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DH AND COOLING

FINAL PROJECT REPORT

SOCIAL SUSTAINABILITY IN THE CONTEXT OF DH BUSINESS MODELS

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1 Executive Summary

District Heating (DH) is a technology used for providing heat and hot water to buildings. The installations are large infrastructure investments composed of heat generation and distribution network. The business logic is based on economy of scale and the systems are often very cost efficient. Depending on the way that heat is generated the solution can also be sustainable (combustion of non-fossil fuels or other renewable heat sources). In sum, the sector can have both strong economic and environmental sustainability features. As a result of increasing fuel prices in combination with uncertainty about what is considered sustainable in the future the sector is challenged. Direct competition from other heating alternatives such as heat pumps are adding to the challenged situation. In a challenged situation it is important to capitalize on all values that can be offered to customers leading to the objective of this project; namely to understand if the social dimension of sustainability can change the business models of DH companies and increase their competitiveness.

A team composed by one university, one research institute, one industry association and a DH project under development has engaged in understanding possible social values in the DH business context. To do so, value chain analyses were made on DH in three DH markets (Sweden, Denmark and Belgium) and for the case study located in Burnaby, Canada. Additionally, literature screenings were performed and social key performance indicators (SKPIs) that can be of relevance to DH companies were identified. Together with factors of relevance for social value creation in DH value chains, the potential SKPIs were condensed into an interview guide applied to stakeholders in the context of the forming DH facility. 28 interviews were performed with stakeholders surrounding the case study. Based on the literature screenings, value chain analyses and interview results information were collected and used to build a social layer for a DH business model canvas. Also, a comparative analysis of different heat supply alternatives and social value creation (gas, electricity and DH) was made.

Results show that social values beyond expected ones (Environmental, Social, Governance (ESG) values) exist in the DH context. They are however, not capitalized on to any large extent in the case study. When explored, social values allow DH companies to anchor to the local community and thereby increase their competitiveness compared to alternatives. To engage in social value creation a systematic approach can be applied across the value chain and the local ecosystem of stakeholders are screened. Thereafter, first actions can be taken to harvest the social values one by one eventually setting the new, company culture. Social value creation adds to and alters current business practice and logic. Hence, it is likely that management support is needed to ensure inclusion of social values into the DH business.

Content

2 Introduction

First, District Heating and challenges facing the sector are introduced (2.1) providing the background to the project. The objective of the project is introduced and the project setup is presented (2.2).

2.1 Background and Objective of Study

District Heating (DH) is a technology used to provide heat and hot water to buildings. In conventional systems, the heat is generated in a central unit from where it is distributed to buildings. At building level, the heat is switched over to the water based, building level system. The water in the DH network is thereby cooled and returned to be reheated at the central unit. Depending on the heat source, the system can be associated with a larger or smaller impact on local emissions. The conventional DH systems have an average supply temperature of 86°C (Werner & Fredriksen, 2013). The dominant business logic in such systems is one of economy of scale (Lygnerud & etal, 2023) which means that the cost of generating another unit of heat should be as low as possible. The conventional district systems have developed over long periods of time (from the first, steam-based installations in late 1880s) and have over time optimized their processes. As a result, DH assets are cost efficient, or put differently, are strong at economic sustainability. As a result of the oil crises (1980s) and later the awareness about the climate crisis (2000s) a shift is ongoing in the conventional systems where fossil heat sources are replaced by sustainable alternatives (an example is the phaseout of oil and gas in favor of renewables). The systems are increasingly green, or put differently, are strengthening their environmental sustainability. In sum, the conventional DH customer value is heat and hot water at a competitive price and (increasingly) from a sustainable heat supply (Ibid).

The conventional DH technology is under development. A shift away from one, central heat supplying heat unit towards using a multitude of heat sources in the same grid, is detectable (Lygnerud & etal, 2022),(Lygnerud & Werner, 2021). Such heat sources can be waste heat from different activities, renewables (notably geothermal and solar thermal) and ambient energy (found in water and air for example) and the need for combustion technologies is limited. The heat sources are often combined with different storage solutions and a prerequisite is an ability to make use of the most cost-efficient heat source when it is available (e.g. smart systems). In such systems, the distribution temperatures are lower than in the conventional systems. Low temperature DH systems have been defined to have an average, annual supply temperature of 70°C (Ibid). The dominant business logic in such systems is one of economy of scope (efficiency by variety rather than by scale (Sakhartov, 2017)). The DH customer value is a cost competitive and environmentally sustainable heating solution based on local heat sources (both economic and environmental values). Both heat suppliers and customers are key partners in the business models. Customers can be "prosumers" that both use heat and provide waste heat to the system or "flexumers" that can support the DH system by allowing it to use thermal inertia in buildings as extra storage capacity.

There are elements of social sustainability in the context of conventional DH operations. Such are good employment conditions, generation of local jobs and supporting selected community activities. These elements are amplified in the context of the new DH technology stemming from the local connection like the explicit use of local heat sources and customer engagement.

Conventional DH systems are experiencing increasing pressure on the economic sustainability aspect. Short term, increasing fuel prices are problematic, also there is increasing demand from other heating alternatives. Long term, shifting perceptions on what a sustainable heat supply is are challenges. When Russia's aggression on Ukraine was initiated, the price on oil, gas and biomass in Europe increased rapidly making it difficult for DH companies to maintain competitive prices. Additionally, rapid shifts were promoted to ensure a reduced need of gas imports further supporting introduction of individual heating alternatives such as heat pumps. In combination with the long-term ambition of the EU to be a climate neutral continent by 2050, the phaseout of fossils and possibly also biomass is desirable (burning biomass should be the last resort according to the EU Taxonomy). The short- and long-term challenges are triggering DH development, and the sector needs to fully explore the values it can propose to customers. In both conventional DH and new DH applications, the economic sustainability is pronounced, and the environmental sustainability aspect is strengthening. However, the social dimension is less explored. **The principal objective of the project is to understand if the social dimension of sustainability can change the business models of DH companies and increase their competitiveness.**

2.2 Description of Project

The project is based on the idea to understand if social values can be generated in a conventional DH value chain. And, if so, understand how such values can strengthen the competitiveness of the conventional DH business model. The project was composed of 4 partners where 2 came from mature DH markets (Sweden and Denmark) and 2 came from new DH markets (Belgium and Canada). From Sweden, the partner was a University (the University of Lund) with experience in DH business model development linked to the new DH technology and shifting customer demands. In Denmark, the partner was an industry organization (the Danish Board of DH) with many member organizations: linking the project to the latest developments in the Danish DH community. In Belgium, the partner was a research institute (VITO: Flemish Institute for Technological Research). Belgium has got a scattered DH development with some old installations and a current expansion. VITO is experienced with DH installations in Belgium and have followed their development over time making them an important partner to understand how a market such as the Belgian is developing. In Canada, the partner was a city (the City of Burnaby) about to invest in a DH system to recover waste heat from an existing waste combustion unit located in Metro Vancouver, British Columbia[1]. The system will be commissioned in 2026-27. Canada is a DH market that similarly, to Belgium has older installations (both high and low temperature) and that is currently experiencing a DH expansion. The City of Burnaby allowed the research team to identify social sustainability values linked to a case study on a DH under development.

A combination of methods has been applied to understand social sustainability in the context of the DH business model: value chain analyses of DH in Sweden, Denmark and Belgium and for the case in Burnaby, literature screenings leading up to an interview guide applied to the

[1]When the project was awarded, the Canadian partner was a DH company in Metro Vancouver named Lonsdale Energy. However, some months into the project there was a change of staff and orientation in the company. As a result, a replacement partner was needed, identified by the project and accepted by the IEA-DHC Executive Committee.

case of Burnaby. The project started in October 2023 and was finalized in October 2025. It has generated one video about the project, 2 podcasts on project results, two publications in the HOT COOL Magazine, a final report and a peer-reviewed, scientifical article (more information is found here: https://dbdh.org/can-a-sustainable-dh-business-model-be-decisive-for-future-competitiveness/).

3 Method

Social sustainability impact on business model competitiveness is an unexplored field of research. The process of research was therefore explorative. It means that the research was started off by certain steps outlined in the proposal and complemented by additional actions to bridge gaps in the initially foreseen process of research. The foreseen process encompassed four steps where a value chain analysis was first. Next was literature screening, followed by interviews and the final step of understanding the social sustainability impact on DH business models The literature screening was deepened by a study of social key performance indicators: an iteration not foreseen in the initial process.

The value chain analysis was performed to identify activities undertaken by DH companies in Sweden, Denmark, Belgium (generic, country level) and at the case company in Canada (specific, local level). To understand what parts of the value chain support different aspects of sustainability, the identified chains were analysed from the point of view of environmental, economic and social sustainability (3.1). The literature screening was initially foreseen to screen literature on what a sustainable and socially sustainable business model are. However, after conducting these first, and foreseen steps (Q1 of 2024) the team identified that there was literature on different kinds of key performance metrics in business models. Hence, an extended literature screening on social key performance indicators (SKPIS) of relevance to DH activities was performed (early Q2 2024), (3.2). Having identified potentially relevant SKPIS, the team went back to the initial value chain analysis and reviewed the activities undertaken in DH companies from the point of view of economic, environmental and social sustainability. Factors that can be of relevance to social value creation in the DH business model were identified (mid Q2, 2024). The value chain analysis and the identification of relevant factors for social value creation were validated by district energy professionals in Sweden, Denmark, Belgium and by the case company in Canada. Based on the identified factors, an interview guide was established and relevant respondents, linked to the case study, were identified and contacted (late Q2, 2024). Thereafter the process of research unfolded as originally intended with interviews being prepared in Q3 and executed in Q4 of 20204 (3.3). During Q1 and Q2 of 2025, analysis was made on the social impact on the competitiveness of the DH business model (based on the insights from the value chain analysis, literature reviews and the interviews jointly), (3.4).

The process of research is outlined in figure 1.

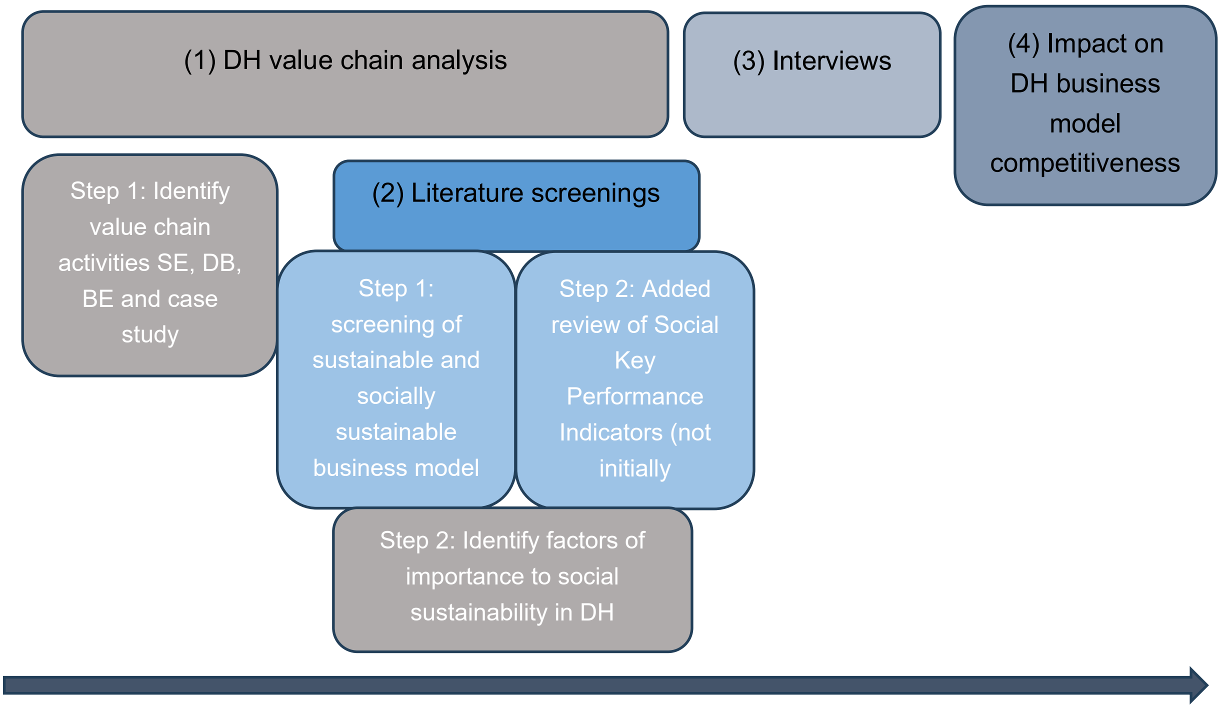

Figure 1: The process of research

The steps of the process are presented in turn (3.1-3.4) and the details of the case study are introduced (3.5).

3.1 Value Chain Analysis

The value chain analysis was aimed at identifying where in the value chains social sustainability values are included or could be included. A generic value chain analysis of DH in mature markets (Sweden (SE) and Denmark (DK)) and in one small but expanding market (Belgium (BE)) was made. Thereto, a value chain analysis of the case company was performed.

First, the generic value chains of DH companies in Sweden, Denmark and Belgium and the value chain of the case company were identified. Doing so, an answer was obtained to whether the national, generic value chains and the value chain of the case company differed. Illustrating activities in the format of value chains was first presented in (Porter.M, 1985). A logic for addressing the value that customers perceive a product or service to was introduced (Ibid). The logic is that value activities unfold in steps building up to so called value chains. The value accumulates per step in the chain. The generic value chain encompasses value adding activities. A distinction is made between primary and supporting value activities. By nature, the two kinds of activities differ. Primary value activities are needed to make the product (inbound logistics, operations, outbound logistics, marketing and sales and services) whereas supporting value activities (firm infrastructure, human resource management, technology development and procurement) are needed to make the cycle from production to sales work. Value chains do not exist in isolation but are embedded in value systems consisting of a multitude of value chains up and down stream. A generic value chain is illustrated in Figure 2.

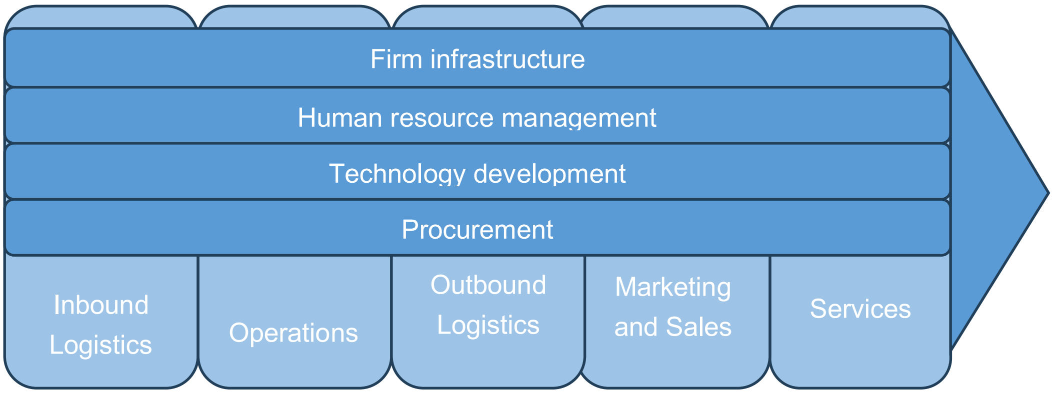

Figure 2: An illustration of a generic value chain (Lygnerud.K, 2006)

Desktop review and validation by the DH community were combined to arrive at representative value chains for DH for the three countries. Each step of the value chain (inbound logistics, operations, outbound logistics, marketing and sales and services) was analyzed from the point of view of factors that can impact the environmental, economic and social sustainability of the DH companies. In Sweden, for validation, the identified value chain was discussed with five representatives from DH companies (three CEOs and two strategy developers) and by one academic representative (professor at Chalmers University of Technology). In Denmark, the identified value chain was discussed with members (DH companies) of the Danish Board of DH. In Belgium, the identified value chain was validated by a researcher in the field of DH working at the research institute VITO. For Canada, the value chain was identified together with the City of Burnaby (in a dedicated digital workshop lasting for two hours). When the value chain analyses were validated, the project team met for two digital workshops (two hours per workshop) to discuss differences and similarities of the value chains of the countries. The main conclusion was that the value chain configurations of DH activity was similar in both mature (Sweden, Denmark) and maturing (Belgium) DH markets. The value chain of the case study was also similar to that of Sweden, Denmark and Belgium.

Next, the literature screenings were performed (3.2). Based on results from them, the value chains were revisited and factors of relevance to generated social values in the value chains were identified. A SWOT analysis[2] was made on the factors for each step of the value chains to understand where factors with a social sustainability value reside (one web-based meeting lasting for 3 hours with the research team). The factors were used to build the interview guide (3.3).

3.2 Literature Screenings

When the value chain analysis was complete, the first literature screening was performed to understand what sustainable and socially sustainable business models are. The intent of the screening was to provide an orientation on what a socially sustainable business model is, but not to make an exhaustive review (for time and budget constraints). The point of departure was previous work and literature review of what a business model is (Lygnerud & etal, 2023). screening on social sustainability in the business model context was performed by reviewing articles in the multi-disciplinary database Scopus. Literature on sustainable business models is contemporary and 10 years cut-off for the analysis (2014-2024) was undertaken, the study was performed in the first two quarters of 2024. Different search strings were combined where “sustainable business model” resulted in 19 522 hits. Thereafter, the search string was refined to “socially sustainable business model” and 429 articles were identified. The search was then further refined by including the word of energy: “energy, socially, sustainable, business model”.

[2] A SWOT is a strategic planning framework allowing to identify what aspects an organization has the possibility to impact itself (internal aspects) and what aspects are not impactable (external aspects).

It amounted to 58 papers. When replacing energy with DH: "DH, socially, sustainable, business model" 2 papers were found.

For each search, the 10 most recent publications per search[3]. In the searches, there were 4 duplicates. Based on these first insights, relevant references were found in the papers and were followed to find additional references of relevance (results presented in section 4).

As mentioned, after the first literature screening, the research team identified a need to investigate literature on Social Key Performance Indicators. A recent review article was found in which social sustainability research in the context of energy had been performed (Afshari et al. 2022). The team used this article as a point of departure for their SKPI screening and resorted to references in it to understand if there were SKPIs of relevance to DH (results presented om section 4).

3.3 Interviews

To understand details on how social sustainability values could be generated in the context of the Canadian case study, an interview study was performed. An interview guide was built, validated and used to collect data. The guide was built around factors of importance identified through the value chain analyses and the literature screenings. The guide was validated on two people from the City of Burnaby and from the organization Metro Vancouver. Metro Vancouver is working across the larger Vancouver area and therefore has knowledge about the DH developments in the area. The test interviews allowed to identify a correct level of detail

[3] (Lutkovska & etal, 2024), (Vitalii & etal, 2024) (Sestino & Nasta, 2024) (Zadorozhnyy & etal, 2024), (Maksymiv & etal, 2024), (Gherbi & etal, 2024), (Affan & etal, 2024), (Waraporn & etal, 2024), (Voronkova & etal, 2024), (Chiangnangam & etal, 2024), (Bezdushna & etal, 2024), (Surenthran & etal, 2024), (Musostova & etal, 20204), (Raihan, 2024), (Correia & etal, 2024), (Gautam, 2024), (Pimenow & etal, 2024), (Gultekin & etal, 2024), (Kodym, 2024), (Usanova & etal), (Jarrah & etal, 2024), (Sharma & etal, 2024), (Radulescu & etal, 2024), (Westin & etal, 2024), (Sharma & etal, 2024), (Nitsdenko & etal, 2024), and the two papers related to DH (Auvinen & al., 2024) and (Heperkan & etal, 2022)

and technical content in the questions. One person from the case company supported the development process by being test interviewed twice. Once with the first interview guide and once with the final interview guide.

The guide was composed of one open and one guided part. The open part was developed to capture the respondent's perception of DH overall. The idea with the guided part was to capture as much input as possible on pre-defined, potential social sustainability value aspects that should be of relevance to the competitiveness of the DH business model. An illustration of the process of generating the interview guide is found in Figure 3.

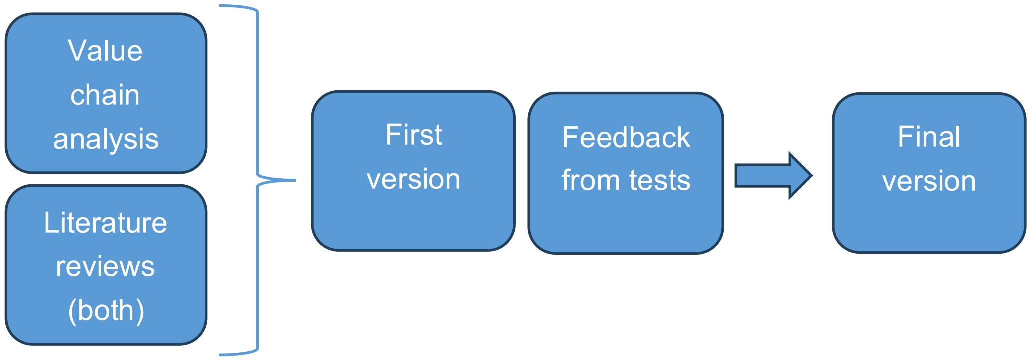

Figure 3: Iteration of interview guide

Social sustainability can add value in different ways to different stakeholders. For example, DH companies will have a direct impact on employees and customers but can also have an indirect impact on people in the neighborhood of the DH company (heavy traffic delivering fuels, noise) and on the people of the town (level of air pollution, access to sustainable energy, local jobs etc.). To ensure the identification of relevant stakeholders within the context of the case company, the City of Burnaby actively supported in defining appropriate stakeholders. The City of Burnaby also facilitated contact with key stakeholders deemed pertinent to the interview study. In- person interviews were conducted over the course of one week in October 2024. Together with the team working on the Burnaby DH project interviewees were identified for the following stakeholder groups:

- DH companies- often utilities- (key stakeholder)
- Burnaby DH team – (key stakeholder)
- Customers – (key stakeholder)

- Engineering companies - (stakeholder)
- Architects and developers - (stakeholder)
- Policy makers - (stakeholder)

Some stakeholders are directly impacted by the actions of the DH company whereas other are indirectly impacted, illustrated in the figure below. The DH company activity is at the center, it impacts different stakeholders to different extents where customers are directly impacted, and policy makers are indirectly impacted as two extremes on the impact scale.

In total, 28 interviews were performed and the number of respondents per stakeholder category is presented in table 1.

Table 1: The respondents, allocation across stakeholder groups

Stakeholder group	Number of respondents
1. DH companies (in Metro Vancouver)	7
2. Burnaby team	4
3. Policy makers and customers	10
4. Engineering companies	3
5. Architects and developers	4

The first group of stakeholders, DH companies, was comprised by interviewees from other, existing DH companies in the greater area of Vancouver. The second group, the Burnaby team, was comprised of two technical staff, the project lead and one person representing the perspective of the city in the project. The third group, the policy makers and customers, was comprised by several, different roles in the Burnaby municipality working with different questions such as energy safety, caretaking of the municipal building stock, city planning, interests of minority groups and other. To identify customers to interview proved to be a challenge, DH companies with existing DH activities in the area were not interested in engaging their customers in the study. However, we were able to secure one customer in an existing, other system than the Burnaby one, because of personal connections in the Burnaby team. The low level of customer input to the interview results is a shortcoming of the study and it should be noted that the results predominantly represent other perspectives than the customer one. The fourth group of stakeholders, engineering companies, was composed of representatives from engineering companies already working with DH installations around Vancouver and elsewhere. The fifth group was composed of one architect and three developers (some build and sell and some keep the buildings). Again, the low number of architects in this stakeholder group will lead to an overrepresentation of other stakeholder opinions in the results.

Each interview was summarized directly in the interview guide in conjunction to the interview being finalized. The interview notes were shared with the respondents by mail so that they could comment on any misunderstandings or overlooked information.

3.4 Social Value Impact on the DH Business Model

An analysis of how social values can impact the competitiveness of the business model of DH was undertaken. A relevant analytical framework containing the social value dimension is the triple layered business model canvas. It is a further-development of the original business model canvas that allows to visualize- in separate layers- the economic, environmental and social dimensions of the business model. The possibility to explicitly study the social sustainability value made us choose the triple layered business model canvas as analytical framework. The initial version of the canvas (Ostewalder.A & Pigneur.Y, 2010), was designed to highlight the key components necessary for delivering a commercially viable product or service. In it, three main areas are in focus.

- Four components focus on customer-related aspects, covering customer segments, distribution channels, customer relationships, and value propositions.
- Three components examine operational elements, including value delivery activities, required resources, and essential partnerships.
- The final two components detail the business's cost structure and revenue streams from realized sales.

The updated, triple layered version expanded this framework by incorporating environmental and social sustainability dimensions. The environmental analysis adopted a life cycle perspective, examining the product´s or service´s impact during production, usage, and post-use phases. Meanwhile, the social value dimension is focused on the organization's stakeholder and society impact, often aligning with company´s vision or mission (Joyce & Paquin, 2016).

In the environmental life cycle analysis of the business model canvas, the focus is on understanding how resources are sourced and utilized to create the product. It also emphasizes how residuals – such as waste, emissions, or by-products – are managed or disposed of. By examining the flow of materials across production, use, and post use phases, the analysis highlights how processes can lead to either positive or negative environmental impacts.

In the analysis of the social values, the focus shifts to the broader value an organization can create for customers and other stakeholders. In this version of the model, the customer is viewed as just one stakeholder among many. The analysis considers both internal actions – such as ensuring fair working conditions and cultivating a positive company culture – and external engagement with stakeholders in the local community and beyond. It assesses the reach of the organization's social value creation and highlights both the positive and negative impacts on social sustainability.

DH Both the economic and environmental layer of the DH conventional DH business model are known. They are presented in turn (3.4.1-2). Based on value chain analyses and interviews, the study identified what social values could be added to the social layer of the DH business model. The social layer is introduced in 3.4.3 and the results from applying it to the case company are presented in section 5.1. To further understand if social values can strengthen competitiveness, a comparison was made between different heat providing alternatives (results presented in section 5.2).

3.4.1 The Economic Layer

Since the Burnaby project did not have any ready business model to start from, the starting point of the business model analysis was a conventional business model canvas for DH:

reflecting the setup in mature DH markets. The business model canvas is displayed in Figure 8. More details can be found in the original work from Lygnerud, K (2018).

In it, the customer value is heat and hot water supply. The key customer segment is professional customers (large building owners), the customer relationship is at arm's length and limited. Key resources are the heat production units and the distribution network, with key activities being operations and maintenance. Key partnerships are entered with fuel providers. The cost structure is dominated by fixed costs, fuel costs and staff costs. Different price model structures exist, often they are composed of fixed and variable component/s (Ibid), (Lygnerud.K, 2018). The conventional, economic, business model characteristics are illustrated in Figure 4.

Key Partners	**Key Activities**	**Customer Value**	**Customer Relationships**	**Customer Segments**
Fuel providers	Operation and maintenance	Heat and hot water Security of supply, comfort, carefree at reasonable cost Green energy Efficient Carefree	Automated	Professional building owners Professional and private end-users
	Key Resources		**Customer Channel**	
	DHN Production unit Operations system Staff		Invoice Campaigns Webpage	

Cost Structure	**Revenue Streams**
Fixed costs (production unit and network) Staff Fuels	Customer sales

Figure 4: The economic layer of the DH business model (Source: Lygnerud 2018)

3.4.2 The Environmental Layer

The next layer in the triple layered business model canvas is the environmental. In it, a value chain logic can be identified where the inbound logistics are addressed under the headline of “Supplies and outsourcing”. Thereafter, what is called operations in the value chain context are labelled “Materials (materials used)” and “Production (production process)”. The outbound logistics of the value chain are referred to as “Distribution” and the customer use is referred to as “Use-Phase”. The value chain activities often entail some kind of activity to recycle materials, referred to as “End-of-life”. In the conventional business model canvas the customer value is referred to. In the environmental layer a functional value is referred to. It reflects the positive aspects of production (quality, function, durability), use (reliability, efficiency, performance, user friendliness) and post use (disposal of product). The activities undertaken generate positive or negative environmental impact. Putting the environmental layer on the conventional DH business model led to the following interpretation of each of the components of the environmental business model (it is also summarized in Figure 9).

Supplies and outsourcing: activities are undertaken to acquire heat sources (fuel trade and fuel acquisition of different kinds of fuels, renewables and waste heat). In some markets the heat supply is outsourced. One example is the DH system in Copenhagen where the heat is supplied into the grid by other operators than those owning the distribution system. A study on the future DH business model (Lygnerud & etal, 2023) indicated that in the future outsourcing might become more pronounced. For example, outsourcing storage functionality and operation & maintenance of digital tools for digitalization of DH systems (Ibid). Depending on how far fuels need to be transported there will be a higher or lower impact on the environment (locally available assets will leave a smaller imprint).

Materials: The materials used for producing heat and hot water are electricity (for pumping water), fuels (combusted or recovered by means of other machinery) and water[4].

Production process: A conventional setup has a central production unit/ place from where heat is distributed throughout the grid (using the media of water). Equipment used is either a heat generation unit (often a combined heat and power unit, or a heat boiler) or an equipment facilitating recovery of waste heat (with or without a combination of heat pump depending on the temperature of the heat source). In many systems there is a storage unit and assets for peak load usage. For customers that also provide heat to the DH system, investments are made in the heat recovery equipment. This investment can be undertaken by the DH company, the customer or jointly. Depending on the setup, there can be costs and environmental aspects to consider related to the equipment. Production necessitates forecasting, maintenance, monitoring, storage management (for flexibility). Worker safety is a key element. Depending on the fuels used, how well flue gases are cleaned etc. the impact on the environment will vary. There are some well-known residues to manage and those are different kinds of ashes, some can be returned to forestry whereas other ashes need to be deposited.

Distribution: Distribution of hot water necessitates pressure management, maintenance of pumping stations, ensuring efficiency by low return temperatures, forecasting and flexibility measures (for example shifting loads in buildings over time to benefit from the thermal inertia in them). Ensuring the right temperatures to avoid legionella is also an important activity. Maintenance and efficient distribution in the systems (avoiding pressure or temperature peaks, having the right quality of the DH water etc. minimizes the tear of the pipes). High quality pipes are important to avoid breakages that give rise to leaks and thereby excessive use of make-up water and heat losses. Worker safety is again a key element.

[4] Note that there is ample material going into the construction of a DH plant. Such decisions and impacts are already taken and have occurred when the business model for the ongoing operations are undertaken and therefore not considered in the analysis.

User Phase: For the customer, to get heat and hot water from DH system, the buildings are often equipped with a heat exchanger (shifting the heat over to the water-based system of the building) and with water-based radiator systems. Both substation and water-based radiator systems have a long operational life (20 years or more). The impact on the environment is large when the installation is made (metals and minerals are needed for the building level equipment) but is thereafter negligible for a long period of time. During the user phase electricity is used for pumping the water in the network, for the circulation pump in the building and for other uses, depending on the origins of the electricity the impact on the environment will vary.

End of life: The user does not need to dispose of any residual materials after having consumed the heat or the hot water. End of life of DH is therefore associated with a conversion of heating system (dismantling the radiators and the heat exchanger) in the customer buildings.

Functional value: The functional value can be split into production phase, user phase and end of life. The benefits of DH during the production phase are those of a system perspective allowing to use heat sources that would otherwise be lost in a cost-efficient way (allowing the system to have a very positive environmental impact if the right heat sources are resorted to). Once invested in the heat supply is durable and the quality of domestic hot water is legislated. The benefits of DH during the user phase are that it is reliable, efficient, carefree (the customer does not need to undertake much maintenance). The benefits of post use life are that there is nothing to dispose of for the customer after every use of heat and hot water.

Environmental impact: Seen from the activities outlined above, the heat source will have a large impact on the positive or negative impact of DH. In this study we looked at mature DH markets in Sweden and Denmark, those are markets with high shares of biomass as fuel. Given current regulations (EU Taxonomy for example), it is a sustainable heat source. Other sustainable heat sources come from renewables or waste heat. In DH water is used, maintenance and well-functioning pipelines are therefore important to reduce the waste of water and heat. From the ashes in the production, it is standard in mature markets to recover metals and to reuse it as fertilizer. A strong environmental benefit is that there is no residuals from the end use of heat and hot water for the customer. The origins of electricity will impact the environmental impact of DH. The environmental layer is summarized in Figure 5.

<table>
<tr>
<td rowspan="2">Supplies & Outsourcing
Fuel trade, acquisition
Future (?) outsource storage functions, digitalization</td>
<td>Production
Heat generation
Manage storages (flexibility)
Forecasting</td>
<td rowspan="2">Functional Value
<u>Production phase</u>
Depending on fuel: sustainable
Durable
High quality of drinking water
Use phase
Reliable
Efficient
Carefree</td>
<td>End-of -life
No residuals at end user from consuming heat and hot</td>
<td rowspan="2">User phase
Electricity is needed</td>
</tr>
<tr>
<td>Materials
Electricity
Fuels
Water</td>
<td>Distribution
Pressure management
Maintenance
Water quality</td>
</tr>
<tr>
<td colspan="5">Environmental impact drivers (positive or negative will depend on configuration of driver)
Fuel source
Electricity origins
Well-functioning pipelines
No residuals at end user</td>
</tr>
</table>

Figure 5: The environmental layer of the DH business model (Source: from this study)

3.4.3 The Social Layer

The point of departure for drafting the social sustainability layer of the DH business model has been a conventional DH configuration. Resorting to the information collected from the value chain analysis, literature screenings and interviews, potential social values that could be added to the DH business model have been identified.

Two of the components of the social business model layer of the canvas are inward looking: “Employees”, “Governance”. The first one addresses the elements of social values in the ESG values mentioned earlier in this study (working conditions, gender balance, diversity). The second one addresses the governance values of the ESG (structure, sustainable investments, company culture etc.). One component, “Societal culture” reflects the kind of societal culture that the company can contribute to build for the customer but also stakeholder beyond the customer and “the scale of outreach” indicates how widespread the societal culture is (across stakeholders and geographies). The social values generated for the customer are labelled “End user” and the engagement with local stakeholders “Local communities” reflects the social values generated for stakeholders beyond the customer. The “social value” are the social values that the company has on different stakeholders. The impacts of social values can be positive or negative addressed by “Social impacts” and “Social benefits”.

Putting the social layer on the conventional DH business model was done based on the inputs from the value chain analysis and interviews performed. The results are shown in section 5.1.

3.5 The Case Study

Case studies have the upside that deep analysis is possible whereas the possibility to generalize results is limited. However, case studies will provide information that other companies in the sector can learn from (referred to as critical case) (Flyvberg, 2006) which was the motivating factor for undertaking a case study. The case selected was the Burnaby municipality´s new DH system. It is situated within an emerging DH market (Canada). In Canada, low-carbon electricity and gas dominate the heat markets. Many of the DH systems are small and two-thirds are operated on university, government or military campuses. Most larger systems are older and operated with steam or high temperature water. Finally, the distances between waste heat sources such as the Alberta Industrial Heartland area near Edmonton and existing DH systems have tended to be too long for cost efficient solutions. A lack of a general DH infrastructure in Canada limits the opportunity for use of industrial waste heat. In sum, the market technically heterogenous since there are some conventional installations in parts of the country (around Toronto and at campus estates but also around the Metro Vancouver area) whereas there are low temperature installations (a known example is Drake’s landing) or very small systems in other parts (Lygnerud & Werner, 2021).

In British Columbia (where Vancouver is located), there has been an increase in DH system since 2008 following legislation requiring municipalities to undertake an inventory of greenhouse gas emissions, create a plan to reduce their levels and implement the plans. It has triggered interest in renewable energy including DH. The first installations were high temperature but increasing interest has been expressed in ambient heat recover from sewage water and boreholes (Ibid). Main competition to DH in Metro Vancouver is gas or direct electricity. There are also low temperature elements identifiable in most of the Metro

Vancouver systems as a result of the Olypic Village from 2010, resorting to energy from sewage water, something that has spread across the area. Canada has experienced severe heat waves in recent years, there is no national cooling mandate, rather provincial regulation is forming. In British Columbia, the 2024 Building Code requires all newly constructed homes to have a living space designed to prevent indoor temperatures for rising too high (Government & BC, 2024). To advance sustainable district energy systems, new solutions are needed. It was assumed that in a less mature DH market, the degree of freedom for identifying and including both new technical solutions and non-technical dimensions in the value creation is higher than in the mature markets. The case was chosen based on three criteria. First, the case needed to be situated in a DH market that was not yet mature. The heterogeneity of installations in Canada and the fragmented DH penetration in the market were qualifiers. Second, the DH system should still be in the planning phase, allowing the research team to engage early and contribute to discussions around alternative and desirable business model features. The district energy system of the City of Burnaby is not yet commissioned (foreseen for 2026-27). Third, the DH project had to demonstrate strong potential for both economic and environmental sustainability: such a system would enable the research team to shift their focus toward exploring the dimension of social sustainability, rather than concentrating on the already well-addressed economic and environmental aspects. According to the descriptions provided by the City of Burnaby their foreseen network was qualified on both items: the system is foreseen to provide heat at a cost competitive price and make use of the waste heat from the waste to energy plant in the Metro Vancouver area, operating 24/7 since 1988 (receives approximately 25% of the region's annual solid waste). Up to 100 MW of waste heat is accessible from the plant. The average designated DH supply temperature has been set to 90 degrees Celsius. Depending on demand rates, other sources can be added to the fuel supply over time.

An initial stretch of the network was planned, with the expectation that the system will gradually expand over time. Future developments include connecting to major institutions such as Burnaby hospital and the BC Institute of Technology. Once fully developed, the DH system is to supply heat to approximately 25 000 apartments and span a total length of around 11 km. In Figure 6, the first stretch between Metrotown and Edmonds is shown (7 km to Metrotown and 4 km to Edmonds).

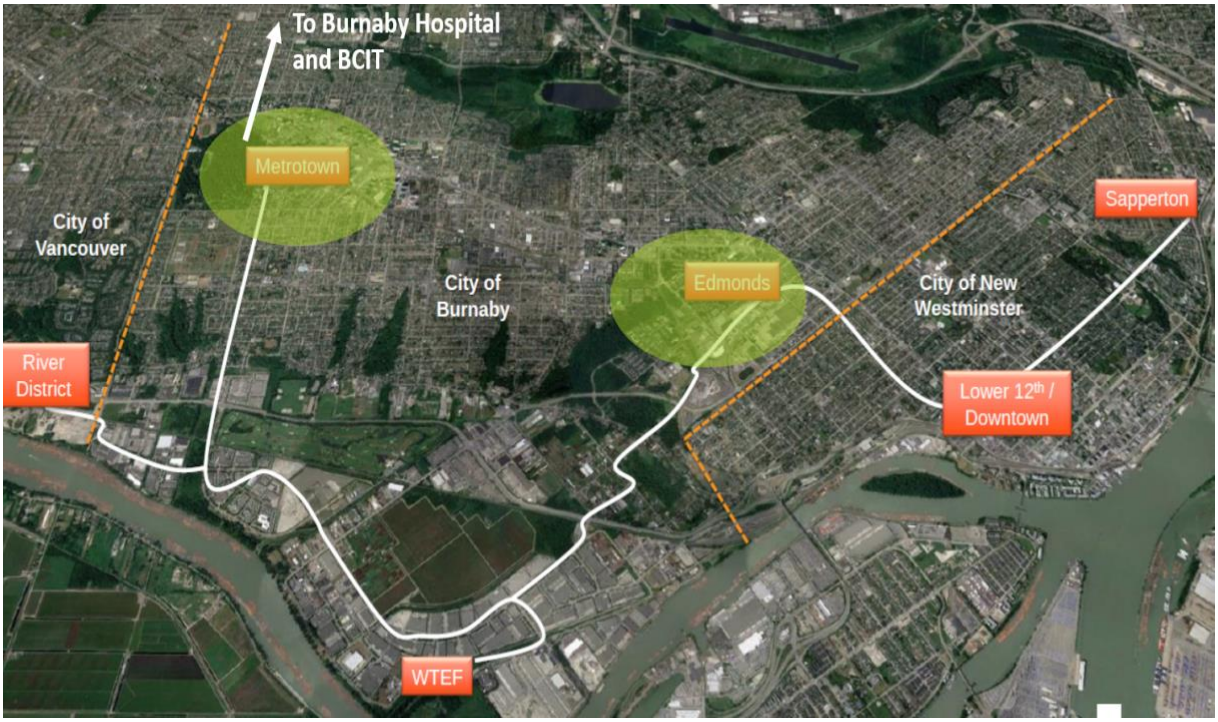

Figure 6: An illustration of the first stretch of the district energy system in the city of Burnaby, WTEF (Waste to Energy Facility) and BCIT (British Columbia Institute of Technology)

The system will be one of the largest DH networks in Canada, with the capacity to reduce carbon dioxide emissions by approximately 30,000 tons per year (by not resorting to the conventional gas boiler solution). For comparison, the City of Burnaby currently generates around 14,000 tons of CO_2 emissions annually for its municipal operations. This means that the DH system will offset more than twice the city´s operational emissions, representing a significant contribution to local climate goals.

It is foreseen, that the municipality will own and operates the district energy system. The waste to energy plant is operated by the regional government, Metro Vancouver, and access to the waste heat at a set rate is enabled via an energy access legal agreement. The investments undertaken to realize the network and the heat recovery will be borne by the Burnaby waste to energy district energy system, with the waste heat for the use in the Burnaby DH available at a reasonable charge. Analyses indicate that the DH price will be competitive compared to the other local alternatives (gas and electricity). Another, foreseen advantage is that the district energy price will be less volatile (short term) than alternative heat supplies of gas or electricity.

Currently the rate design is thought to be a variable pricing model. However, fixed and motivational components are being considered.

The case study is not foreseeing to provide domestic hot water (DHW), instead other solutions for DHW that are resorted to in the context of heat supply from gas or direct electricity will be resorted to. The reason is to avoid the matter of managing the aspect of Legionella.

4 Results

The results from the value chain analyses (generic information from Sweden, Denmark and Belgium and from the case company) are presented first (4.1). Next, results from the literature screenings are presented (4.2). Third, interview results from the case study are shown (4.3).

4.1 Value Chain Analysis

First, the value chains were identified. The analyses included two mature DH markets, Sweden and Denmark, a less mature market in Europe (Belgium) and the case study in Canada. Data were gathered through a combination of desk research on DH activities and direct dialogue with practitioners in the sector, who also helped to validate the identified generic value chains.

When the literature screenings were complete, the identified value chains were analyzed and factors of importance to economic, environmental or social sustainability were identified in the chains.

4.1.1 Generic Value Chain Features- Sweden, Denmark & Belgium

The characteristics of the value chain activities in Sweden, Denmark and Belgium are presented per value chain activity. The characteristics are summarized in Table 2.

A. Inbound Logistics

Inbound logistics refer to the materials and other goods coming into the company. In DH this relates to the acquisition of fuels. In Belgium, main fuels are gas and municipal waste. In Denmark, main fuels are municipal waste, gas and biomass and in Sweden municipal waste and biomass dominate. Also waste heat recovery from industries and urban infrastructure is well established in both Denmark and Sweden. In Denmark, geothermal energy is an emerging source, with several projects underway. In contrast, Sweden has faced challenges with geothermal development, as initial deep drilling efforts have proven difficult due to the need of very deep boreholes. In addition to fuels for heat generation, there is also an activity of green certificates and guarantees of origin ongoing for the purchase of electricity and renewable biogas.

B. Operations

Operations refer to the production of a product or service. In DH this relates to the generation of heat. In all countries, combined heat and power plants (CHPs) are common but boiler only systems exist too, especially in smaller thermal systems. To operate the plants, a number of activities are performed such as; pressure control, charge and discharge of storage units, management of central control rooms, maintenance of assets, reading of meters (done remotely) for invoicing, creation of forecasts, running production assets in the most flexible way (use the most cost efficient heat source at all times and match supply and demand) and when needed, start up and operation of peak load units.

C. Outbound logistics

Outbound logistics refer to the distribution of a product or service. In DH this relates to the distribution of heat from the heat production plant through the distribution grid to the customer and then returning the water that has cooled off to the production facility. To operate the network, several activities are performed such as pressure control, substation management (often the substations are, however, owned by the customers), connection of new customers, and managing DHW security by keeping the growth of Legionella bacteria in the DHW supply low.

D. Marketing and sales

Marketing and sales encompass activities aimed at creating awareness of a product or service and ultimately leading to a sale. Examples of such activities include advertising, promotion, and pricing. In the context of DH, these activities primarily involve customer service (often handling complaints) and issuing invoices. Additional activities can be found in the mature markets like Sweden and Denmark. These include marketing events such as site visits, “get rid of your old Christmas tree” campaigns, barbecues for customers and similar initiatives. Communication, which was previously limited to the webpage (unless you were a large, key account customer) is now growing in importance. This shift is leading to more direct dialogue with a wider range of customers. In Denmark, the transition away from gas for many households is driving the need for increased communication as is the prevalence of cooperatives owning the DH assets.

There is also an increasing communication with organizations that have waste heat that could be recovered in the DH systems in both Sweden and Denmark. In these markets co-creation with selected customers (often key accounts) is evident. The co-creation encompasses new solutions and new ways of doing business that generate win-win situations for both parties. In Sweden, where DH prices are not regulated, there is a voluntary outreach initiative called “the price dialogue” where customers are invited to discuss upcoming price changes with their DH companies.

E. Post sales activities

Services are considered part of after-sales-activities. In DH, this primarily involves operation and maintenance services. Additional service arrangements have also been introduced in Sweden and Denmark. Such can include options regarding ownership of substations, where the DH utility takes over the substation and leases it to customers. This approach allows for better control of the secondary system and can enhance overall system performance and customer experience. Other, win-win arrangements are emerging in the DH sector, where providing an optimal indoor climate to the customer represents the highest level of service. This approach emphasizes providing a functional outcome – comfort and control – rather than focusing on specific equipment or technical components. Such function-oriented services remain relatively rare in both Sweden and Denmark, but they signal a shift toward more customer-centric and performance-based offerings that enhance value and satisfaction. By doing so, the DH companies are offering more than heat and hot water.

Table 2: Generic, value chain characteristics based on review of Swedish, Danish & Belgian DH practice (there are some differences between the countries, highlighted in the text)

Inbound Logistics	**Operations**	**Outbound Logistics**	**Marketing & Sales**	**Post Sales Activities**
Fuel purchase *-Biomass* *-Waste* *-Waste heat* *-Biooil (peak)*	Heat generation *-Combined heat and power* *-Heat pumps* *-Heat only boilers*	Distribution and circulation of water *-Pressure management* *-Pumping stations* *-Maximized Δt*	Customer service	Different service arrangements *-From maintenance to win-win arrangements*
Fuel trade	Maintenance	Maintenance	Invoicing	Complaint management
	Flexibility & forecasting	Flexibility measures	Key account management	
	Control room	Connect & disconnect customers	Marketing	
	Remote reading	Legionella management	Communications	
	Storage management	Substation management	Co-creation (including waste heat dialogues)	
	Safety		Price dialogues	
			Interaction with city heat planning	

The research team found that the structure of the DH value chain is similar across the three countries. Interestingly, the results for Belgium closely mirrored those of the more mature markets, Sweden and Denmark. The similarity is likely due to the adoption of comparable heat generation across the countries: particularly combustion-based systems. While Sweden and Denmark have been frontrunners in developing and implementing these technologies Belgium appears to have followed their lead, resulting in a convergence of value chain characteristics.

4.1.2 Value Chain Features- the Case Company

The value chain similarities and differences (to the SE, DK, BE markets) of the case company are summarized in Table 3.

A. Inbound logistics

Waste heat from the local waste management plant - based solely on combustion and without CHP generation - serves as primary heat source for the system. In the future, additional waste heat recovery from sewage water (and possible, other sources) is planned to be integrated. For peak load management, supplementary boilers are foreseen, which will operate on electricity, renewable gas or (possibly in the future, if available) hydrogen, depending on availability and system requirements.

B. Operations

Maintenance and control activities are expected to align with practices currently used in Sweden, Denmark and Belgium. The available waste heat volumes are abundant and should be sufficient to meet demand, so no thermal storage unit is planned initially. Discussions are underway about establishing a CHP plant to generate electricity, which is in high demand in the region.

In the Metro Vancouver region, resorting to waste heat from sewage water is commonplace. As a result, the opportunity to resort to this heat source is being reviewed as on interesting alternative for future expansion of the grid. Once heat recovery from sewage is implemented, heat pump operation and maintenance will be added to the systems' operational activities. Additionally, there is growing demand for cooling, and an investigation is ongoing to identify whether a centralized cooling system or one based on absorption chillers would be the most viable solution.

C. Outbound logistics

The distribution activities will be similar to the ones undertaken in Sweden, Denmark and Belgium. Green electricity - from hydro power - is used for running the pumps in the system. The substations will be owned either entirely by the company or jointly with the customer through a public private partnership. This arrangement involves crossing the property line which is considered unconventional in the Canadian context. The benefit is to control as large a share as possible of the secondary system. The system must be energy-efficient, and management of the return temperature (secured cooling by maximized Δt between supply and return temperature) is important. The need for a shared control room between the waste management plant and the DH company is investigated.

DHW will not be provided through the DH grid, so Legionella is not an issue for the heating supply in this case. For a supply of cooling, it could be relevant to account for.

D. Marketing and sales

The marketing and sales activities will be similar to the ones undertaken in Sweden, Denmark and Belgium. The investments for harvesting the heat are shared between the owner of the waste management plant (Metro Vancouver) and Burnaby municipality. There will be no price associated with the waste heat per se, making the price of DH rates competitive to both electricity and gas prices in the area. DH

DH is not a well-known or widely accepted heat supply technology in Canada. Hence, there is anxiety within the customer community about the new heat supply system. In this context, it is important to be transparent and explain how both the technology and the business model are configured. It is important that the system works well and without complications, because the experience of DH is limited, and any bad story may impair the notion of DH. There is a strong need to communicate well and to be transparent about the end-customer price. the city vouches for social justice and fairness (social equity) and must be involved in any changes to the design of the heat rate.

The city is closely collaborating with the company for city development, which will allow a rapid expansion. The city-company dialogue is frequent.

E. Post sales activities

The post sales activities will be similar to the ones undertaken in Sweden, Denmark and Belgium. With the setup of substations allowing control of parts of the secondary system, it will be possible to engage in motivational tariffs with the customers for remedying inefficiencies in the indoor heating system installations. Energy Performance Contracting can be relevant, especially for key account customers and for customers particularly sensitive to energy supply disruptions (like the hospital).

The value chain of the case is illustrated in Table 2.

Comparing the different parts of the value chain to the generic features identified for the Swedish, Danish and Belgian DH markets it is identifiable that:

- Inbound logistics is not based on combustion technology; rather recovering waste heat is in focus
- Operations are similar to the ones Sweden, Denmark and Belgium
- Outbound logistics in Burnaby are characterized by the substations being owned by the DH company or co-owned with the customers to ensure control over the system. In Sweden, Denmark and Belgium this is not always the case but there is a development in this direction. Flexibility management and forecasting are forthcoming, In Sweden, Denmark and Belgium flexibility management is increasingly common. In Canada there is also a forthcoming development; to provide cooling. It makes Legionella management (a new element) relevant. In Sweden, Denmark and Belgium DHW is usually provided when DH is provided and Legionella is managed.
- To marketing and sales waste heat dialogues, forthcoming options are co-creation dialogues, win-win arrangements (like motivational tariffs) and closer interaction across city planning units are elements added to conventional activities. Waste heat dialogues have a potential to expand in Sweden, Denmark Belgium and in Burnaby.

- Post sales activities are characterized by an idea to offer different service arrangements to customers (one such alternative is EPC). In Sweden and Denmark, a similar trend of customer-centric services is starting up.

To conclude, it appears as if the value chain of the case study is more advanced on waste heat dialogues than in the markets of Sweden, Denmark and Belgium. It also appears as if the foreseen ownership of substations can support the control of the system as well as the ability to offer various win-win arrangements and services.

Table 3: Similarities and differences of value chain characteristics based on review of the Burnaby case. Similarities and differences are compared to the value chains in SE, DK and BE

Inbound Logistics	**Operations**	**Outbound Logistics**	**Marketing & Sales**	**Post Sales Activities**
The fuel supply is waste heat supply	Like value chains in SE, DK and BE	Control of substation facilitates energy services	Waste heat recovery dialogue exists, co-creation & collaboration will come	Different service offerings are foreseen
Forthcoming: low temperature waste heat from sewage		Forthcoming: manage Legionella in cooling		

Next, results from the literature screening are provided. In Section 4.2.3, the literature findings were applied to the value chains to identify important areas to include in the interview guide.

4.2 Literature Screenings

4.2.1 Sustainable Business Model & Socially Sustainable Business Model

There is a variety of business model definitions in current literature, but the concept is still unclear as there is no shared terminology (Zott.C & Amit.R, 2008). A business model is often linked to value creation, proposition, delivery and capture (Teece.D, 2010), (Zott.C & etal, 2011), (Bocken & etal, 2013), (Hamelink.M & Opdenakker.R, 2019). It is now recognized as a relevant unit of analysis for businesses and the academic literature appears to have developed along three axis: e-business, strategy and innovation/technology management (Teece.D, 2010) (Zott.C & etal, 2011). Some theoretical frameworks to visualize and analyze business models exist, one of the most used is the business model canvas (Ostewalder.A & Pigneur.Y, 2010), focusing on nine components to analyze existing business models: key partnerships, key resources, key activities, customer value, customer segment, customer channel, customer relationship, cost structure, income structure. The business model canvas was developed jointly by academics and practitioners and has been widespread due to its intuitive structure. Business models are not frozen in time. Known triggers for their business model development are internal changes or external pressure (Lygnerud.K, 2018). A field of research which has emerged linked to the dynamics of business models is business model innovation. Innovation can be a new business model in an existing market or “a new business logic or way to create and capture value” (Markides.M & Charitou.C, 2004; Hamelink.M & Opdenakker.R, 2019) (Casadesus-Mansanell.R & Richart.J, 2010), (Hamelink.M & Opdenakker.R, 2019). According to (Clauss.T, 2016), business model innovation can be measured through three types of innovation: in the value creation, in the value proposition and the value capture.

It is not easy to create a new business model, especially as stakeholders can be locked into an outdated logic (Teece.D, 2010), (Lygnerud.K, 2018). Another hurdle is that there is often a need of updated legislation to create incentives and flexibility for a change in business logic. Changes are thereto often needed both on the customer side (Hamelink.M & Opdenakker.R, 2019) and on the supplier side (Lygnerud.K, 2018), (Teece.D, 2010), (Lygnerud.K, 2018), (Hamelink.M & Opdenakker.R, 2019), (Bocken.N & Gerardts.T, 2020). One specific type of innovation has growing interest in the academic community: sustainable business model innovation.

Sustainable business models are distinct from "conventional" business models in that they *"incorporate pro-active multi stakeholder management, the creation of monetary and non-monetary value for a broad range of stakeholders, and hold a long-term perspective"* (Coffay, M, Bocken, & N, 2023). Sustainable business model innovations have been defined as *"innovations that create significant positive and/or significantly reduced negative impacts for the environment and/or society, through changes in the way the organization and its value-network create, deliver and capture value in their value-propositions"* (Bocken.N & etal, 2014). Literature on sustainable business models is divided in three main streams that are strongly interlinked (Boons.F & Leudecke-freünd, 2013): technological, social and organizational.

To theorize sustainable business models, scholars have categorized them into patterns and archetypes (Bocken.N & etal, 2014), (Lüdeke-Freund, F, & etal, 2018) often based on the triple-bottom line of sustainability: economic, social and ecological. Example of patterns are closing-loops (like circular business models or industrial ecology), service & performance (like product-service systems: PSS), or repurposing for society (like cooperatives and social enterprises), (Yunus, A, & etal, 2010), (Bocken.N & etal, 2014) (Lüdeke-Freund, F, & etal, 2018), (Geissdoerfer, M, & etal, 2018). Despite the potential for sustainable business model innovations to contribute to significant positive outcomes for firms, there is a 'design-implementation gap'. Firms struggle with designing and successfully implementing sustainable business models in practice (Coffay, M, Bocken, & N, 2023).

Socially sustainable business models are a further innovation to sustainable business models, focusing on the social pillar of sustainability. Despite the increased attention on social sustainability, there is a lack of clear theoretical explanation of what it is (Missimer.M & etal, 2015), (Dempsey.N & etal, 2011), (Westin & etal, 2024). Some important and guiding information can be identified in the UN report: the Bruntland Commission. In it, a definition of sustainability is made: *"meeting the needs of the present without compromising the ability of future generation to meet their own needs"*. This definition was expanded over time into the three pillars of sustainability that are commonplace today. There is unclarity of the origins of the three pillars of sustainability (Purvis.B & etal, 2019) but the articulation of distinct social, economic, and environmental aspects of "sustainable development" can be seen in Agenda 21 (1992), (Ibid). Pursuing UN documentation to identify the meaning of the three pillars, the UN 2020-2030 Environmental Sustainability Strategy (CEB, 2024) addresses a need for environmental sustainability in the area of management (phase I) and strengthened leadership in environmental and social sustainability (phase II). The plan indicates five environmental impact areas (GHG emissions, waste, water, air pollution and biodiversity) and six management functions (procurement, human resources, facilities management, travel, events and ICT). Hence, our interpretation is that these eleven factors are to be accounted for when considering environmental sustainability. On the note of social sustainability, the UN identifies that it is about identifying and managing business impacts, both positive and negative, on people. The quality of a company's relationships and engagement with its stakeholders is critical. Directly or indirectly, companies affect what happens to employees, workers in the value chain, customers and local communities, and it is important to manage social impacts proactively (UN.Global.Compact, 2024). Returning to the third pillar, the economic one, it reflects activities that are environmentally and socially sustainable and that does not compromise the ability of future generations to meet their own needs.

In the context of society and cities, the importance of social sustainability has grown over time (Sachs.D, 2017) and things like policy co-design with DH stakeholders has been addressed as (Auvinen & al., 2024). (Boyer, R, & etal, 2016) have shown how social sustainability has been applied in literature and in practice: (i) as a stand-alone pillar, (ii) as a constraint on the other two pillars, (iii) as a foundation for the other two pillars, (iv) as a stimulus for the other two pillars or (v) as a fully integrated element in processes. Social sustainability aspects often appear in the context of urban planning. Examples of important, social aspects in that context are quality of life, equity, equality, employment, stakeholder participation, culture and heritage, compensation strategies and human rights (Vijayakumar.A & etal, 2023). Social sustainability is also found in the context of health addressing safety, equity, social inclusion and cohesion and quality of life (Ahn.M & Cope.M, 2023). A drawback in the existing studies is the lack of analysis of interrelationships between the indicators that influence the social sustainability performance (Murray.A & etal, 2010), (Wilson.J, 2007).

In sum, it is concluded that there is limited knowledge on how sustainable business models generate value and even less so on how socially sustainable values materialize. We also concluded that there does not seem to be any previous study on the topic of socially sustainable business model in DH.

4.2.2 Social Key Performance Indicator Screening

The first observation was that there are numerous studies on how companies can work with their employees to ensure a rewarding, social workplace. It can be things like work safety, gender equality, ethnicity, age, the opportunity for training on the job etc. Such factors are the social factors that are part of the concept of Environmental, Social and Governance (ESG). ESG was coined by the UN Global Compat report in 2004. In it, recommendations for incorporating the ESG factors in financial analysis, asset management and brokerage were presented. The use of ESG factors has become widespread and used as a non-financial factor impact assessment of company activity. We discussed the social factors of the ESG and identified that such factors are mainly linked to the activities undertaken by the DH company, to realize its core activities. Some aspects, like worker safety is managed by legislation (identified in the value chain analysis) whereas other aspects are voluntary and can be ways to establish a reputation of being a good employer and trigger employee satisfaction.

In this study, we wanted to understand what social values can be realized that can enhance the competitiveness of the DH business case. We concluded that the social aspects of the ESG framework are already known and that they strengthen the business model of companies by ensuring that the well-being and motivation of employees are boosted. We decided to focus the attention of this study beyond the social values that can be generated by the social dimension of the ESG framework.

The second observation was that there are several SKPIs that can be of relevance to the supply of heating/ cooling (be it through district energy, electricity, gas or other). The SKPIs, what they intend and the stakeholders to whom they generate a value, that can be relevant to DH, are listed in Table 4.

Table 4: Social Key Performance Indicators of potential relevance to the supply of heating/ cooling (Source: result of the research teams review of SKPIs as explained in the method section)

	SKPI	SKPI explained	Stakeholders to whom the SKPI generates value
1	Carbon footprint	Of the heat supply	Energy company, customer, wider community
2	Air pollution issues	From, combustion but also transports of fuel	Energy company, customer, wider community
3	Fairness	Who can get the heat (juste and fair energy transition)	Energy company, customer, wider community
4	Make use of locally available heat supply	Limited transports, recover assets otherwise wasted	Energy company, owner of local heat source, wider community
5	Local collaboration	On heat supply and other	Energy company, owner of local heat source
6	Inclusive buildings	People can see what happens on the inside, visit the premises for recreational purposes like a park or for educational purposes	Energy company, construction company, architect, wider community
7	Aesthetic buildings	No disturbing or enriching the cityscape	Energy company, construction company, architect, wider community
8	Indoor space	Limiting the space needed of equipment for heating	Energy company, construction company, architect, customer
9	Sector coupling	Gas-electricity-district energy for flexibility gains	Energy company, wider community

10	Philanthropic activity	In the sense that energy companies can undertake the activity	Energy company, wider community
11	Education of the young	Site visits, traineeships and other	Energy company, wider community
12	Research & development	For example, dedicated projects	Energy company, wider community
13	Sustainable investment thresholds	Low interest rates for sustainable projects	Energy company, wider community
14	Resettlement issues		Energy company, wider community
15	Disruptive road works	Limited in time, to construction phase	Energy company, wider community
16	Jobs	Long term, local jobs	Energy company, wider community
17	Indoor comfort		Energy company, customer
18	Customer empowerment	Manage customer behaviour, encourage co-creation, prosumers	Energy company, customer
19	Transparency across the value chain	Including end customer dialogue	Energy company, customer
20	Safe energy use	No explosions, shocks, floodings	Energy company, customer
21	Reliable heat supply		Energy company, customer
22	Carefree	No need for customer to maintain assets	Energy company, customer
23	Stable price		Customer
24	Affordable price		Customer

4.2.3 Sustainability Factors

Based on the literature screenings the research team returned to the value chain analyses to understand where in the value chains factors that can generate social sustainability can be found. The factors are introduced per activity group in the value chain. Some factors have more than social values. The values that a factor has, is denoted by an "X" in the table. Economic (E), environmental (G; Green) and social (S) values are accounted for. Factors that had economic or environmental value only were not accounted for. Also, if the factor is internal or external to the company has been marked (I/E).

Sustainability factors related to inbound logistics

Three factors impacting one or several of the three sustainability aspects were identified in conjunction to inbound logistics.

FACTOR 1: Price of heat supply

Heat sources come at a cost (decided by a market on an external party) and the price will impact operational choices and thereby both environment and economy.

One DH strength is fuel flexibility. The pass-through mechanism of heat source price increases being passed on to DH customers can be a short-term strength to DH companies but also a long-term threat (as customers might leave DH- can have economic and social impact).

FACTOR 2: Using local heat sources

Making use of locally available sources can impact economy (cost efficient), environment (sustainable alternative and limited transport) and social (generating local job opportunities and a sense of pride to contribute to the community). This choice is internal but not possible to realize without external support.

The strength is that this activity anchors the DH company to the local community, the sources can be environmentally sustainable and cost efficient. The weakness is that the business model becomes complex and risky (many heat providers and contracts); compared to the conventional setup (resorting to one main heat source allowing the DH company to produce exact volumes of heat at desired temperatures). It should, however, be noted that the price of fuels that is imported from other countries also brings a risk, and often local heat sources are not associated with that kind of risk.

FACTOR 3: Policy shifts

In Europe, there is an ambition of becoming a climate neutral continent by 2050. This is reflected in different policy documents. One document that has gained much attention is the EU Taxonomy. Its' intent is to increase sustainability in economic activities. It can impact DH too by, for example, over time phase out both biomass and waste as fuels leading to a replacement of the combustion technologies. Such changes would impact the economics of DH (shift away from current assets leaving them stranded), environmental impact (increased sustainability) and the social values connected to DH (make use of local assets). The opportunity is that environmental sustainability is advocated. The threat is that reconstruction costs could be high. In Canada, energy efficiency is increasingly included in building codes. As a result, there is increased interest in DH. The building code is an opportunity for DH expansion. The three factors are listed in figure 7. Price of heat supply and policy shifts are external to the DH companies whereas making use of waste heat is both an external and internal factor (access to it is external and making use of it is an internal decision).

SE, DK, BE markets- Inbound logistics	**Case - Inbound logistics**
Fuel purchase -Biomass -Waste -Waste heat -Biooil (peak) Fuel trade	Waste heat from waste manage-ment facility Forthcoming: Waste heat from sewage water and other Forthcoming: Peak boilers

	Value chain activities/ Factors	**Inbound logistics**			
		Internal/ External	Econo-mic	Green	Social
1	**Price of heat supply**	E	X	X	X
2	**Use of locally available heat sources**	I/E	X	X	X
3	**Policy shifts**	E	X	X	X

Figure 7: The link between the value chain activity of inbound logistics and internal/external (I/E) factors that can impact economic (E), and/or environmental (G) and/or social sustainability (S) of the DH business model

Sustainability factors related to operations

In the context of DH, operations are the activities associated to provide heat for the DH system. Five factors impacting one or several of the three sustainability aspects were identified in conjunction to operations.

FACTOR 1: Stable price compared to other heating alternatives

DH price stability is both a result of long processes and production & distribution cycles. It is also often a choice of DH companies to offer fixed rather than dynamic pricing (likely a result of necessary level of digitalization for dynamic pricing missing). It results in economic stability for the DH company and in economic stability which, in turn, can also impact the social well-being (reasonable budget of the household goes to heating costs without large changes short term) of the DH customers.

The strength is that price changes are infrequent (annual or biannual often) whereas the weakness is that the DH price is often pass through which means that the DH customers will pay higher production & distribution prices over time (and also if the underlying heat source has an increasing price which, for example, was the situation in Europe in conjunction to the Russian aggression on Ukraine which increased the price of both biomass and gas). Another weakness is that there is a risk to overprice the customer (the DH company ensures its margin) which can reduce the competitiveness of DH compared to alternatives.

FACTOR 2: Smart systems/ digitalization

Digitalization is something that DH companies invest in to ensure their systems are efficiently sized and operated, allowing for supply and demand response for example. It can generate increased system efficiency (economic value), an optimized heat supply (green value) and potential for local assets to be included in the heat supply mix. It also allows matching demand just in time and transparently showcasing customers how their behavior impacts the DH production, distribution and cost (social values from local job creation, matching heat demand with the most cost-efficient heat supply and customer engagement).

The strength is that the system efficiency improves all the way from technical operations to customer interaction and engagement. One weakness is that data are not available/ not of sufficient quality or possible to use due to data protection regulation (at least at the early stages of digitalization) and that not all customer segments have the capacity to use and understand data/ information provided.

FACTOR 3: Local solutions to customers distant to the grid

To offer DH in areas with very low heat density is not cost efficient, because of high cost for infrastructure and high costs from heat losses (depends of course on the cost to produce the heat). Hence, the DH networks have a geographical limit. To offer other solutions to potential customers that are outside the network is a different kind of business model (micro grids). Economic gain is that a customer is obtained that would otherwise resort to another heat supplier, environmental impact will be present if locally available heat supply is used and social gain is that even customers not on the main DH grid can get an efficient heating solution, reflecting a just and fair energy transition.

The strength is that the company can expand its customer base and possibly, long term build enough heat demand to extend the main grid to what is initially an isolated, smaller heat island. The weakness is that it can be a costly solution.

FACTOR 4: Use thermal inertia (buildings as a storage)

The thermal inertia of buildings or building level storage units (water tanks etc.) can be resorted to. The economic gain is cost-efficiency, environmentally less heat supply is needed and socially there can be room for building-owner/ DH company interaction and co-creation of joint business opportunities. The driver is internal but needs to be realized together with the building owner.

Another strength is that it increases system flexibility. One weakness is that it can be difficult to implement if the buildings need retrofitting or digitalization before they can be used as an efficient storage. Another weakness is that if financial incentives are given to lower indoor temperatures periodically it risks being unfair since end users with lower disposable incomes might be more responsive than wealthier households. Beyond the technical difficulty it can be challenging to identify an efficient contractual arrangement between building owner and DH company.

FACTOR 5: Workplace safety

In the DH plant is key and must comply to legislation. Safety supports economy (activities can be pursued), environment (no major disasters as a result of injuries and disabled staff) and social (reputation of being a good employer). To abide by safety regulation is mandatory by law and not associated with any strength or weakness.

The five factors are listed in figure 8. All but making use of thermal inertia are linked to internal decisions (the use of thermal inertia necessitates collaboration with building owners and/or tenants). Stable price has an impact on economic and social sustainability, digitalization, local solutions to customers distant to the grid, buildings as a storage and the workplace safety bring economic, social and environmental sustainability values. Lock in effects impact economic and environmental sustainability.

SE, DK, BE market- Operations

Heat generation:
- CHPs

-Heat pumps

-Heat only boilers

- Peak assets

-Flexibility management & forecasting

-Maintenance

-Control room

-Remote reading

Storage charge/discharge

Case- Operations

- Manage waste heat recovery unit

- Forthcoming: Heat pumps for sewage wastewater heat

- Forthcoming: Peak assets

-Flexibility management & forecasting

-Maintenance

-Control room

-Remote reading

	Value chain activities/ Factors	**Operations**			
		Internal /External	Econo-mic	Green	Social
1	**Stable price**	I	x		x
2	**Digitalization**	I	x	x	x
3	**Local solutions to customers distant to the grid**	I	x	x	x
4	**Buildings as storage**	I/E	x	x	x
5	**Safety**	E	x	x	x

Figure 8: The link between the value chain activity of operations and internal/external (I/E) factors that can impact economic (E), and/or environmental (G) and/or social sustainability (S) of the DH business model

Sustainability factors related to outbound logistics

In the context of DH, outbound logistics are the activities associated to distribute heat through the DH system, to the customer buildings. Three factors impacting one or several of the three sustainability aspects were identified in conjunction to outbound logistics.

FACTOR 1: Substation management

In some cases, the customer owns the substations and in other cases the DH company owns them. Malfunction in substations are common an reduce the system efficiency. When the substations are owned by the customer, it is harder to get access and fixing the faults is up to the customer. The toolbox of the DH companies can be to offer service or maintenance agreements and to enforce incentivizing components in the price model, so that the customer get economic consequences if the substation is malfunctioning. It should be noted that another weakness is if the building owner has tenants and is not properly maintaining the substation, the end users will pay for the malfunction. For example, to charge for the mass flow through the heat exchanger or to have some fee for bad return temperatures would be possible. But still, it is up to the customer to understand and act according to the price model. The substation can be an item that the DH company communicates with the customer about, if the dialogue is positive, it can have a positive social impact if the dialogue is negative the opposite can apply.

If the substation is owned by the DH company, it is easier to ensure its efficiency, if it is owned by the customer, it offers an opportunity to engage in dialogue.

FACTOR 2: Maximized cooling of return water is an important factor for DH system efficiency

Lower return temperatures increase the temperature difference (Delta T) between supply and return, which improves heat transfer efficiency. This allows for smaller pipe diameters and lower pumping costs, reducing both capital and operational expenses. It also effects the performance of different heat production units like condensing boilers, heat pumps and CHP. Condensing builders operate more efficiently at low return temperatures because they can condense water vapor in flue gases, recovering latent heat. Heat pumps benefit from lower return temperatures as it reduces the required temperature difference between source and supply improving their coefficient of performance (COP); whereas combined heat and power units can be more flexible and efficient when return temperatures are low, especially in systems designed for variable loads. Lowering return temperatures can therefore have both economic and environmental benefits depending on the configuration of the DH system.

The strength is that the return temperatures can be monitored and managed by the DH company, but the weakness is that, for example, inefficient substations can increasereturn temperatures and similarly to the point of the substation above, the end user will have to pay for high return temperatures if the building owner is not investing to reduce them.

FACTOR 3: Maintenance of the distribution grid

Maintenance of the distribution grid is a critical long-term responsibility for DH companies. Given the long economic lifespan of the network – dependent on the materials and components used – insufficient or inappropriate maintenance can lead to significant consequences. Economically, it may result in costly issues such as leaks or major system failures. Environmentally, poor maintenance can reduce system efficiency, increased heat losses and to accidents affecting the environment. Socially, service disruptions can affect costumer in various ways. Professional customers may experience reduced productivity, vulnerable individuals may face health risks and residential customers may endure discomfort due to lack of heating. In cold climates outages can be extra serious. Damages on pipes can also occur due to external interference, such as excavations damage caused by other utility owners, or from intentional terror activities.

The strength is that DH companies are aware and undertake maintenance activities on an ongoing basis. The weakness is that the companies are not always taking efficient measures or replacing the worst pipes.

The three factors are listed in figure 9. The substation management and reduced return temperature factors are internal and external: they cannot be realized without the building owners being engaged. Maintenance of pipes is, however, in the jurisdiction of the DH company (internal). From the three factors it can be concluded that factors 1 and 2 can generate social value by stable utility- customer interaction/ co-creation. Factor 3 impacts safety of DH customers and wider society.

SE/DK/BE markets- Outbound logistics	Case- Outbound logistics
Distribution and circulation of water -Pressure management -Pumping stations -Maintenance -Maximized Δt -Substation management -Connect/ disconnect customers -Manage legionella -Flexibility management & forecasting	Distribution and circulation of water -Pressure management -Pumping stations -Maintenance -Maximized Δt -Substation management -Connect/ disconnect customers -Forthcoming: Manage legionella in cooling -Flexibility management & forecasting

	Value chain activities/ Factors	Outbound logistics			
		Internal /External	Econo-mic	Green	Social
1	**Substation manage-ment**	I/E	x	x	x
2	**Reduce return tempera-tures**	I/E	x	x	x
3	**Mainte-nance of pipes**	I	x	x	x

Figure 9: The link between the value chain activity of outbound logistics and internal/external (I/E) factors that can impact economic (E), and/or environmental (G) and/or social sustainability (S) of the DH business model

Sustainability factors related to marketing, sales and post sales

In the context of DH, marketing, sales and post sales are the activities associated to sell or follow up on DH sales. Six factors impacting one or several of the three sustainability aspects were identified in conjunction to marketing, sales and post sales.

FACTOR 1: Interaction with society

DH can make an impact on society in different ways —such as snow-free bike lanes[5], driveways, and soccer fields, as well as the creation of public recreational spaces like parks or the famous ski slope atop the DH facility in central Copenhagen— and in that way generates social value by engaging both customers and the broader community or by offering services outside the core business.

The strength is that DH companies can make an important difference in the lives of many people within its core activity (providing ground heat on the return line is, for example good for both society (fewer broken legs and hospital beds in Winter and health benefits from green sports fields in the Winter). The weakness is that the social added values come at a cost (more heat is needed, lines need to be drawn under walkways and soccer fields etc.).

FACTOR 2: Efficient customer behavior

Efficient customer behavior can be achieved by different pricing structures referred to as motivational tariffs. If a company has smart systems it can engage with customers to both impact their heat consumption patterns and to ensure that waste heat sources can be used, heat can be stored in buildings and return temperatures lowered. Such actions can have an economic impact, reduce the heat supply needed, incentivize renewable sources and waste heat coming into the system and create a mutually beneficial relationship between DH companies, their customers and other, local stakeholders. As mentioned above, if the building

[5] Note that such action would possibly necessitate extra heating energy and must be balanced against reduced costs of, for example, health care associated to injuries from sliding and falling.

has tenants, they might not be able to benefit from motivational tariffs if the building owner is not engaged.

The strength is that DH companies have the mandate to engage in motivational tariff construction. The weakness is that motivational tariffs may have a low impact on customer behavior and that there is sometimes a “malus” component, if the building is not performing according to certain criteria end users might have to pay a fee for it which can impact the perception of DH negatively.

FACTOR 3: Carefreeness

The carefreeness of DH is the unique selling point (limited service needed, high indoor comfort, no noise) in both mature markets and in the context of the case study. Carefree is linked to a social value where the customer does not have to spend time and energy on satisfying its heating needs. Energy as a service is one way of packaging the carefreeness to customers.

The strength is that the DH system provides carefreeness to the customer compared to many other ways of heating buildings. Another strength is that limited space is needed at the building level compared to other heating alternatives. The weakness is that all the costs associated with providing heat on time, at the right temperature can be higher than foreseen which will be troublesome (short term, until the tariff is updated) if the DH price is fixed.

FACTOR 4: Local produce is in demand

The demand for local produce is spreading (from locally grown food to energy), incentivizing DH companies to invest in local heat supply technologies. For the companies it is an initial cost which is, for example, mitigated by savings in conventional fuels. Also, investing in staff with new skillsets might be necessary (operators of heat pumps, people who can co-create solutions with local stakeholders). The local heat supply can replace fossil fuels and lead to the creation of local jobs and local community engagement.

The strength is that this activity anchors the DH company to the local community, the sources can be environmentally sustainable and cost efficient. The weakness is that the business model becomes complex; compared to the current setup; with a multitude of contracts and heat suppliers.

FACTOR 5: Resilient energy is in demand

In the light of the current geopolitical situation in Europe. Resilience has become a more prominent selling point than in the past. For DH companies, this shift necessitates strategic investments to diversify heat sources and avoid overreliance on a single supply. While this may influence the environmental footprint of the heat mix, it also strengthens the perception of DH as a key contributor to societal resilience.

FACTOR 6: There is an increasing demand of cooling

As a result of heat waves in recent years, cooling is in increasing demand. In mature markets the common solutions for providing heating and cooling by resorting to district energy has been to build one network for heating and one for cooling. The economics of the district energy case are impacted if cooling is to be provided; new customers can be secured but also new assets need to be invested in. On the social dimension, cooling is important for secured well-being and increasingly seen as a mandatory part of indoor comfort (for example, there is upcoming legislation on including cooled space in new buildings in Canada from 2026).

The strength is that DH companies have expertise to provide district cooling in buildings. This strength coincides with the opportunity of the increasing cooling demand as a result of regulation. Also, a surplus of heat could be used in summer for absorption chillers which would benefit the DH system. The DH system can also get waste heat from compression chillers during transition periods (Spring/ Fall). The threat is that it is costly to build a district cooling network from scratch, possibly it can be offset by the opportunity of installing reversible heat pumps that can provide heating and cooling depending on the need, in conjunction to the DH systems.

The six factors are listed in figure 10. That resilient energy supply, cooling and local energy are in demand are externa factors. The local energy demand can only be used if there is an internal decision to collaborate with the heat owners. To interact with society and incentivize customer behavior necessitates both internal decisions in the DH company and collaboration with external parties. To offer a carefree heating alternative is in the jurisdiction of the DH company (internal). Incentivized customer behavior and local heat supply generate economic, environmental and social sustainability. Local heat supply, cooling and resilient energy supply generate economic and social values. Interaction with society only generates a social value.

Mature markets and case	
Marketing & sales	**Post sales activities**
Customer service Invoicing Key Account Management Marketing events Communica-tions Waste heat collaboration dialogues Co-creation dialogues Price dialogues Heat plan interaction	Different service arrangements (from pure maintenance to win-win arrangements) Complaint management

	Value chain activities/ Factors	**Marketing, sales and post sales**			
		Internal /External	Econo-mic	Green	Social
1	**Interact with society**	I/E			x
2	**Efficient customer behavior**	I/E	x	x	x
3	**Carefree**	I			x
4	**Local produce in demand**	E/I	x	x	x
5	**Resilient energy supply in demand**	E	x		x
6	**Cooling in demand**	E	x		x

Figure 10: The link between the value chain activity of marketing, sales and post-sales and internal/external (I/E) factors that can impact economic (E), and/or environmental (G) and/or social sustainability (S) of the DH business model

From the value chain analysis, it is identified that social values can be generated across the value chain.

4.3 Interview Results

4.3.1 Contents of Interview Guide

The literature reviews and the value chain analyses jointly provided inputs allowing the research team to build an interview guide. In tables 5-6, how SKPIs and factors from the value chain were selected is summarized. Motivations for choices are provided.

Table 5: Selection of factors from SKPIs from literature screening included in the interview guide

	Aspects of relevance to social sustainability in DH	Included in the interview guide (X)	Section of the interview guide where the factor is included
1	Carbon footprint	Should be a main driver, will likely be captured in open part of interview	
2	Air pollution	x	Use local energy
3	Fairness	Should be reflected in affordable pricing	
4	Make use of locally available heat supply	x	Use local energy
5	Local collaboration	x	Use local energy
6	Inclusive buildings	x	Supports local community
7	Aesthetic buildings	x	Aesthetics
8	Indoor space	x	Supports local community
9	Sector coupling	x	Sector coupling

10	Philanthropic activity	If important should appear in open part of interview	
11	Education of the young	x	Supports local community
12	Research & Development	If important should appear in open part of interview	
13	Sustainable investment thresholds	If important should appear in open part of interview	
14	Resettlement issues	x	Community engagement
15	Disruptive road works	x	Community engagement
16	Jobs	x	Supports local community
17	Indoor comfort	x	Quality of life
18	Customer empowerment	Digitalization and relevant empowerment outcomes are forthcoming in Burnaby – if important should appear in open part of interview	
19	Transparency across the value chain	x	Community engagement
20	Safe energy use	Should be standard- if important should appear in open part of interview	
21	Reliable heat supply	Should be standard- if important should appear in open part of interview	
22	Carefree	x	Quality of life

23	Stable price	x	Affordable/ stable price
24	Affordable price	x	Affordable/ stable price

Table 6: Selection of factors from value chain analysis included in the interview guide

	Value chain activity	Included in the interview guide (X)	Section of the interview guide where the factor is included
Value chain input- inbound logistics			
1	Price of heat supply	x	Affordable/ stable price
2	Locally available heat sources	x	Use local energy
3	Policy shifts	If relevant policy measures, they will be mentioned in the open part of the interview	
Value chain input- operations			
1	Stable price	x	Affordable/ stable price
2	Digitalization	Forthcoming in Burnaby not relevant to discuss now- should appear in open part of interview if seen as important	
3	Local solutions to customers distant to the grid	If an important social feature it will be mentioned in the open part of the interview if seen as important	
4	Buildings as storage	If an important social feature it will me mentioned in the open part of the interview	

5	Safety	ESG factor	
	Value chain input-outbound logistics		
1	Substation management	Of relevance to DH companies- not an issue in Burnaby where the substations are to be owned by the DH company	
2	Return temperature management	Of relevance primarily to the DH company, too technical to address	
3	Maintenance of pipes	Of relevance primarily to the DH company, too technical to address	
	Value chain input-marketing, sales and post sales		
1	Interact with society	x	Community engagement
2	Efficient customer behaviour	Forthcoming in Burnaby not relevant to discuss now- should appear in open part of interview if seen as important	
3	Carefree	x	Quality of life
4	Local produce in demand	x	Use local energy
5	Resilient energy supply in demand	Forthcoming in Burnaby not relevant to discuss now- should appear in open part of interview if seen as important	
6	Cooling in demand	x	Quality of life

The research team made interviews in two parts, first an open part to collect the perception of DH from the respondent and a second part split into sections. The sections are (1) supports the local community (2) community engagement, (3) aesthetics, (4) customer affordability & price stability, (5) use of local energy, (6) quality of life and (7) sector coupling.

The main categories of the interview guide have been summarized below to facilitate the reader to follow the presentation of results.

Table 7: Interview guide- overall sections summarized

Interview guide	
1	**Supports the local community**
	Inclusive buildings
	Educational efforts towards young/ society
	Save indoor space
	Creation of local, long-term jobs
2	**Community engagement**
	Transparent communication (across value chain)
	Impact on local community (resettlement issues, construction disturbances)
	Partnerships (win-win solutions, co-creation of value, co-investments etc.)
3	**Aesthetics**
	Pipes not seen
	Signature buildings: beautiful: enhancing the city scape
	Signalling buildings: sustainability message
4	**Affordable/ stable price**

	Lower price than alternatives
	Driver of energy poverty
	Stable price (not volatile)
	Predictable price
5	**Use local heat supply**
	Less local transports (air pollution)
	Partnerships (local economy is strengthened)
6	**Quality of life**
	Carefree
	Indoor comfort
	Both heating and cooling
7	**Sector coupling**
	Take load off electricity sector
	Resort to CHP technology for producing both heat and electricity
	Provide electricity for the own DH system

4.3.2 Results from Interviews

The results from the open sections of the interviews are provided first (4.3.3), then the results from the interviews are provided per section: supports the local community (4.3.4), community engagement (4.3.5), aesthetics (4.3.6), customer affordability &price stability (4.3.7), use of local energy (4.3.8), quality of life (4.3.9) and sector coupling (4.3.10). Last, the most important social values that can be generated in the DH context are summarized (4.3.11).

The answers provided by the respondents were quantified into percentages; to allow comparisons of responses across the stakeholder categories. The results are provided for the respondents at an overall level, and a comment is made whenever a particular stakeholder group did not match the overall responses. The results reflect the way that the respondents allocated social value to the different factors.

4.3.3 Results from the Open Section of Interviews

All interviews started with an open section where the interviewers presented the project and that the intent was to understand what values that can be associated with DH, if any, based on a personal reflection from the interview persons. We asked the interviewees to reflect on positive values and negative values that DH can bring and to whom. Thereafter we entered the structured part of the interview (split into different areas as outlined above).

The respondents provided one or several positive values of DH. Condensing the results from the open part, the most frequently addressed positive value was the green solution, and the positive impact on climate goals (21 respondents). Thereafter came cost efficiency/ affordability (10 respondents), reuse resources (waste heat from waste combustion in Burnaby: 8 respondents), energy security (DH seen as a stable system: 8 respondents), green and local jobs (7 respondents) and sector coupling (7 respondents). Negative values were scattered across unknown maintenance costs (for building owners/ tenants: 1 respondent), high investment costs (1 respondent), question marks around DH being a solution for the future (2 respondents), low social equity (fairness/ justice: 2 respondents) and negative reputation (1 respondent). The positive and negative values have been summarized in figure 11.

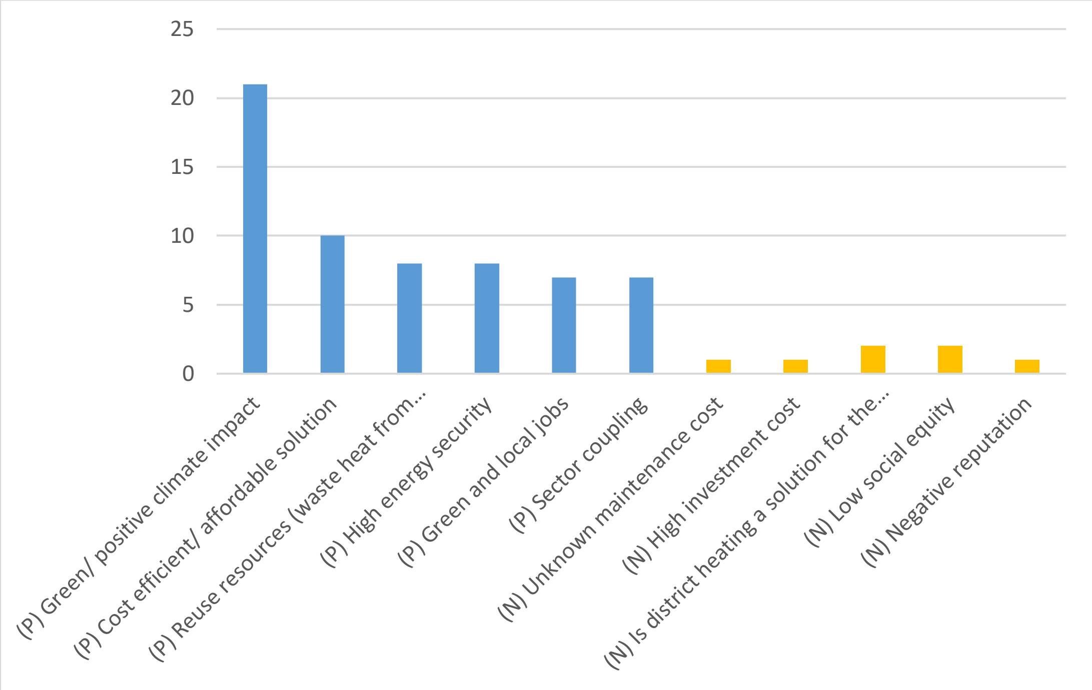

Figure 11: Positive (blue bars) and negative (yellow bars) values associated with DH according to interviews.

4.3.4 Supports the Local Community

In the table, the questions asked in relation to ways that DH companies can support the local community are summarized. The table shows the share of respondents (in %) associating a social value with four different factors.

The “overall column” reflects the share of the 28 respondents attributing a value to the 4 different ways listed that DH can support the local community.

The other columns reflect the share of the respondents per group (architects & developers, engineers, DH companies, policy & customers and Burnaby team).

Table 8: Results related to factors with potential to generate social value in the local community

Supports the local community		Overall	Architects & develop-pers	Engineers	DH	Policy & customer	Burnaby team
1	Inclusive buildings	57	50	67	57	60	50
2	Educational efforts towards	39	75	100	100	60	50
3	Save indoor space	25	0	100	29	50	25
4	Jobs	36	50	100	100	70	75

At an overall level, buildings that are inclusive (have a glass façade allowing people to see what is going on inside the building, have some kind of openly accessible space for recreation like a park or similar) were highlighted most. In second place came education of the young and in third place the creation of local jobs was identified.

Amongst architects & developers, educational efforts towards young/ society scored highest. For engineering companies' educational efforts, saving indoor space and creation of long-term local jobs scored highest. For the DH companies, educational efforts and creation of long-term local jobs were most important. For the policy makers & customer as well as for the Burnaby team the creation of local jobs was deemed most important.

4.3.5 Community Engagement

In the table, the questions asked in relation to ways that DH companies can engage with the local community are summarized.

Table 9: Results related to factors with potential to generate social value- community engagement

Community engagement		**Overall**	**Architects & developers**	**Engi-neers**	**DH**	**Policy & customer**	**Burna-by team**
1	Transparent communication	46	25	67	57	40	50
2	Impact on local community (resettlement issues, construction disturbances)	14	0	67	14	30	50
3	Partnerships (win-wins, co-creation, co-investments etc.)	18	50	33	29	10	50

At an overall level, to have a transparent value chain got the highest score. The other factors scored much lower indicating that they are factors of smaller importance to social sustainability in conjunction to the Burnaby DH project.

The engineering companies, the DH companies and the policy & customer interviewees gave highest score to transparent communication. The architects & developers had partnerships in second place. Whereas the engineers and the policy & customer interviewees place impact on local community in second place. The Burnaby team put equal emphasis on the three factors.

4.3.6 Aesthetics

In the table, the questions asked in relation to ways that DH companies can work with aesthetic features are summarized.

Table 10: Results related to factors with potential to generate social value- aesthetics

Aesthetics		Over -all	Archi- tects & deve- lopers	Engineer s	DH	Policy & custom er	Burna- by team
1	Pipes not seen	14	0	33	43	20	25
2	Signature buildings: beautiful: enhancing the city scape	39	25	67	57	40	25
3	Signalling buildings: sustainability message	46	25	67	71	40	25

At an overall level, the signaling buildings scored highest among the listed factors.

Both engineering companies and DH companies ranked buildings that signal a sustainability value (for example through displays on renewable energy generated or similar) highest. The architects, policy makers & customer and Burnaby team scored buildings that enhance the city scape and have a sustainability message equally. The DH companies scored buildings enhancing the city scape second. The lowest score was given to the invisibility factor, maybe because this is an inbuild factor for many infrastructures providing different services to the community.

4.3.7 Affordability and Price Stability

In the table, the questions asked in relation to ways that DH companies are generating values across affordability and price stability are summarized.

Table 11: Results related to factors with potential to generate social value- aesthetics

Affordability		Over-all	Architects & deve-lopers	Engi-neers	DH	Policy & customer	Burnaby team
1	Lower price than alternatives	54	25	67	57	60	50
2	Driver of energy poverty	29	25	33	29	40	0
3	Stable price	14	0	33	14	0	50
4	Predictable price	18	0	33	29	0	50

At the overall level, the lower price than alternatives scored highest. Then came the link to energy poverty where high prices can lead to a future with increasing problems associated to energy poverty. Price predictability and stability scored lowest.

All respondent groups scored the price level highest: it is important that DH has a competitive price compared to alternatives. Thereafter, the potential problem of energy poverty – if the price is high- was raised by all respondents, but the Burnaby team. Reflecting on this result with them after the survey we realized that energy poverty is a less common and less discussed topic in Canada than in Europe (as a result of historical access to heat supply at very low cost), in the future it might grow in importance also in Canada. Price stability and predictability was scored equally high by the Burnaby team and did get the same score as the lower price than alternatives option.

4.3.8 Make Use of Locally Available Heat Supply

In the table, the questions asked in relation to ways that DH companies can make use of locally available heat supply are summarized.

Table 12: Results related to factors with potential to generate social value- locally available heat supply

Locally available heat supply		**Over-all**	**Architects & develop-pers**	**Engi-neers**	**DH**	**Policy & customer**	**Burnaby team**
1	Less local transports	21	0	33	29	20	25
2	Partnerships -benefits local economy	32	25	67	57	10	25

Engineers, DH companies and Architects& developers put a higher score on partnerships than on local traffic conditions improving. Policy & customer respondents scored the other way around. The Burnaby team put the same score on both factors.

4.3.9 Quality of Life

In the table, the questions asked in relation to ways that DH companies can impact the quality of life are summarized.

Table 13: Results related to factors with potential to generate social value- quality of life

Locally available heat supply		**Over-all**	**Architects & developers**	**Engineers**	**DH**	**Policy & customer**	**Burnaby team**
1	Carefree	61	25	67	71	70	50
2	Indoor comfort	25	0	67	29	20	25
3	Both heating and cooling	68	75	33	57	70	100

At an overall level, the possibility to get cooling and heating from the energy supplier was ranked highest and inn second place came “carefree” heat supply.

Architects & developers, policy & customer and the Burnaby team ranked the possibility to get heating and cooling as the most important one. The policy & customer interviewees also placed carefreeness at the same score. For the DH companies carefreeness scored highest and combined heating and cooling got the second highest score. The engineers scored carefreeness and indoor comfort at the top.

4.3.10 Sector Coupling

In the table, the questions asked in relation to ways that DH companies generate values associated with sector coupling are summarized.

Table 14: Results related to factors with potential to generate social value- sector coupling

Locally available heat supply		**Over-all**	**Architects & develop-pers**	**Engi-neers**	**DH**	**Policy & customer**	**Burnaby team**
1	Take load off from electricity sector	29	0	67	29	20	25
2	Resort to CHP technology	18	0	0	29	20	25
3	Own electricity for DH operations	0	0	0	0	0	0

At the overall level, taking load off electricity sector is seen as a possibility to ensure continuous heat supply and it scored the highest, second place was held by the possibility to use CHP technology providing both electricity and heat to the city. The engineers place high value on taking load off the electricity sector, the other respondent groups place same value on taking the load off electricity and using CHP technology. The architects & developers chose not to provide any answers on the topic as they felt that they were not familiar with it.

The low scores overall reflect that sector coupling is not yet commonplace in the Burnaby context.

4.3.11 Summary of the Most Important Social Values

In table 15, overall (for all respondents) scores given to factors to indicate their ability to generate social values in the DH context are shown (mid column). How important the factor was for generating social value is indicated in an increasing order (1 is highest).

Table 15: Summary of the possible, social values in the DH context- case study results

Area of the interview guide	Overall	#	Architects & developers	#	Engineers	#	DH	#	Policy & customer	#	Burnaby team	#
1 Supports the local community												
Inclusive buildings	57	1	50	2	67	2	57	2	60	2	50	2
Educational efforts	79	2	75	1	100	1	100	1	60	3	50	2
Save indoor space	39	4	0	3	100	1	29	3	50	4	25	3
Jobs	82	3	50	2	100	1	100	1	70	1	75	1
2 Community engagement												
Transparent communication	46	1	25	2	67	1	57	1	40	1	50	1
Impact on local community	14	3	0	3	67	1	14	3	30	2	50	1
Partnerships	18	2	50	1	33	2	29	2	10	3	50	1
3 Aesthetics												
Pipes not seen	14	3	0	2	33	2	43	3	20	2	25	1
Signature buildings: beautiful	39	2	25	1	67	1	57	2	40	1	25	1
Signalling buildings	46	1	25	1	67	1	71	1	40	1	25	1

4 Affordable/ stable price													
	Lower price than alternatives	54	1	25	1	67	1	57	1	60	1	50	1
	Driver of energy poverty	29	2	25	1	33	2	29	2	40	2	0	2
	Stable price	14	4	0	0	33	2	14	3	0	3	50	1
	Predictable price	18	3	0	0	33	2	29	2	0	3	50	1
5 Use local heat supply													
	Less local transports	21	2	0	2	33	2	29	2	20	1	25	1
	Partnerships	32	1	25	1	67	1	57	1	10	2	25	1
6	**Quality of life**												
	Carefree	61	2	25	2	67	1	71	1	70	1	50	2
	Indoor comfort	25	3	0	3	67	1	29	3	20	2	25	3
	Heating & cooling	68	1	75	1	33	2	57	2	70	1	100	1

7	**Sector coupling**												
	Offload electricity sector	29	1	0	1	67	1	29	1	20	1	25	1
	CHP (el & heat)	18	2	0	1	0	2	29	1	20	1	25	1
	Electricity for the own DH system	0	3	0	1	0	2	0	2	0	2	0	2

An analysis of the overall results shows that factors that should have the largest potential to generate social sustainability values in the Burnaby DH project context are (i) to create local jobs, (ii) ensure transparent communication across the value chain, (iii) invest in buildings to signal sustainability value, (iv) keep the DH price at the same level or lower as other heating alternatives, (v) engage in partnerships with the local community (local heat supply recover, joint co-creation of commercial values), (vi) offer both heating and cooling and (vii) consider sector coupling between DH and electricity.

It is also identifiable that some areas are getting higher scores across the groups of interviewees, indicating that those areas are the ones that the interviewees are most informed about. These areas are: 1 (supports the local community), 4 (affordable/ stable price) and 6 (quality of life).

5 Social Values and Competitiveness in DH

To understand if the social dimension of sustainability can change the business models of DH companies the results from the value chain analyses and the interviews performed were used to identify what the social layer of a DH business model can look like (5.1). Thereafter, to further understand if the social values can increase the competitiveness of DH business models an analysis of how DH and heating alternatives to it (gas and electricity) can work with social sustainability for increased competitiveness was made (5.2).

5.1 Social Layer of the DH Business Model

The point of departure for drafting the social sustainability layer of the DH business model has been a conventional DH configuration. Resorting to the information collected from the value chain analysis and interviews, potential social values that could be added to the DH business model have been identified.

Putting the social layer on the conventional DH business model leads to the following interpretation of each of the components of the social business model: (it is also summarized in Figure 12).

Employees: the conditions of work, diversity, gender balance, fair remuneration schemes, possibility to develop at the workplace are factors that impact on the wellbeing of the employees. In the conventional DH context, such factors are usually well covered, and the companies are compliant to existing legislation and sometimes have complementary programs. In our study, we have tried to understand other social values than the social ones under the ESG umbrella hence, no additional social values were identified as possible additions from our study.

Governance: the vision and mission of a company are found here. As are the processes of everyday work and management. From our study, we identified that several choices could be made at governance level, that could have a social impact. Such are for example, lower investment criteria for sustainable investments (longer pay back accepted, lower rates of return accepted), the will to co-create and co-invest with customers (sharing investment costs), undertake philanthropic activity (in support of the local community), educate the young and the wider society (in energy efficiency/ energy use), build new knowledge through research & development engagements (knowledge that benefits the company and the wider society), efforts for empowering customers/ heat providers (investing in digitalization for example) and have a policy of transparent dialogue across the value chain. Based on the interview material it appears as if only a few of the possible choices to foster social values are identified in the context of the Burnaby DH case.

Societal culture: DH companies can foster a culture of circularity where waste and the negative impacts on the environment are minimized. Beyond environmental impact there is also a possibility to foster a sharing economy by co-creating business opportunities (such as recovering local heat sources) in the local community. In mature DH markets this practice exists but could be expanded. Sweden is the country in the world with the largest share of waste heat recovery into DH systems but even there the volumes are as low as 9% of the total heat supply (Lygnerud & Werner, 2018). In the context of Burnaby, the main fuel is waste heat from waste combustion. The waste comes from several municipalities in the metro Vancouver area and the reuse of it is therefore a first step towards joint use of local heat assets. Apart from the waste heat from the waste combustion plant there is a practice to recover waste heat from municipal sewage water in the metro Vancouver area, since the successful use of waste heat from sewage water to the Olympic Village. Hence, at municipal level there seems to be a first steppingstone for a culture of sharing. However, public-private collaborations are not yet in place (for making use of locally available heat sources).

Scale of outreach: DH activity is per definition geographically delimited to the region where the DH assets are. In the context of Burnaby there are several DH companies that are operating in parallel. Hence, there could be a potential to spread the idea of a sharing culture across these entities. In terms of stakeholders a sharing community would benefit some stakeholders directly (those involved in the sharing activities) and the wider community indirectly (ensuring the most cost efficient heat sources are used increasing affordability of heat and hot water supply, the use of local and environmentally sustainable fuels leading to reduced levels of air pollution and possibly a culture of sharing knowledge to the young/ wider community etc.). The scale could be further expanded by resorting to inclusive, aesthetic and signaling buildings.

End user: social values that the end user benefits from are a carefree, resilient heat and hot water supply of high indoor comfort. Another possible benefit is to have access to recreational spaces at building level (saving space), be engaged in one's heat and hot water supply (empowered through digital tools allowing the customer to follow his/her consumption patterns, joint collaboration with the energy company to become a prosumer), affordable heating and enjoy the feeling of being included and part of a resource efficient and sustainable heating solution.

Local communities: there is a possibility to engage with local heat supply owners to establish win-win solutions. As mentioned above, this engagement is underexplored both in mature DH markets and in the context of Burnaby. Other ways than heat supply to engage with the local community are to make governance decisions leading to an impact for many stakeholders in society, either directly or indirectly (research & development, education of the young, philanthropic activities etc.).

Social values: DH can generate social values to multiple stakeholders. Examples are:

- Employees: by providing positive working conditions
- Customers: providing a carefree, resilient heat and hot water supply that is environmentally sustainable making use of local assets (generating a pride in the customer), an affordable heat and hot water supply and the possibility to engage in one's consumption of heat
- Wider society: job creation, improved air quality, affordable heating and hot water, recreational spaces, inclusion, knowledge/ education and other

Social impacts: The social impacts of DH can be both positive and negative. If the fuel supply is not environmentally sustainable many of the positive social values are lost (improved air quality, making use of resources otherwise lost and the co-creation element with local community stakeholders). If government choices are made that isolate the DH activity from other stakeholders, the positive social impacts are further reduced (by minding its own business, the DH companies in mature DH markets reduce their potential to generate social value or to mitigate negative impact related for instance to unfair access to energy).

The social layer is summarized in Figure 12.

<table>
<tr><th>Local communities</th><th>Governance</th><th>Social values</th><th>Societal culture</th><th>End User</th></tr>
<tr>
<td rowspan="2">Local collaboration on heat supply
<u>Governance choices</u>
Educational actions
Philantropic activity
Sustainable investment thresholds
R&D activities</td>
<td><u>Governance choices</u>
Educational actions
Philanthropic activity
Sustainable investment thresholds
R&D activities
Co-create & co-invest
Customer empowerment</td>
<td rowspan="2"><u>Employees</u>
Positive working conditions

<u>Customers</u>
Carefree
Resilient
Affordable
Empowerment

<u>Wider society</u>
Jobs
Improved air quality
Recreational spaces
Inclusion
Knowledge transfer</td>
<td>Circularity and shared economy</td>
<td rowspan="2">Carefree
Resilient
Affordable
Empowerment</td>
</tr>
<tr>
<td>Employees
Working conditions</td>
<td>Scale of outreach
Geographical area of the DH system
Across stakeholders
(employees, customers, wider society)</td>
</tr>
<tr><td colspan="5">Social impact drivers (positive or negative will depend on configuration of driver)
Fuel (fossil/ renewable)
Sourcing of fuel (remote/ local)
Governance decisions (promoting social sustainability or not)</td></tr>
</table>

Figure 12: The social layer of the DH business model (Source: result from study)

The social sustainability layer identified above reflects a potential, maximized integration of social sustainability drivers in the DH business case. The interviews in the context of the Burnaby DH project resulted, on an overall level, to the following factors being ranked as most important for generating social sustainability values:

- Job creation
- Transparent communication across the value chain

- Signaling buildings
- Cost competitive heat solution
- Partnerships with local stakeholders
- Heating & cooling supply

All points above are possible to impact by the DH companies themselves and are directly linked to government decisions in the companies. To generate strong social values there needs to be a conscious decision made, by DH companies. When making the decision, an analysis needs to be made of what it means for the current business model. For example, including additional heat sources into a system hinges upon the system being smart enough to use different heat sources at different points in time (when most cost efficient to use them). Additional investments might be needed in connection lines (to waste heat sources), storage units, heat pumps (for heating and cooling and for heating waste heat up to desirable system levels) and staff with new capabilities (to manage a diverse heat supply and co-creation with heat suppliers: leading to several contractual agreements). Smart systems/ digitalized DH activities facilitate empowerment of customers so that they can start impacting their heating demand and can support the function and flexibility of the system.

To make changes to business models that are in operation and functional is challenging, however, shifting towards social value creation has many upsides for the DH system because it anchors it to the local community.

5.2 Social Values in Electricity, Gas and DH

An analysis was made to compare how different heat providers could work on social value creation. The analysis is based on an overall understanding about electricity and gas company practices and on DH information from the case study in Burnaby.

Electricity can be generated from different sources where combustion of fossil fuels generates ample greenhouse gases and air pollution whereas other alternatives such as solar, wind, hydropower or nuclear do not. If nuclear generated electricity is green or not has been much discussed. It is, however included in the EU Taxonomy (a framework for sustainable investments) as a transitional activity that can be sustainable given strict, technical criteria during a limited time (Directorate-General for Financial Stability, 2022). Gas providers tend to resort to natural gas. As with nuclear generated electricity, gas can be sustainable under strict, technical criteria during a limited time (Ibid). The Burnaby DH system will resort to local waste heat from waste combustion. Waste heat is seen as a renewable source (EU, 2023).

It should be noted that the analysis assumes electricity, gas and DH price to be at a similar level. The economic and environmental value proposition of the three heating alternatives are summarized in Table 16.

Table 16: Economic and environmental value propositions of alternative heat supplying technologies (DH reflects the case in Burnaby)

	Electricity	**Gas**	**DH**
Value proposition	Reliable	Reliable	Reliable
	Green- if based on hydropower, wind, solar and nuclear -the latter is debated- a sustainable transition activity according to the EU Taxonomy	Green- debated- a sustainable transition activity according to the EU Taxonomy	Green (waste heat)
	Cost competitive	Cost competitive	Cost competitive
	Local supply or central supply	Central supply	Local supply

With the value propositions as point of departure, a comparison is made of the potential of electricity, gas and DH providers (represented by the DH in Burnaby case) to generate social values for each of the SKPIs identified during the literature screening.

The social value addition is graded accordingly:

- Already adds social value
- The social value is diluted by some factor (explained)
- Can add social value if explored
- Is not adding social value
- Is taken for granted and thereby does not add social value

Two SKPIs are closely linked, namely carbon footprint (SKPI 1) and air pollution (SKPI 2):

Greenhouse gases and air pollution have negative impact on health and environmental justice. Generation of electricity with fossil fuels like coal and oil would have a larger footprint than natural gas whereas other generation of electricity would not have any impact. Combustion of coal, oil and natural gas also generates emissions that contribute to air pollution (the extent depends on if/ how the flue gases are cleaned). Recovery of waste heat does not generate greenhouse gases nor air pollution.

Table 17: SKPI: 1 & 2 Carbon footprint & Air pollution

Electricity	**Gas**	**DH**
Is not adding social value or already adds social value (depends on fuel used)	Is not adding social value	Already adds social value

SKPI 3: Fairness

Fairness is linked to the possibility to obtain electricity, gas and DH. Electricity and gas are usually widely accessible. DH will be available to those in proximity to the grid but the DH company in Burnaby is also making micro grids around individual buildings allowing for wider expansion of DH. The idea is to later on, link the micro grids to the main grid.

Table 18: SKPI: 3 Fairness

Electricity	Gas	DH
Already adds social value	Already adds social value	Social value diluted by not being available to all

Two SKPIs are closely linked, namely uses locally available heat supply (SKPI 4) and local collaboration on heat supply (SKPI 5).

For electricity, a usage of wind, solar and hydropower locally is possible. Solar PV would likely have the largest, local outreach (professional and private investors). Natural gas is usually transported long distances. Waste heat recovery from the waste combustion unit is a local asset and the DH company has plans to increase the use of local waste heat (for example from sewage water).

Table 19: SKPI: 4 & 5 use locally available heat supply and collaboration on local heat supply

Electricity	Gas	DH
The social value is diluted (not all can afford to invest in PV and wind/ hydropower is not always possible)	Is not adding social value	Already adds social value

Two SKPIs are closely linked, inclusive buildings (SKPI 6) and aesthetic buildings (SKPI 7).

Buildings that are inclusive can be so by showing what is inside (glass facade), hosting informative displays about the activities of the company, provide recreational space for the wider public (like a park or a skislope like the one on top of a CHP plant in Copenhagen) and other. This opportunity is, to our knowledge, not commonly explored by electricity or gas companies and not by the DH company in Burnaby.

Buildings that are aesthetic can contribute positively to the city scape. They can, for example, signal a sustainability value (like a certain share of waste heat or renewables being used in the system currently). This opportunity is sometimes explored to show the share of renewable electricity at building level (initiated by owners of buildings) but, to our knowledge, not much explored by electricity companies or gas companies and not by the DH company in Burnaby.

Table 20: KPI: 6& 7 Inclusive buildings & Aesthetic buildings

Electricity	Gas	DH
Can add social value if explored	Can add social value if explored	Can add social value if explored

SKPI 8: Space use

Is linked to the building-space that is used by a heating installation. Different installations are needed; an electrical panel/center (electricity), a gas boiler (gas) or a substation (DH). The space needed will vary but the largest space is, to our knowledge, usually needed by gas boilers. By saving space there can be areas in the building that can be explored for joint, recreational purpose.

Table 21: SKPI: 8 space use

Electricity	Gas	DH
Already adds social value	Is not adding social value	Already adds social value

SKPI 9: Sector coupling

It is possible to couple across energy carriers (for example using heat pumps or storage solutions connected to the grids). This possibility is, to our knowledge, not yet commonplace for electricity or gas grids and not resorted to by the DH company in Burnaby.

Table 22: SKPI 9: Sector coupling

Electricity	Gas	DH
Can add social value if explored	Can add social value if explored	Can add social value if explored

SKPI 10: Philanthropic activity

Philanthropic activities can be undertaken to support the local community. The extent of such activity in electricity and gas companies is not known to us. The DH company in Burnaby is not engaged in such activity.

Table 23: SKPI 10: Philanthropic activity

Electricity	Gas	DH
Can add social value if explored	Can add social value if explored	Can add social value if explored

SKPI 11: Education of the young

Educational activities can be to invite students to the company to inform about what actions are performed and the impact the company has on the local community. The extent of such activity in electricity and gas companies is not known to us. The DH company in Burnaby is not engaged in such activity.

Table 24: SKPI 11: Education of the young

Electricity	Gas	DH
Can add social value if explored	Can add social value if explored	Can add social value if explored

SKPI 12: Research and development projects

To engage in research and development projects with the local community can foster local capacity building as well as innovation and practices that benefit the wider community. The extent of such activity in electricity and gas companies is not known to us. The DH company in Burnaby is engaged in such activity.

Table 25: SKPI 12: Research and development projects

Electricity	Gas	DH
Can add social value if explored	Can add social value if explored	Already adds social value

SKPI 13: Sustainable investment thresholds

To have lower investment thresholds for investments that are sustainable is one way to propel such investments. The extent of such activity in electricity and gas companies is not known to us. The DH company in Burnaby is not applying this approach.

Table 26: SKPI 13: Sustainable investment thresholds

Electricity	Gas	DH
Can add social value if explored	Can add social value if explored	Can add social value if explored

SKPI 14: Resettlement issues

In the expansion of/ erection of large infrastructure, resettlement might be needed. For both gas and electricity, it can, to our knowledge, occur because of the need to acquire land. For DH in Burnaby, it is not an issue.

Table 27: SKPI 14: Resettlement issues

Electricity	Gas	DH
Is not adding social value	Is not adding social value	Already adds social value

SKPI 15: Construction disturbances

When infrastructure is built there is often disturbances on traffic and there can be sound pollution. The disturbance passes over time. It is applicable to electricity, gas and DH.

Table 28: SKPI 15: Construction disturbances

Electricity	Gas	DH
Is not adding social value	Is not adding social value	Is not adding social value

SKPI 16: Creation of local jobs

The possibility of an organization to create local jobs will have a direct impact on the local community. For gas, electricity and DH local jobs will be generated. For DH there can also be spillover effects on jobs related to making use of local heat supplies (like waste heat).

Table 29: SKPI 16: Creation of local jobs

Electricity	Gas	DH
Already adds social value	Already adds social value	Already adds social value

SKPI 17: Indoor comfort

The quality of the indoor comfort will have a direct impact on the well-being of people. In Burnaby it is taken for granted that electricity, gas and DH will provide the same level of comfort.

Table 30: SKPI 17: Indoor comfort

Electricity	Gas	DH
Is taken for granted and thereby does not add social value	Is taken for granted and thereby does not add social value	Is taken for granted and thereby does not add social value

SKPI 18: Customer empowerment

Empowered energy customers can actively impact their energy use, ensure that peak loads are shaved and possibly also generate energy into the system: one example is electricity generated by local PVs another is locally generated waste heat. The extent of such activity in electricity and gas companies is not known to us. It is not yet explored by the DH company in Burnaby.

Table 31: SKPI 18: Customer empowerment

Electricity	Gas	DH
Can add social value if explored	Can add social value if explored	Can add social value if explored

SKPI 19: Transparency across the value chain

Dialogue across the value chain is important from suppliers to end customers. The extent of such activity in electricity and gas companies is not known to us. It is somewhat explored by the DH company in Burnaby.

Table 32: SKPI 19: Transparency across value chain

Electricity	Gas	DH
Can ad social value if explored	Can add social value if explored	Already adds social value

Two SKPIs are closely linked, namely safe energy (SKPI 20) and reliable heat supply (SKPI 21).

Safe energy is that the energy supply is safe for the end customer and therefore free from shock, flooding or explosions. Reliable heat supply intends that there are not disruptions in the heat supply to the customer. In Burnaby, the energy supply across electricity, gas and DH is seen as reliable.

Table 33: SKPI 20 & 21: Safe energy & reliable heat supply

Electricity	Gas	DH
Is taken for granted and thereby does not add social value	Is taken for granted and thereby does not add social value	Is taken for granted and thereby does not add social value

SKPI 22: Carefree energy supply

Carefree energy supply means that maintenance and manual operations by the end customers are not needed. In Burnaby, the carefreeness of heat supply is seen to be at the same level for gas, electricity and DH.

Table 34: SKPI 22: Carefree energy supply

Electricity	Gas	DH
Is taken for granted and thereby does not add social value	Is taken for granted and thereby does not add social value	Is taken for granted and thereby does not add social value

Two SKPIs are closely linked, namely stable price (SKPI 23) and affordable price (SKPI 24).

Energy prices need to be affordable to avoid energy poverty. In Burnaby, the price of electricity and gas have been low historically. The DH price will be at similar levels made possible by using waste heat.

Table 35: SKPI 23 & 24 Stable price & affordable price

Electricity	Gas	DH
Is taken for granted and thereby does not add social value	Is taken for granted and thereby does not add social value	Is taken for granted and thereby does not add social value

Returning to the value propositions of gas, electricity and Burnaby DH, the analysis of how SKPIs could be pursued indicates that electricity and DH are in a better position to harvest local assets than gas. Electricity companies could, for example encourage PV installations, and the DH company could engage with additional, local stakeholders in possession of heat supplies. The nature of the local heat supply differs where DH engagement in local heat supply would likely lead to a stronger anchoring to the community because of close dialogue and tailor- made solutions (compared to PV installations).

Electricity and DH share the feature that space indoor can be saved and air pollution can be mitigated (if the electricity production sources are green).

Electricity, gas and DH appear to have several unexplored, government options: transparent value chain, empowerment of the customer, educational efforts, inclusive and aesthetic buildings, sustainable investment thresholds, sector coupling. Actively pursuing the options, social sustainability values that can generate profit (lower costs) and a local anchorage appear feasible.

6 Discussion

The principal objective of the project was to understand if the social dimension of sustainability can change the business models of DH companies and increase their competitiveness.

One main result of the study is the design of a potential, social layer of the DH business model. Several of the factors that can add social value are linked to choices of the companies themselves (setting sustainability thresholds, educating the young, empowering customers, engaging in co-creation activities and other). It is, however, well known that it is difficult to change the way things are done if a business model is in place that still generates profit. Indeed, pursuing social value creation is a strategic task and needs to be included in the way that companies are undertaking both operational activity and investment decisions. Doing so, it appears possible to capitalize on social values in DH.

Depending on the ecosystem in which the DH company is located, there will be different levels of incentives to pursue social values. Institutional structures like public goals and procurement standards that support social sustainability would likely support social value creation at company level. For example, establishing clear social requirements in DH procurement could be one way forward. Indeed, a supportive surrounding will also make outreach to local heat suppliers easier, which lowers the hurdle of co-creation and co-investments. However, even in the absence of institutional incentives it appears as if social values can generate new, profitable business opportunities (directly by saving money in the fuel procurement process and indirectly by anchoring the company to the local community making it difficult to be outcompeted in the mid-long term).

In the context of the case studied, there is a pronounced will to recover waste heat from the waste to energy unit which also foster an openness to other, waste heat collaborations in a future expansion; a feature that is stronger in the context of the case company than in mature markets. The openness to local waste heat collaborations is rather reflecting the development of new business values and logics related to the new DH technologies than the conventional DH solution. Also, the decision to keep ownership over the substation or co-own it with customers reflects an openness to energy service development also reflected in conjunction to the development of new DH technology. Hence, as the new DH technology spreads it might well be that social value creation is increasingly relevant for DH business model design.

Circling back to the principal objective of understanding if the social dimension of sustainability can change the business models of DH companies, we conclude that, yes, that is the case.

To understand the aspect of competitiveness, we compared how applicable social values are to three different heat supply alternatives (electricity, gas and Burnaby DH). All three have the possibility to make government decisions to account for social sustainability that can generate profit (lower costs) and a local anchorage. **Circling back to the principal objective and the aspect of increased competitiveness the answer is conditioned to taking active action.** If the DH companies decide on integrating social value creation as part of the main strategy and work actively to capitalize on them, then yes: competitiveness can increase. If not, there is a risk that social values are diluted and reduced to a tick in the box rather than generating competitiveness.

Last, based on the results in the study, companies that are interested in assuming the strategic position of including social values in their business case are recommended to take the following steps:

1. Review the value chain and understand where there is room to include factors that can generate social values.

2. Turn to the surrounding ecosystem of stakeholders and engage in dialogue with them to identify where there is potential interest and room for co- creation and co-investment.

3. Make social sustainability a management matter, establish a strategy and identify relevant social key performance metrics to follow up on.

4. Revisit the business model logic and understand how the ongoing activities need to shift to pursue social values. Do any risks or opportunities occur? Can contracts be standardized?

5. Start small: identify social values that can generate both economic gain and anchor the company to society. For DH companies, engaging in local waste heat recovery would be an interesting case to pursue.

As mentioned, our project was conducted around a case study. For future research, it would be relevant to understand how social sustainability can be fostered in a larger set of companies (to allow generalization of results). Another, relevant topic would be to understand the importance of different social key performance indicators to the competitiveness of DH: an in-depth analysis of such factors is missing to date. Finally, a longitudinal long-term study on the implementation and effects of integrating social sustainability within DH business models would provide valuable insight and results on the efficiency of social value generation in DH.

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