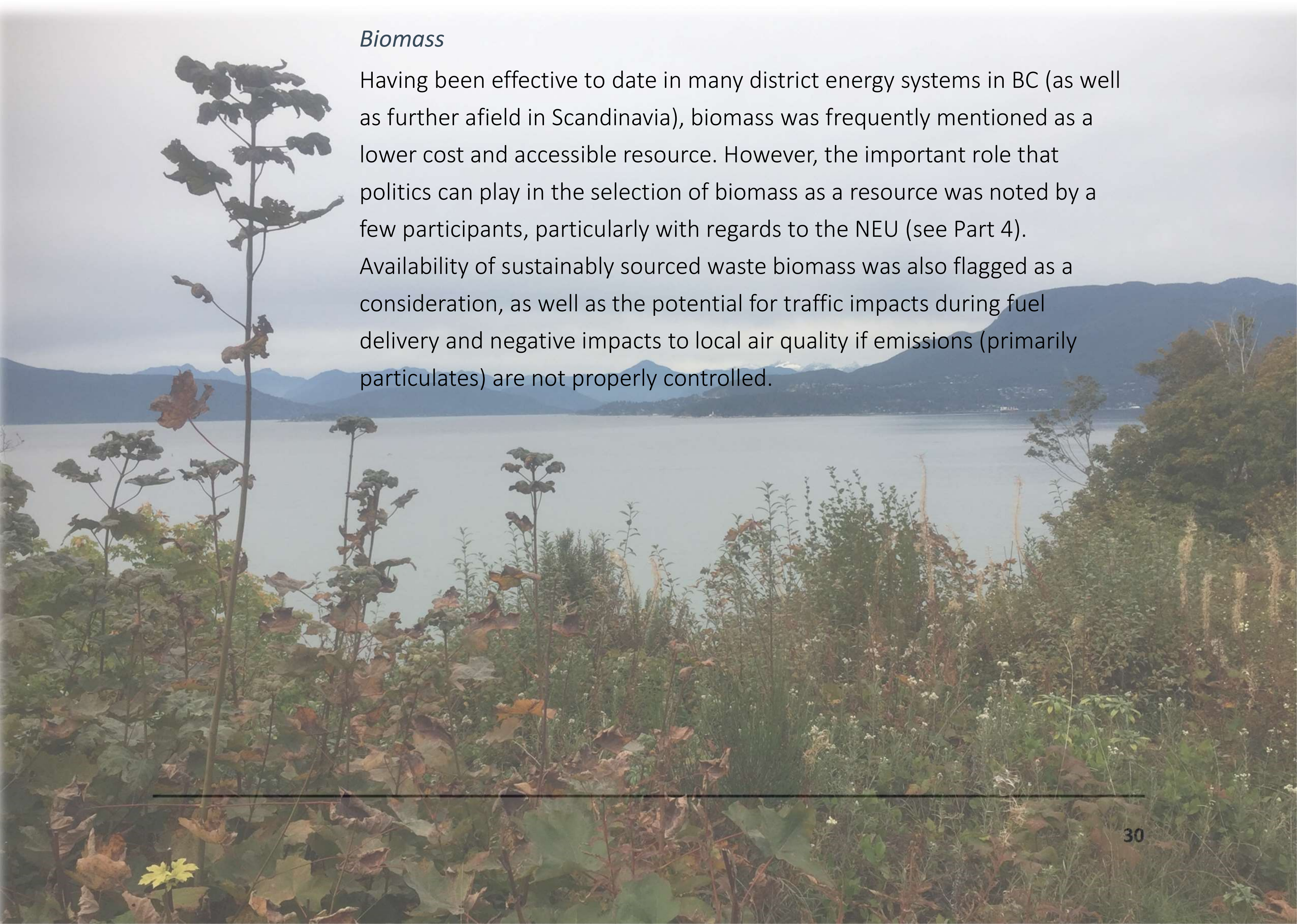
Several participants noted the benefits of tapping into to "spare" heat from local resources, for cost and accessibility reasons. Geothermal, sewage waste heat and air source all evolved out of the same concept of recycling residual heat. An assessment of available waste heat sources is a good start when evaluating low carbon opportunities, as these are inevitably site specific.

RNG

Within BC, RNG was consistently identified as an attractive resource, due to its relative cost and compatibility with existing systems. However, for these same reasons, availability was flagged by many respondents as an ongoing issue, with demand currently outstripping supply. With RNG there is also some discussion around the assignment of credit for off-site energy production; however, it is generally viewed as a positive step in the transition from natural gas to RNG.

Biomass

Having been effective to date in many district energy systems in BC (as well as further afield in Scandinavia), biomass was frequently mentioned as a lower cost and accessible resource. However, the important role that politics can play in the selection of biomass as a resource was noted by a few participants, particularly with regards to the NEU (see Part 4). Availability of sustainably sourced waste biomass was also flagged as a consideration, as well as the potential for traffic impacts during fuel delivery and negative impacts to local air quality if emissions (primarily particulates) are not properly controlled.



Question 3

One of the biggest challenges we've identified is meeting peak demands (daily and seasonal) with renewables in a cost-effective way. What methods have you seen for meeting peak demand in district energy? What renewable technologies do you think would be most cost effective for meeting peak demand?

The "rule of thumb" for district energy suggests that around 70% of energy needs can be met with baseload. This leaves around 30% of energy demand that is considered peak.

Traditionally, peak demand has been met with gas boilers, because this is the cheapest and most effective way of providing energy without having to scale-up other expensive technologies. As such, when converting these existing systems to renewable, RNG often proves to be one of the most effective options for meeting peak demand. However, as was noted in the response to the previous question, there is currently limited availability of RNG in BC (and further afield).

When addressing peak demand, the need to look in-depth at the load profile so that risks can be managed was highlighted. Demand-side management was also flagged as an important starting point, including the need to fully understand contributors to the peak. This understanding provides opportunities for targeted, building/customer specific measures such as distributed thermal storage or heat pumps, as well as building control and setpoints to "shave the peak" (described further in Part 4).

Other options noted

Participants noted that thermal storage appears to present an exciting opportunity. Electric boilers are attractive as they can be turned on and off with ease. The downside being that they have higher operating costs and are less efficient than other options (the efficiency of an electric boiler is 100% compared with heat pumps at 3-400%). Operating at a lower efficiency also leaves a system more exposed to increases in the cost of electricity.

Biomass boilers were suggested as an option for handling seasonal peaks (being turned on in the winter); however, they are not well suited for handling the short daily peak as they are cumbersome to turn on and off.

Question 4

Below I have set out some potential technologies that we have identified for the NEU project and our 100% renewable target. Based on your experience and knowledge of the NEU project, please rank the technologies listed in order of which you consider to be most to least viable (technologically and financially) for providing baseload and peaking energy (5 being most viable):

1. Sewage heat recovery
2. Waste heat from data centers/cooling
3. Air-source heat pumps
4. Ocean heat recovery
5. Renewable Natural Gas
6. Electric boilers
7. Biomass
8. [Electrolysis (hydrogen)]
9. Thermal storage
10. Other [Geo – exchange]

As described previously, some participants chose to abstain from ranking technologies that they had little knowledge or experience of. The results of the data collection for Q4 reflect this, with some technologies receiving votes from 6 or 7 participants, as opposed to 8. The graphs on the next page have been separated to account for this variance. It has been factored into the pie charts on page 34 by way of a percentage score. Three respondents chose to refrain from ranking technologies in question 4 altogether, so the maximum score is 40 (8, being the number of participants multiplied by 5, being the maximum score).

Results from Expert Interviews (individual technologies)

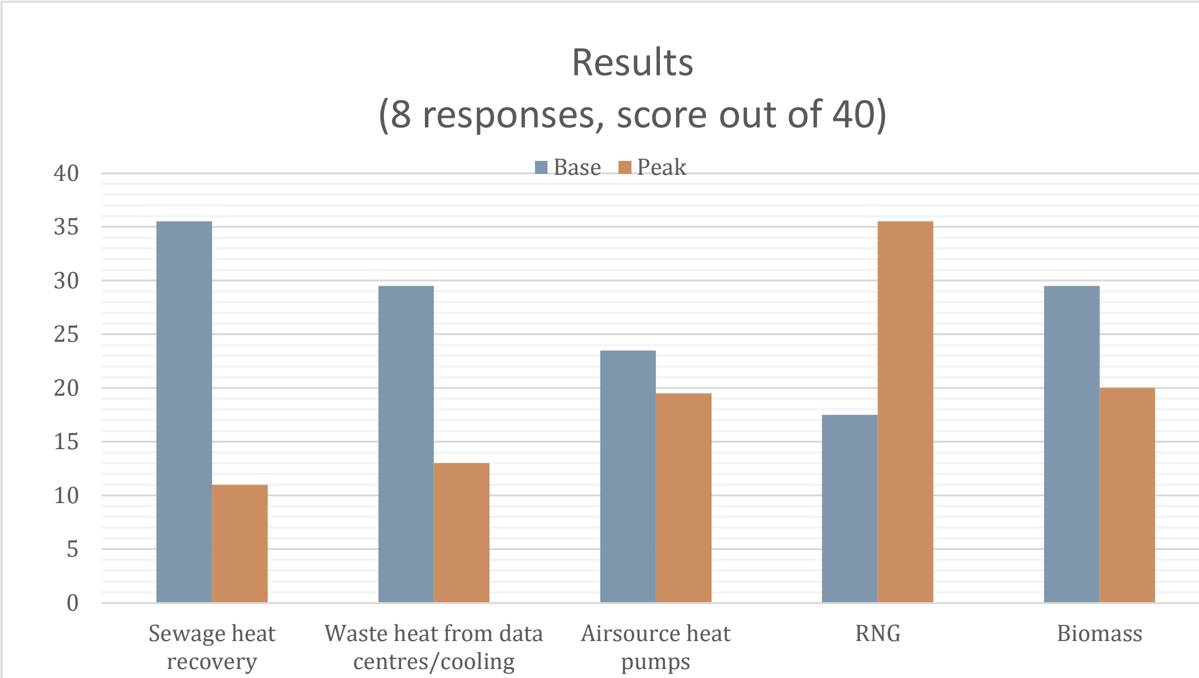


Figure 10: Results 1

Figure 10 shows RNG scoring highly as a peak energy source, with a score of 35.5/40. Electric Boilers and Thermal Storage also scored highly for peaking with score of 26.5 and 24.5 respectively (See figure 12 below). With regards base load energy, sewage heat recovery received the highest score with 35.5/40, followed by biomass and waste heat recovery from data centres/cooling with a tied score of 29.5/40.

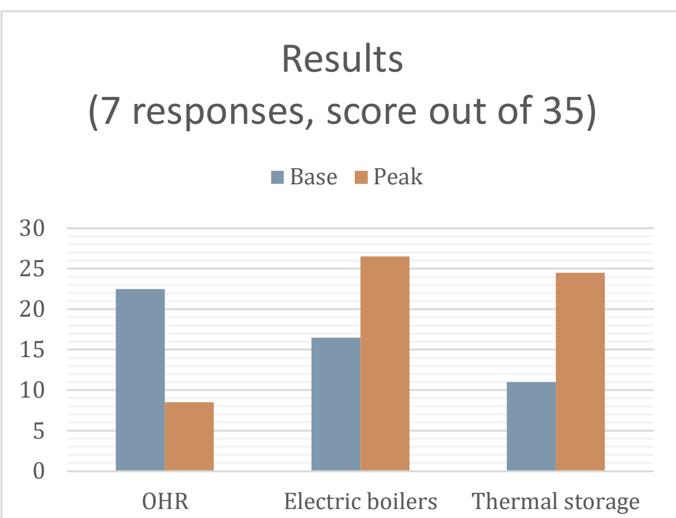


Figure 12: Results 2

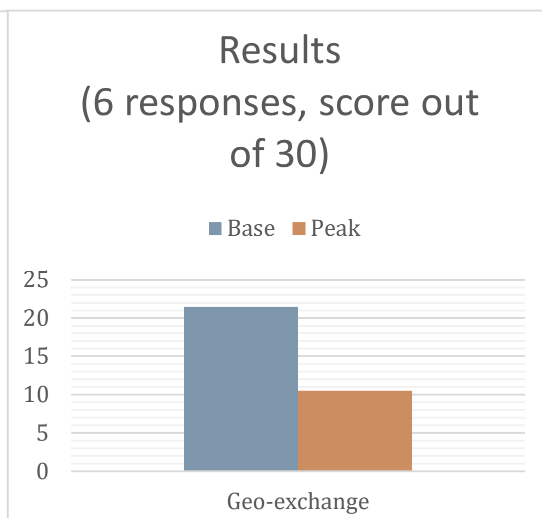


Figure 11: Results 3

Results from Expert Interviews (overall)

In order to enable comparisons to be made between the technologies (bearing in mind the difference in number of respondents to each question) the following graphs show a proportionate representation of each technology for base and peak load.

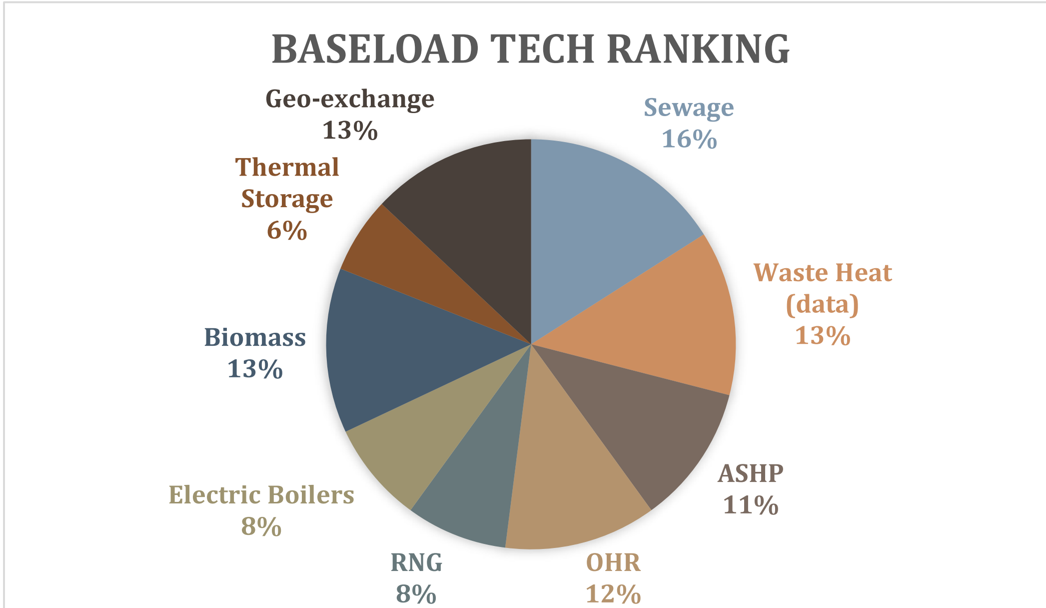


Figure 13: Results 4

The base load pie chart (figure 13) replicates the results discussed above, with sewage scoring highest (16%), followed by geo-exchange, biomass and waste heat with 13% each. Thermal Storage (6%) was seen as least effective for baseload, followed by RNG and Electric Boilers on 8% each.

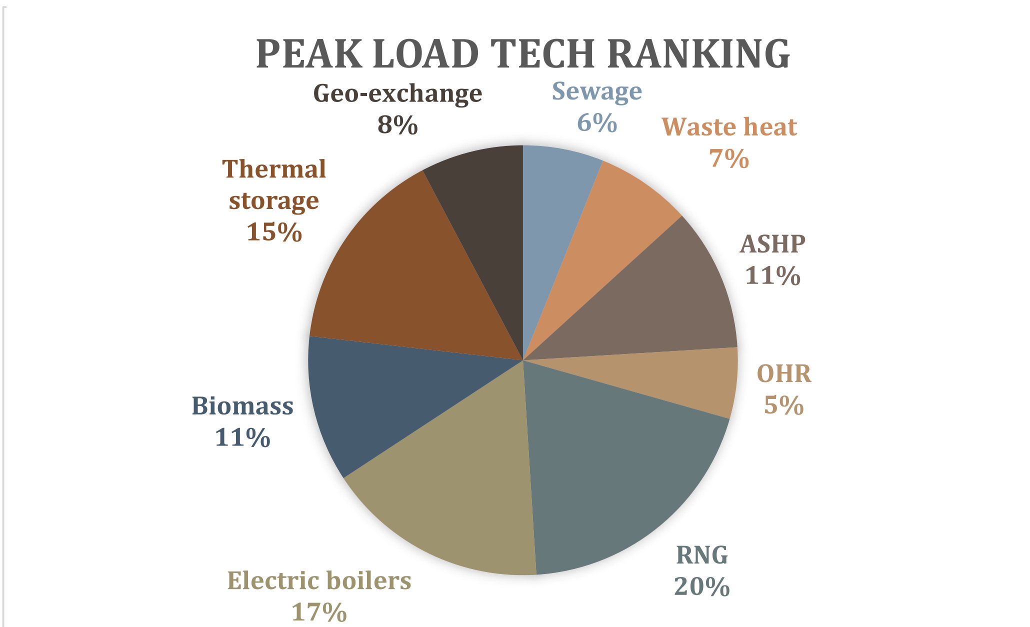


Figure 14: Results 5

The peak pie chart (figure 14) confirms that RNG scored the highest with 20%, followed by Electric Boilers (17%) and Thermal Storage (15%). Ocean heat recovery (5%), sewage (6%) and waste heat from data centres (7%) featured at the bottom.

The results show that those technologies that scored well for peak scored worst for base load (and vice-versa). This is logical and highlights the difficulty in scaling up baseload technologies to reach peak demand, as discussed earlier. The next section sets out some of the comments given by participants whilst ranking each technology.

Sewage heat

Sewage heat recovery scored highest for base load, but 8th for peak load. The capital cost of the technology and the necessity of dealing with raw sewage were noted as disadvantages, but overall, its high score for base demonstrates that participants believe it is a good investment for the NEU. Scaling up to meet peak, however, would not make financial or technical sense.

Waste heat from data centres/cooling

Although waste heat recovery from data centres/cooling scored relatively well for base load (coming in at joint 2nd), some participants noted that in the case of commercial cooling this form of energy would likely not be well matched for peak as the waste heat is unlikely to be available when it is needed most. This was reflected in the scoring for peak with this technology ranking 7th. Another difficulty comes with the uncertainty of security of supply, for example a data centre could go out of business or change location.

Air-source heat pumps

ASHPs were ranked 6th for base and 4th for peak, representing a middle-of-the-range score for both. With regards to peak and to some extent base, participants noted that efficiency drops as the outside air temperature drops, meaning when heat is most needed it is less available.

Ocean heat recovery

Ocean heat recovery scored lowest for peak, but 5th for base. Its ability to provide a constant and relatively unfluctuating source of base heat was noted, particularly given the location of the NEU next to False Creek as a source of ocean water. Some participants regarded its expense as a drawback (making it particularly unsuitable for peak), other challenges include the difficulty of navigating the permit and regulatory system and operational challenges in processing seawater which is both corrosive and conducive to biological growth.

Renewable Natural Gas

RNG was the top scorer for peak energy, most respondents noting its ability to be used within the existing boiler infrastructure as a clear benefit. RNG ranked joint 7th for base, with participants highlighting that availability in BC is currently an issue (a factor that was also mentioned with regards peak).

Electric Boilers

Coming 2nd for peak and joint 7th for base, electric boilers emerged as a preferred peak technology. Many participants noted their operating cost as a disadvantage, making them prohibitively expensive for meeting base load, particularly given their low efficiency compared to a heat pump. However, their ease of handling (ability to be turned on-and-off) made them a good match for peak load.

Electrolysis

Though included in the original list of technologies, it became clear during the interviews that most respondents felt they did not have enough experience or expertise of electrolysis to give an opinion on its viability for the NEU. As such, there are no results presented for this technology. However, there does appear to be some momentum worldwide with respect to hydrogen production through electrolysis. As such this technology is noted as 'one to watch' in Part 4, particularly given that there is low carbon electricity available in Vancouver to drive the electrolysis..

Biomass

Biomass featured as joint 2nd with geo-exchange and waste heat from data centres for base load and joint 4th for peak load (tied with ASHP). A popular choice in BC and the focus of several experts' work, respondents noted its advantages for base. However, some respondents commented that the history of the NEU's development meant that biomass would probably be unsuitable for the site (more on this in Part 4). For peak it was noted that difficulties with handling would likely hold it back from receiving top scores, coupled with expense for scaling up.

Thermal Storage

Thermal storage was very much regarded as a peak technology by interviewees, ranking 3rd. Scoring lowest for base load, participants commented that it is not a means of producing energy. For peak it was regarded as a good option, though some participants noted it is still an emerging technology. Given that thermal storage does not produce energy of itself, it would need to be coupled with another technology with excess energy in order to function (more on this in Part 4).

Geo-exchange

During the course of the interviews, geo-exchange was mentioned so frequently when discussing 'other' that a decision was made to include it as an option. It ranked 6th for peak and joint 2nd for base. It was noted that it is cost intensive, with the need to balance summer and winter intake and outtake. There are successful examples of this technology in BC, such as the ADEU in Richmond and the Blatchford District Energy Sharing System in Edmonton (See Table 2).

Part 4: NEU Specific Opportunities and Recommendations

NEU Specific Baseload Opportunities

As the NEU continues to expand the system, additional baseload capacity will be required to meet the new demand. By expanding the boundaries of the system, however, new opportunities to access local resources become available.

Industry consensus was for heat pump driven thermal energy production technology for baseload energy production where possible. While high in capital cost, the elevated efficiencies of a heat pump (ranging from 200-400%) translate to low operating costs which has been shown to result in cost effective renewable energy when there is high utilization of the equipment.

For heat pumps to work a source of heat is required. While air-sourced heat pumps have the advantage of not being constrained by resource availability, the efficiency of the heat pump decreases as the outside air temperature drops. This, of course, coincides with when the energy is needed the most. Under the right conditions, sewage and waste heat can offer more stable temperatures and therefore should be considered first when assessing baseload options. Figure 15 shows some potential waste heat sources for the NEU to assess when expanding baseload capacity.

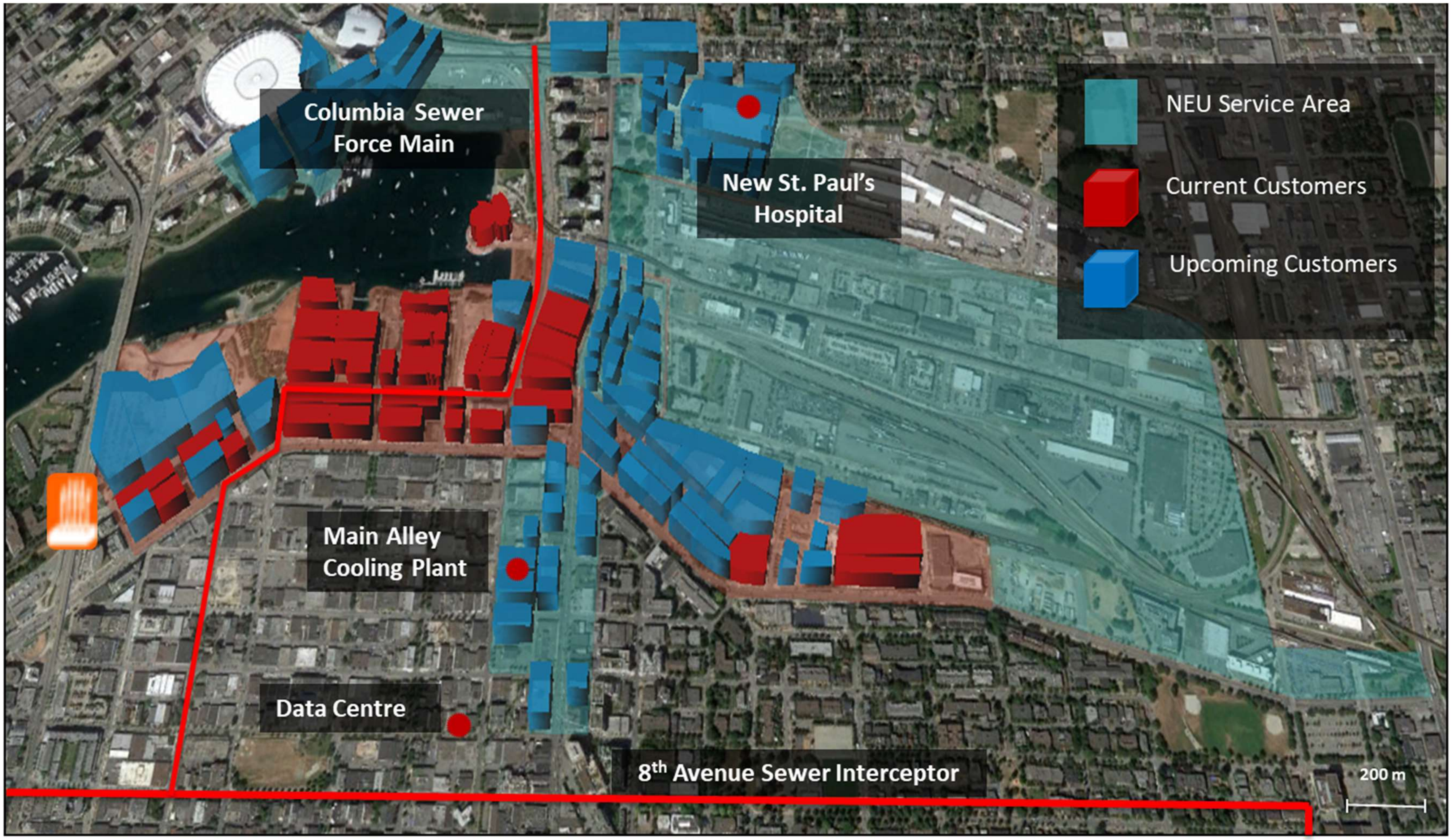


Figure 15: Potential waste heat resources

1.1 Sewage Heat Recovery

Sewage heat recovery scored the highest for baseload energy production; however, it is largely dependent on access to an abundant and consistent supply of sewage. The NEU is currently working on expanding its existing sewage heat recovery system from 3MW to 8-10MW. This expansion will fully utilize the remaining available sewage at the False Creek Energy Centre.

Through the expansion of the utility, the NEU will be coming into close proximity with some new sewage resources. Of greatest significance is the 8th avenue interceptor, a major sewer main that – according to existing sewage data- carries with it approximately 3-5 times the sewage available at the False Creek Energy Centre. With as much as 50 MW of available waste heat, this represents a major opportunity that should be explored further. Although the interceptor is owned by Metro Vancouver, the regional body has existing policy on liquid waste heat recovery to support the utilization of waste heat from its sewer infrastructure.

1.2 Waste Heat Recovery from Data Centre/Cooling

Scoring 2nd for base load energy production, this is another energy source that is dependent on the availability of waste heat. At the present time, known potential waste heat sources in proximity to the NEU service area include:

- a data centre (located at 7th and Quebec)
- a cooling utility planned for the new 'Main Alley' development at 5th and Quebec
- waste heat from cooling at the new St. Paul's Hospital planned for construction in the False Creek Flats.

In addition to exploring these opportunities, it is recommended that a detailed inventory of existing and future waste heat opportunities within the NEU service area is conducted. Furthermore, the City should investigate the use of its planning/zoning influence to promote the siting of data centres and other waste heat producers in close proximity to the NEU service area.

A note on biomass

The popularity of biomass in BC has been noted throughout this report. It also scored relatively well for both base and peak load in the interviews, despite participants emphasising the local political situation in Vancouver. The NEU explored the use of biomass in detail alongside sewage recovery during its initial planning process; however, public opposition to biomass stemming from concerns around impacts to local air quality trumped its anticipated benefits (including the lowest supply costs and largest reduction in GHG emissions). At the time it was noted that there simply was not enough time to change public opinion on the matter and sewage heat was ultimately selected. It is worth noting that this certainly isn't the only place in which biomass has been noted as controversial (see the Helsinki Energy Challenge below). Situations such as these are a reminder that in selecting the preferred technology(s), cost is not the only determinative factor.

NEU Specific Peak load Opportunities

1.1 Renewable Natural Gas

RNG was ranked highest in the expert interviews. The advantages of RNG in making use of the boilers already in place and the existing gas distribution network-as well as its competitive price-put it firmly in the lead for overall fit with the NEU System. Other advantages include its potential to be produced locally and its overall ease of use.

> *"There is no bad technology, just bad applications."*
>
> Interview Participant, June 2020

Availability was repeatedly noted as an issue for RNG in BC, a matter that the NEU is already familiar with following Fortis' inability to fulfil its contracted amount of RNG in 2019 (which lead to a dip in the NEU's environmental performance that year). However, RNG is an emerging renewable in Vancouver and this trend seems set to continue, partly in response to increased demand from customers. Reflective of this demand, Fortis is aiming for to supply 15% of its energy gas from renewable sources by 2030. As such, Fortis is actively trying to increase its access to RNG.[28] For example, in April 2020, Fortis announced it was teaming up with REN Energy International Corporation, based in Fruitvale, BC to create RNG from wood waste.

The City of Vancouver has also recently partnered with Fortis to recover methane from the Vancouver Landfill. Scheduled to come online in year 2022, this project would recover between 200,000-250,000 GJ (56,000-69,000 MWh) of RNG each year. As part of this partnership, the City has secured a right of first refusal on RNG produced, which is sufficient to cover the approximately 130,000 GJ (37,000 MWh) of conventional gas forecast to be needed in 2030 to allow the NEU to go from 70% to 100% renewable.

1.2 Electric Boilers

Electric Boilers ranked 2nd in the expert interviews. Their status as a relatively well-established technology and ease of use contributed to their popularity among participants. In addition- similar to gas boilers- they have a relatively low capital cost, which is an important consideration for a piece of equipment that will have limited utilization. The downside of this technology is that while more efficient then gas boilers, the ~100% efficiency of electric boilers is low compared to heat pumps. This results in higher operating costs and with the current BC Hydro rate structure, utilities are penalized for having a "peaky" system through a monthly demand charge.

From an environmental standpoint, BC has a fairly unique advantage with regards electric boilers, as electricity supplied from the grid is already mostly renewable (roughly 95%). However, the potential for increasing electricity costs as other areas of society continue to electrify must be taken into account when the in-depth cost-benefit analysis of this technology is carried out.

BC Hydro is currently conducting phase 2 of the Comprehensive Review of BC Hydro. Included in this review is the potential for optional rate designs to encourage the shift away from fossil fuels. As part of this process, the City has formally requested that a rate offering be considered to support fuel switching in the district energy context. Consideration for a time-of-use rate offer has also been requested. Under this scenario, electric boilers could pair well with thermal storage where the storage tanks could be charged during off-peak times and deployed as needed.

[28] Fortis, "Meet our Renewable Natural Gas suppliers" Fortis online: https://www.fortisbc.com/services/sustainable-energy-options/renewable-natural-gas/meet-our-renewable-natural-gas-suppliers

1.3 Thermal Storage

Thermal Storage was also considered an attractive option for the NEU system, ranking 3rd. Perhaps the most innovative option of the three, thermal storage is a technology that has been making rapid improvements in recent years as industry has realized its potential to 'shave the peak'. Peak shaving refers to the practice of storing thermal energy during off-peak times to be deployed during future peak times (in the short term). By shifting peak demand in this way, the system requires less energy to be produced to meet peak demand, instead relying on stored excess energy from times of lower demand.

Since thermal storage is not a means of producing energy in and of itself, it must be combined with another technology with excess production in order to function effectively. This could make thermal storage an attractive option for coupling with an increased baseload for the NEU, allowing for better utilization of the baseload equipment and minimizing reliance on RNG for peaks. For biomass boilers, in which challenges with quick starting and stopping were flagged, thermal storage could be deployed to enable more steady operation. Likewise, with electric boilers, thermal storage could be used to allow for a steadier output which would be advantageous by reducing peak demand charges.

In order to determine the viability of thermal storage for the NEU, the potential load profile of the system must be understood and modelled in detail, as short-term storage is generally only available for use in the near term (maximum of a few days, depending on the system). The Stanford Energy System Innovation (see Table 2) has integrated thermal heating and cooling storage into its district energy system. Coupled with smart technology (see below), the system "*incorporates model predictive control to look at least 168 hours (seven days so as to always include weekends) into the future at any given time to predict hourly system energy loads and grid electricity prices and then produce the optimal hourly dispatch plan for the central energy facility over that period to meet projected loads at the lowest possible cost*." [29]

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[29] Stagner, Joseph *supra note* 17

Project Specific Recommendations

1. ***Utilize waste heat opportunities available through the expansion of the system to meet growing baseload demands:***
    a. Conduct a detailed inventory of waste heat opportunities in the NEU service area
    b. Given the magnitude of energy available at the 8th avenue sewer interceptor, key in on this opportunity early for further analysis
    c. Bring the waste heat to the NEU service area by exploring City policy tools that could be used to attract waste heat producers like data centres to the area

2. ***Prioritize RNG, electric boilers, and thermal storage for addressing peak demand:***
    a. The biggest barrier for RNG is around availability/security of supply. With upcoming City access to large volumes of RNG through the landfill gas project, securing this RNG for NEU use should be a priority
    b. Keep a close watch on the outcomes of the BC Hydro Phase 2 Review as this may enable more cost-effective use of electric boilers
    c. Explore the use of thermal storage to optimize utilization of baseload technology and to potentially pair with biomass or electric boilers to improve their effectiveness for meeting peak demands.

3. ***Explore options for demand-side management***: conduct a study of possible demand-side response approaches to determine if there are measures that can be taken to help reduce or shift the peak. This should include looking at existing system data to evaluate the effectiveness of in-building thermal storage on reducing domestic hot-water peaks.

4. ***Follow emerging trends:*** Following the development of emerging trends (see below) as studies are carried out for the NEU is the best way to ensure future proofing of the final choice.

Other recommendations

Projects to watch: Helsinki Energy Challenge, Finland

The city of Helsinki is in the midst of a design competition to decarbonize its energy supply. As part of a move towards a carbon neutral Helsinki by 2035, the city is looking for innovative ways to eliminate emissions from heating, which- similar to Vancouver- currently accounts for a large percentage of its overall emissions. Aside from the obvious climate benefits, to provide some added context to this move, the government of Finland has mandated that from May 2029 there can be no coal in energy production in the country. Currently, 53% of urban heating in Helsinki is coal.

> *"How can we decarbonize the heating of Helsinki, using as little biomass as possible?"*
>
> Helsinki Energy Challenge

The competition

The city has invited participants to submit designs to answer the question: "*How can we decarbonize the heating of Helsinki, using as little biomass as possible?"*[30] The prize fund is 1 million Euro. The city wants to use Helsinki as a "test bed", with the possibility of scaling up results for other cities around the world. As such, the city has committed to share the results of the competition globally. Interestingly, the city has explicitly stipulated their desire to steer away from biomass solutions. Recognizing that though other Nordic countries have successfully decarbonized their energy systems in this way, it is not possible for all cities to sustainably decarbonize using biomass. As was noted by some of the interviewees to this project, the city has also expressly acknowledged its debated carbon impact. The Helsinki Energy Challenge is therefore specifically targeting wide-ranging implementable designs. This makes the project particularly interesting to watch, given the opposition to biomass that the NEU has previously experienced.

Timeline

The competition is currently underway, with a number of webinars and events taking place over the course of the next few months. Applications are due at the end of September, with finalist teams to be selected by early November 2020. The winner will be selected by February 2021.

[30] "Helsinki Energy Challenge" accessed at: https://energychallenge.hel.fi/

Emerging Trends

Smart technology

Following on from the trend in electricity supply (where smart tech has been identified as critical to optimal functioning of the grid as society continues towards electrification), smart technology in district heating is beginning to gain traction in Europe. Smart technology refers to technologies (including products and services) that increase the 'communication' between electricity producers and end users, providing benefits such as better matching of supply and demand in energy consumption For the most part, the technology is still in the relatively early stages, and focussed on systems which integrate both electricity and heating. However, its potential for heating-only systems has also been recognized. As with thermal storage, this technology is a means of managing energy produced, as opposed to a form of energy production. The technology can therefore be an 'added extra' of the wider district heating network. The European experience suggests that the usefulness of this technology increases as the system grows in size and multiple different renewables are integrated, as demonstrated by larger systems such as those found in Grenoble, France and Brandenburg town in Germany (see Table 2).

UBC has recently implemented a district energy management platform (TERMIS) which allows for enhanced system optimization based on real-time measured and predictive system temperature and pressure data. System controls can be programmed to prioritize environmental performance and energy cost. Following up with UBC to learn about their experience with this smart technology is recommended.

Demand-side response

Similar to smart technology, some system designers have begun to focus on demand-side flexibility and as a means of shaving the peak. Exploring ways in which end-users' demand can be staggered or varied can lessen the burden on the system during peak hours and was highlighted by at least one interviewee as worth exploring as possible "low hanging fruit".

Low temperature heat systems (50-60°C range)

Particularly identified as part of the move towards 'fourth generation' district energy systems, low temperature district heating is designed to provide efficient, environmentally friendly and cost-effective supply by lowering the temperature of heating supplied within the system.[31] Its

[31] For more on this, see International Energy Agency, "Annex TS1: Low Temperature District Heating for Future energy Systems" 2017. Schmidt, Dietrich & Kallert, Anna (eds), accessed at https://www.euroheat.org/wp-content/uploads/2017/12/IEA-Annex-TS1-Final-Report.pdf

compatibility with the NEU as a means of reaping the benefits of energy efficiency is worth exploring, particularly in new expansion nodes of the system such as NEFC and the Innovation Hub.

Electrolysis and the hydrogen economy

The possibility of using hydrogen to fuel our heating needs is gaining traction worldwide, particularly in Europe. Though it is a technology that has been discussed for several years, there are now a number of studies underway and a renewed interest in its potential as an energy source, particularly in the form of green hydrogen. Green hydrogen is created with power-to-gas technology, using electricity and water via a process called electrolysis. Increasingly, developers are looking to the possibility of using renewables to drive this process, resulting in low carbon energy in the form of hydrogen, that has the added benefit that it can be stored. Another advantage of hydrogen is its potential to be used in existing infrastructure, as demonstrated by recent studies such as that in Leeds, UK.[32]

Leading Policy

Perhaps not strictly an "emerging trend", the importance of effective policy is increasingly being recognised as critical for encouraging the behaviours needed from industry to make decarbonisation decisions. Cities such as Stockholm in Sweden (see Table 2) have been innovative in their policy design as a means of attracting data centres to connect to their district heating and cooling network. Using a patented business model (Open District Heating™) the Swedish policy seeks to attract large energy users (over 10MW) by offering free cooling for the facility for free in exchange for their excess heat.

[32] Clark, Stuart, "Is hydrogen the solution to net-zero home heating?" March 21 2020, the Guardian online: https://www.theguardian.com/science/2020/mar/21/is-hydrogen-the-solution-to-net-zero-home-heating

Limitations of Research

1. Although interviews were conducted with 11 experts, some participants chose not to answer question 4. Whilst acknowledging the effect that this may have had in skewing the results slightly for this question, a decision was made that the data was still valuable and worthwhile.
2. This project took place during the COVID-19 pandemic. Unfortunately, this meant that the original contracted hours had to be scaled back and the project outline adjusted accordingly. I am grateful to the NEU team (in particular Derek) who worked hard to ensure the remote working situation did not affect the study (as far as possible).

Concluding remarks

The process of compiling this report confirmed that though there are emerging and improving district heating technologies, there is no "silver bullet" when it comes to decarbonizing district energy. Thus, understanding the immediate factors affecting the system such as access to resource and locality is critical in selecting an appropriate technology or technologies to move forward with. Understanding these factors in light of the emerging trends highlighted in this report such as smart technology and leading policy provides added opportunity for efficiency. The pace of change in the renewable world is fast, and it is likely to increase as countries take their Paris commitments more seriously. Interest in district heating is also likely to increase over the next ten years through to 2030, as fourth generation systems become more well established. Just as it has to date, the NEU has the opportunity shine as a flagship system to inspire other cities in BC and beyond to reap the benefits of a centralized heating system.

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Appendix A Copy of email sent to Expert Panel

Overview

As a brief overview, the False Creek Neighbourhood Energy Utility (NEU) provides low-carbon heat and hot water to buildings in the False Creek area through the recycling of sewage waste heat and the use of renewable natural gas. This results in a substantial reduction of greenhouse gas emissions from the building sector compared with traditional methods for providing building heating and hot water.

The NEU currently operates with a target for 70% of its energy to be supplied from renewable sources. In alignment with the Climate Emergency Response report approved by Council in April 2019, the NEU will be transitioning to 100% renewable energy before 2030. This will allow the NEU to deliver near-zero emissions energy to all buildings served by the system.

The objective for my time with City of Vancouver is to identify, assess, and evaluate options for increasing the NEU's renewable energy supply to 100%. The questions below are intended to give you a steer on the sorts of issues we have been considering, but please feel free to mention anything else that you feel we should address.

Interview Questions

1.4 What is your experience with district energy systems?

1.5 What technologies have you found to be most effective in decarbonizing district energy, and why?

a) How did cost considerations influence the selection of technology?

b) How did access to the energy source influence the selection of technology?

1.6 One of the biggest challenges we've identified is meeting the peak demands (daily and seasonal) with renewables in a cost-effective way. What methods have you seen for meeting peak demand in district energy? What renewable technologies do you think would be most cost effective for meeting peak demand?

1.7 Below I have set out some of the potential technologies that we have identified for the NEU project and our 100% renewable target. Based on your experience and knowledge of the NEU project, please rank the technologies listed in order of which you consider to be most to least viable (technologically and financially) for providing baseload and peaking energy (5 being most viable):

Technology	Base load	Peak load	Comments (justification)
	Score [1 – 5, 5 being high]		
Sewage heat recovery			
Waste heat from data centres/ cooling			
Air-source heat pumps			
Ocean heat recovery			
Renewable Natural Gas			
Electric boilers			
Biomass			
Electrolysis (hydrogen)			
Thermal Storage			
Other Geo-exchange			

1.8 Are there any other technologies you think we should consider or other comments you would like to make with regards the NEU project?

1.9 Are there any studies, reports, or existing systems that you would recommend we explore as part of this study?

Please let me know if there is any more information that you need, or if you have any questions or concerns. Otherwise I shall look forward to connecting with you to arrange a convenient time for an interview.

Alternatively, if you would prefer to email me with your responses, please just let me know.

Best regards

Alex

Appendix B Accelerated Action No. 8

Category		Accelerated Action		How this Action Reduces Carbon Pollution	New Action vs. Next Step	Next Milestone	Department Lead(s)
6	Neighbourhood Energy Transition the City-owned Neighbourhood Energy Utility to 100% renewable energy and expand the system.	a.	**Renewable Energy Supply:** Transition the Neighbourhood Energy Utility (NEU) to 100% renewable energy before 2030. This could include a mix of expanded sewer heat recovery, waste heat recovered from data centres, thermal energy storage, bio-fuels (e.g., renewable natural gas), hydrogen, or other renewable energy sources. Currently, 70% of the NEU's energy comes from renewable sources, and opportunity exists to transition to a higher blend of renewable energy in future years.	By transitioning to 100% renewable energy, NEU-connected buildings will not need to rely on fossil-based natural gas for space and water heating. Factoring in the long-term growth of the utility, transitioning to a 100% renewable energy target could eliminate an additional ~10,000 tonnes of CO2 per year by the mid 2030s, above and beyond the current 70% renewable energy target for the NEU (current 70% target would net ~24,000 tonnes per year reduction at build-out of the customer base).	Next Step	Adoption of 2030 100% renewable target subject to evaluation using the NEU's existing investment decision framework and competitivenes s with other low carbon energy options for buildings	ENG
		b.	**Expand Service Area:** Evaluate feasibility for expansion of the City-owned NEU service area. Opportunity areas include areas of the Central Broadway Corridor adjacent to SE False Creek, Jericho Lands and False Creek South.	To be determined, following establishment of proposed land uses and densities for these areas (needed to inform business case analysis for expansion).	Next Step	Report back to Council in 2021 (timing dependent on timing of area plan completion).	ENG