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Preliminary Study of a District Heating Project in Temuco, Chile.

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Authors:
Jonathan Stemmelen, Engie Latin America, Santiago, Chile.

Supervised by:
UN Environment (Celia Martinez and Pilar Lapuente)
UN Environment – DTU Partnership (Dr. Romanas Savickas)
ENGIE Latin America (Loic Gruson and Pierre Garbit)
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1. Executive Summary

The city of Temuco (Chile) has been trying for years to fight extreme air pollution coming from the combustion of wet wood in old and inefficient woodstoves during the cold season. Within the framework of implementation of UN Environment’s District Energy in Cities Initiative in Chile, the Municipality of Temuco committed to advance on the deployment of district heating as a solution to improve urban air quality and as a clean alternative to traditional heating systems. In 2018, the city was selected as the pilot city for the Initiative and is receiving technical support and guidance to develop a district energy pilot project and an enabling framework to attract investment. UN Environment provides this support through the public-private partnership built under the District Energy in Cities Initiative and in collaboration with the Ministry of Energy and the Ministry of Environment.

Engie, one of the world leaders in development and operation of district energy networks around the world and key partner of the District Energy in Cities Initiative, has offered this study to evaluate the potential of district heating in Temuco as in-kind contribution to the work performed by the Initiative to accelerate the uptake of district energy in Chile. Engie has a true conviction that a District Heating Network is the solution to tackle air pollution in Temuco and is willing to be part of this sustainable project.

The main objective of this study is to identify a potential area to kick-start a District Heating Network in the city as well as to select the best technologies for heat generation to reduce air pollution. The study involved collecting data from selected areas, an energy consumption analysis, a costs analysis, visiting buildings in the city, and meeting stakeholders from the national government, the private sector and the municipality.

After performing an initial scan of the city, one area (Area n°1) was selected as the most promising location to start a district heating network in Temuco. In its Initial Scope, the study analyses the viability of connecting “key clients” to the network, those considered as large and reliable heat consumers such as public buildings. These anchor clients resulted in 26 buildings, approximately 180,000 m² of constructed area, consuming around 12 GWh per year of heat and requiring a network of 2.4 kilometres. In its Final Scope, the study analyses the possibility of connecting the residential buildings situated along the district heating network, which are equivalent to 140 houses (approximately 19,500 m²). Those additional connections should be carried on at the beginning of the project or during the following years but always anticipating future connections. It has been assumed that the company in charge of the concession would also be in charge of developing the network and commercialising the heating service.

To produce the heat required to cover the demand of public and residential buildings, this study considers a thermal plant with two biomass boilers: one to supply heat during cold season (5 MW) and one for hot water outside the cold season (1 MW). Both boilers are expected to have incorporated the latest technology on emissions reduction. Two natural gas boilers (7 MW each) have been considered as backup for peak demand. It is estimated that these technologies would drastically reduce emissions (around 4,000 fewer tons of CO₂ per year) and would reflect the best compromise between energy prices and emissions reduction. The figures considered correspond to the thermal plant for all key clients (anchor loads) and 140 extra houses.

Concerning the financial assessment, the investment required to build the power plant and the distribution network connecting only anchor clients (Initial Scope) is estimated at 6,290 MCLP (9.435 MUSD). The additional investment to connect the residential buildings to the network (Final Scope) is estimated at 1,170 MCLP (1.755 MUSD), which includes

---

1 The rule to write numbers in this report is the following: “,” is for thousands and “.” is for decimals (English language rules)
2 Exchange rate 1CLP equivalent to 0,0015 USD
an estimated budget of 8 MCLP (12,000 USD) to install a centralized distribution system in each average house of 140 m². Thus, total investment for final scope is estimated in 7,460 MCLP (11.190 MUSD).

As part of this study we made a comparison of unitary prices between different technologies available to supply heat in Temuco. These unitary prices concern OPEX. The following graph illustrates the comparison in terms of OPEX cost between different technologies:

As shown in the graph, the OPEX, including O&M, heavy maintenance and energy cost is lower for district heating than for the other scenarios studied: individual electric system, individual pellet system, individual LPG system and individual NG system.

However, to this OPEX concerning the district network, we must add the investment (CAPEX for the Final Scope), which is shown in the next figure. The unitary total heating cost (OPEX+CAPEX) has been calculated for different amounts of financial support considering a concession of 30 years and an interest rate of 8% for the reimbursement of the investment to build the network and connect all clients.

The results show that the price for heat will be about 90,3 CLP/kWht\(^3\). It is estimated that a subsidy of 1,560 MCLP would be necessary to supply heat at 80 CLP/kWht and be more competitive than the LPG system.

\(^3\)KWh = kWh thermal unit. Corresponds to the actual energy delivered at the end of the process taking in to account efficiency of power plant and losses from the network or efficiency of the individual system for the current situation (75%).
2. General Context

2.1. Overview of the District Energy in Cities Initiative

Heating, cooling and hot water represent 60% of the energy demand in buildings worldwide\(^4\). There is an urgent need to reduce demand and shift to sources that are consistent with our global climate and energy ambitions. However, even with demand-side reductions in buildings, cities will still have significant demands for heating and cooling from the buildings sector and other sectors, which will need to be supplied from efficient, low-carbon sources. District energy systems create synergies between the production and supply of heat, cooling, domestic hot water and electricity and can be integrated with municipal systems such as power, sanitation, sewage treatment, transport and water, meaning that heating and cooling can be low-carbon, energy-efficient and maximise local renewable resources.

District energy systems provide the means to make use of low-quality thermal energy (waste heat) to provide buildings with heating, cooling and hot water services. These systems allow high levels of affordable renewable energy supply through economies of scale, diversity of supply, balancing and storage. This makes them a key measure for cities/countries that aim to achieve 100% renewable energy or carbon neutral targets.

The District Energy in Cities Initiative (DES Initiative) is a multi-stakeholder partnership coordinated by UN Environment with financial support from DANIDA, the Global Environment Facility, and the Italian Ministry of Environment and Protection of Land and Sea, with the goal of accelerating the transition of cities in emerging economies and developing countries to low-carbon, climate-resilient societies through modern district energy systems.

As one of six accelerators of the Sustainable Energy for All (SEforALL) Energy Efficiency Accelerator Platform, launched at the Climate Summit in September 2014, the Initiative is supporting market transformation efforts to shift the heating and cooling sector to energy efficient and renewable energy solutions. The Initiative aims to double the rate of energy efficiency improvements for heating and cooling in buildings by 2030, helping countries meet their climate and sustainable development targets.

The initiative provides technical assistance to local and national governments that wish to develop, retrofit or scale up district energy systems. It also facilitates peer-to-peer learning through partnering opportunities/ by partnering cities, investors, and the private sector, while advocating for the policy and regulatory enabling environment that can attract private sector investment. The Initiative and its partners are currently providing technical support to cities in four pilot countries (Chile, China, India and Serbia) and ten replication countries (Argentina, Bosnia and Herzegovina, Colombia, Egypt, Malaysia, Mongolia, Morocco, Russia, the Seychelles and Tunisia).

\(^4\) Source: IEA
The Initiative creates a market for district energy by:

- **increasing awareness** of the potential of district energy and its role in achieving multiple socio-economic and environmental benefits;
- **demonstrating viability** through the development of pilot projects, thereby strengthening the capacities of city planners, policymakers and stakeholders to develop, implement and monitor district energy projects;
- **creating an enabling regulatory framework** that will unlock private sector investment and ensure sustainable implementation;
- **replicating** our approach in different cities in the same region to foster industry growth;
- **exchanging experiences** between city/country partners on district energy innovation and best practice through a 'cities for cities' twinning process.

The District Energy in Cities Initiative in Chile

Chile is one of the four pilot countries of the District Energy in Cities Initiative. As such the country is receiving tailored technical assistance and guidance to initiate a market on modern district energy. From the 10 cities that have joined the Initiative in Chile, Temuco has been selected as “pilot city” to demonstrate the viability of the technology in the country. For the implementation of activities in Chile, the Initiative counts with the support and collaboration of the Ministry of Energy and the Ministry of Environment.

This assessment falls under the framework of implementation of the District Energy in Cities Initiative in Temuco as pilot city of the Initiative in Chile, and is part of the technical assistance that is being provided to the Municipality to advance in the development of a district energy demonstration project. It responds to the requests made by the Municipality to analyse the area of Balmaceda as a potential area for the development of a district heating network.
2.2. City of Temuco

Temuco is the capital city of the province of Cautín and of the region La Araucania (IX region). The city is located approximately 650 km south of Santiago. It has an area of approximately 464 km² and a population of 283,000 inhabitants. Today the city is facing a major environmental problem related to air pollution (Figure 1 below illustrates the air pollution faced by the city). Dangerous particles are emitted by burning wood and fossil fuels with old and individual traditional systems, without any relevant filters. This phenomenon sharply strikes during and around wintertime (from April to October). During this period of the year, the area experiences low temperatures and low winds inducing a densification of smoke in the air. Population exposed to this smoke has higher risks of being affected by cardiovascular diseases among other diseases related to air pollution. Air pollution is responsible for 4,000 annual cases of premature death from cardiovascular diseases in Chile, costing US$8 billion per year in medical expenses and loss of labour productivity, according to the first environmental report from the Ministry of Environment of Chile in 2014. In 2016, Temuco experienced 26 days of environmental emergency due to high air pollution levels.

![City of Temuco](image)

Figure 1: City of Temuco

To face this environmental problem the Municipality of Temuco decided to analyse the viability of implementing district heating in the city and joined the District Energy in Cities Initiative to receive support and guidance to identify and develop a pilot project.
3. How Does a District Heating Network Work?

3.1. Major Tool for Energy Transition

A district heating network is a group of installations producing and distributing heat to buildings door-to-door. Thus, the heat delivered by the network can be used to heat buildings, ensure hot water supply or other specific needs. As shown in Figure 2 above, a heating network can supply heat to any kind of building in a city, from hospitals to swimming pools, government institutions, residential houses and other types of buildings. Pipelines are underground so the network does not create any visual pollution in public areas.

Production – Thermal Plant

The production station consists of one or more heat power plants using primary energy to supply the network with heat. The primary energy used to produce heat can come from several sources: renewables (geothermal, biomass ...) or fossil fuels. Inside these thermal plants are boilers to produce the heat if the local primary energy comes from a fuel such as wood chips or natural gas. If the energy comes from underground, as is the case for geothermal energy, the power plant consists of an underground pump connected to a heat exchanger transporting hot water.
A primary underground network using pipelines carries the energy thanks to a heat transfer fluid, which can be in the form of hot water, from the production station to the buildings. The network has an “outgoing pipe” dispatching the hot transfer fluid and a “return pipe” bringing it back once it is used and therefore colder. A low-pressure network with pre-insulated steel piping is recommended to cover the perimeter of the network. Heat distribution is usually done in modern systems using a network of pre-insulated pipes conveying hot water. In some older systems, steam is used but with several disadvantages. For example, steam pipes are inherently more dangerous and more expensive to install.

Supply – Delivery Stations

Heat is dispatched and measured at the level of a delivery station (or sub-station) with the use of heat exchangers. This marks the separation between primary and secondary networks. It is also the limit for the contracted service generally just after the heat exchanger. There can be a heat exchanger for heat and one for sanitary hot water (or one for both). The heat exchanger transfers the heat from the water in the district heating network to the water in the internal network.
Preliminary study of a DHN in TEMUCO – Engie Latin America

Internal Distribution - Secondary Network

The internal network guarantees distribution of internal heat in the building (heat and sanitary hot water). This network consists of pipes going inside or outside the buildings and delivering hot water through radiators. The client will also have a sanitary hot water balloon to secure hot water production and temperature. The Internal network can be built and installed by the client or by the service company and is usually backed-up with a contract.

Figure 7: Internal Distribution Network

Key figures in France

- Around 600 district heating networks
- 4800 km of pipelines
- 22,800 GWh delivered of which 50% come from renewable sources
- 2.27 million buildings supplied
3.2. Key Arguments for Developing a District Heating Network in Temuco

District heating networks offer several benefits compared to individual heating solutions such as wood stoves, electricity or fossil fuel-based solutions. In the case of Temuco, we can list the following benefits:

- **Technical:**
  - Reduction of fossil fuel supply;
  - Possibility to use existing production units to be part of the network;
  - Absence of operation & maintenance of individual systems in buildings bringing reduction of risks, noise, gain of space, and so on.

- **Energetic:**
  - Higher energy efficiency (more performant equipment, better maintenance & operation);
  - Adaptable energy sources regarding the local context (biomass supply, heat recovery, …);

- **Environmental:**
  - Reduction of GHGs emissions and Particular Matter;
  - GHGs and PM emissions much lower and better reduction of air pollution thanks to centralized industrial systems (better filters, better control of air emissions but also emissions into the water and the ground).

- **Social:**
  - Reduction of health risks related to air pollution;
  - A base to create local employment and professionalising the community around district energy;
  - Fight against energy poverty.

The possibility to use existing production units in the future network has not been analysed in this study. Using existing units will not only decrease the power needed by the plant and reduce investment but also bring flexibility to the network. The flexibility here consists of being able to supply heat to different parts of the network without having to turn all production units on at the same time. For example, if demand is low in one area of the city, one could think about separating the network in sections with valves and only turning on the production site of the required area.

Another benefit for customers connecting to a district energy network is the gain of space. Individual heat generation systems (gas boilers/woodstoves) would be substituted by a sub-station underground that would supply heat to the whole building. An additional benefit is the reduction of risks. In fact, having a boiler in a building is always a risk; having a sub-station underground with no combustion units is lowers this risk.

Having the best technologies in an industrial site will secure energy efficiency for heat production in the city. Today, district networks are integrating more and more smart devices and performant materials to deliver a precise demand to the client with as few losses as possible. In Chile, companies already operate heating and cooling systems for skyscrapers or big residential buildings and condominiums. Although these systems cannot be called “district energy networks”, the technology is the same. Thus, there is an existing technological market to develop district energy.

Another advantage of having an industrial thermal plant will be to drastically reduce GHGs and PM emissions by using the latest technologies in filters and using a local, well-managed energy source. It seems that in Temuco, biomass would be the most adequate energy source for the district heating plant from an economic, environmental and availability perspective. The use of a local energy source, such as biomass, will bring additional benefits such as helping the country reduce its dependence on imported fossil fuels.

District networks are long-term projects highly related to the community. In countries like Denmark, district energy has been developed for 100 years and is still evolving. Providing heating and cooling must be acknowledged as a right for citizens as much as electricity is in many countries.
4. Technical Feasibility of a District Heating Network in Temuco

4.1. Decision Matrix to Select Potential Areas

In the case of Temuco, it has been decided that the selected area must have key clients with high energy density and high building diversity. These key clients may be hospitals, malls, schools or public buildings and they are considered as anchor loads for the project. Their high energy consumption and reliability facilitates the business case for district energy, making them key to kick-start a new project.

One could say the district network should target areas with low to middle class households, which are using wet wood as fuel for heat thus constituting areas with high emissions. However, in order to secure a profitable network, as much for the local population as for the private investor, it is advisable to start a project where key clients (anchor loads) are. Once the network is secured it will naturally expand towards these residential areas year after year. That being said, to accelerate the process of expansion, local authorities as well as government may work towards exploring mechanisms to incentivise the connection of low- and middle-income families who may have difficulties in affording this new service.

The following graph illustrates the criteria to select a potential area:

![Graph illustrating criteria to select a potential area]

Although the largest percentage of air pollution is actually not coming from key clients, they are essential to the business case for district energy. For this reason, the potential area to kick-start district energy in Temuco should be characterized by:

- **High building diversity**: different types of buildings such as health, education, etc.
- **High energy density** calculated with the consumption of clients divided by the linear meters of pipelines to install between the heating plant and the clients.
- **Constant consumption** during the year and even on a daily basis to have a flat curve of demand facilitating the response of the industrial equipment.
- **Air pollution** level is also one of the main factors to select an area to kick-start the district network.
- Other criteria such as the land background (high hills, rivers, etc.), energy availability (waste energy, etc.) can be analysed.

4.2. Identification of Potential Areas and Selection of a Preferred Zone

The methodology used for this study was to locate potential clients in the city that would provide enough demand for the project to be feasible. What we look for are “anchor” clients: those that have a high level of demand and are reliable. Such clients could be collective residential buildings, sport infrastructures such as swimming pools, education buildings such as universities and schools. In order to search for this kind of client, a local expert was contracted by UN Environment to provide insight and collect data in the city. Apart from anchor clients, a district network project can be boosted when the diversity of clients is important. Diversity of clients helps to have a “flat” demand curve, enabling the system to work constantly without interruption.

In the city of Temuco, three potential areas were identified to develop a heating network: Area n°1, Area n°2 and Area n°3. In these areas, we identified 60 potential clients.

![Figure 8: Potential Areas to Develop a District Network](image)

When selecting a potential area in the city, often multiple sites will appear as “potential”. Technical figures cannot be the only criteria to follow. It is essential to go on the ground and “feel” the opinion of the clients in the selected area. In the case of Temuco, meetings were held with the representatives from the Municipality: as explained below, area n°1 was pointed out as the most interesting area for the local government at an early stage of the project. The selected area has an available field to install the plant, many public buildings that are considered anchor clients and high diversity, among other reasons. This is why, in this study, we focused essentially on this area.

That being said, the main objective of the network should be to address air pollution. The Final Scope of this study consists of connecting houses that currently use firewood as their main energy source to supply heat. However, local authorities should consider social and environmental guidelines for the expansion of the network in the following years.
Figure 9: Network’s Future Expansions

The orange area presents essentially low- to middle-income neighbourhoods mostly using firewood for heat. Thus, orienting the network towards this area would have a strong impact on environmental issues and energy poverty. However, this area certainly has the higher challenge in terms of profitability for the network.

The yellow area corresponds to an orientation following key clients and connecting houses in between them. In this area, we have key clients such as the university “de la Frontera” which could secure financial assets for the network. Moreover, connecting an existing non-heated swimming pool and other buildings as schools and stadiums could provide a good image to the network as well as improving local services.

Finally, the blue area could be an interesting orientation for the network as new constructions for residential buildings are being planned. The area has potential key clients such as a casino and a mall. Meanwhile the orange area contains many middle- to low-income houses that are definitely targets to fight against air pollution.
Area n°1 is located close to Ñielol Hill in the northern part of Temuco between Balmaceda Avenue and Caupolican Avenue. The area is characterized by having 26 potential clients, including many public buildings such as universities, schools and government institutions. This is why this area of 180,000 square meters has a high potential to develop the district network. Concerning thermal uses, the buildings use biomass boilers (pellets), Liquefied Propane Gas (LPG) and individual heaters inside the offices (electric or wood). Moreover, the thermal power plant could be implemented in this area. According to the municipality, there could be available land in the Pablo Neruda School where existing pellet boilers are installed.

In this study we considered adding the regional hospital of Temuco to Area n°1. This building, by itself, has 85,000 square meters (half the surface of Area n°1) and would be a key client to implement the district heating network. This building already has its own heating network where hot water for heat is supplied towards heaters. This means that the investment to connect this client to the district network will be less than in a building without the proper distribution. Another key building in the area is the penitentiary facility which faces important lack of infrastructure for heating and sanitary hot water. Buildings analysed in this area can be found in the appendix.

The description of Area n°2 and Area n°3 can also be found in the appendix as those areas where not selected for further study.
In the following graphs, the energy mixes for Area n°1 in terms of fuels used for heat & hot water are shown:

For both cases, the consumption of the regional hospital represents half of the consumption in the area and comes from use of natural gas. The next most commonly used fuel is liquefied petroleum gas at 20-25%, followed by firewood, pellets and electricity, together making up around 10% and diesel at about 3%.
Below, we can find a summary table about relevant information of the three areas:

<table>
<thead>
<tr>
<th>AREA</th>
<th>AREA n°1 (Initial Scope)</th>
<th>Area n°1 (Final Scope)</th>
<th>AREA n°2</th>
<th>AREA n°3</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of buildings</td>
<td>26</td>
<td>166</td>
<td>16</td>
<td>18</td>
<td>200</td>
</tr>
<tr>
<td>Heated Surface (m²)</td>
<td>160106</td>
<td>177728</td>
<td>61294</td>
<td>89711</td>
<td>328733</td>
</tr>
<tr>
<td>Estimated Power for heat &amp; SHW (MW)</td>
<td>11</td>
<td>12</td>
<td>3</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>Estimated Thermal Consumption (GWh)</td>
<td>12</td>
<td>13</td>
<td>6</td>
<td>7</td>
<td>26</td>
</tr>
<tr>
<td>Network Distance (m)</td>
<td>2339</td>
<td>2339</td>
<td>3576</td>
<td>4230</td>
<td>10145</td>
</tr>
<tr>
<td>Provided Land for production site</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>AREA 1</td>
</tr>
<tr>
<td>Start DES project</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>AREA 1</td>
</tr>
</tbody>
</table>

Figure 13: Energy Features for all Areas

As mentioned before, Area n°1 has been selected as the area with higher potential to kick-start district energy in Chile from a private sector perspective. The reasons for this are:

- Availability of a landfill to implement the power plant is a major plus (the municipality is willing to provide this land as an example of their support to the project)
- Anchor clients are larger in this area than in the other two areas, in this preliminary stage of the project
- Area n°1 was the only area where the local expert actually collected data

Figure 14 shows the calculation of the Heat Density and especially the Linear Density:

<table>
<thead>
<tr>
<th>AREA</th>
<th>AREA n°1 (initial scope)</th>
<th>Area n°1 (final scope)</th>
<th>AREA n°2</th>
<th>AREA n°3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Density (kWh/m²)</td>
<td>73</td>
<td>76</td>
<td>90</td>
<td>81</td>
</tr>
<tr>
<td>Linear Density (kWh/m)</td>
<td>5023</td>
<td>5745</td>
<td>1545</td>
<td>1727</td>
</tr>
</tbody>
</table>

Figure 14: Heat and Linear Density Comparison

Although heat density is the lowest in Area n°1, it is close to the values of the two other areas. On the other hand, Linear Density is approximately four times higher than in the other areas (without future connections). This means that it could be less expensive to implement the heating network in Area n°1 in a first phase of the project.

Note that linear density strongly depends on the position of the thermal plant. In this case, the location parameter for the thermal plant was decided with the municipality and remains for this study a fixed parameter.
4.3. Proposed network design in area n°1

Another key point in the design of a district heating system is the design of the distribution network. The main goal is to connect all potential clients.

![Diagram of network design](image)

Figure 15 illustrates the path of the network as well as potential connected buildings and the potential location of the thermal plant.

**Figure 15: Possible Design of the Heating Network in Area n°1**

The red line represents the main network and the green lines correspond to the pipeline from the client’s sub-station to the main network. We estimate around 19,580 m² of potential additional surface considering the houses in the path of the network. An assumption has been made for those future clients: they represent residential houses of Temuco with an average total surface of 140 square meters and consuming firewood for heat. With this it is possible to estimate 140 houses added to the network.
4.4. Location of the production site

The municipality of Temuco is contemplating making available a field located in the Pablo Neruda School in order to implement the thermal power plant. Today, the site contains biomass boilers (pellets) to heat the school. The implementation of the thermal plant in this location might not be the only viable option and the developer of the future district network should identify other locations if needed.

Figure 16: Potential Site to Install Production Site

Figure 17: Current Location of School’s Production Site
4.5. Methodology to estimate heating needs

**Heating Degree Days**

Heating degree day (HDD) is a measurement designed to quantify the demand for energy needed to heat a building. HDD is derived from measurements of outside air temperature. The heating requirements for a given building at a specific location are considered directly proportional to the number of HDD at that location. To calculate HDD it is essential to know the outside temperatures of Temuco in order to establish the Costic Methodology for the calculations. Costic’s model uses a reference or base temperature (in this study we use 18°C) which is the supposed temperature when heating should be turned on.

Three possibilities then apply:

- if $T_{max} < X$ (base temperature) then $HDD = X - T_{average}$
- if $T_{min} < X < T_{max}$ then $HDD = (X - T_{min}) \times (0.08 + \frac{0.42 + (X - T_{min})}{(T_{max} - T_{min})})$
- if $T_{min} \geq X$ then $HDD = 0$

![Figure 18: Heating Degree days in Temuco during 2017](image)

Climate in Temuco is oceanic, so that through the year cyclonic and anticyclonic influences alternate, with a drier summer (though not as dry as Santiago’s). This means median temperature fluctuates between 8°C and 15°C through the year. The following graph illustrates the heating degree-days (HDD) and relevant temperatures of Temuco across 2017.

HDD are at the highest level during winter (June, July and August) when the temperatures decrease to close to 0°C on average. According to this graph, the months where heating for householders is needed extend from April to September, which is roughly half of the year.
Since 2004, HDD have been constant. Average HDD per year between 2004 and 2017 is of 1796 Degree Days. In the following graph, years where HDD are above the average are highlighted in red and year 2017 in green. Years below the average are in yellow. Thus, in 2017 the city of Temuco experienced an increase of 1.4% compared to average.

For this study, we decided to use 1822 HDD to estimated heating consumption between April and October. The rest of the year, householders use heat mainly for sanitary hot water.
Heating needs

According to the local expert, data on energy consumption of potential clients such as bills were very hard to get. As data availability was not the same for all buildings and studied areas, this study takes a general approach to estimate heat consumption. Buildings were identified according to their surface and their type (e.g. residential, educational facility). Knowing the heating degree days during the year and precise ratios\(^6\) for heat consumption per square meter, we deduced heat consumption for the studied areas.

In Figure 20, we show estimated heat consumption for selected Area n°1 in 2017:

![Area n°1: heat consumption 2017](image)

*Figure 20: Heat Consumption Estimation during 2017 for Area n°1*

If we only consider the initial scope, the total heating for selected Area n°1 is estimated at 9.244 GWh (thermal unit) during 2017. To this, we must add heat for hot water consumption. Assuming sanitary hot water is used throughout the year, it has been estimated at 2.506 GWh of consumption. Thus global heat consumption for Area n°1 is equal to:

\[
9.243 \text{ GWh (heat)} + 2.506 \text{ GWh (SHW)} = 11.749 \text{ GWh (total heat)}
\]

For the final scope, the result would be the following:

\[
10.415 \text{ GWh (heat)} + 3.021 \text{ GWh (SHW)} = 13.437 \text{ GWh (total heat)}
\]

It is important to notice that heat consumption comes from estimations based on heated square meters. Thus, these values correspond to the heating that should be provided to respond properly to clients’ needs.

Consumption profiles for all areas according to type of building are shown below:

---

\(^6\)Engie’s district heating and cooling networks around the world have provided ratios per type of building to estimate client’s consumption. These ratios are confidential information. They reflect the “ideal” heating consumers in Chile should use in order to have the same standards as in Europe. Units for these ratios are [kWh LHV/m²/HDD].
With these curves, we can deduce a global profile:

From this global profile, we can observe a base line from 00:00 to 5:00 followed by a soaring curve when householders start their day. High peaks of demand occur between 7:00 and 8:00 and in the night between 20:00 and 22:00.
From these profiles and consumption estimations we were able to calculate the power demand for heat across heating season 2017 (for hot water, calculations estimate there is a constant demand during the whole year). In Figure 23, we show the power distribution for heat and hot water in Area n°1:

![Area n°1: Heat & SHW Power Demand 2017](image)

*Figure 23: Thermal Power Demand in 2017 for Area n°1 for Final Scope by Type of Building*

From the graph, we observe that there is a seasonal tendency for heat demand: a heating season between April and October and a hot water demand the rest of the year.

The following graph is a different representation of the power demand, called “Monotone Curve”, where power peaks are sorted from largest to smallest. The graph from the Monotone Curve helps us to determinate the maximum power value in 2017. According to our estimations, we deduced maximal power for heat and sanitary hot water equals to 12.22 MW for an estimated consumption of 13.44 GWh (for 26 buildings and 140 extra houses).

![Monotone Curve for Power Demand in 2017](image)

*Figure 24: Power Demand Sorted from Higher to Lower*
4.6. Design of a hot water production system

In this study, one type of technology was considered in order to supply heat to the selected area of Temuco. The technology chosen is a biomass boiler house complemented with a natural gas boiler for peaks and another one as backup. In order to choose this kind of technology, we performed a quick analysis of some options. The following figure illustrates the features selected to choose the right technology for Area n°1:

- Energy availability (locally):

The first criterion is the identification of the local primary energy in the geographical area to secure heat production. Today, in Temuco, energy for heat comes from gas, electricity, biomass and oil, among others. Although geothermal energy could be an ideal energy source in the area, not enough studies have been carried out to be able to select it as a potential source for this study. In the future, it would be recommended to take into account this renewable source of energy. The location of the energy source is also essential in terms of costs and the local economy. Ideally, this source has to boost local economy and limit costs of transportation.

- Energy prices:

The price of the energy source is essential. Fossil fuels and electricity are usually more expensive than biomass in the geographical area of Temuco. Another factor is the volatility of the prices. It is usually better to work with a fuel with a constant price over the years, as is the case with biomass.

<table>
<thead>
<tr>
<th>ENERGY SOURCE</th>
<th>PRICE (^7)</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEAVY FUEL</td>
<td>464</td>
<td>Clp/Litre</td>
</tr>
<tr>
<td>DIESEL</td>
<td>470</td>
<td>Clp/Litre</td>
</tr>
<tr>
<td>LPG</td>
<td>387</td>
<td>Clp/Litre</td>
</tr>
<tr>
<td>NATURAL GAS</td>
<td>550</td>
<td>Clp/m(^3)</td>
</tr>
<tr>
<td>PELLETS</td>
<td>145</td>
<td>Clp/kg</td>
</tr>
<tr>
<td>WOOD CHIPS</td>
<td>40</td>
<td>Clp/kg</td>
</tr>
<tr>
<td>ELECTRICITY</td>
<td>100</td>
<td>Clp/kWh</td>
</tr>
<tr>
<td>FIREWOOD</td>
<td>100(^8)</td>
<td>Clp/kg</td>
</tr>
</tbody>
</table>

\(^7\) Prices are considered without TVA and correspond to prices for non-residential clients estimated in 2017 (except for firewood)

\(^8\) As firewood is not regulated, we took average prices from the “Estudio de precios de Leña y Pellet en Temuco y Padre las Casas Región de la Araucanía” from the Ministry of Environment. In this case, the price corresponds to residential clients.
Prices above were determined from reference prices given by local providers and projects.

- **Emissions:**

The energy chosen for heat production has to be as environmental friendly as possible. This means low emissions in terms of GHGs and PM.

- **O&M:**

Complexity of the operational site can induce costs and hours of overtime. The adequate expertise has to be present locally to secure the long-term operation of the site. Fossil fuel boilers (natural gas for example) present more flexibility in terms of operation to respond to power demand compared to biomass, which needs a constant operation.

- **CAPEX:**

Usually prices for fossil fuel boilers are cheaper than biomass boilers and even cheaper compared to geothermal industrial equipment.

From these features, a summary table has been made to quickly compare technologies for heat production:

<table>
<thead>
<tr>
<th></th>
<th>Geothermal</th>
<th>Biomass</th>
<th>Natural Gas or LPG</th>
<th>Firewood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local resource</td>
<td>N.A.⁹</td>
<td>+ +</td>
<td>-</td>
<td>+ +¹⁰</td>
</tr>
<tr>
<td>Energy prices</td>
<td>N.A.</td>
<td>+ +</td>
<td>- -</td>
<td>N.A.</td>
</tr>
<tr>
<td>O&amp;M cost</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>CAPEX</td>
<td>- -</td>
<td>-</td>
<td>+ +</td>
<td>+ +</td>
</tr>
<tr>
<td>CO₂ Emissions</td>
<td>+ +</td>
<td>-</td>
<td>- -</td>
<td>-</td>
</tr>
</tbody>
</table>

Based on the information included in this table, we have decided to choose biomass as the main source of energy for the study case in Area n°1. The type of biomass would probably be wood chips with a Low Heating Value of 3 kWh/kg (35-40% Relative Humidity) and an average price of 40 Clp/kg.

In Temuco, biomass is an interesting source of energy as forestry residues are available from several activities in the area. For example, many forestry by-products from municipal woodcutting are sent many kilometres away from the city to be processed or simply disposed of. Using these residues for the biomass heat plant would then alleviate this concern for the municipality, reducing transport costs and other municipal expenditures. These synergies between industrial activity and the municipality would have a positive impact on the community as it contributes to the circular economy.

---

⁹ In order to implement geothermal energy in the area, deeper studies concerning geothermal potential should be done.

¹⁰ Available but not regulated. Even though a new legislation is coming to regulate firewood, illegal cuts and selling is still a major concern in the country.
Design of the plant for Area n°1

To respond to heat power demand, we recommend to use a heating plant using biomass (wood chips) as base and a natural gas plant for peak demand and as backup. Clearly, this is not the only technology that could be implemented in Temuco. Natural gas has been chosen to answer peak demand, as it is the most flexible technology for a quick answer. A biomass boiler has to be used for baseload as this technology works better without high fluctuations of the demand.

The following graph is an example of response where 40% of maximal power (4.9 MW for Final scope) is covered by biomass during heating season and the rest by gas boilers (peaks during heating season). Moreover, hot water outside of heating season is covered by a 1 MW biomass boiler:

![Area n°1: Heat & SHW Supply 2017](image)

*Figure 25: Heat Power Supply during 2017*

In this configuration, the energy balance would be 96% of consumption\(^{11}\) covered by biomass and 4% by natural gas.

To get those results, we made assumptions about global efficiency for both systems. In the case of the current situation, we defined that the global efficiency of an individual system is of 75%. For the District Heating Network, global efficiency is estimated at 83% with network heat losses (8% losses on average) and the boilers’ efficiency in the thermal plant.

<table>
<thead>
<tr>
<th>Boilers theoretical efficiency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass boiler for heating season</td>
<td>90%</td>
</tr>
<tr>
<td>Natural Gas boilers</td>
<td>92%</td>
</tr>
<tr>
<td>Biomass boiler for SHW outside heating season</td>
<td>90%</td>
</tr>
</tbody>
</table>

The following table illustrates the difference in consumption between the current situation and the District Heating Network.

<table>
<thead>
<tr>
<th></th>
<th>Actual situation</th>
<th>DHS key clients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Consumption (MWh thermal)</td>
<td>11 750</td>
<td>11 750</td>
</tr>
<tr>
<td>System’s Global Efficiency</td>
<td>75%</td>
<td>83%</td>
</tr>
<tr>
<td>MWh LHV</td>
<td>15 665</td>
<td>14 149</td>
</tr>
</tbody>
</table>

The table shows that moving from the current situation to a District Heating Network will also reduce energy consumption.

\(^{11}\) To run the plant electricity has to be used representing 2% of consumption.
The following table illustrates industrial equipment for the configuration of heat demand in Area n°1:

<table>
<thead>
<tr>
<th>Industrial Equipment</th>
<th>Initial scope</th>
<th>Final scope</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Biomass boiler for heating season</td>
<td>4 to 4.5 MW</td>
<td>4.5 to 5 MW</td>
<td>Will respond to main consumption during heating season</td>
</tr>
<tr>
<td>2 Natural Gas boilers</td>
<td>6 to 7 MW each</td>
<td>7 to 8 MW each</td>
<td>One NG boiler for peaks and one as backup</td>
</tr>
<tr>
<td>1 Biomass boiler for SHW outside heating season</td>
<td>1 MW</td>
<td>1 MW</td>
<td>Will respond to hot water demand outside heating season</td>
</tr>
</tbody>
</table>

## Emissions

Among quantified benefits, we have greenhouse gas reduction and particular matter emissions reduction. To estimate this, we need to compare the energy balance of the current situation with the energy balance for a District Heating Network using a biomass thermal plant as suggested.

With the energy balance, emissions can be calculated for both scenarios. These emissions are summarised in Figure 26:

<table>
<thead>
<tr>
<th>Emissions</th>
<th>District Network</th>
<th>Current Situation</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM10 (kg/yr)</td>
<td>70</td>
<td>3008</td>
<td>98%</td>
</tr>
<tr>
<td>PM2.5 (kg/yr)</td>
<td>60</td>
<td>2575</td>
<td>98%</td>
</tr>
<tr>
<td>CO (kg/yr)</td>
<td>146</td>
<td>7985</td>
<td>98%</td>
</tr>
<tr>
<td>NOx (kg/yr)</td>
<td>54</td>
<td>3973</td>
<td>99%</td>
</tr>
<tr>
<td>VOC (kg/yr)</td>
<td>4</td>
<td>6174</td>
<td>100%</td>
</tr>
<tr>
<td>SOx (kg/yr)</td>
<td>6</td>
<td>2370</td>
<td>100%</td>
</tr>
<tr>
<td>NH₃ (kg/yr)</td>
<td>0</td>
<td>182</td>
<td>100%</td>
</tr>
<tr>
<td>CO₂ (tons/yr)</td>
<td>48</td>
<td>3969</td>
<td>99%</td>
</tr>
</tbody>
</table>

*Figure 26: Comparing Emissions, DHS vs Current Situation*

On the DHN scenario (with extra houses), the biomass boiler house has a fabric filter with a cell cyclone to reduce emissions whereas in the current situation the emissions come from domestic generators for each specific fuel.
In the following paragraph, we made a quick analysis of how a district heating network could benefit the entire city of Temuco if all residential clients were connected.

Accordingly to local sources, Temuco has approximately 95,000 houses and the average consumption of firewood per house is 12,773 kWh per year\(^{12}\), which gives 1,213 GWh per year. During heating season (April to October), this is a main air pollution problem in the city. For Temuco in 2017, 26 emergency days were detected. The emergency days correspond to critical days where PM2.5 levels are higher than the recommended levels. The following graph shows the number of days of environmental emergency in 2016 and 2017 for several cities in Chile:

\(^{12}\) Source: “Medición del Consumo Nacional de Leña y otros Combustibles Sólidos Derivados de la Madera”, CdT. No specifications about the type of house studied in their pool was given.
Implementing a District Heating Network would be a tremendous help in reducing gas emissions as shown in Figure 29:

These estimations of GHG emissions reductions are calculated by changing the source of fuel (here firewood for biomass and natural gas). Emissions are essentially reduced by the use of filters in the thermal power plant. In the long term this would lead to a drastic change in air pollution, and a reduction or elimination of the number of emergency days in Temuco.
5. Economic feasibility of the district heating network

As for the energy mix in Area n°1, we performed an analysis of the costs between the implementation of a District Heating Network in this area and the current situation. The costs for this case study have been split into two different types: CAPEX and OPEX.

5.1. Capital Expenditures

For this technology, investment is divided between the costs of construction of the thermal plant, the costs related to the purchase and installation of pipelines for the network and the costs related to connecting clients without a proper centralized heating system. Most of the time, in these kinds of projects, a third of the price will come from the network, another third from the production plant and the last third from the retrofitting. For this reason, it is very important to locate a thermal plant as near as possible to the clients. This also reflects the importance of a high energy density area to develop the network and install as few meters of pipes as possible. In the case of Area n°1, half the CAPEX comes from the network, which means this is where most of the efforts to reduce costs must be made. However, reducing costs should not influence the material’s quality and safety requirements.

<table>
<thead>
<tr>
<th>CAPEX for DHN Area n°1 (Final Scope)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial Plant [MClp]</td>
</tr>
<tr>
<td>Network [MClp]</td>
</tr>
<tr>
<td>Connection [MClp]</td>
</tr>
<tr>
<td><strong>Total [MClp]</strong></td>
</tr>
</tbody>
</table>

*Figure 30: Investment\(^{13}\) to install Production Site, Network and Connect all Clients*

- The industrial plant corresponds to the boilers, internal pipes and civil engineering for the plant (around 1,000 m² of construction).
- The network consists of pipes from the plant to all key clients for initial scope. This includes the sub-stations with heat exchangers for each building.
- The connection corresponds to the installation of a centralized distribution system (radiators, internal pipes...) for residential houses as well as for some key clients that do not have one yet.

We also calculated an indicative cost to install a centralized distribution system in a single house of 140 m². This cost includes all components for the centralized distribution system in the house. The indicative cost is of 8,126 kClp per house (which gives a ratio of around 16,000 Cpl/m²).

---

\(^{13}\) The study was made with the fixed rate of 1 euro = 740 clp, as some prices correspond to European prices.
### 5.2. Operational Expenditures

#### Energy costs

These costs are related to the consumption of clients selected in Area n°1. The energy mix is fundamental for this case study as choosing one type of fuel for a future thermal plant can balance the economics from one side to another.

In Figure 31, we summarize costs of energy for Area n°1:

![Figure 31: Energy costs, DHS vs Current Situation](image)

Thus, choosing biomass as the main fuel for the thermal plant could be one solution to reduce energy costs. In this case, yearly reduction costs would make up 74% of the total bill.

#### O&M

In terms of Operation and Maintenance, a potential client has to pay for operation and maintenance of his individual system (suppose a boiler). Today a technician contracted by the client supervises all installations in the building. In the future, this technician charge will probably not disappear but the cost of O&M related to the boiler will (permits, costs of expert supervision...). This boiler will be replaced (if not used for the future network) by a heat exchanger in the substation. In other words, today’s costs for operation and maintenance for each boiler in the area will be replaced by the cost of a team supervising the thermal plant and the network.

This is explained in the following figure:

![Figure 32: O&M configuration, DHN vs Current situation](image)
Scope of work for O&M:

- In the current situation: the O&M concerns the individual system and the cost required for this work. This cost has been estimated for each individual system and when studying the area will be multiplied by the number of individual systems.
- In the District Heating Network, there will be a team of technicians and supervisors in charge of the operation of the thermal plant and the network.

A global estimation of O&M prices\textsuperscript{14} has been made on a yearly basis in Area n°1, as shown below:

<table>
<thead>
<tr>
<th>DHN estimation</th>
<th>Current situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>146,688 kClp/year</td>
<td>75,891 kClp/year</td>
</tr>
</tbody>
</table>

When comparing O&M between both scenarios, in the case of the current situation O&M, numbers increase each time a new client is added to the scope of the study. Whereas in the case of the district network the supervising team could provide the service for a wide number of clients before needing more personnel.

From a client’s point of view, this does not mean there is no more operation and maintenance for the secondary circuit (client’s network). That operation is still needed and could be provided by the company operating the network or another provider. The only cost that the client will not bear is the cost of operating and maintaining his or her individual heating system as it will be replaced by the sub-station, which the district operator is in charge of.

\textbf{Heavy maintenance}

Heavy maintenance and revamping usually are costs to replace essential parts of the system. For this study, these costs are calculated as a percentage of CAPEX. This time, there is a difference for heavy maintenance prices between the initial scope and the final one.

\textbf{Totals}

The next table summarizes costs related to the implementation of a District Heating Network in area n°1:

<table>
<thead>
<tr>
<th>Costs</th>
<th>Initial Scope</th>
<th>Final Scope</th>
<th>Current Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy costs (MClp/yr)</td>
<td>219</td>
<td>263</td>
<td>1013</td>
</tr>
<tr>
<td>O&amp;M (MClp/yr)</td>
<td>147</td>
<td>147</td>
<td>76</td>
</tr>
<tr>
<td>Heavy maintenance (MClp/yr)</td>
<td>118</td>
<td>141</td>
<td>105</td>
</tr>
<tr>
<td>CAPEX (Mclp)</td>
<td>6290</td>
<td>7459</td>
<td></td>
</tr>
</tbody>
</table>

\textit{Figure 33: Financial Summary Table for Scenarios in Area n°1}

\textsuperscript{14} OPEX prices correspond to estimations made with local providers in Chile.
5.3. Simplified financial analysis

From these economic results, we made a simplified business plan analysis. The point of view chosen for this business plan is the municipality’s view as provider of the concession. The objective of the business plan is to highlight the feasibility of the project by comparing energy prices and estimating any financial funding that should be considered to secure a competitive price for the energy delivered. Energy, Operation & Maintenance, Heavy maintenance and Capex for both scenarios (Final Scope vs Current Situation) were compared during the concession period.

The following figures illustrate the unitary costs\textsuperscript{15} for each scenario:

![Figure 34: Comparison of Unitary Costs between DHN and Current Situation](image)

The current situation is a mix of all energy systems used for area n°1 considering key clients and the 140 residential houses.

![Figure 35: Comparison of Unitary Costs for Each Solution](image)

These results illustrate the low costs of the district heating system in terms of OPEX compared to the current situation.

\textsuperscript{15} In practice, heat prices and sanitary hot water prices will be different. In this study we estimated a global price for heat.
However, we have to add to these costs the CAPEX during the period of the concession. In the following figures, we show a sensitivity analysis to estimate the impact of subsidies on the unitary cost of thermal energy.

### Hypothesis for sensitivity

<table>
<thead>
<tr>
<th>Hypothesis for sensitivity</th>
<th>30 years</th>
<th>2%</th>
<th>8%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concession period</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflation rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest rate to reimburse CAPEX</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxes</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

No taxes were applied in this study

From these hypotheses, we could deduce the following results:

![Figure 36: Impact of Financial Support on Unitary Heating Cost](image)

From these results, the following conclusions can be made:

- **Competitive with “Pellet reference”:** subsidies should be of 61% → 4,580,000 kClp
- **Competitive with “LPG reference”:** subsidies should be of 21% → 1,560,000 kClp
- No subsidies or incentives will result in a unitary heating cost higher compared to other sources of energy used today in the city (except for electricity).

### 5.4. Particular case of firewood consumption in residential buildings

As mentioned before, the final scope for the network also focuses on residential buildings on the path of the main network. In this analysis, we assume that these buildings are characterized by:

<table>
<thead>
<tr>
<th>Hypothesis for residential buildings</th>
<th>140</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of houses</td>
<td>140 m²</td>
</tr>
<tr>
<td>Surface per house</td>
<td></td>
</tr>
<tr>
<td>Consumption of firewood per house</td>
<td>12.733 kWht</td>
</tr>
<tr>
<td>Firewood price</td>
<td>100 Clp/kg</td>
</tr>
<tr>
<td>Type of firewood used</td>
<td>2,7 kWh LHV and 40% humidity</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of firewood used</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,7 kWh LHV and 40% humidity</td>
</tr>
</tbody>
</table>
From this table we can deduce the following results:

![Prices: District Network vs Firewood](image)

**Figure 37: OPEX Comparison between District Network and Firewood**

As seen from the graph above, the OPEX for the district network is still lower than the OPEX for firewood consumption (the latter being mainly impacted by energy costs as O&M and Heavy maintenance for individual firewood stoves are almost negligible). However, adding CAPEX for the network increases global price by almost double and remains almost twice as high as the price for firewood.

<table>
<thead>
<tr>
<th>Consumption costs per year</th>
<th>kClp/yr</th>
<th>Difference in price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average house before DHN</td>
<td>664</td>
<td>0%</td>
</tr>
<tr>
<td>Average house after DHN (no grant or financial support)</td>
<td>1,153</td>
<td>+74%</td>
</tr>
<tr>
<td>21% financial support (1,560 MCLP)</td>
<td>1,022</td>
<td>+54%</td>
</tr>
<tr>
<td>41% financial support (3,070 MCLP)</td>
<td>894</td>
<td>+35%</td>
</tr>
<tr>
<td>61% financial support (4,580 MCLP)</td>
<td>766</td>
<td>+15%</td>
</tr>
<tr>
<td>82% financial support (6,100 MCLP)</td>
<td>639</td>
<td>-4%</td>
</tr>
</tbody>
</table>

Once again, the competitiveness of the network will depend on the will of the public-private partnership to fight against air pollution. Regulation of firewood could lead to higher prices for this energy or on the other hand, financial support to implement the network could lead to more affordable district energy.
6. Policies for District Energy

When it comes to district energy supply, there is a huge lack of enabling policy and regulatory framework in Chile, which increases projects’ risks and has a deterrent effect on private investors. Policies and regulation concerning the production site exist and are well applied. However, for the distribution and connection to clients there is no relevant jurisdiction today. Therefore, the question is, what kind of policies should the country put in place in order to facilitate the development of district energy?

After discussing this question with personnel from the municipality, the Ministries of Energy and Environment and other stakeholders in the business, we compiled several recommendations in order to facilitate the development of a district network in the city of Temuco:

- **Existing efforts of regulation:**

The Ministry of the Environment already works on regulations and laws to fight against air pollution in the country. These initiatives are found in the so-called “Atmospheric Plan Against Pollution” (Plan de Descontaminación Ambiental Temuco y Padre las Casas 2016). For example, for residential buildings the plan is focused around four core topics:

  - **Improvement of house insulation:**

    Subsidies for 40,000 houses are granted for thermal insulation in existing houses. The subsidies are expected to be granted over a period of 10 years. The Ministry of Housing and Urbanism (MINVU) leads this initiative. Better insulation standards are established. Capacity-building for stakeholders in the construction area are being undertaken.

  - **Quality improvement of domestic heat stoves:**

    There is a mandatory registration of domestic heat generators lead by the Ministry of the Environment. Subsidies to replace 27,000 domestic heat generators are approved with the objective to eradicate individual heat systems using firewood. For commercial buildings and public buildings, it is now prohibited to install these systems. In saturated areas, domestic stoves that do not comply with emission norms are prohibited.

  - **Improvement of fuel quality:**

    A short-term initiative is to fight against the unregulated use of firewood. In order to do so the municipality and the Superintendence for the Environment (SMA) have to execute a regulated commercialisation of firewood. The Regional Secretary for Health (SEREMI de Salud) has to work on the mandatory use of dry rather than humid firewood, as the latter more negatively impacts air pollution. Other institutions such as the Production Development Corporation (CORFO) or the National Forestry Corporation (CONAF) must work on programs to facilitated production of dry firewood.

  - **Education of the local community:**

    Seminars promoting PDA’s initiatives are being held so that the population will be better informed.

These are only some of the initiatives addressed in the PDA for Temuco in 2016 and are strongly recommended to be pursued in parallel to new DHC initiatives.

The problem is that householders usually use wood to heat their houses. According to SERNAC (National Consumer Service), in 2017 the cost of biomass, in this case wood, was six times cheaper than electricity, five times cheaper than
LPG and four times cheaper than oil. Therefore, wood is the lowest-cost choice. However, air pollution and climate change are costs that are not reflected in the marketplace.

Of course, no utility company is going to choose the higher price unless it is forced to bear the true costs of using a primary energy harmful to the environment or unless it is encouraged with incentives. This is called “Corrective Pricing” and can be implemented by putting a tax on CO₂ emissions. Another way to correct the market is by giving permits to emit CO₂ and making these permits tradable.

---

**Incentives & Risk Reduction:**

- **Tax policy:**

  An example of an incentive used in France concerns energy production. 5.5% of VAT is applied to energy consumption when this energy is produced at least with 50% renewable sources of energy. If not, the applied VAT is 20%.

In Temuco, making digging on public streets exempt of taxes while constructing the district network could be an incentive for the investors and constructors on district energy systems. There are already existing articles about Municipal Rights concerning this kind of constructions on public land ("Ordenanza N°002, artículos n°14, n°23 sobre Derechos Municipales").

- **Risk reduction:**

  Reducing the projects’ risks can attract more private investment, which is needed in Chile to develop District Heating Networks. Ministries, regional governments and municipalities should backup the project during the tender by adding mandatory connections for public buildings (penitentiary facilities among other public buildings). This should be extended to guaranteed offtake arrangements for the life of the concession for private buildings such as universities or hospitals. This was the case for many DHN such as in Birmingham (UK), Phoenix (USA) and many other places (examples are explained in “Governance Models and Strategic Decision-Making Processes for Deploying Thermal Grids” by IEA).

In the case of Arcueil Gentilly, a geothermal power plant in France, the municipality made a list of potential future clients. This list had the name of the potential clients and their features such as heat & SHW consumptions, surface, installed power, type of fuel used, among others. In order to attract investors, the municipality should develop Memorandums of Understanding (MoU) with potential clients (at least with the public sector). The scope of this agreement will depend on the willingness of each client to be connected to the future network.

- **Helping “social housing”:**

  As stated earlier in this study, the ultimate objective of this initiative driven by UN Environment is to fight against energy poverty and air pollution. Therefore, the mid-term objective should be to connect households using wood as a source of heat. Of course, these householders will probably face a higher bill in the future if connected to the district network. In Paris (France), the city exerts some downward pressure on energy prices for “social housing” which allows the city to keep
the services affordable for residents who often have significant strains on their finances. In Temuco, a similar approach should be considered.

- Defining permits:

According to EBP’s District Energy Manual, there is no clear definition of the use of the land for district energy systems. This could influence the possible location of the thermal plant. The municipality should lead the definition of these permits. For now, the municipality has located a potential site in a school. Thus, permits should be given to confirm this decision.

That been said, without strong political will the district heating network will endure a very difficult development stage. This political will is even more important for projects integrating the dense urban tissue where important urban works are necessary.
7. Business models

This part of the report concerns the kind of business model that private-public partnership should choose in order to develop a district heating system in Temuco. Several business models have seen the light around the world. The business model will depend mainly on two factors:

- Return on investment
- Degree of control and risk appetite of the public sector

The next table summarizes the types of business models and their characteristics:

<table>
<thead>
<tr>
<th>Return on investment</th>
<th>Control &amp; Risk</th>
<th>Business Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>High</td>
<td>Public</td>
</tr>
<tr>
<td>Medium</td>
<td>Medium</td>
<td>Hybrid</td>
</tr>
<tr>
<td>High</td>
<td>Medium/Low</td>
<td>Private</td>
</tr>
</tbody>
</table>

Concerning the “Control & Risk” column, the qualification of this characteristic is from the municipality’s point of view.

**Public Business Model**

This model would reflect the desire of the municipality to control the provision of heat in the city. Indeed, the local authority in this business model has full ownership of the DHN. This allows focusing the DHN around social and environmental benefits (such as lowering tariff for poor households or restricting energy sources to renewables). The DHN is generally developed by a subsidiary or a department of the local authority. A specific body could be created if the authority plans to sell it afterwards.

**Risk & Governance:** The local authority takes on most of the risk. If economic indicators are low (for example an IRR between 2-6%), the project can be undertaken by a department of the authority in order to reduce costs and facilitate development. The local authority can also outsource some of the work by creating a subsidiary that would lower risks.

**Financing:** If the project is characterized by a low IRR then public investment should ensure its development and goals. It is possible only when the public authority has the financial capability to do so.

**Control:** The local authority has complete control of the DHN. The advantage is the authority would receive all profits and that, once the project’s financial assets are recovered, it could invest in its social and environmental priorities.

**Hybrid Business Model**

This model is generally used when the return on investment can attract private investors. The local authority will assume some of the control and risks of the DHN. The private sector will bring expertise and capital. In this model, a clear vision and mutual efforts must be undertaken to succeed. Under this model, the local authority has a wider panel of options to follow:

- **Private Joint Venture:**

  A joint venture is a business entity created by two or more parties, generally characterized by shared ownership, returns and risks. It involves the creation of a SPV (Special Purpose Vehicle) with split ownership to reduce the administration burden. A special purpose entity is a legal entity created to fulfil temporary objectives and typically used to isolate a firm or authority from financial risk.
Risk & Governance: As the risks are shared, the local authority can reduce them by guaranteeing contracts, working on lowering barriers. Usually the private entity will carry design, construction and operation risks.

Financing: Both parties provide equity. The private sector can provide capital while the public sector could search for grants, development loans, land and tax incentives.

Control: Usually a board of directors is created to manage the company.

- Concession Contract: recommended for Temuco’s study case

Public authority develops a prefeasibility study (in Temuco’s case a private initiative carried out this) and then tenders it to the private sector as a concession which runs for a specified period. After the end of said period, the city can take over the concession or make a new tender.

Risk & Governance: The private entity bears all risks from design, construction and operation. The local authority can regulate the tariff of this entity.

Financing: A large private entity could bring large amounts of capital and the city could provide land (for example, available land in Pedro Neruda’s school).

Control: The local authority via the concession contract manages the control of the concession. At the end, assets can be returned to the private or public sectors.

- Cooperative: Non-profit organisation (usually for low-cost projects)

Risk & Governance: The local authority takes on a large share of risks. Some risks can be passed on to contractors.

Financing: The local authority can leverage low-cost funds.

Control: Members of the cooperation elect representatives.

Private Business Model

In this model, IRR usually varies between 12-20% (or lower for lower-risk projects). It is used when the local authority has a low risk tolerance and relatively low desire for control. This does not mean the local authority is removed from the project. For example, it could attract financing and grants, help with connections, develop initiatives to encourage social and environmental objectives such as low-carbon generation and social tariffs.

Risk & Governance: In this model, the private company carries risks, although the company could enter into a Joint Cooperation Agreement with local authority to mitigate these risks. This is called a Strategic Partnership Model. In return the local authority could benefit from reduced tariffs.

Financing: Financing is provided by the private company and the local authority could attract international loans and grants.

Control: The private company determines the governance structure and usually offers a minority representation to the local authority.

The definition of these models may differ depending on the source. There are no fixed models, they all can be modified and should be according to the project’s environment. However, once a model is defined in a region, the replication of this model could be an advantage for rapid development of DHN. More details of business models are provided by the International Energy Agency in the references section.

The history of the development of DHN in Temuco and its environment suggests following a Concession Contract Model.
In Figure 38, we explain the general approach we suggest:

![Diagram](image)

**Figure 38: Suggested Scope of Work to develop a DHS in Temuco**

Although this should be closely discussed with the municipality, call for tender is advised to go in the direction shown in the picture above. The first argument for this is that the municipality of Temuco will not be able to bear all risks, especially risks of design, construction and operation. Investment will also be a major barrier for the project. Most likely, private investment will secure most of the project. Investors will also be looking for a long-term contract for the concession. That being said, the municipality could make efforts towards finding loans or working with the government to provide subsidies or incentives to lower the CAPEX. For example, as the major goal of the DES initiative is to tackle energy poverty, subsidies to provide heat for households unable to pay for it will be essential. Thus, the municipality will have to play a supporting role in the development of the project as it is playing today.
8. Conclusion

Although Chile already has some small-scale private heating networks (e.g. Torres de San Borja and Cumbres del Condor), many pre-feasibility studies to develop district energy systems have been developed without further progressing into commercialization. Among the reasons for this are:

- Most of these studies have been focused on trying to start the project in residential neighbourhoods, which are in fact the main target but which are also the hardest areas to start with. This report focuses on anchor clients such as public buildings and hospitals, which will give the necessary boost to start the project.
- Today, there is a much stronger political will to develop district energy than in the past. This political support comes as much from local and regional governments as well as from the Ministry of Energy and the Ministry of the Environment without forgetting UN Environment’s push to develop these technologies.

The present report describes the potential to develop a District Heating Network in the city of Temuco. Area n°1 has been identified as the most attractive area to start a DHN project. The main conclusions of this study are:

- In order to have a competitive price, incentives would need to be considered if the main goal of the district network continues to be the fight against air pollution.
- A Concession Contract is recommended as the business model to operate the project.
- Private and public sectors should discuss the future expansions of the network depending on achievable objectives.
- There is still work to be done regarding legislation to implement a district network in Chile. However, this should not be an impediment to the development of this technology as innovation usually comes before legislation.

Key figures of these conclusions are summed up in the following table:

<table>
<thead>
<tr>
<th>Key numbers</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Lenght</td>
<td>1 year to build production site and network</td>
</tr>
<tr>
<td>Concession Lenght</td>
<td>30 years</td>
</tr>
<tr>
<td>CAPEX</td>
<td>7460 MClp (11.190 MUSD)</td>
</tr>
<tr>
<td>OPEX</td>
<td>551 MClp/yr (826 kUSD/yr)</td>
</tr>
<tr>
<td>Heat unitary price (no financial support)</td>
<td>90.3 Clp/kWht (135 USD/MWh)</td>
</tr>
<tr>
<td>Heat unitary price (1.560 Mclp (2.3 MUSD) of financial support)</td>
<td>80 Clp/kWht (120 USD/MWht)</td>
</tr>
<tr>
<td>Heat consumption cost for average house before DHN (using firewood)</td>
<td>664 kClp/yr</td>
</tr>
<tr>
<td>Heat consumption cost for average house after DHN</td>
<td>1153 kClp/yr</td>
</tr>
<tr>
<td>Emissions before DHN (current situation)</td>
<td>2575 kg/yr of PM2.5 and 4000 tons/yr of CO₂</td>
</tr>
<tr>
<td>Emissions after DHN (final scope)</td>
<td>60 kg/yr of PM2.5 and 48 tons/yr of CO₂</td>
</tr>
</tbody>
</table>

Figure 39: Key Figures for District Heating Network
The municipality of Temuco is proactive on the initiative and momentum in the country is growing every day. Now it is time to work on the call for tenders and present the most attractive context for investors to succeed on implementing the first city-scale district heating network in the south of Chile. The hope is that this initiative will trigger the same movement in other cities of the country. A potential schedule for the development of a district network in Temuco could be the following:

Finally yet importantly, call for tender in this particular project should be well structured but not restrictive for potential tenders. This document should guide tenders and the municipality towards a public/private partnership for this project with the following information:

- General dispositions of the concession: length of the concession, missions and obligations of the contracted company, particular conditions, etc.
- Technical aspects of the project: encourage the use of renewable energy sources, presenting potential clients (obligation of connection for public buildings and letters of interest), etc.
- Financial aspects of the project: grants to develop the network to fight against air pollution, insurances to present, etc.

The company to develop the district network should be chosen from the comparison of final offers with the following selection criteria:

- **Reduction of air pollution**
- **Competitiveness of the price for heat**
- **Use of renewable energy**

Lessons learnt point to the fact that many governments misguided feel the need to sacrifice environmental considerations for the sake of improving a country’s economic conditions. Many studies point to the fact that the existence of unsustainable environmental practices aggravates poverty in the concerned areas, creating a cyclical effect between poverty and the environment. In the case of Temuco, air pollution contributes to the decrease of public health. Taking a step back, this means low- and middle-class households then have to spend more money on health to fight disease. Therefore, the poverty trap continues its downward spiral. On the other hand, if households no longer have to endure health costs this could lead to rising standards of living.
9. Acknowledgements

Heartfelt thanks are due to Pilar Lapuente, local technical coordinator for the District Energy Initiative in Cities, for her help and devotion to this initiative.

This report would not have been possible without the help of many individuals who contributed with their insights, suggestions, time and experience to this assessment, including:

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- Rodrigo Dittborn, Profesional División de Calidad del Aire, Ministerio de Medio Ambiente
- Celia Martínez, Technical coordinator Latam and Africa, District Energy in Cities Initiative, UN Environment
- Werner Baier, Ingeniero Consultor, Originaenergia
- Romanas Savickas, Senior Energy Advisor, UNEP-DTU Partnership
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Websites:


Irish bioenergy association:

AP-42: Compilation of Air Emissions Factors:

PDF:


Ministerio del Medio Ambiente (2017): “Calefacción como solución para la descontaminación del aire en las ciudades en el sur de Chile”

Corporación de Desarrollo Tecnológico, Cámara Chilena de la Construcción: “Estudio de usos finales y curva de oferta de la conservación de energía en el sector residencial” + “Medición del Consumo Nacional de Leña y otros Combustibles Sólidos Derivados de la Madera”


Books:
ENGIE (2013): “Guide d’exploitation des chaufferies biomasse”
Annex 1: Glossary of terms

UN Env: United Nations Environment
SHW: Sanitary Hot Water
DHS: District Heating System
DHN: District Heating Network
IEA: International Energy Agency
NG: Natural Gas
LPG: Liquefied Propane Gas
EE: Energy Efficiency
Annex 2: Missions of the contracted company

The contracted company has the duty to provide heat for signed clients. For this, it will have to ensure:

- Conception, financing and development of necessary works for the heat production which includes distribution and supply of heat in the territory of Temuco city
- Operation of the thermal production, distribution and supply
- Construction and extension of the district heat network, allowing future clients to connect
- Renovation and maintenance of all equipment intended to operate the public service
- Cost spreading of all installations
- Organisation and Management of all contract-related relations
- Management of the network including billing to clients, purchasing fuel, water and electricity and all other products and charges related to the management of the public service

The contracted company will have to estimate, during all the concession, the charges ensuring the execution of the contracted duties. The development of a district network will have as main focal points:

- Reduction of energy poverty
- Reduction of air pollution

Indeed, the main objectives of the contracted company will be:

- Guarantee power supply to the urban heating network on a safe and sustainable basis
- Offer a competitive heating price

The contracted company will have to implement the power installations to meet local demand. Specially:

- Implement a thermal heating plant to supply a determined area
- Develop a heating network using hot water to guarantee heating and hot water supply

The will of the municipality is to ensure a competitive energy price compared to the current situation. With this in mind, we expect that the contracted company will execute the necessary work within the scope of heat cost agreement.

In the case of France, tariffs are usually split in two terms:

- R1 (variable): according to energy consumption
- R2 (fixed):
  - R21: electric power to secure production and distribution of heat
  - R22: operation and day-to-day maintenance
  - R23: heavy maintenance, revamping
  - R24: CAPEX financing

The tariff for clients would be calculated as shown below:

\[ R1 \times MWH \text{ consumed} + (R21 + R22 + R23 + R24) \times \text{Power delivered} \]

Sometimes, when there are subsidies in the country, the tariffs will have a negative term (R25) that would lower the bill for the client.
### Annex 3: Buildings analysed in area n°1

<table>
<thead>
<tr>
<th>Name</th>
<th>Area</th>
<th>M2</th>
<th>Type</th>
<th>Equipment</th>
<th>Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Juzgados de Garantía y Tribunal de Juicio Oral en lo Penal</td>
<td>1</td>
<td>5210</td>
<td>Office</td>
<td>Boiler (Centralized)</td>
<td>GLP (L)</td>
</tr>
<tr>
<td>Corte de Apelaciones de Temuco</td>
<td>1</td>
<td>3051</td>
<td>Office</td>
<td>Boiler (Centralized)</td>
<td>GLP (L)</td>
</tr>
<tr>
<td>Teletón</td>
<td>1</td>
<td>2849</td>
<td>Health</td>
<td>Boiler (Centralized)</td>
<td>PELLET (kg)</td>
</tr>
<tr>
<td>Contraloria General de la República</td>
<td>1</td>
<td>2601</td>
<td>Office</td>
<td>Electrical Heating</td>
<td>Elec</td>
</tr>
<tr>
<td>Pabellón El Amor de Chile (Ex Pabellón Expo Milán)</td>
<td>1</td>
<td>1600</td>
<td>Community</td>
<td>Boiler (Centralized)</td>
<td>GLP (L)</td>
</tr>
<tr>
<td>Liceo Office Tiburcio Saavedra</td>
<td>1</td>
<td>4355</td>
<td>Education</td>
<td>Individual Heaters</td>
<td>GLP (L)</td>
</tr>
<tr>
<td>DIDECO, Municipalidad de Temuco</td>
<td>1</td>
<td>3573</td>
<td>Office</td>
<td>Boiler (Centralized)</td>
<td>GLP (L)</td>
</tr>
<tr>
<td>Futuro Centro de Justicia (3 buildings)</td>
<td>1</td>
<td>11831</td>
<td>Office</td>
<td>Electrical Heating</td>
<td>Elec</td>
</tr>
<tr>
<td>DAEM, Departamento de Educación Municipal</td>
<td>1</td>
<td>2900</td>
<td>Office</td>
<td>Boiler (Centralized)</td>
<td>PELLET (kg)</td>
</tr>
<tr>
<td>Jardín Infantil Ñielol</td>
<td>1</td>
<td>571</td>
<td>Education</td>
<td>Individual Heaters</td>
<td>PELLET (kg)</td>
</tr>
<tr>
<td>Fiscalía Local Temuco y Regional de la Araucania (2 buildings)</td>
<td>1</td>
<td>3856</td>
<td>Office</td>
<td>Boiler (Centralized)</td>
<td>Diesel (L)</td>
</tr>
<tr>
<td>Edificio Santa María</td>
<td>1</td>
<td>1989</td>
<td>Residential</td>
<td>Individual Heaters</td>
<td>GLP (L)</td>
</tr>
<tr>
<td>Edificio Corporativo Aguas Araucania</td>
<td>1</td>
<td>2910</td>
<td>Office</td>
<td>Boiler (Centralized)</td>
<td>Diesel (L)</td>
</tr>
<tr>
<td>Liceo Pablo Neruda</td>
<td>1</td>
<td>5303</td>
<td>Education</td>
<td>Boiler (Centralized)</td>
<td>PELLET (kg)</td>
</tr>
<tr>
<td>Internado Pablo Neruda</td>
<td>1</td>
<td>7604</td>
<td>Residential</td>
<td>Boiler (Centralized)</td>
<td>PELLET (kg)</td>
</tr>
<tr>
<td>Liceo Industrial Pedro Aguirre Cerda</td>
<td>1</td>
<td>4668</td>
<td>Education</td>
<td>Individual Heaters</td>
<td>GLP (L)</td>
</tr>
<tr>
<td>Escuela Especial Ñielol</td>
<td>1</td>
<td>2800</td>
<td>Education</td>
<td>Individual Heaters</td>
<td>GLP (L)</td>
</tr>
<tr>
<td>Escuela Especial Ñielol</td>
<td>1</td>
<td>0</td>
<td>Education</td>
<td>Individual Heaters</td>
<td>PELLET (kg)</td>
</tr>
<tr>
<td>Edificio corporativo PDI</td>
<td>1</td>
<td>7442</td>
<td>Office</td>
<td>Electrical Heating</td>
<td>Elec</td>
</tr>
<tr>
<td>Biblioteca Municipal Galo Sepúlveda</td>
<td>1</td>
<td>3034</td>
<td>Community</td>
<td>Individual Heaters</td>
<td>GLP (L)</td>
</tr>
<tr>
<td>Instituto Superior de Especialidades Técnicas</td>
<td>1</td>
<td>5314</td>
<td>Education</td>
<td>Individual Heaters</td>
<td>GLP (L)</td>
</tr>
<tr>
<td>Juzgados Civiles de Temuco</td>
<td>1</td>
<td>1185</td>
<td>Office</td>
<td>Boiler (Centralized)</td>
<td>GLP (L)</td>
</tr>
<tr>
<td>Centro de Cumplimiento Penitenciario</td>
<td>1</td>
<td>8250</td>
<td>Community</td>
<td>GLP (L)</td>
<td></td>
</tr>
<tr>
<td>Hospital Regional</td>
<td>1</td>
<td>85000</td>
<td>Health</td>
<td>Individual Heaters</td>
<td>Natural Gas (L)</td>
</tr>
</tbody>
</table>
Annex 4: Area n°2 and n°3 scans

Area n°2 scan

**18**  
Number of buildings **99.679**

Area n°2 is in a more commercial part of the city, with buildings of at least two floors close to one another. Building density is therefore higher than in other areas and this is a factor that improves heating performance. It is located at what we could call the city centre of Temuco. We identified 18 potential clients in the area with approximately 100,000 square meters. Most of the identified clients are residential buildings and the rest are educational buildings and offices. Once again, data from area n°2 and 3 should be verified with more precision when the project begins as many buildings could not be identified for the study.

Area n°3 scan

**16**  
Number of buildings **68.104**

Area n°3 is a mix between public buildings and residential buildings with a total area of approximately 70,000 square meters. It is located west from the city centre, between Pedro de Valdivia Avenue and Bernardo O’Higgins Avenue. Many of the residential buildings in this area are high floors buildings (up to 20 floors). The use of wood chips is high in this area with some buildings providing heat with oil and liquefied gas. An important fact about this area is that Pedro de Valdivia Avenue, which is north of it, will be renovated with new buildings. This could be helpful to install the pipelines for the future network and therefore reduce costs of implementation.
Annex 5: Networks for area n°2 and n°3

The calculated distances for the network are approximate measures that will have to be verified by the contracted company.
Annex 6: Future constructions in the city of Temuco

In a near future, new constructions in the city will be undertaken. Therefore, the contracted company for the project has to be aware of these urban changes in the city. Some of these renovations appear in the following figure:
Annex 7: Biomass boiler house

A district heating boiler can use wood-chips derived from forestry and/or from the wood industry, for example. Primary energy is considered renewable and therefore CO₂ neutral (or almost neutral if we consider upstream energies). According to European sources ("Best available technologies for the heat and cooling market in the European Union"), the investment costs are estimated to be between 0.3 and 0.7 Meuros/MW. The operation costs are estimated to be around 5% of the investment costs for heat generating capacities between 1 to 50 MW.

The following diagram explains the process of this technology:

Advantages and disadvantages

The advantage of this technology is that it uses a waste product and that it is considered to be a CO₂ neutral technology. However, use of fossil fuel has to be considered, especially for transport of primary energy. Clearly in order to be CO₂ neutral, primary energy must come from sustainably-harvested forest. The disadvantages include high investment costs and limited availability of the energy source. However, transformed biomass materials to pellets or wood-chips have several advantages related to handling, shipping and storage. From a global cost point of view, the higher the calorific value, the lower the cost of transport. In this case, we decided to add a boiler house to the possibly available land field in area n°1 (Pablo Neruda School).
Annex 8: Abatement technologies

Measures to control emission levels from biomass combustion appliances are generally easier to implement in industrial installations rather than smaller appliances intended for domestic use. Many different techniques are available. Examples include:

- **Single Cell Cyclones:**

  Cyclones make use of a centrifugal force within the rotating gases formed from combustion to separate PM. As heavier particles experience a higher centrifugal force, these particles cannot be maintained within the gas glow and hit the wall of the collector before sliding down into a container. This is a highly reliable and simple technology that can work at a wide range of temperatures and is relatively cheap compared to other abatement techniques. However, cyclones are not capable of reducing fine PM that is smaller than 10 microns.

- **Multi Cell Cyclones:**

  Multi cell cyclones are used in parallel. They are longer in length than single cell cyclones, enabling PM to be retained for a longer period and allowing for a more efficient reduction of PM levels.
Fabric filters comprise a fabric bag, which acts as a filter, trapping particles in flue gas as they travel through this filter. These filters are a highly effective PM abatement technology and become even more effective when used alongside a cyclone to ensure the removal of large particles.

Electrostatic Precipitators:
ESP make use of electric fields to remove PM from flue gases. They incorporate both a charging section and a collecting section – a negative charge is transmitted to the particles from electrodes in the charging (ionising) section, which results in the attraction and subsequent attachment of the particles to positively charged electrodes (collection plates) in the collection section.

Other abatement technologies are available. The effectiveness of the above abatement techniques in reducing PM levels is identified in the following table:

<table>
<thead>
<tr>
<th></th>
<th>PM10</th>
<th>PM2.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Cell Cyclone</td>
<td>50%</td>
<td>5%</td>
</tr>
<tr>
<td>Multi Cell Cyclone</td>
<td>75%</td>
<td>10%</td>
</tr>
<tr>
<td>Electrostatic precipitator</td>
<td>95%</td>
<td>90%</td>
</tr>
<tr>
<td>Fabric Filter with cyclone</td>
<td>99%</td>
<td>99%</td>
</tr>
</tbody>
</table>