THERMOS

Thermal Energy Resource Modelling and Optimisation System

D3.3 - THERMOS Pilot and Replication City Case Studies

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Deliverable Authors:

Valdis Rieksts Riekstins – Jelgava City Council

Inga Kreicmane – Jelgava City Council

Ioana Baba – Alba Iulia Municipality

Maria Elena Seemann – Alba Iulia Municipality

Wojciech Stańczyk – KAPE

Marta Kęsik – City of Warsaw

João Dinis – Município do Cascais

Luis Dias – Município do Cascais

Rita Ehrig – Deutsche Energie Agentur GmbH (dena)

Marta Chillida Munguet – Ajuntament de Granollers

Judit Tarradellas Font – Ajuntament de Granollers

Marc Vives Llovet – Ajuntament de Granollers

James Wilson – Islington Council

Juan Varo López – Creara

Celia Valero Vitores – Creara

Reviewers:

Paolo Michele Sonvilla – Creara

Martin Holley – CSE

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1 Introduction

The THERMOS project aims to accelerate the development of new low-carbon heating and cooling systems across Europe, and enable faster upgrade, refurbishment, and expansion of existing systems. The overall aim of the project is to provide the methods, data, and tools to enable more rapid, cheap and sophisticated planning of thermal energy systems.

This deliverable corresponds to a project task called "Embedding THERMOS in City Energy Planning". The main objective of this Task is to ensure that THERMOS is used by the cities in their energy planning processes, and that the knowledge gained from this experience is captured for replication and dissemination purposes by other local authorities. It provides initial guidance on modelling case studies with the THERMOS Tool[1]. For further information, the reader should refer to other publications[2] of the THERMOS project, as indicated in the relevant sections, or to the online THERMOS Tool user manual[3].

The aim of this deliverable is to provide feedback on the experience from the seven THERMOS cities using the Tool, including recommendations for replication and dissemination processes. Additionally, as the cities were using a former version of the tool, the preparation of this document was also useful to receive feedback in terms of user-testing and improving the tool. This report includes the most relevant case studies selected by each of the cities, the reason for their selection, the stakeholders involved, the inputs included, the results obtained, and the conclusions reached.

1. **Jelgava** has used the THERMOS Tool to determine whether it is feasible to connect a private residential area to an existing district heating network, as some end-users have expressed their eagerness to get clean and sustainable energy with very high-level comfort compared to wood or coal boilers.
2. **Berlin** has used the THERMOS Tool to analyse the possibility of expanding an existing heat supply network accounted with zero CO_2 emissions to surrounding residential buildings.
3. **Alba Iulia** has tested THERMOS to compare the technical and economic feasibility of developing two different networks to supply heat and sanitary hot water to several administrative buildings.
4. **Warsaw** has evaluated the best possible heating solution in an area where different sectors are found. The city of Warsaw already has an extensive district heating network, but due to insulation energy efficient measures applied throughout the years, it is now oversized and has the thermal capacity to add new neighbourhoods.

[1] https://tool.thermos-project.eu
[2] https://www.thermos-project.eu/resources/publications/
[3] https://tool.thermos-project.eu/help/index.html

5. **Cascais** aims to identify the best solution for building a district heating network for residential and commercial buildings in a given urban development area.
6. **Granollers** has analysed the viability of including several public facilities in a district heating network instead of using individual systems, with an emphasis on reducing GHG emissions.
7. **Islington** intends to evaluate the potential expansion of an existing network using additional council connections and a new energy centre.

This document will allow local authorities and other stakeholders using THERMOS to address the following topics:

- Strategic issues to be addressed to achieve a better experience for cities using the THERMOS Tool;
- Ideas on how to identify and engage the key stakeholders that will influence the development of the thermal energy planning project;
- The added value brought by THERMOS that can help cities to achieve their local thermal planning objectives;
- Examples on how the projects explored with THERMOS could be part of the local Sustainable Energy and Climate Action (SECAP) processes and the challenges that might be faced.

2 Jelgava

2.1 Specific energy planning goals

Jelgava set its specific energy planning goals in their Sustainable Energy Action Plan 2010 – 2020 (hereinafter SEAP), elaborated in accordance with the Covenant of Mayors in 2009. This document was elaborated under the management of Zemgale Regional Energy Agency (ZREA) in close cooperation with the institutions of Jelgava City Council.

The SEAP was designed to achieve three goals by 2020 with respect to the baseline values (2005):

- To reduce CO_2 emissions at least by 20%;
- To increase the energy efficiency by 20%;
- To supply 20% of total energy consumed from renewable energy resources.

In the city of Jelgava, the heat supply for homes, public buildings and industrial facilities is mostly provided by a district heating system (85%). Between 2010 and 2020 there has been a transition from consuming only fossil fuels to using renewable energy as the main source, leading to a 20% reduction in the city's fossil fuel consumption. The current monitoring report comparing the base year 2005 with 2018 shows that energy consumption has increased by 9% due to the significant development of the city. However, due to the town's great effort, the energy efficiency measures implemented and the transition to RES, CO_2 emissions have decreased by 28%, exceeding the expected goal of 20%.

During 2020 the SEAP will be upgraded to SECAP 2021 – 2030, considering further commitments with climate change.

In order to set more aggressive emission reduction targets according to the new SECAP and the new Latvian Energy and Climate Action plan of 2019, Jelgava is planning to expand its district heating to supply more end users who are currently being supplied with local heating sources, such as wood or coal boilers.

2.1.1 Qualitative objectives

The SEAP of Jelgava City includes the following three main objectives with regard to District Heating: reduction of heat losses, improvement of heat supply security and the promotion of alternative, renewable energy sources.

Reduction of heat losses in the district heating system and improvement of the heat supply security

According to the SEAP, the following developments are planned:

- Improvement of the heat supply security by introducing alternative fuels
- Improvement of energy efficiency in the heat production process enlarging the heat amount produced in co-generation by using new technologies

- A planned renovation of mains and pipeline network by replacing parts with large heat losses with preinsulated pipelines
- Integration of autonomous boiler houses into the common district heating system
- Ensuring of competitive and predictable sales prices for heat energy
- Increase in amounts of heat production and supply
- Ensuring of a high quality and competitive service to the pipe entry in the customer's building by registering the consumed heat in MWh using heat meters
- In cooperation with Jelgava municipality and residential project developers to develop new district heating areas and construction of new infrastructure for the territories of prospective building works of the new residential houses

Promotion of renewable energy sources for provision of heat and hot water

A new bio-fuel combined heat and power (CHP) plant is being developed and there is already an existing gas CHP plant. These plants will be operated within the base load regime around 8,000 hour per year and will supply heat to customers located in both sides of the river Lielupe.

According to the SEAP, the following further developments are planned:

- Building of a cogeneration power station (using wood biomass)
- Building of a connection of the 2 district heating systems located in the right and left banks of the river Lielupe
- Integration of autonomous boiler plants in the DH
- A planned renovation of the nonrehabilitated heat supply network (15.1 km)
- Creation of a management system for a joint district heating operation
- Creation of an automated reading system of heat consumption meters
- Measures to attract new clients for joining the district heating system

The implementation of these developments is allowing Jelgava to achieve a modern district heating system with low heat losses, located in both banks of the river Lielupe and interconnected under the river, thus creating one common district heating system for the city that is operated and monitored from the biomass CHP plant.

2.1.2 Quantitative objectives

GHG reduction goals

The SEAP's goal related to GHG emissions is to achieve a 20% reduction in CO_2 emissions by 2020, compared to 2005 (107,706 tCO_{2e}).

The SECAP will aim for a more ambitious target with a 40% reduction in 2030, compared to 2005 (pending approval in 2020).

Climate action goals

The SEAP does not include any action related to climate change. Given the increasing need for action in this area, the inclusion of such goals in the SECAP 2021 – 2030 are being considered.

Other

District heating networks played a very important role in achieving the reduction targets set in the 2010 – 2020 SEAP. As a result, it is expected that the SECAP will continue to promote its development.

2.2 Overview of the local case study analysed with THERMOS

2.2.1 Introduction to the case study

Jelgava's heating company "Fortum" is responsible for the development of the district heating of the city (built during the 1990s). District heating provides up to 85% of the city's total heat consumption, however, there are several areas which have not been connected to the existing network yet, even though they are in nearby areas. The lack of software to analyse different cost calculations and modelling of the network layouts did not allow for an analysis of the district heating network potential development at city level.

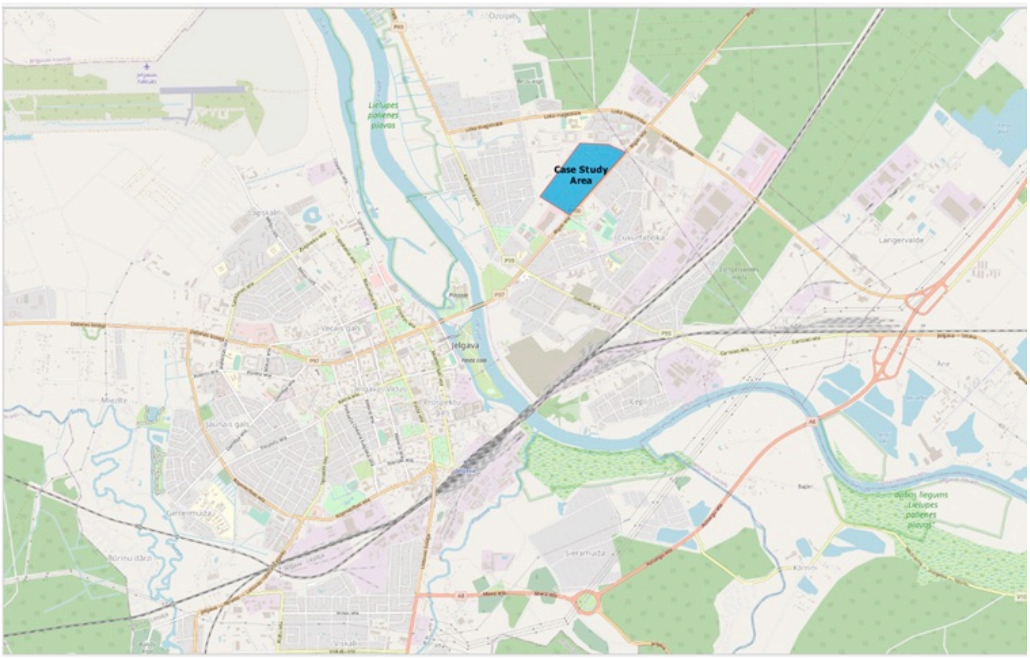

Figure 2-1. Location of the case study's area

Some end-users (mainly private houses) have expressed their willingness to switch to district heating to get clean and sustainable energy with very high-level comfort, compared to wood or coal boilers, but their individual connection to the network does not make sense for the financing parties.

Jelgava is using the THERMOS Tool to test the potential of connecting more private residential housing to the plant currently under construction. This case study has been chosen because both the city and the citizens would benefit economically (i.e. stability in the price of the electricity), environmentally (i.e. improved air quality through reduced consumption of coal and wood) and technically (i.e. improved efficiency of the entire district heating system).

Figure 2-2 BIO CHP plant in Jelgava

2.2.2 Key objectives of developing the analysis

"Fortum" is currently reviewing its long-term district heating strategy which includes network optimisation and expansion. By autumn 2020, decisions regarding the possibility of including some private house areas in the future district heating network should be taken.

The results of THERMOS will provide an economic justification for the case study, helping to focus on the area with the highest potential. By ensuring a minimum energy demand resulting from the expansion of the network, the investment will have a positive return and the district heating company will have arguments to invest in the network.

However, it should be noted that one of the main obstacles is the necessary investment in the heating substations, that must be covered by the end users. To overcome this barrier, a marketing strategy on different financing options will be carried out before starting active work on expansion.

The main characteristics of the demand are shown in the table below:

	Demand
Number of residential buildings involved	199
Tot. energy demand to be satisfied	2,920 MWh/year

Table 2-1. Main characteristics of the demand

Regarding the supply, it is an existing BIO CHP plant built in 2013. For peak loads and backup natural gas Heating-only boilers (HOBs) are used. The main characteristics are:

	Supply
Technology	BIO CHP (bubbling fluidised bed boiler)
Fuel used	Woodchips (residues and clearings of agricultural lands)
Maximum capacity	10 MW (existing BIO CHP plant)
Capacity cost	0 (No costs as the plant is already constructed)
Supply cost	2.4 c€/kWh

Table 2-2. Main characteristics of the supply

2.2.3 Involvement of local stakeholders

Identification of the stakeholders

For this project, three key strategic areas that would need expert advice in order to achieve a cohesive district heating and cooling network, which fulfilled the needs of all parties involved, were identified. The chosen areas were social/city-oriented perspective, technological expertise, and citywide energy planning. Once these areas were defined, the team began to search for the specific players who could provide this knowledge. When found, these players would were invited to join the Local Liaison Group.

The first one was provided by the Development and City Planning Department (from Jelgava City Council), which offered input from a community-oriented point of view.

For the second one, it was the management staff at Fortum who provided the expertise regarding heat supplies and consumer data since they have the closest ties to them.

Lastly, it was ZREA who offered advice from the energy development point of view as they have been entrusted with the implementation of the Thermos project.

Engagement of the stakeholders

Jelgava City Council, ZREA and Fortum are the key stakeholders working together to align strategies, to build a clean city where affordable energy is a unifying element. They were eager to collaborate since they are the ones promoting the use of the THERMOS Tool.

Fortum also notice the beneficial aspects of this project, which for them would be the addition of demands to their network, increasing revenue and efficiency.

During the development of the THERMOS Tool, a wider scope of actors was involved, to help the key stakeholders to identify possibilities for improvement.

2.3 Case Study information and data

2.3.1 Data preparation

To ensure accurate results and estimations there are several data sets that need to be considered. The table below presents the main data sets used by the team during the development of the case study, as well as their source:

Geographical data	
Buildings	• Origin: OSM • Source: OSM • Type: Public
Paths	• Origin: OSM • Source: OSM • Type: Public
LIDAR	• LIDAR layer: Yes • Source: Jelgava Municipality Operative Information Centre (POIC). • Type: private
Demand data	
Buildings	• Origin: THERMOS estimations
Cost data	
Tariffs	• Origin: Real data • Source: Fortum Jelgava • Type: Public
Pipe cost	• Origin: Real data • Source: Fortum and external experts • Type: Private

Table 2-3. Data information

2.3.2 Issues faced

Barriers

While working on Jelgava's case study, the team faced some problems related to data input.

- As the THERMOS Tool users may not have a deep technical knowledge of different data formats, the data input tasks could be challenging for some of them;
- There were some difficulties in entering piping costs as the city had internal data for costs of each size. It took some time to convert this data into the format used by the tool, which uses a fixed part and a variable one to calculate the cost.

Recommendations

Some of the recommendations for cities facing the same problems are:

- Since Jelgava's own GIS layer was not in a format allowed by the Tool and developing a new layer would be very time consuming, it was agreed that the optimal solution was to use OSM data combined with LIDAR data (that provides accurate results in residential sector).
- THERMOS allows utilisation of estimations as a starting point, but it is advisable to use real energy demand data (if available) to have a more precise outcome
- Using only OSM could lead to inaccurate demand and peak capacity estimates.

2.4 Results

2.4.1 Network topology

Jelgava used the THERMOS Tool to evaluate the potential of connecting a private housing area near the existing network. The existing production units can supply enough heat for this area without any new investments associated with capacity but with the construction of the network. One of buildings that is already connected to the network was set as a supply point with zero demand and zero costs. The only cost that was included, was the supply cost. The network that was already in place was marked as existing to prevent it from influencing the necessary investment volume.

Figure 2-3. Jelgava city case study network layout

According to the results of the THERMOS Tool it would be economically justified to expand the network by connecting 199 residential private house buildings with total annual demand of 2.2 GWh with heat peak capacity of 5.8 MW.

When making a deeper analysis for smaller areas, the THERMOS Tool helps the user to evaluate different scenarios to include the lower number of new connections in order to reach positive business results. The table below presents the main results obtained with the Tool.

Pipework	
Length	6,930 m
Linear Cost	156.0 €/m
Total Cost	1.08 M€
Demand	
Total Undiversified[4] Peak Demand	5.8 MW
Total Demand	2,920 MWh/year
Revenues	0.16 M€/year
Supply	
Total Capacity Required	3.6 MWp
Output	4,130 MWh/year
Capital Costs	No extra investment required
Heat Production Costs (fuel)	0.10 M€/year

Table 2-4. THERMOS network solution summary

2.4.2 Economical results

Comparing the Tool results regarding investment, revenues and costs with real data, Jelgava City Council has found that the estimations are accurate. As per Jelgava experience, the data produced by the Tool is precise enough to consider it when planning a network extension.

Regarding these results, the most concerning one when considering the expansion is the payback period, which seems to be long, but is still acceptable according to the city´s interests.

Jelgava team believes that the project´s scale might be affecting costs negatively. As the project is quite small, it cannot benefit from economies of scale, which raises the overall cost of the project. Jelgava team believes that, at the due scale, there could be a significant reduction in investment costs.

As the city has an ongoing discussion on whether the fuel mix should be changed, as well as other related aspects, Jelgava team has used different values for operating costs. This way the

[4] This value represents the sum of the peak thermal energy demand of each building in the solution. However, since the peak demands of a set of buildings are unlikely to occur at exactly the same time, the total capacity required by the supply is considerably less that this value.

Tool has also been used to depict the costs difference among a number of different energy sources.

	Capital costs)	Operating costs	Operating revenues	NPV
Pipework	1.08 M€	-	-	-1.08 M€
Heat supply	-	3.96 M€	-	-2.36 M€
Demands	-	-	6.31 M€	3.76 M€
Overall	**1.08 M€**	**3.96 M€**	**6.31 M€**	**0.32 M€**

Table 2-5. Economic solution summary – operating costs and revenues are considered over 40 years

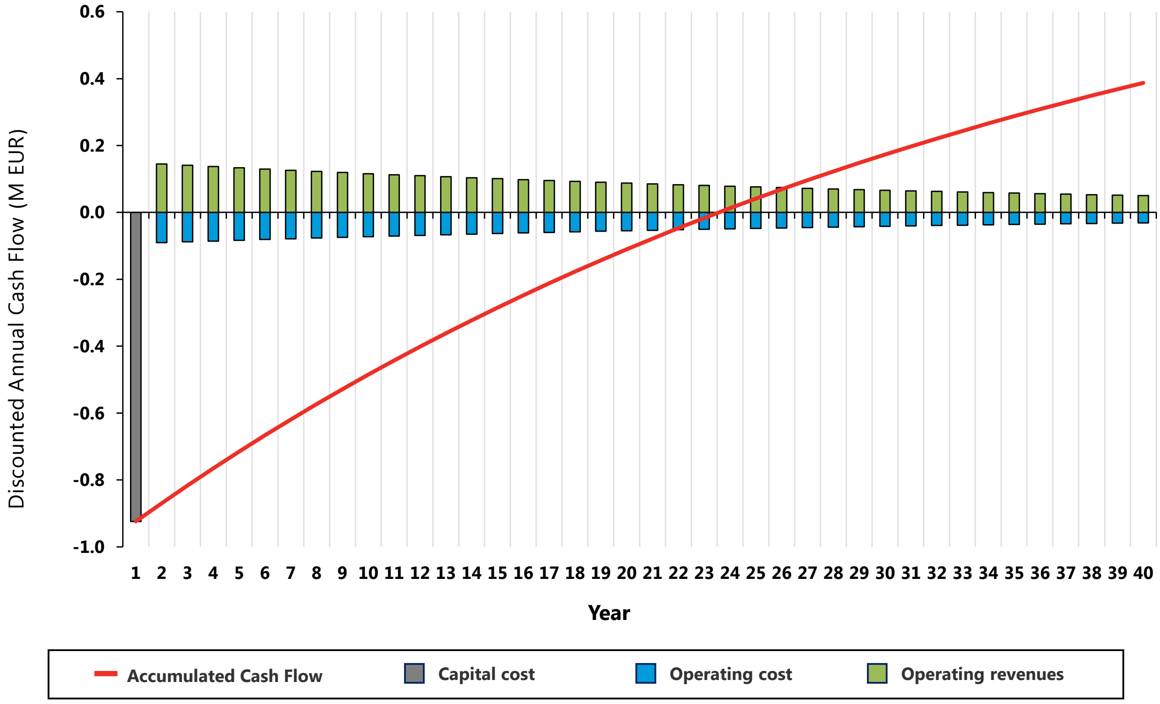

Figure 2-4. Cash flow of Jelgava's case study

2.5 Conclusions and next steps

2.5.1 *Status quo* of the case study

The results produced by the Tool have provided both Jelgava city and Fortum with valuable data. In the beginning there were some doubts about the economic feasibility of looking to connect private house areas. Now, those doubts no longer exist since this case study has showed that it would be profitable to consider connecting them to the existing network.

Also, some of THERMOS output data were validated – the necessary investment, heat losses, total demand were compared to real data or internal estimates, which were all close to the THERMOS outputs.

When Jelgava heating company Fortum did more complicated financial analysis in internal calculation systems they also got positive results, which would qualify this investment project for the next stage. The THERMOS Tool helped evaluate the use of district heating in private house areas, which had never been done ever before.

2.5.2 Challenges

There are several challenges that can limit the development of district heating projects other than the connection of private house areas to the network, which was the one covered more extensively in this case study. One of them being that, despite the positive results obtained, the payback time is quite long, and the investment resources can be allocated to the projects with higher investment return estimates.

Even more challenging is the competition with the existing heating solutions for private houses. Jelgava heating company has received several requests from private house owners that consider connecting to the district heating network. It would be possible if some nearby neighbours would also agree to connect, as the joint demand would justify the needed investments. No activities have been done in this direction so far. Surveys about district heating show that a significant proportion of households perceive district heating as old fashioned, expensive, and inflexible heating solution. Stereotypes are hard to change in short period of time.

In Latvia heat supply to private houses in most cases is not strictly regulated and is not included in the energy planning programs. There is weak political support for the development of district heating despite it being mentioned in the National Energy Plan as one of best solutions for cities. Also, the municipality has limited capabilities to influence conditions to support the development of district heating networks.

2.5.3 Future outlook

If there are no significant changes in the legislation and energy markets, this case study could be explored deeper. The next step is to continue would be smaller scale models. It is planned to analyse the potential at a single street level to get a better understanding of what the minimal demand and density is, so the investors know at which point the project is economically feasible.

Prior to developing a large scale offering intensive work with potential customers and the first real pilot project should be undertaken. If the results satisfy all the included parties, The THERMOS Tool will be used for the next stages - identifying city areas that have the highest potential to develop district heating successfully.

3 Berlin

3.1 Specific energy planning goals

Berlin greatest goal regarding energy planning is to become a climate neutral city by 2050. It has therefore introduced the "Berlin Energy Turnaround Act" ("*Energiewendegesetz*") in 2016, which aims to implement the Energy Turnaround and to Promote Climate Protection in Berlin. It authorises the Senate of Berlin to establish compulsory connection and use regarding a public local or district heating supply which should be a driver for heat networks in the city.

Currently, Berlin's two largest energy providers for private households are the Swedish Company Vattenfall and the Berlin-based company GASAG. Both offer electric power and natural gas supply. Vattenfall is operating and holding the largest part of the existing district heating network in Berlin – the central and some local networks. A much smaller share of heating networks is operated by smaller companies such as the public Berliner Stadtwerke GmbH and private suppliers Naturstrom AG, Fernheizwerk Neukölln AG, BTB GmbH, Harpen EKT GmbH and EAB Fernwärme GmbH. Berlin's district heating network is about 1,800 km long and supplies about 1.2 million households with heat.

Berlin's energy supply is currently characterised by a high proportion (more than 90%) of fossil fuels, including a few older large-scale power plants. While Berlin is considered as the CHP capital, a large proportion of electricity is still generated uncoupled. Most of the district heating production and supply is also generated using CHP plants fuelled by hard coal, which could also be based on natural gas, leading to a significant CO_2 savings potential.

3.1.1 Qualitative objectives

The necessary strategies and measures to become carbon neutral are included in the "*Berlin Energy and Climate Protection Programme 2030*" (BEK) which is also approved by the Berlin Senate. The BEK can be regarded as a roadmap towards climate neutrality. The BEK contains strategies and measures for several fields of action in the city, most of them of importance for the objectives of THERMOS, such as energy supply, buildings, urban development, and private households.

Since 2019, a Service Point for City District Development has been installed. It should bring together relevant stakeholders in the districts, analyses the targets regarding city development and energetic actions and serves as a neutral contact point for energetic restructuring of districts.

Furthermore, local climate protection managers on district level support the implementation of local climate action and facilitate cross-sectoral and interdisciplinary coordination of targets and implementation of activities.

3.1.2 Quantitative objectives

Sustainable energy goals

Berlin wants to phase out coal-based power and heat generation by 2030 at the latest. So far, the district heating network in Berlin is mainly fuelled by coal and gas. This is where decentralised heat generation and the utilisation of THERMOS could considerably gain in importance.

GHG reduction goals

The "Berlin Energy Turnaround Act" stipulates to reduce carbon dioxide emissions, compared to the base year 1990:

- 40% by 2020
- 60% by 2030
- 85% by 2050

By "climate neutrality" the city understands a 95% reduction by 2050. The act requires the Berlin Senate to come up with an overall climate action plan and to monitor its implementation. It also requires the public administration to be a good role model. Since heating causes a major part of Berlin's emissions, the increase of efficiency of heat supply and the decarbonisation of the heating systems are crucial issues.

Climate action goals

Berlin's administration wants to set a good example in climate-friendly behaviour for its citizens. That is why the Berlin Energy Turnaround Act requires the central and district administrations to organise their work in a carbon-neutral manner by the year 2030.

The legislation also requires the establishment of refurbishment roadmaps for public buildings, in which the building stock of the central and district administrations will be systematically documented, and the necessary energy-related refurbishment measures put into an expedient order of priority. By implementing these refurbishment roadmaps, public building stock will be comprehensively refurbished for energy efficiency by 2050

In 2014, a public energy utility (Berliner Stadtwerke) was founded, which plans, builds, and operates local renewable energy systems and sells electricity and heat in Berlin. It implements measures that support the goal of supplying Berlin with 100% renewable energy in the future.

Other

The city of Berlin is participating in a series of European and International Climate protection initiatives. Berlin has joined the "Covenant of Mayors" ("Mayors summit") in 2010. In 2018 Berlin's Senate passed a resolution to renew its commitments under the Covenant of Mayors and adjourn them according to the conclusions of the Paris summit.

Berlin is also a member of the Climate Alliance, Eurocities, C40 Cities and ICLEI.

Open Source data and respective tools are considered to be of particular importance to Berlin. Energy Atlas maps Berlin's energy supply, usage, and efficiency. It should allow stakeholders to explore where improvements could be made and where more renewable energy can be used. Dena carried out several liaisons with the city officials to explore possibilities to merge or closer cooperate between Berlin City Atlas, Open Data Initiatives and THERMOS.

3.2 Overview of the local case study analysed with THERMOS

3.2.1 Introduction to the case study Möckernkiez

Dena has started to consult and involve local district heating planners and operators up from 2018. With several big and medium-size district heating operators, discussions on the evaluation of different city district started in 2017 and have been continued during 2018 and 2019. In this period, the district being assessed here has been fully planned and built as a modern district in passive house standard with 16 6-floor-buildings for residential and commercial use. The district is organised as cooperative, ensuring social, sustainable, and collaborative financing of the buildings. For confidentiality reasons, the district and the heat supplier are kept anonymously. The district and its surrounding environment are exemplary for the situation of new building projects in Berlin and therefore gives good learning and replication aspects for other districts.

Figure 3-1. Location of the case study's area

The observed district is situated in the inner-city borough Kreuzberg-Neukölln and is a direct neighbour to the existing district with 4-5 storied houses from around 1900. These buildings have mixed ownership, that means single houses or even single flats are owned by different private owners. The houses are predominantly supplied by typical individual gas heating installations in each apartment.

The district considered here is supplied with heat from a new 1.1 MW CHP plant fuelled with biomethane (purchased from regional biomethane producers). On the roofs of the buildings, 5 PV installations with a capacity around 150.0 kW are installed. The PV installations producing power for own demand will not be subject for the further analysis.

Figure 3-2. Möckernkiez map

3.2.2 Key objectives of developing the analysis

While the district analysed in this case study is already in the state-of-the-art best ecological standard and its heat supply is accounted with zero CO_2 emissions, the present case study should analyse the possibility to extent the heating grid to surrounding residential buildings. This approach is in line with the city's aims to extend district heating networks, and it could potentially contribute to a higher utilisation rate of the existing heat supply infrastructure, corresponding to potentially better economies and would increase the supply of renewable, carbon neutral heat in the city.

The surrounding buildings are typical houses built in the phase of industrial expansion of Berlin (around 1900) and are predominantly not insulated. The present case study should analyse, if an extension of the existing grid is technically and economically feasible, how the costs and heat prices would change. In an advanced stage, a solution could cover the scenario that the buildings to be connected are insulated to a higher standard.

The case study solutions should provide indications on whether an extension of the heat network could be feasible and which aspects to consider for an in-depth analysis. This can be the basis for strategic planning of the heat grid operator or owners of surrounding buildings to discuss their future heat supply and possible collaborations.

The current total demand in the observed district to be satisfied is 2,000 MWh, including all 16 residential and commercial buildings mentioned before. The main characteristics of the demand are illustrated in the table below.

	Demand
# of buildings involved	16 buildings with approximately 40.000 m^2 of heated floor area
- Residential	92%
- Commercial	8%
Tot. energy demand	2,000 MWh/year
- Residential	Approximately 1,000 MWh/year
- Commercial	Approximately 1,000 MWh/year

Table 3-1. Main characteristics of the demand

The supply of the buildings to be connected should be based on the existing gas CHP plant with 1.1 MW thermal capacity (207.0 kW base load and 900.0 kW peak load boiler). The main characteristics of the additional supply are the following.

	Supply
Technology	Gas CHP plant
Fuel used	67% biomethane, 33% natural gas as back up
Maximum capacity	10 MW
Fixed costs	700,000 €
Capacity costs	326.0 €/kW
Annual O&M costs	18.0 €/kW/year
Supply cost	6.0 c€/kW

Table 3-2. Main characteristics of the supply

Sources: Technology data provided by DH operator; cost assumptions based on ASUE 2016, FNR 2020, Prognos et al 2019, KfW 2020

The cost data include basic funding for planning of new CHP plants by state bank KfW. For the overall project, a discount rate of 1.5% has been considered.

Costs for CHP are originally estimated for each kW_e and has been converted in the respective values for kW_{th}. The present analysis is based only on the heat related aspects. Fuel and supply costs applied here are reference values. The actual costs rely on specific supply contract between CHP plant operator and supply company.

3.2.3 Involvement of local stakeholders

Identification of the stakeholders

For the application of the THERMOS Tool in the Berlin city framework, dena identified two key stakeholder groups that could compose the Local Liaison Group, as they would be needed to provide practical expertise regarding this type of projects.

The first group, aimed to provide technical support due to their experience in DHV projects were the main heating network providers Vattenfall, GASAG, BTB. Also, several representatives of single urban development projects were engaged and included, e.g. the TXL project in the Schumacher Quartier, Stadtwerke Berlin and Naturstrom AG.

The second group was focused on aiding from the institutional standpoint. In order to achieve this, the Senate Department for Energy, Buildings and Commerce was contacted in order to consider the embedment of THERMOS into the broader strategic approach that Berlin is tackling.

Engagement of the stakeholders

All contacted and involved stakeholders are very engaged to enlarge their district heating network in Berlin and to transform it to carbon neutrality until 2050. With Berlin's exit coal, the existing coal heat and power plants (owned by Vattenfall) will be substituted by climate-friendlier options (gas plants) by 2030.

While the large district heating operators are engaged to extend their network above all in the existing districts in the inner city, the development of new districts offers the potential especially to "new" smaller heat operators to establish sustainable district heating options.

3.3 Case Study information and data

3.3.1 Data preparation

Geographical data	
Buildings	• Origin: already connected buildings: OSM data + Data by district heating operator. Buildings to be connected: OSM data, own calculations based on AGFW 2016 • Type: Private, mainly residential buildings
Paths	• Origin: OSM data • Type: public
LIDAR	• Yes (Berlin LIDAR data included)
Demand data	
Buildings	• Origin: existing buildings: own data. Neighbouring buildings: Google Street Map and city reference values (AGFW 2016) • Source: calculation based on technical code for heat cost comparison VDI 2067 • Type: private
Cost data	
Tariffs	• Origin: own real data • Source: Real district heating bill in Berlin • Type: private real data
Connection costs	• Origin: own data • Source: own data cross-checked with heizung.de) • Type: private
Pipe cost	• Origin: THERMOS estimations and default data
Others	• Accounting period: 40 years, discount, and credit rate: 1.5% (according to credit subsidies by funding bank KfW) • Cost data do not include public funding for building new district heating grid infrastructure

Table 3-3. Input data information

3.3.2 Issues faced

Barriers

- The paths illustrated in OSM show some deviation from the real pipe situation. In order to adjust this and get an equilibrium between supply and demand in the baseline situation, a 1% higher supply capacity has been applied.
- Open data on the energy demand of buildings is scarce in Germany as most individual information covered by strict data protection. In the present case study, the used heat demand data for buildings in the extended network is based on own estimations for average residential buildings in the city. By experience, the real heat demand of

buildings can relevantly derivate and should be individually assessed for further analyses. Moreover, more data on residential consumption and a dynamic illustration of future energy planning, e.g. insulation incentives, could help estimate future district heat demands.

- The technology-based costs assumed here are reference values, which can derivate from real life and project specific costs.

Recommendations

For those cities willing to use the THERMOS Tool, the following are some recommendations that will facilitate its use.

- In a detailed analysis, heat demand has to be estimated starting from real consumption data of the concerned buildings;
- For the pipe run, a detailed planning and adjustment of directions and costs has to be elaborated for getting estimations that are closer to the real situation;
- Perform a thorough research on dynamic capacity-dependent costs and technology-specific parameters, as it can help finding the optimum supply capacity and costs for a given demand.

3.4 Results

3.4.1 Network topology

As shown in Figure 3-3, the existing district heating area comprises 16 buildings, of which one includes the supply point. When increasing the supply capacity, it is technically feasible to connect the directly surrounding old buildings on the other sides of the enclosed streets. The present network cannot reach more remote heat demands.

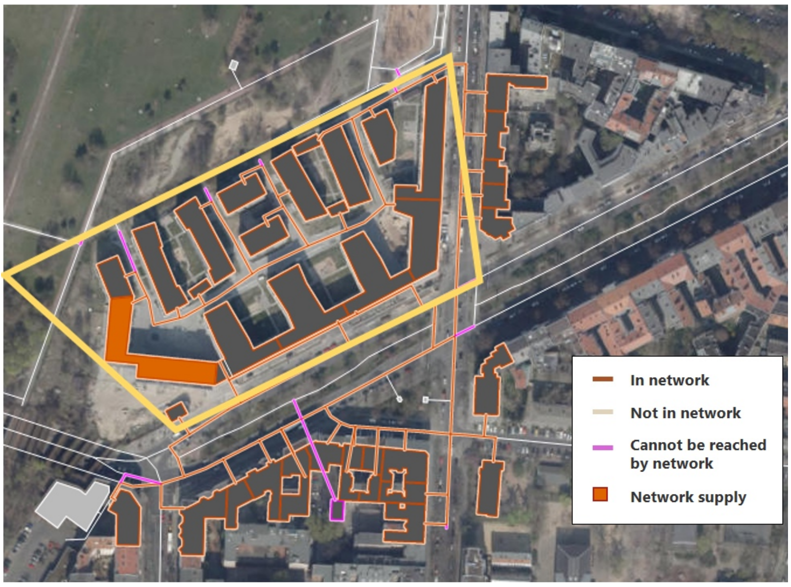

Figure 3-3. Solution presentation of the new district connected with neighbouring old district (yellow shaped existing district heating supply area)

In the present solution, the currently connected 16 buildings as well as 19 more surrounding buildings can be connected to the supply point. For covering the extended demand of 5.43 GWh/a heat demand of the whole area, the supply capacity has to be increased to around 10 MW_{th}. More details can be found in Table 3-4.

Pipework	
Length	2,020 m
Linear Cost	433.6 €/m
Total Cost	0.87 M€
Demand	
Total Undiversified[5] Peak Demand	4.3 MW
Total Demand	5,820 MWh/year
Revenues	0.95 M€/year
Supply	
Total Capacity Required	2.4 MWp
Output	5,730 GWh/year
Capital Cost	1.5 M€
O&M Cost	0.044 M€/year
Heat Production Cost (fuel)	0.344 M€/year

Table 3-4. THERMOS network solution summary

3.4.2 Economical results

Exemplary economic results of the case study in the THERMOS Tool are presented in Table 3-5. As shown, the key cost components are the capital costs associated with the heat supply and the pipework, as well as the operating costs. In this solution, these are outweighed by the operating revenues. The revenues in Table 3-5 are related to the operating revenue results accounted for the network. The present economic results are illustrative. For getting a solid solution, the economic assumptions and results have to be investigated further.

[5] This value represents the sum of the peak thermal energy demand of each building in the solution. However, since the peak demands of a set of buildings are unlikely to occur at exactly the same time, the total capacity required by the supply is considerably less that this value.

In a further detailed analysis, the cost components and the actual revenues should be estimated in detail based on a complete set of real data and a dynamic cost assessment. Furthermore, it should be considered in more detail which cost components of the existing system have to be integrated to the cost accounting and which components can be excluded from the calculation (because already financed/ amortised).

Also, further calculations should include comparable costs and emissions from existing heat supply systems. With the German CO_2 pricing starting with 25€/t CO_2 allowance for fossil fuels in 2021, renewable heating systems can approach more competitive levels compared to gas or oil fuelled supply.

	Capital cost	Operating cost	Operating revenue	NPV
Pipework	0.87 M€	-	-	-0.87 M€
Heat supply	1.5 M€	15,75 M€	-	-13.46 M€
Demands	0	-	37.87 M€	28.75 M€
Overall	**2.37 M€**	**15.75 M€**	**37.87 M€**	**14.42 M€**

Table 3-5. Economic solution summary – operating costs and revenues are considered over 40 years

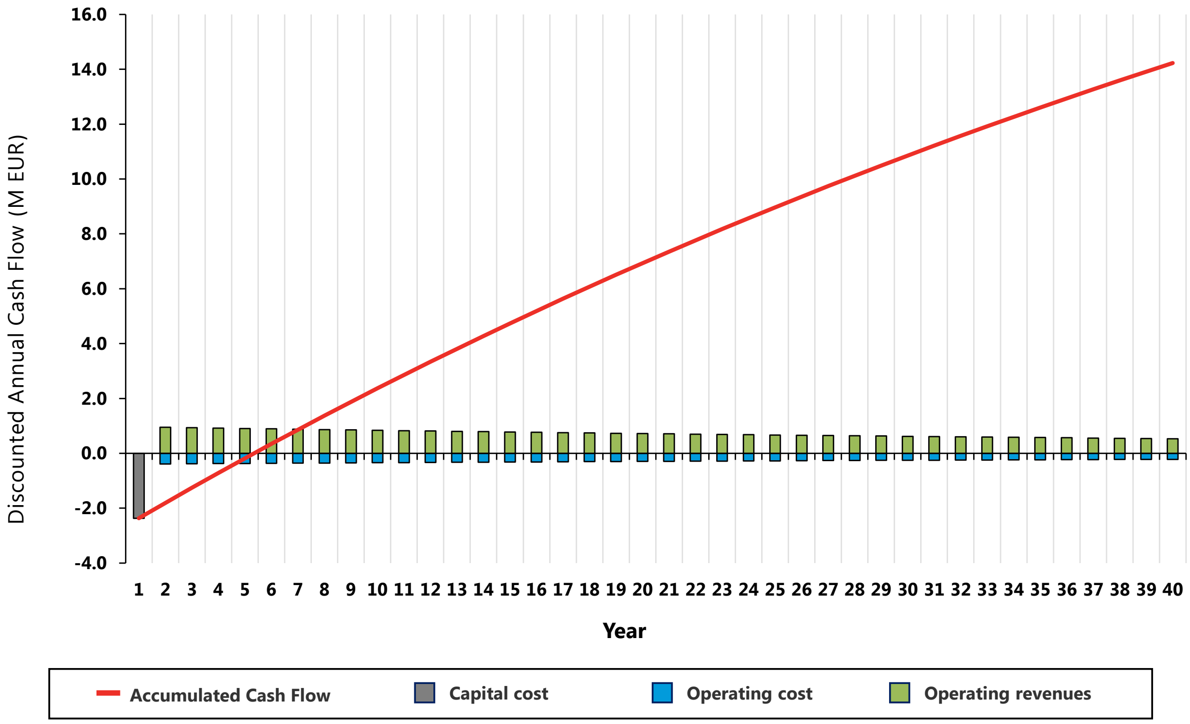

Figure 3-4. Cash flow of Möckernkiez case study

3.5 Conclusions and next steps

3.5.1 *Status quo* of the case study

At the moment, there is not yet a pending plan to realise an extension of the present district heating. But as this approach is explicitly aimed in the Berlin Energy and Climate Programme, the continuous expansion of district heating by multiple stakeholders is a very crucial step to fulfil the climate protection targets by 2050.

In framework of the THERMOS project, Dena is continuing to approach responsible entities for urban development projects to support their district heating planning. Further examinations and approaches to increase economies and organise stakeholders for establishing renewable energy communities can help establish an enabling environment for advanced energy districts.

3.5.2 Innovative results

Dena is currently intensifying an exchange with several city districts of Berlin, which show a particular interest in THERMOS. The idea is to use THERMOS for connecting and enforcing new district and neighbourhood development projects such as Eichkamp-Heerstraße, Olympiapark or Mierendorffinsel.

Expanded areas for development is the integration of other renewable heat sources such as geothermal or solar thermal energy, which is a dedicated aim in the Berlin Energy and Climate Action Programme. For considering solar thermal energy, the Tool should integrate specifications to consider seasonal differences in supply and demand.

Besides renewable heat sources, the use of heat from waste water or waste excess heat from commercial and industrial processes is turning out to be a very interesting and rich new heat source for cities.

In the future, integrated solutions combining heat and power supply will be of increasing interest for cities. Power-to-heat technologies and the electrification of the heat sector are key issues for further observation. Energy districts and communities have the potential to showcase innovative solutions, which can be replicated at other locations.

3.5.3 Challenges

The main challenge for attracting users for the THERMOS Tool right now is the fragmented stakeholder landscape in city districts, very limited capacity for strategic planning and the right timing for involving stakeholders. Most projects are beginning with a long planning period. Often the district stakeholders consult a planning company in the early stage to develop a first supply conception. These companies use proprietary systems for calculating the roll out of heating networks. As one responsible of a major district heating company has put it: "*I use Excel for a first preliminary approximation, if these turns out to be positive, I use a professional tool for further calculations*".

Still, building new district heating grids is a very investment intensive project. Also, the extension of district heating grids comes along with relevant costs for building new infrastructure. In light of currently very cheap gas and oil prices, costumers tend to adhere to cheap fossil fuels. Furthermore, the district heating market is still characterised by few big network operators (with fossil fuels still dominating in the portfolio), which makes it difficult to smaller energy suppliers to offer renewable heat at a competitive price level.

A general barrier for the extension of district heating to old city buildings is the very fragmented ownership of individual apartments and buildings. Usually, that means supply contracts have to be made with each individual household. That is another administrative effort, which is much easier to handle by big market players with higher capacity in distribution.

3.5.4 Future outlook

In the next step, the city districts and other energy communities outside Berlin are being approached in order to get in contact with the companies rolling out new district heating.

In case there is no commercial city planner involved in the early stage, the THERMOS Tool can help especially small players in the early strategic idea and planning phase to make first supply estimations and map a supply scenario. As a free software, THERMOS has the potential to empower especially small, individual players to participate in this strategic planning process and elaborate own energy supply ideas. This approach can foster bottom-up approaches, competition in the heat market and enhance the diversity of market actors.

It seems that if the Tool keeps being mainstreamed, it could end up being a standardised solution in DHC planning, as the companies use self-developed tools, based on their own procedure, that are quite simple when compared to THERMOS. Dena is continuing to approach district stakeholders, companies, or other legal entities to encourage using the THERMOS Tool for planning.

A driving force for increasing renewable heat supply could be the introduction of the German CO_2 price on fossil fuels, assuming that the pricing will be high enough to attract a shift from (so far too cheap) fossil fuels to renewable solutions.

Beside efforts to increase the share of renewable heat, cities like Berlin have to take more actions to increase building renovations and enhance the insulation standard of the building stock. In combination with district heating solutions these measures can significantly increase energy efficiency in the city.

Specific (regional) support to small-scale communities and heat plant operators could facilitate the network extension. The Service Point for Energetic District Development (located at the Berlin Energy Agency) is already supporting initiatives in the organisational efforts for assembling district heating communities in the city.

A driver to use open software like the THERMOS Tool is the availability of open data on local energy demand, supply, and infrastructure, together with a data pool on standard technology solutions and specifications. User-friendly, easy to access tools together with available data sets could substantially democratise energy planning and potentially speed up the implementation of sustainable, bottom-up solutions.

4 Alba Iulia

4.1 Specific energy planning goals

Alba Iulia describes its energy planning goals in several key documents such as "The Energy Efficiency Improvement Programme (PIEE)", "The Integrated Urban Development Strategy (2014-2023)", "The Energy Strategy of Alba County 2018 – 2023" and "2030 Sustainable Energy and Climate Action Plan" (hereinafter SECAP). All these plans include actions that the Municipality has carried out or intends to pursue in sectors such as public buildings, public lighting, residential buildings, tertiary buildings, public and private transport, etc.

Alba Iulia Municipality is focused towards the transformation of Alba Iulia city into a "green city" by approaching its resources in a rational and long-term way in order to ensure a competitive, inclusive, and sustainable energetic future. Therefore, one important priority is the outlining of energy efficiency measures along with the rationalisation of energy consumption through development projects in energy, transportation, and environmental protection.

The municipality strongly believes that an optimised energy planning is one of the best options to meet the reduction targets that have been set. In Alba Iulia there used to be an extensive district heating network (31). However, this has fallen into disuse, with most households heated by individual gas boilers. The city is interested in reintroducing DH, both to reduce carbon emissions and to improve air quality. The lack of an existing system means that the current requirement is for a Tool which enables the appraisal of options for new networks serving existing buildings, with the ability to specify the inclusion of user-defined existing routes and connections.

4.1.1 Qualitative objectives

For Alba Iulia Municipality there are several key objectives for the sustainable use of natural resources which are aimed to ensure a high level of environmental protection and public health, the availability of natural resources for future generations, effective contribution to the stability and prosperity of the economic and social system, as well as limiting the use of resources to reduce its impact on the environment.

4.1.2 Quantitative objectives

Sustainable energy goals

The quantitative sustainable energy goals of the Municipality are included in its various sustainable development strategies:

- To reduce the energy consumption by at least 30% after thermal rehabilitation of the residential buildings
- To increase the energy efficiency of educational buildings in Alba Iulia
- To boost the renewable energy production, together with smart energy planning, public procurements, and local community involvement

GHG reduction goals

By officially adopting the Covenant of Mayors for Climate and Energy, Alba Iulia Municipality committed to the reduction of CO_2 emissions (and possibly also reducing other greenhouse gases) on its territory by at least 40% by 2030, by improving the efficiency of energy and through increased use of renewable energy sources.

Other

Alba Iulia Municipality is a signatory of the Covenant of Mayors since 2010. By signing the Covenant of Mayors, Alba Iulia engaged itself to reduce 24% of CO_2 emissions until 2020, compared to the reference year 2008. The first initiatives aimed at meeting the European standards for energy efficiency created in 2010, when Alba Iulia Municipality decided to join the Covenant of Mayors Initiative promoted by the European Commission. This commitment is the local government's response regarding energy and environment with the intent to counter the challenges posed by the urban development of the municipality in recent years: the environmental pollution induced by accelerated development, the management of the expanding traffic network, the constructions boom, the urban waste management, the need for public utility services of decent quality. The SEAP has been upgraded with new objectives and goals to 2030 (SECAP), where the THERMOS project has been taken into consideration as a valuable resource.

Since March 2014, Alba Iulia Municipality is also a member of ICLEI - Local Governments for Sustainability, an international network of organisations and public authorities which has committed to engage in the sustainable development of the cities or areas they represent.

4.2 Overview of the local case study analysed with THERMOS

4.2.1 Introduction to the case study

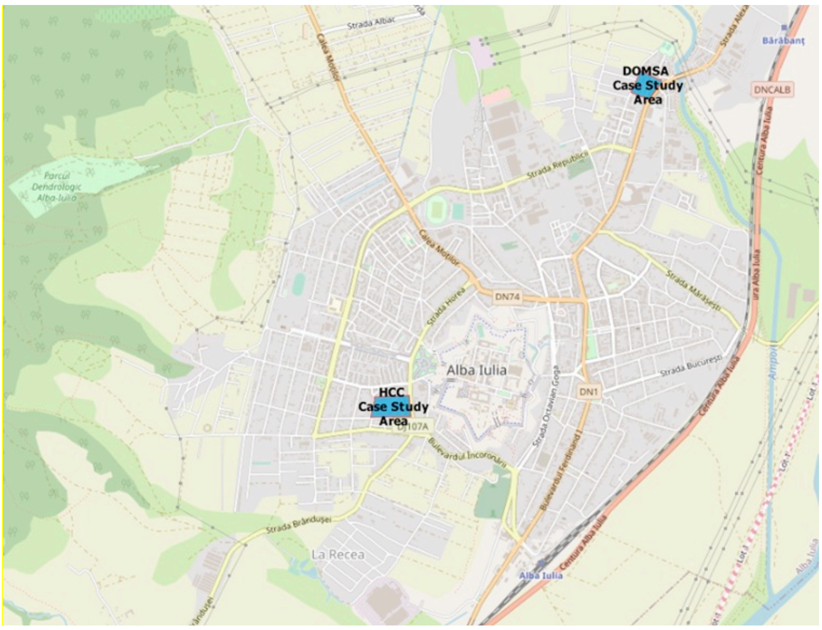

Figure 4-1. Location of the case study's area

Since Alba Iulia's strategy is to promote the reduction of CO_2 emissions and due to the fact that two of the former district heating networks are managed by the Municipality, they have been used for the case study.

During the preparation phase, GIS specialists worked with the mayor, analysing, and prioritizing the most relevant case studies. The selected options were two:

- ***Horea, Closca and Crisan National College (HCC):*** aimed to connect a high school, several administrative buildings belonging to the high school, one college, one secondary school and a gym though a district heating network to supply heat and sanitary hot water.
- ***Alexandru Domsa Technical College (DOMSA):*** included the connection between a college, a gym, a boarding house, and several administrative buildings belonging to the college though a district heating network to supply heat and sanitary hot water. One of the main reasons for selecting this case study was the existence of technical and economical documentation of the buildings assemble. On this basis, the input required for the THERMOS Tool was more accessible for the design of the local heating system.

Both case studies fit perfectly within the development strategies of Alba Iulia Municipality, contributing directly to the optimisation of the local energy planning process, thus improving the living conditions of the local community.

Figure 4-2. Case study 1 (HCC) and Case study 2 (DOMSA)

4.2.2 Key objectives of developing the analysis

The proposed case studies can become potential pre-feasibility studies for the Municipality in order to contribute to the optimisation of the local energy planning by promoting the district heating networks.

The results of the THERMOS Tool will provide a pre-feasibility justification which will allow for deeper analysis. However, the implementation of these projects depends on the financing sources. Considering that the current financial framework (2014 – 2020 EU funding) has come to an end and that the estimated costs are significant in comparison to the existing local budget for public investments, the Municipality will need to focus on future financing mechanisms.

The main characteristics of the demand are illustrated in the following table.

	HCC	DOMSA
Number of buildings involved	8	9
Tot. energy demand	2,010 MWh	1,840 MWh

Table 4-1. Main characteristics of the demand

The supply is an existing construction that will be rehabilitated, with the following characteristics:

	HCC	DOMSA
Technology	Natural gas burner	Natural gas burner
Fuel used	Natural gas	Natural gas
Maximum capacity	1.9 MW	1.9 MW
Fixed cost	300,000 €	300,000 €
Capacity cost	1,000 €/kW	1,000 €/kW
Annual cost	10 €/kW	10 €/kW
Supply cost	4.0 c€/kW	4.0 c€/kW
CO_2 emissions	250 g/kWh	250 g/kWh

Table 4-2. Main characteristics of the supply

4.2.3 Involvement of local stakeholders

Identification of the stakeholders

At the beginning of the development process of the case studies, Alba Iulia Municipality managed to make a list of potential members of the Local Liaison Group and other stakeholders in order to achieve a proper development. These included:

- Different areas of the local Municipality to offer input from a community-oriented point of view
- Local Agency for Energy (ALEA) who advised from an energy development point of view
- Energy utilities who provided data to develop the case studies
- Local institutions, organisations, and private actors

Along the working frame of the case studies development, the main stakeholders were ALEA, the local energy utilities companies and administrators of the selected use case properties, in collaboration with representatives of all relevant departments within the Municipality, The following table summarises the description and role of the stakeholders involved in the THERMOS case study.

Name of organisation	Type of stakeholder	Main topical engagement	Role during the pilot development process
AI Municipality - City Manager's Office	Decision maker	Stakeholder engagement	Active participation in the definition of the proposed case studies
AI Municipality - Investment Department	Public administration	Stakeholder engagement	Active participation in internal and international meetings. Main data supplier and advocate with respect to the local energy providers
AI Municipality - Smart City Team	Public administration	Intelligent Solutions	Active participation in internal meetings
Local Agency for Energy - ALEA	Energy Agency	Stakeholder engagement	Active participation in internal meetings. Data supplier and main collaborator for developing the THERMOS use case.
E.ON ENERGY ROMANIA	Utility	Energy Distribution	Provide energy data/ information
SC Electrica Distribution SA	Utility	Energy Distribution	Provide energy data/ information
Flash Lightning	Business	Energy Services	Provide energy data/ information
ENEROM INSTAL SRL	Investors	Urban Planning	Provide energetic data/ information
'1 Decembrie 1918' University Alba Iulia	Science and research institutions	Stakeholder engagement	Active participation in local meetings. Logistics provider for the organisation of the transnational meeting in AI
VEGACOMP Consulting	Business	Stakeholder engagement	Provide technical data/ information

Table 4-3. Local stakeholders

In the definition phase of the case studies the association of resident was also contacted as it was proposed to include some of the multi residential blocks in the case studies. The collaboration between Alba Iulia Municipality and this association was relevant for obtaining input on existing data about whether the apartments are used or not, how many people live in the apartments, providing information of the most relevant winter bills (gas, electricity), etc.

Engagement of the stakeholders

Alba Iulia Municipality and ALEA are the key stakeholders working together with the aim of contributing directly to the optimisation of the local energy planning process. They are the ones promoting the use of the THERMOS Tool in Alba Iulia.

The energy providers also noticed that the use of the Tool could benefit them by creating new district heating networks and thus increasing revenues and efficiencies.

Local institutions and private actors were involved in the project to help the key stakeholders to identify potential improvements.

4.3 Case Study information and data

4.3.1 Data preparation

The Municipality thought it would be interesting to identify a group of public buildings which are situated closely one to each other, to propose a potential feasible "mini" district heating system. All the necessary data was prepared in close collaboration between Alba Iulia Municipality and ALEA. The table below presents the main data sets and a brief explanation of the problems faced by the team during the development of the case study:

Geographical data	
Buildings	• Origin: Own data + OSM • Source: Urban planning municipality • Type: Public
Paths	• Origin: Own data + OSM • Source: Urban planning - municipality • Type: Public
LIDAR	• No
Demand data	
Buildings	• Origin: Real data and THERMOS estimations • Source: Urban planning - municipality • Type: Public
Cost data	
Tariffs	• Origin: Real data and THERMOS estimations • Source: Energy invoices • Type: Private
Pipe cost	• Origin: THERMOS estimations • Source: THERMOS estimations • Type: Public

Table 4-4. Data information

4.3.2 Issues faced

Barriers

While working on Alba Iulia's case studies, the ALEA team faced some problems related to data preparation. The lack of specific data (energetic and non-energetic) for the foreseen case studies can distort the results of the analysis.

Even for public buildings, the Municipality has found difficulties in obtaining specific consumption data from the private utilities.

Recommendations

Some of the recommendations for cities facing the same problems are:

- Energy consumption data for public buildings could be gathered from the energy invoices, in order to have a more accurate result.
- For those municipalities that do not have real information on energy consumption of the buildings, the use of a Digital Elevation Model (such as LIDAR), will be very useful to obtain a more accurate demand estimation data.
- It is necessary to be careful in the design of the GIS layer as the THERMOS Tool will not automatically check for short gaps at the end of the segments (often invisible) which could generate changes in the optimal network path.

4.4 Results

4.4.1 Network topology

Alba Iulia used the THERMOS Tool to evaluate the potential of two case studies that represent a group of public buildings (schools and administrative buildings), with different characteristics.

Figure 4-3. Case study 1 (HCC). Network topology

The first one, "Horea, Closca and Crisan National College (HCC)" aimed to connect a high school, several administrative buildings, one college, one secondary school and a gym with a total annual demand of 2,010 MWh and a heat peak capacity of 1.9 MW.

The solution proposed by the Tool connects all but three buildings in a district heating network of 404 meters long and a supply with a required capacity of 1.2 MWp.

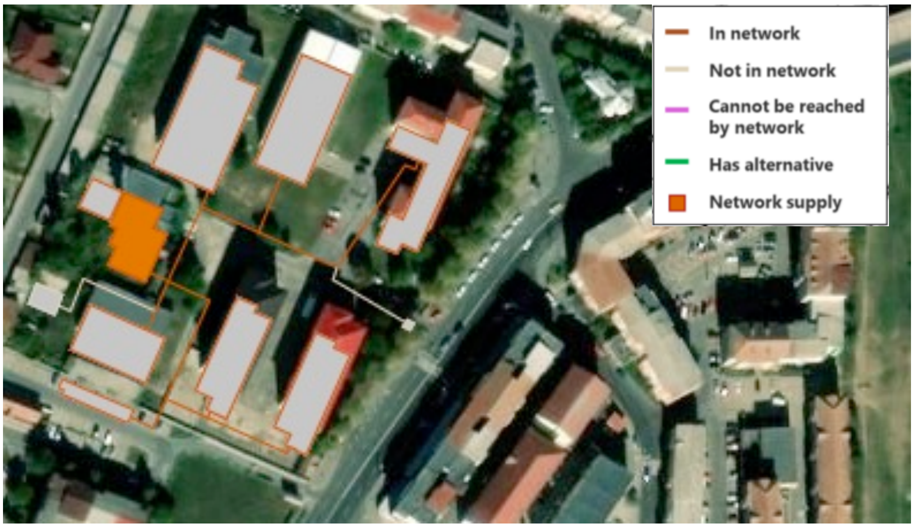

Figure 4-4. Case study 2 (DOMSA). Network topology

The second solution "Alexandru Domsa Technical College (DOMSA)" included the connection between a college, a gym, a boarding house, and several administrative buildings with a total annual demand of 1,840 MWh and a heat peak capacity of 1.3 MW.

In this case study the THERMOS Tool proposed connecting all the buildings in a district heating network of 316 meters long and a supply with a required capacity of 0.9 MWp.

	HCC	DOMSA
Pipework		
Length	403.8 m	316.0 m
Linear Cost	733.3 €/m	368.8 €/m
Total Cost	0.30 M€	0.12 M€
Demand		
Total Undiversified Peak Demand	1.9 MW	1.3 MW
Total Demand	2,010 MWh/year	1,840 MWh/year
Revenue	0.024 M€/year	0.022 M€/year
Supplies solution		
Total Capacity Required	1.25 MWp	0.9 MWp
Output	2,100 MWh/year	1,890 MWh/year
Capital Costs	1.55 M€	1.17 M€
O&M Costs	0.012 M€/year	0.009 M€/year
Heat Production Costs (fuel)	0.008 M€/year	0.007 M€/year

Table 4-5. Network solution

4.4.2 Economical results

Due to the fact that the solutions are applied on two different groups of school buildings, each with their own supply, the net profitability cannot be sustained solely by their profit.

However, if external funding (e.g. European funds) were used for capital costs, then the solution would become profitable compared to the current state of heating costs for paid by the municipality for these buildings.

	Capital cost	Operating cost	Operating revenue	NPV
Pipework	0.29 M€	-	-	-0.29 M€
Heat supply	1.55 M€	0.83 M€	-	-2.04 M€
Demands	-	-	0.98 M€	0.58 M€
Network	**1.84 M€**	**0.83 M€**	**0.98 M€**	**-1.76 M€**

Table 4-6. Economic solution summary – operating costs and revenues are considered over 40 years

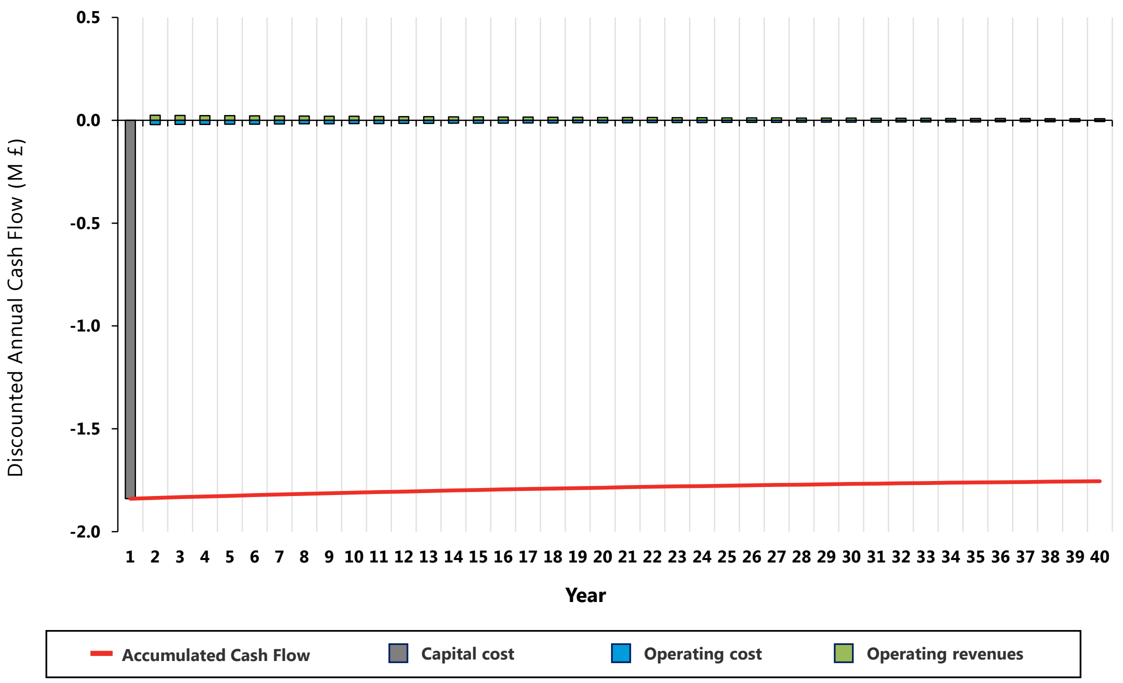

Figure 4-5. Cash flow of HCC's case study

	Capital cost	Operating cost	Operating revenue	NPV
Pipework	0.12 M€	-	-	-0.12 M€
Heat supply	1.17 M€	0.65 M€	-	-1.56 M€
Demands	-	-	0.90 M€	0.54 M€
Emissions	-	-	-	-
Network	**1.29 M€**	**0.65 M€**	**0.90 M€**	**-1.14 M€**

Table 4-7. Economic solution summary – operating costs and revenues are considered over 40 years

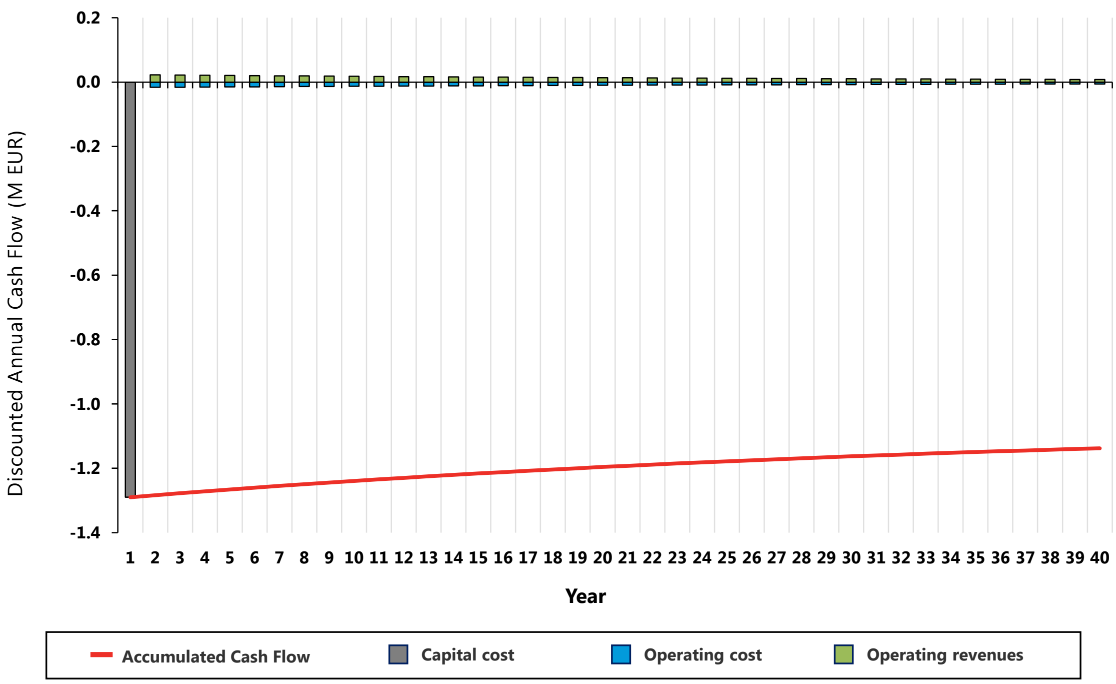

Figure 4-6. Cash flow of DOMSA's case study

The operating revenue has been generated only for comparison purposes, as there will only be a cost reduction for the municipality, not a profit, in these scenarios.

4.5 Conclusions and next steps

4.5.1 Status quo of the case study

The results produced by the THERMOS Tool have provided both ALEA and the Municipality of Alba Iulia with valuable information about the economic feasibility of the solutions.

These case studies are not profitable themselves due to the initial capital costs. Alba Iulia Municipality is looking for some external funding to cover these costs and build them.

4.5.2 Challenges

There are several challenges that can limit the development of district heating projects in Alba Iulia. As in most other cities from Romania, there would be major costs with the pipework and structural changes of the buildings, as most of the buildings currently have individual heating systems and the old underground pipework of the city has been degrading beyond recovery for the last 20 years.

On the other hand, the Municipality of Alba Iulia considers interesting to approach the planning of the new residential neighbourhoods taking into account the possible integration of pipework in the construction stage since this could help the launch of this technology in the municipality.

4.5.3 Future outlook

The work with THERMOS software has been included as an action in the Sustainable Energy and Climate Action Plan 2030 (SECAP) of Alba Iulia Municipality.

The future financial framework for 2021 – 2027 represents an important Tool for Alba Iulia Municipality as it can provide financial resources for implementing at local level modern technology and equipment for more accurate data and analysis of pre-feasibility studies, which can lead to relevant public-private partnerships.

DHS networks are being considered for implementation for certain building groups with constant heat demand, if external financing schemes can support their initial capital costs.

If the natural gas will be used in co-generation systems or if other primary fuel source will be used (e.g. biomass), then a district heating system is one of the first to be considered, as a result of the experience with THERMOS.

5 Warsaw

5.1 Specific energy planning goals

5.1.1 Qualitative objectives

The City of Warsaw is a signatory of the Covenant of Mayors and adopted the Sustainable Energy Action Plan for Warsaw in the perspective of 2020. Warsaw will join the new Covenant of Mayors for Climate and Energy and will set new reduction goals in the near future. In terms of energy, a new Energy Policy will be prepared in the following years, bearing in mind the perspective of the year 2050 and the goal of becoming a zero-emission city.

Along those lines, the city plans to partially switch two of their CHP plants from coal to natural gas. It is planned for this to happen in 2021 for the first one and in 2027 for the second one. This action will impact the city´s energetic performance greatly, as these plants produce most of the heat used by the district heating and cooling network.

Also, Warsaw´s district heating network is one of the biggest in Europe with 1,800 km of pipes, covering the heating needs of 80% of its inhabitants. Nevertheless, the city intends to continue with its development, including plans such as the connection of areas with new large residential estates or connection of existing social buildings in in the three districts on the right bank of Vistula river, which is considered an important area of urban revitalisation.

5.1.2 Quantitative objectives

Sustainable energy goals

New goals for the sustainable energy will be developed for the perspective of 2050. The general long-term goal is to become zero-emission city in 2050. The possible path to reach this goal is to meet the energy needs of the inhabitants only from electricity produced from not emitting sources, (i.e. RES). Specific, mid-term goals to 2030 for RES production and energy efficiency will be established for the new SECAP (Sustainable Energy and Climate Action Plan).

GHG reduction goals

Specific GHG reduction goals for the city of Warsaw are 20% CO_2 emission reduction in 2020, 40% CO_2 emission reduction in 2030 (to be adopted by the city council) and the long-term goal of zero emission to be set out for 2050.

Climate action goals

Climate action goals are to be set out in SECAP, concerning mitigation (GHG emission reduction) and adaptation, which the city will be basing on the adopted 2019 strategy for adaptation to climate change.

Other

City of Warsaw is the signatory of Covenant of Mayors and plans to join new Covenant of Mayors for Climate and energy.

5.2 Overview of the local case study analysed with THERMOS

5.2.1 Introduction to the case study

As mentioned before, Warsaw has an extensive district heating network, as well as the intention to keep developing it. In order to explore the options of network development, as well as promoting innovation, the city has decided to model a case study using the THERMOS Tool. The location selected for the case study is the *Białołęka* district, located in the northern part of the city of Warsaw. It is one of the districts with the highest number of new–built residential buildings and highest potential for development. Also, there would be no need to change the existing pipework of the installation as there is a possibility of connecting new buildings to the network since the pipes are oversized compared to the current demand.

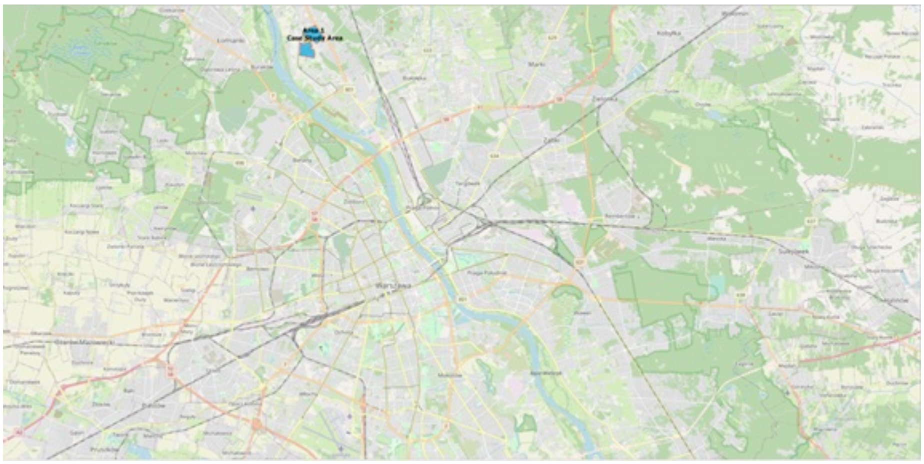

Figure 5-1. Location of the case study's area

5.2.2 Key objectives of developing the analysis

The objective of this case study was to establish the best possible heating solution in an area of mixed development, where both multi-family and single-family buildings could be found. While some of the multi-family buildings are connected to the district heating network, others have their own individual gas based heating systems. For the single-family houses, the most common solutions are individual boilers, usually fuelled by gas, oil or coal.

The case study should allow to identification of an ideal solution that should not only be economically viable, but also provide air quality benefits and reduce the GHG emissions to achieve the city's goals.

The analysed area was divided into two parts, Area A and Area B.

- **Area A:** there are 14 buildings planned to be built in coming years with an estimated heat consumption of 11 GWh/year. The buildings are close to the existing network and could be easily connected. The objective of this case study was to determine which heating solution (DH or individual boiler) was optimal. The first solution considers the connection to the existing heat network, that uses coal as fuel in CHP plants and the second one uses individual heat sources (multiple options are considered).

- **Area B:** is located south from Area A. The aim of this case study was to analyse the possibility of joining existing buildings (i.e. multifamily buildings, single family buildings and non-residential buildings such as schools, supermarkets or churches) that are less than 100 meters from the district heating network, but not currently connected to it.

There is no real consumption data available for non-connected buildings. For the estimation of this value different datasets were used to better understand and to validate the results of the Tool. The chosen solution determines these values with the tool and uses Warsaw's own GIS map with height, floor area of buildings and information whether it is residential or not. The main characteristics of the demand are:

	Demand Area A	Demand Area B
# of buildings involved	157	208
- Residential	108	112
- Commercial	2	6
- Other or unclassified	47	90
Tot. energy demand	15,880 MWh	19,130 MWh
- Residential	13,396	14,930
- Commercial	1,540	1,150
- Other or unclassified	944	3,050

Table 5-1. Main characteristics of the demand

Compared to two other datasets analysed (based on OSM and own estimations), the coefficient of variation of heat demand is 9% for Area A and 23% for Area B which means that the uncertainty in heat demand estimations should impact the second area more significantly.

Given that this case study aimed to depict a real network, both the fixed and capacity costs of the technologies applied have been set to zero. The reason behind this methodology is that these systems were installed several years ago, and their costs were considered at that time. For the ongoing project, this means that there will not be any costs associated with the heat supply construction, only with operational aspect of the system.

The supply is a model of existing network heat sources. Currently, most of the heat comes from cogeneration plants that run on coal. There are also boilers used as a source, which are used mostly to cover peak demands. The main characteristics of the supply are presented in the following table.

	Supply
Technology	Existing CHP plant and boilers
Fuel used	Coal
Maximum capacity	40 MW
Supply cost	13.0 gr/kWh
CO_2 emissions	358 g/kWh
$PM_{2.5}$ emissions	26 g/kWh
NO_x emissions	326 g/kWh

Table 5-2. Main characteristics of the supply input in THERMOS

5.2.3 Involvement of local stakeholders

Identification of the stakeholders

The stakeholders included in the THERMOS Local Liaison Group are divided into two groups:

- **Internal:** various departments of the Warsaw Municipality, which provided different point of view on the case studies and gave feedback and data. These were:
  - Infrastructure Department
  - Architecture and Spatial Planning Department
  - Air and Climate Department
  - Białołęka District authorities
- **External:** the most important are:
  - Veolia: district heating network owner
  - PGNiG TERMIKA: district heating energy producer
  - Building owners and managers: in terms of single-family buildings these are mainly owners who are decision-makers when it comes to switching the heat supply. In the case of multi-family buildings there are two different groups, housing cooperatives and associations that manage existing building stock and investors who build new houses and decide which heat source should be implemented in those buildings

Engagement of the stakeholders

Different levels of stakeholders are involved in different ways. City departments that are involved in the creation of climate, energy and spatial policies were involved during the international meetings with twinning cities organised within the THERMOS project, but also in internal discussions on the possibility of obtaining relevant information from their data sets to develop the case study. They are also involved indirectly in THERMOS, while creating policies and spatial plans for specific parts of the city.

Veolia and PGNiG TERMIKA were also involved during the international meetings with twinning cities and in the local stakeholder group meetings. Direct contact in terms of possibility of obtaining the data from them was established. Housing owners will be involved directly during next steps, when the outcomes of the case study can be presented to them.

5.3 Case Study information and data

5.3.1 Data preparation

As multiple data sources were used, some preparation steps were needed. The main issues encountered were the size of the heat network in Warsaw as well as the fact that multiple energy sources were considered but none of them fell inside of the analysed area.

At early stages of the THERMOS tool development, the network size created technical difficulties. In order to work around this difficulty, the project´s area was limited to a part of Białołęka, which helped decrease computing time. A theoretical source was defined for each dataset used in order to account for the size and diversity of the network in a simplified way.

All case studies used the same GIS file for the paths. The reason behind this is that using one source for each case would eliminate additional variables when comparing the solutions, as the standard input from OSM creates many unnecessary connections. This path GIS file does not include many smaller roads, forcing the building to connect to the main roads in an accurate way.

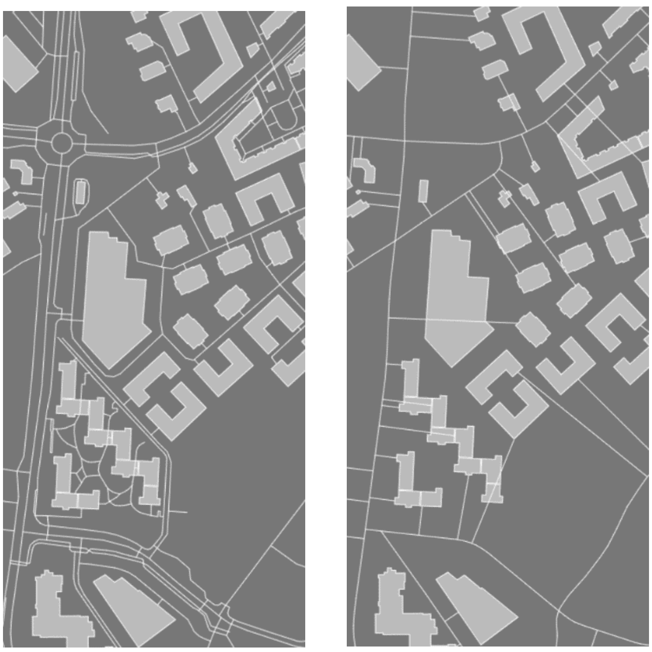

Figure 5-2. Comparison of view of paths in the THERMOS Tool prepared with standard OSM input (left) and simplified GIS input (right).

Apart from heat demand estimation and map preparation other relevant parameters were common for all data sources. For example, according to the network operator, the most common 2019 heat tariff was used.

Regarding network costs, two benchmarks based on real data from previous experience were used. However, the real investment cost is difficult to estimate, as it could vary significantly between cities or even locations within the city. This is why setting universal benchmarks was difficult and could lead to potential under or over estimation of pipework investment costs. In order to be more precise when defining those costs, more insight would be needed.

The costs for the individual heating sources were based on experience and public data sources. The alternatives regarding these systems were diverse. Some examples of this could be:

- Boilers powered with coal, biomass, natural gas, oil, and electricity
- Heat pumps (both air and ground) with and without additional PV as a local electricity source matched with the heat pump

Geographical data	
Paths	• Origin: Own data • Source: City of Warsaw • Type: Private
Cost data	
Tariffs	• Origin: Tariff data • Source: a Veolia Energia Warszawa S.A.[6] • Type: Public
Pipe cost	• Origin: Benchmarking • Source: KAPE's experience • Type: Private
individual sources	• Origin: Benchmarking • Source: KAPE's experience • Type: Private

Table 5-3. Common assumptions

In order to prepare the GIS file to be uploaded to the Tool a set of steps were needed. The first one being the differentiation of the most relevant information for the Tool to build the model. Regarding technical parameters, it was noted that the heat demand estimation only depends on the building´s size (height and floor area) and general use. These parameters were introduced as well as a distinction which classified buildings depending on if they were either residential or non-residential. Another reason why these were the chosen parameters is the ease to access this information, since this type of data would be available for most of Warsaw´s neighbourhoods, making the case relatively easy to replicate.

Also, some of the buildings from the GIS file were represented as multiple polygons. Even though this might not seem a problem at first, it could lead to unnecessary connections as well

[6] Extract from the Tariff for heat of Veolia Energia Warszawa S.A. Prices and rates applicable from 01/09/2019, 2019

as mistakes in the demand´s estimation. In order to avoid this, multipolygon representing a single building were merged using an external tool before they were uploaded to THERMOS. The result was a reduction in the objects' count from 1,145 to 774. Moreover 14 buildings were added representing the planned buildings from Area nº 1. This task was also performed before uploading the files into the Tool. The preparation of the map required attention to detail, as well as some basic knowledge of a GIS software, and was quite time consuming.

Figure 5-3. Part of original map of Area nº 2 before and after solving multipolygon issue the prepared with QGIS.

Regarding the origin of data:

Geographical data	
Buildings	• Origin: Own data • Source: City of Warsaw • Type: Private
LIDAR	• No (height is included to make the estimations better)
Demand data	
Buildings	• Origin: THERMOS estimations

Table 5-4. GIS without demand estimates data source assumptions

In order to estimate the counterfactual heating sources for both areas, maps were used. These maps depicted both heat and gas networks, as well as their respective connections. For the chosen area, it became apparent that most buildings were using gas boilers as their counterfactual heating source. Also, buildings which were not connected to any of the previously mentioned networks were supposed to have coal boilers as their counterfactual heating source. The reason behind this choice was that this kind of boilers is the most common individual heating source in Poland.

These calculations do not take into consideration the planned modernisation of the network's heat sources. Another improvement that could be implemented into the model would be a better estimation of future costs and emission factors. In order to achieve this a closer cooperation with the network's operators would be required. For Warsaw´s case this cooperation is especially important in the perspective of the 2050 zero emission city goal as the network will have a significant impact on achieving this goal. Cooperation with network and heating sources operators could be of great help when building a case study.

5.3.2 Issues faced

Barriers

The main barriers found when developing the case study were:

- Some of the tool features are fixed once you upload the GIS files and cannot be modified in the tool. The only solution would be to use a external GIS tool in order to perform the desired changes and the upload the file once again. This iterative process can be quite time consuming as it is difficult to predict what the Tool´s requirements will be at the early stage of the project preparation.
- Moreover, also related to the previous barrier, replicating projects with intrinsic characteristics could also be quite time consuming. The reason behind this is that for each new project the user needs to set all parameters as if it were a new one. This barrier could be avoided when the changes needed could be performed in the tool. The way to do it would be just to modify the desired parameters, change the project's name and saving it, a new project will be created with the same characteristics of the initial one.
- Another barrier was the use of generic currency, as it could cause confusion when implementing the financial factors.
- Lastly, when analysing the results, only the information regarding the current case study is depicted. This means that in order to analyse the impact of each parameter, compare the different options within the network´s distribution or establish baselines the user would need to create new projects. If the aforementioned barriers are also considered, the creation of multiple projects, which would help validate and compare the model, could turn out to be quite time consuming.

Recommendations

Apart from further Tool features' development which would help lessen the number of barriers present at this time, the users could also follow a couple of good practices that would ease the development of a THERMOS project.

- In the case of using GIS files a set of preparatory steps should be made to make the map fit the THERMOS Tool. The polygons in GIS should avoid overlapping. Each polygon should represent a building that has a separate connection to the network, so some polygons may need to be merged. When merging polygons it is important to remember that the tool will provide a demand estimation based on the geometry (volume) so appropriate height should be assigned to the merged polygon (i.e. an average height of each separate polygon weighted by the polygon area).

- The THERMOS Tool is very useful for the early stage of the project development which could also work with input estimations or simplified inputs. Those simplifications and estimations will influence the accuracy of the outcome; however, they usually can be easily corrected whenever more detailed information is available. Keeping track of the estimations will help you specify them in the next stages of the project development. In many cases it is easy to also see the impact of the estimation just by changing the value and running the optimisation.
- When running multiple solutions to see the impact of different factors or to compare projects it is very useful to name the projects accordingly to what is analysed. The explanatory titles can help other invited stakeholders to better understand what is shown in each network. It will make it easier to keep track of changes and help limit the confusion for new people joining the project on later stages.

5.4 Results

5.4.1 Network topology

The results of the optimisation showed that all new buildings in the area would be connected to the network. Also, in the studied area, 119 buildings were suggested to maintain their counterfactual heating source. For those buildings, the alternative was considered to be gas boilers, as they are the most common individual heating source in the area. Furthermore, 14 buildings that use coal as an individual heating source were changed to gas, leaving the optimisation only with network or gas solutions.

The paths and amount of buildings connected to the network changed depending on the data source used. However, the network covered most of the demands and all new buildings were connected in all of the generated projects. The total length of the network was not significantly different depending on the solution (coefficient of variation of length of the network in all analysed cases was 7%).

Figure 5-4. Area nº 1 network topology solutions 1-3

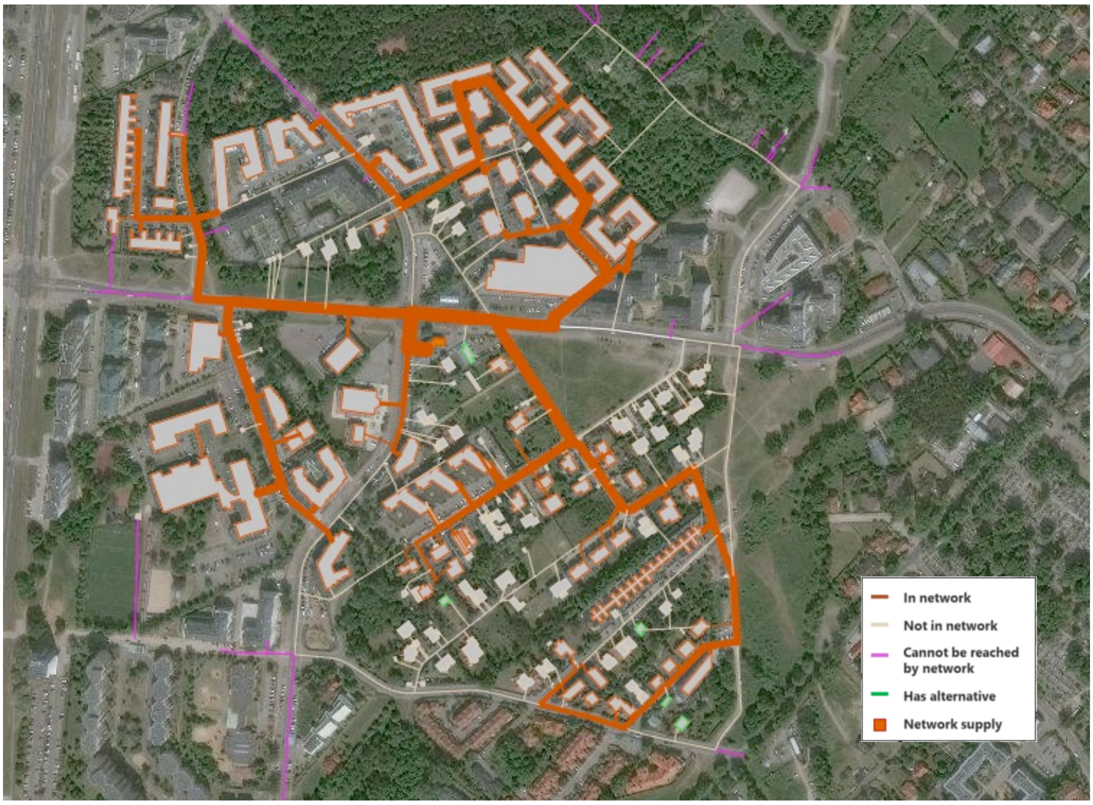

Figure 5-5. Area nº 2 network topology solutions 1-3

According to the optimisation, in Area B, as in first one, most of the demands are supplied by the network. Also, the alternative chosen for the remaining buildings was natural gas systems. While 123 of the buildings already used an individual gas source as their counterfactual, 5 buildings that were using coal switched to gas.

As in Area nº 1, the paths and amount of buildings connected to the network would change if a different data source were used. However, the difference was more significant than they were for the first area. The total length of the network was significantly different depending on the chosen solution (coefficient of variation was 23%).

A breakdown of the results can be seen in the following table:

	Area nº 1	Area nº 2
Pipework solution		
Length	2,120 m	4,170 m
Linear Cost	559 PLN/m	950 PLN/m
Total Cost	1.18 MPLN	3.96 MPLN
Demand solution		
Total Undiversified[7] Peak Demand	6,950 MW	9,780 MW
Total Demand	12,900 MWh/year	16,190 MWh/year
Revenue	3.02 MPLN/year	3.89 MPLN/year
Supplies solution		
Total Capacity Required	4,450 MWp	6,060 MWp
Output	13,310 MWh/year	17,170 MWh/year
Heat Production Costs (fuel)	1.73 MPLN/year	2.23 MPLN/year

Table 5-5. Network solution

5.4.2 Economical and emission results

The chosen option for the optimisation was *Maximise whole-system NPV* option. The reason behind this was that this option analyses the whole system point of view, which may not be the optimal solution for the network operator. This way the results could be analysed and used to plan the city´s alternatives from development point of view, not to prioritise any type of heat

[7] This value represents the sum of the peak thermal energy demand of each building in the solution. However, since the peak demands of a set of buildings are unlikely to occur at exactly the same time, the total capacity required by the supply is considerably less that this value.

source and considering the interests of all inhabitants. Also, costs of emissions were assigned to represent the negative impacts of emissions. Furthermore, it was considered to add limitations to emissions to better represent the city´s objectives.

As it was previously mentioned, many of the buildings were assigned a counterfactual gas source or connection to the current heating network, both based on the use of fossil fuels. However, for both areas, the solution generated by the Tool had higher CO_2 emissions than the counterfactual.

For Area nº 1 this is mostly due to the fact that new buildings had no counterfactual source, which means that the initial emissions were zero, creating an increase estimated by the Tool as over 3 times the counterfactual value. If gas sources were assigned to the new buildings, the increase would be only 30% in comparison to the counterfactual value.

For Area nº 2 the increase is 30% as well. This is a result of the fact that CO_2 emission factor is higher for the network than for the individual gas source. This is not in line with the city´s CO_2 emissions short- or long-term objectives. However, the plans for the modernisation of network's heating sources are not included in the calculations. In order for them to be included, an estimation of the emissions, as well as other relevant parameters such as heat price, for the new source would be required (currently the emission is based on values reported by the network´s operator). The use of the whole-system NPV optimisation approach did not mean that the network´s NPV would achieve negative values, as it is proven by the results. Also, it became apparent that the network costs influence the final whole system NPV significantly, since most of the demand is provided by the heat network.

	Capital cost	Operating cost	Operating revenue	NPV
Pipework	1.2 MPLN	-	-	-1.2 MPLN
Heat supply	-	43.2 MPLN	-	-25.6 MPLN
Demands	2.4 MPLN	-	75.4 MPLN	42.2 MPLN
Emissions	-	-	-	-
Network	**3.6 MPLN**	**43.2 MPLN**	**75.4 MPLN**	**15.5 MPLN**
Emissions	-	4.1 MPLN	-	-2.5 MPLN
Individual system	205.2 MPLN	25.7 MPLN	-	-15.4 MPLN
Insulation	-	-	-	-
Whole system	**3.8 MPLN**	**68.9 MPLN**	**n/a**	**-44.6 MPLN**

Table 5-6. Economic solution summary for Area 1 – operating costs and revenues are considered over XX years

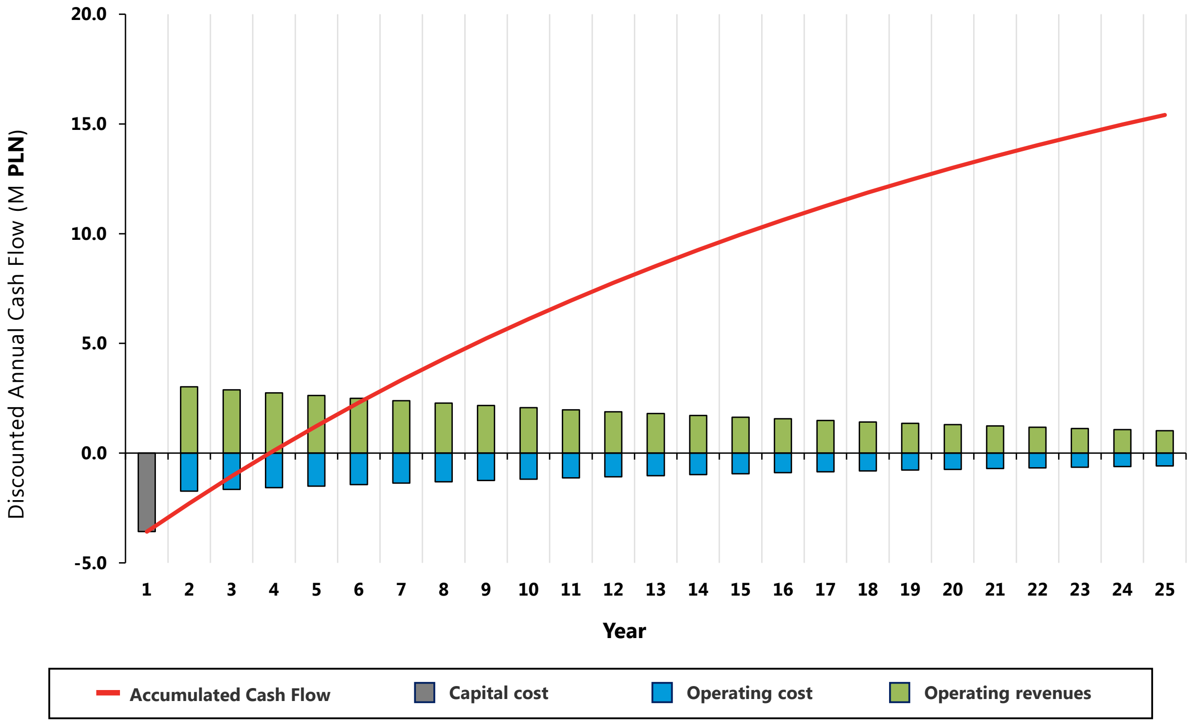

Figure 5-6. Cash flow of Warsaw's Area 1 case study

These results were compared with other datasets in order for them to be validated. The conclusions drawn were that the project´s results are relatively similar, so the model built is consistent. A prove of this is that, for Area nº 1, the difference between highest and lowest NPV form tested cases is around 8 M (coefficient of variation of tested cases is 10%).

	Capital cost	Operating cost	Operating revenue	NPV
Pipework	3.9 MPLN	-	-	-3.9 MPLN
Heat supply	0.0 MPLN	55.8 MPLN	-	-33.0 MPLN
Demands	5.8 MPLN	-	97.3 MPLN	51.7 MPLN
Emissions	-	-	-	-
Network	**9.8 MPLN**	**55.8 MPLN**	**97.3 MPLN**	**14.7 MPLN**
Emissions	-	4.1 MPLN	-	-2.4 MPLN
Individual system	84.1 MPLN	25.4 MPLN	-	-15.1 MPLN
Whole system	**9.9 MPLN**	**81.2 MPLN**	**n/a**	**-57.9 MPLN**

Table 5-7. Economic solution summary for Area 2 – operating costs and revenues are considered over XX years

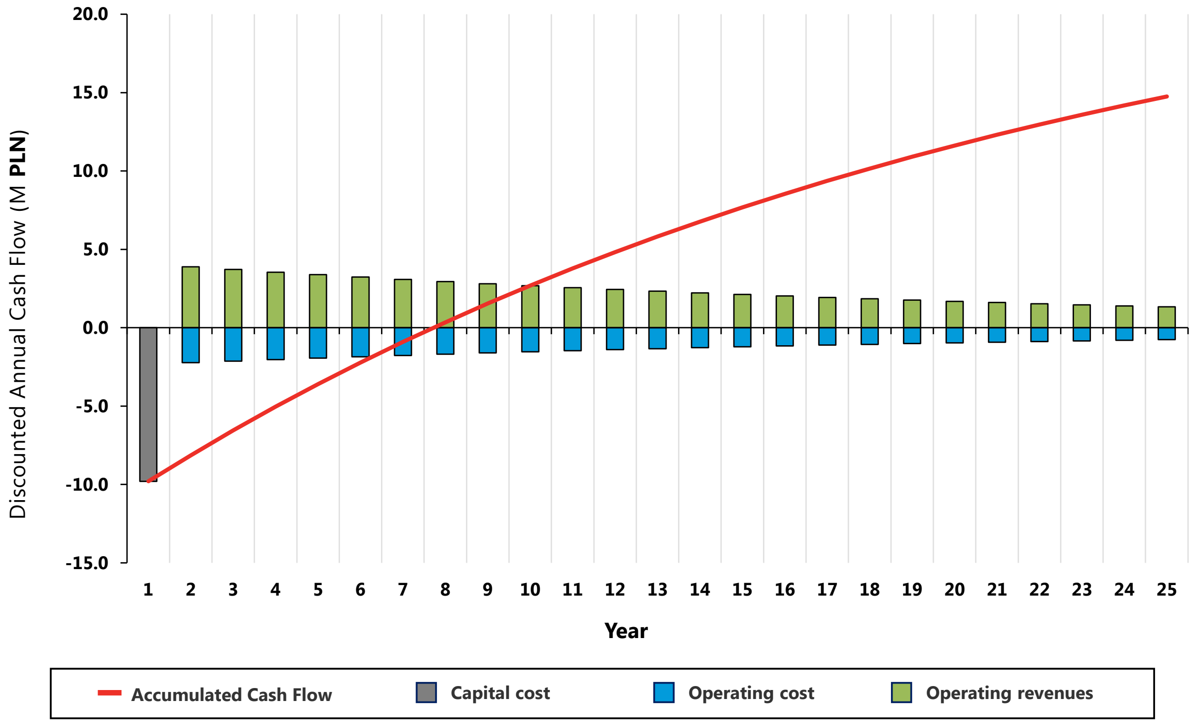

Figure 5-7. Cash flow of Warsaw's Area 2 case study (network only)

For Area nº2 the NPV value for the network was also positive, but it turned out to be lower than in Area nº1. This is a result of higher pipework costs as the network´s length in Area nº 2 is almost twice the one in Area nº 1 (and more than three times the cost). While pipework costs increase the demands are only one fourth higher, directly impacting the project´s revenues.

For Area nº2 the difference between highest and lowest whole-system NPV for all performed tests is around 18 MPLN (coefficient of variation of tested cases is 16%). The increase in the variation might be due to the rise in the amount of small buildings included. This may have impacted the difference between datasets used and caused the more significant differences in the whole-system NPV.

5.5 Conclusions and next steps

5.5.1 *Status quo* of the case study

All solutions suggest that connecting larger buildings with high energy consumption such as multifamily buildings is beneficial from the whole system point of view.

In Area nº 1 all planned buildings were connected. The connection path and results are different if different datasets are considered, which was mostly influenced by differences in heat consumption estimations for smaller buildings.

Better heat demand estimation for buildings in both areas could lead to more precise results. Also, cooperation with network and heating sources operators could enable reaching better estimates and help with results´ validation.

5.5.2 Challenges

Heat sector accounts for 1/3 CO_2 emissions in Warsaw. Therefore, to reach reduction goals, significant investment in both new heat sources as well as improving the efficiency of the already existing system are needed. This investment needs to be defined and embedded into the city´s sustainable energy, climate mitigation and spatial development plans.

As for the Warsaw case study, the main challenges for including it into Warsaw sustainable process is lack of existing SECAP – the document is in planning stage. The second challenge would be that the development plans for the new buildings are very advanced, in some cases construction might even have started. Therefore, the actual stage of the development might create obstacles to later implement the consistent vision created in the THERMOS Tool into reality.

5.5.3 Future outlook

One of the reasons for implementing the THERMOS Tool into the city´s planning processes is that many crucial documents related to energy, mitigation actions and spatial planning, will be adopted in the following years. This means that they are now in planning stage and THERMOS could be embedded into them as a useful tool for assessment of Warsaw´s heat sector challenges in terms of heat planning and reduction of CO_2 emissions. Therefore, possible next steps could include the training of internal stakeholders, responsible for energy and climate policies, to then generate new case studies that could be analysed and embedded into new SECAP. Those analysis will help to calculate investments needed in the heating sector that would bring Warsaw closer to reaching the CO_2 emission reduction goals.

THERMOS might as well be a part of the bigger planning process of the development of the new areas in the city that will happen in the following years, where sustainable estates will be created

6 Cascais

6.1 Specific energy planning goals

Cascais has been actively engaged in the promotion of energy efficiency and innovative sustainable solutions for the last decade. These strategies intend to help citizens and stakeholders alike to reduce energy costs and to be more competitive while engaging in new technologies.

In Portugal, energy consumption is market driven, so there are no public energy companies which can accelerate the development of a certain technology. Municipalities can help the promotion of these values through housing licencing and certification processes (for example).

Despite all this, Cascais does not have a district heating and cooling infrastructure. In fact, Portugal has only one district heating and cooling infrastructure in "*Parque das Nações*" managed by Climaespaço from ENGIE Group located in Lisbon.

Cascais is also a signatory of Covenant of Mayors for Climate and Energy since 2009 and has renewed towards the 2030 goals.

6.1.1 Qualitative objectives

Cascais aims to implement a climate action policy in both mitigation and adaptation. The latest by implementing a long-term Adaptation Action Plan (2017) with resilience target and action goals. Mitigation will be based in the mentioned Carbon Neutrality Plan.

Also noteworthy is the Local Energy Strategy with a 10 year implementation period. This strategy is still under development and will include a set of structural activities to reduce energy consumption through efficiency and renewable energy sources.

6.1.2 Quantitative objectives

Sustainable energy goals

Cascais does not have specific municipality renewable energy targets in place, although its local energy strategy is under development and aligned with national level targets, namely the 2030 National Energy and Climate Plan (NECP).

GHG reduction goals

Cascais municipality has recently developed a roadmap towards carbon neutrality by 2050. This strong commitment is in line with national pledges. It also has the objective of reduce to at least 40% the greenhouse gas emissions by 2030 with the Covenant of Mayors.

6.2 Overview of the local case study analysed with THERMOS

6.2.1 Introduction to the case study

Carcavelos-Sul is an urban area located in the south region of Carcavelos parish in Cascais municipality, Portugal (Figure 6-2). It is composed by residential and services buildings, occupying approximately 47 hectares of area.

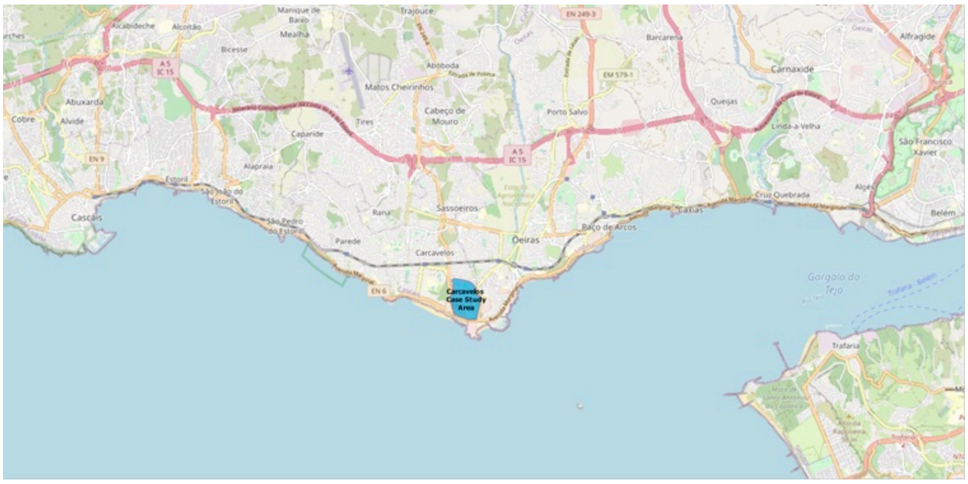

Figure 6-1. Location of the case study's area

It has approximately 1,500 households corresponding to 2500 citizens. Additionally, the faculty campus has 55 classrooms and 26 amphitheatres, serving over 2100 students. Despite requiring high necessities of space heating and cooling demand, it has electric based Heating Ventilating and Air Conditioning (HVAC), partly supplied by 924 solar panels of 270 kWp[8]. The facility has also significant and diverse service buildings, although the majority are located within residential buildings.

The main promoter for this project would be firstly the Cascais municipality which, through organisms like Cascais Ambiente or other public entities, has manifested the interest to implement this kind of solutions. Also, other promoters which are not specifically defined yet are private developers, such as Climaespaço, who may be interested in creating new networks.

The present assessment aims to analyse a heat network configuration covering the heat demand of a (required) residential building's neighbour but also opening the possibility to integrate all additionally other buildings heat demand in the area. The deployment of a new CHP facility is being considered since there is no other heat supply facility in the area or industry activity with that potential.

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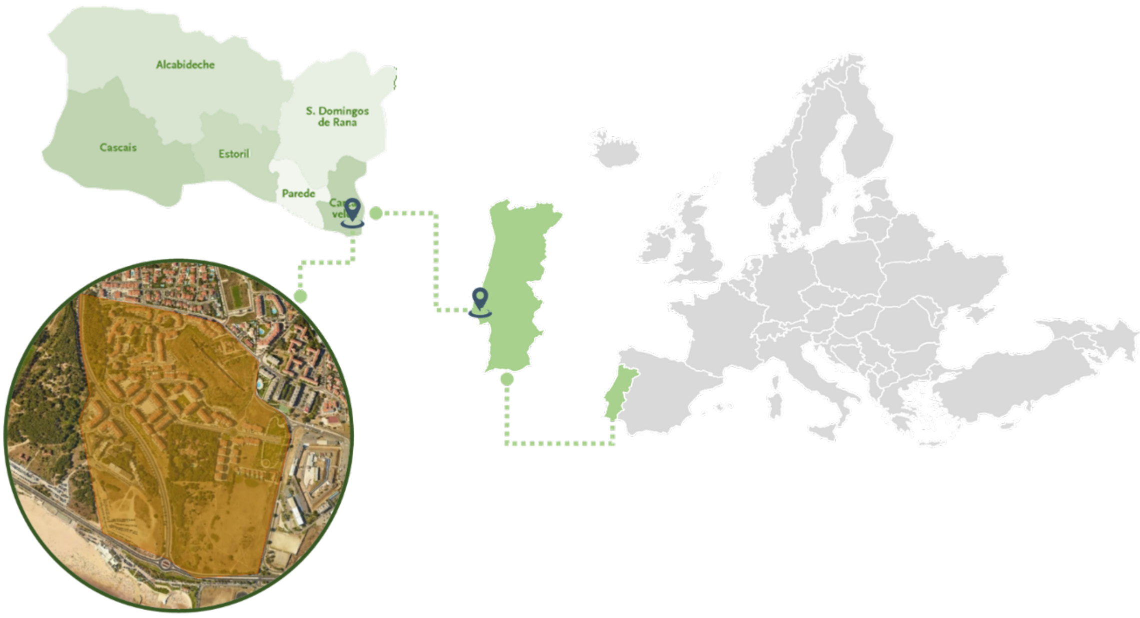

Figure 6-2. Case study location

6.2.2 Key objectives of developing the analysis

Current analysis aims to identify a possible heat network for residential and services building in a neighbourhood and identify optional and additional buildings that can be covered with this network.

The total demand to be satisfied is 10,440 MWh for 77 buildings. The buildings are 87% residential and 10% commercial, the remaining are considered other building types (e.g. dormitory). It was assumed that the buildings that have mixed uses of both households and services (e.g. restaurants typical in the ground floor) were classified as residential considering the representativeness of space heating necessities. Nevertheless, this distinction between services and residential buildings limits the capacity to attribute different heat consumption profiles that in turn can condition intermittent supply technologies. The university faculty was included in the service/commercial sector. There is no industry activity in the case study area. The main characteristics of the demand are:

	Demand
# of buildings involved	77
- Residential	67 (required: 22)
- Commercial	8
- Other	2
Tot. energy demand	10,400 MWh
- Residential	7,400 (required: 2,500)
- Commercial	2,800
- Other	300

Table 6-1. Main characteristics of the demand for space heating

Since the case study area doesn't have industry facilities near the heat supply side considered the hypothesis of the construction of a natural gas combined heat and power plant in the case study area (Figure 6-3). This new infrastructure could have a maximum capacity of 10 MW in order for it to be able to produce enough heat not only for the required buildings but for all the demands enclosed in the case study area. The supply cost associated with natural gas were based on 2019 national prices for industrial facilities published by Directorate General for Energy and Geology (DGEG). The technology technical parameters were based on the IEA-ETSAP Energy Technology Data Source for District Heating Technologies. The project study and related costs (i.e., fixed cost) were based on the costs for the case study of Granollers, since no specific information was available for Cascais. Also, two different connectors were introduced, which were classified as optional, to provide different optimisation alternatives to heat supply output routes. No additional individual systems portfolio was added. Insulation measures were added for wall, floor and roof but limited to 15% of the buildings. The main characteristics of the supply are presented in Table 6-2.

	Supply
Technology	Gas CHP
Fuel used	Natural gas
Maximum capacity	10 MW
Fixed cost	106,300 €
Capacity cost	120 €/kW
Annual cost	2.1 €/kWh
Supply cost	4.5 c€/kWh
CO_2 emissions	203 g/kWh
$PM_{2.5}$ emissions	0.002 g/kWh

Table 6-2. Main characteristics of the supply

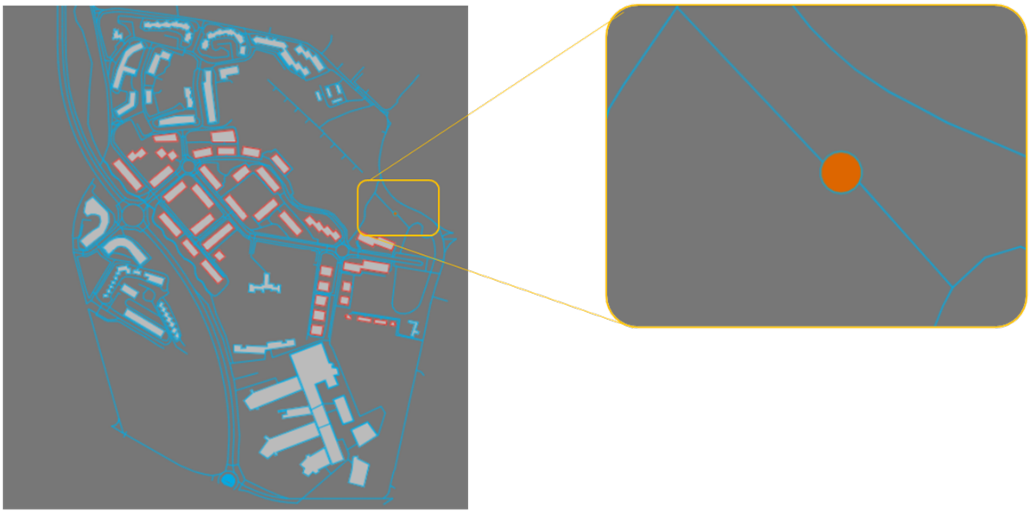

Figure 6-3. New heat supply facility location

6.2.3 Involvement of local stakeholders

Since district heating and cooling Solutions are inexistent in Cascais, it was needed to ensure the collaboration with potential partners and inhouse staff allocated to spatial planning and infrastructure management. This project is an opportunity to introduce district heating and cooling within the municipality and its partners.

Identification of the stakeholders

In order to define the stakeholders to be engaged, the project´s needs were split into three different categories: public, private, and technological.

Firstly, it was noted that the Cascais municipality, specifically through four different departments (spatial planning, urban development, energy efficiency, deputy mayor), would be highly interested not only in the development of the project but also on its definition in order to fulfil the highest percentage of its demand in an environmentally friendly way. Also, regarding this category, Cascais Ambiente was contacted in order to align the project with the municipality´s energy planning and environmental policies.

Secondly, regarding the private sector, Climaespaço was identified. This district heating and cooling company oversees Lisbon´s network, which is considered to be the only relevant district heating and cooling infrastructure in Portugal.

Lastly, the technological expertise was provided by the Faculty of Sciences and Technology, of the New University of Lisbon, which participated as an environment and energy sector stakeholder.

Engagement of the stakeholders

As this exercise was a first approach to local stakeholders, we have focused on addressing the benefits of DHC and technical characteristics of different types of DHS solutions.

Additionally, the stakeholders assess potential urban areas for DHC implementation with regards to market demand and urban areas expansion. Stakeholders interest did not include potential project presentation since currently the new urbanisation projects is still waiting for final approval.

6.3 Case Study information and data

6.3.1 Data preparation

In this case, there was not much data preparation since there is a general lack of information regarding energy consumption and insulation throughout the municipality. That is the reason why it was chosen to take the geographical information directly from OSM, using the option within the Tool, and allow the Tool to calculate the demands, considering 1,071 as the heating degrees days for the case study area. This value corresponds to the heating season climatic zone where the case study is located and establish on national regulation[9].

The only preparation that the dataset needed was the classification. In order to provide an accurate classification for buildings with mixed use it was important to combine the existing information with local knowledge as well as past experience from previous case studies.

[9] *IteCons 2013 DL118/2013 de 20 de agosto Regulamento de desempenho energético dos Edifícios de habitação (REH) -Síntese da regulamentação aplicável (decreto-lei, portaria e despachos) (Coimbra: University of Coimbra)*

Geographical data	
Buildings	• Origin: OSM data + Local knowledge • Source: OSM • Type: Public
Paths	• Origin: OSM • Source: OSM • Type: Public
LIDAR	• No
Demand data	
Buildings	• Origin: THERMOS estimations • Type: Public
Cost data	
Tariffs	• Origin: Real data • Source: ClimaEspaço S.A. • Type: Public
Pipe cost	• Origin: THERMOS estimations • Source: THERMOS database • Type: Public
Insulation measures for walls, roof, and floors	• Origin: Benchmarking • Source: PrioritEE project technological database • Type: Public

Table 6-3. Data information

At investment decision stage the heat demand characterisation would require detailed data regarding building´s physical characteristics (e.g. date of construction and apartments areas) and occupants characteristics namely, family size and income level.

6.3.2 Issues faced

Barriers

A significant barrier found was the impossibility to change certain parameters within the first versions of the tool. For this case, as the building classification was not perfectly defined but instead it was complemented with the developer's know-how, it was tedious when changes in the model had to be performed. This was because the user had to go to the GIS files, then create a new project, upload the new files and the start over, all in order to change the value of a parameter. This was fixed in more advanced stages from the tool development process, so most of the parameters are now adjustable directly on the tool.

Recommendations

Regarding the lack of information, the user should look for the alternatives provided by the Tool when certain data cannot be found. For example, in this case, as neither real demands nor GIS files were available, the maps were taken directly from OSM and the demands estimated through the Tool.

Also, the Tool is versatile, so even though in some cases the input format might be different than what the user is accustomed to, it could be used in different ways. An example of this would be the pathway followed to establish pipe costs. As it was impossible to calculate them accurately, the cost option between "soft" and "hard" was used as a parameter to consider the higher pipeline costs depending on the area´s characteristics. The most impactful variable regarding this classification was proven to be building density.

Last but not least, it was found that it is quite important to properly process the data and make sure it is as consistent as it can be before creating a new project and start working on it. The reason behind it being the difficulty to modify variables set when declaring the case parameters or uploading the files.

6.4 Results

6.4.1 Network topology

The optimal heat network configuration is presented in next figure. It includes the 22 required buildings plus another 12 defined as optional (Figure 12). This includes majority of households and mixed-use buildings (that combine household and services). The case study partial DH grid coverage is justified by the predominance of household buildings typologies in the region that area associated with low heat demand and consequently limiting the cost-benefit of installing an additional or larger supply facility. Also, some of the optional buildings are located in the periphery of the defined case study area and therefore requiring additional pipeline and increasing overall project cost. The total heat power supplied by the network would be 4.6 GWh per year which represents a 44% of the whole demand considered for this project. Also, this value represents a 46% increase over the demand of the buildings originally set as required, which was of 2.5 GWh per year.

Figure 6-4. Case study network solution

Figure 6-5. Solution network – Optional building included (in dark grey)

Pipework solution	
Length	2,670 m
Linear Cost	305.2 €/m
Total Cost	0.81 M€
Demand solution	
Total Undiversified[10] Peak Demand	3.01 MW
Total Demand	4,570 MWh/year
Revenues	0.28 M€/year
Supplies solution	
Total Capacity Required	1.9 MWp
Output	5,110 MWh/year
Capital Cost	0.33 M€
Capacity Cost	0.12 M€
Heat Production Costs (fuel)	0.23 M€/year

Table 6-4. Network solution

6.4.2 Economical results

The model shows that the initial investment needed to perform the project is unevenly distributed by the heat supply and the pipework, being the part corresponding to the first one half the one corresponding to the second. This is mainly explained by the network´s spread, which is around 2.7 km, as well as the high construction costs since the case study is located in a high-density urban area. The heat network model shows a return on investment of 28 years (Figure 6-6) and table 20.

[10] This value represents the sum of the peak thermal energy demand of each building in the solution. However, since the peak demands of a set of buildings are unlikely to occur at exactly the same time, the total capacity required by the supply is considerably less that this value.

	Capital cost	Operating cost	Operating revenue	NPV
Pipework	0.81 M€	-	-	-0.81 M€
Heat supply	0.33 M€	7.02 M€	-	-5.06 M€
Demands	-	-	8.28 M€	5.57 M€
Overall	**1.14 M€**	**7.02 M€**	**8.28 M€**	**-0.30 M€**

Table 6-5. Economic solution summary – operating costs and revenues are considered over 30 years

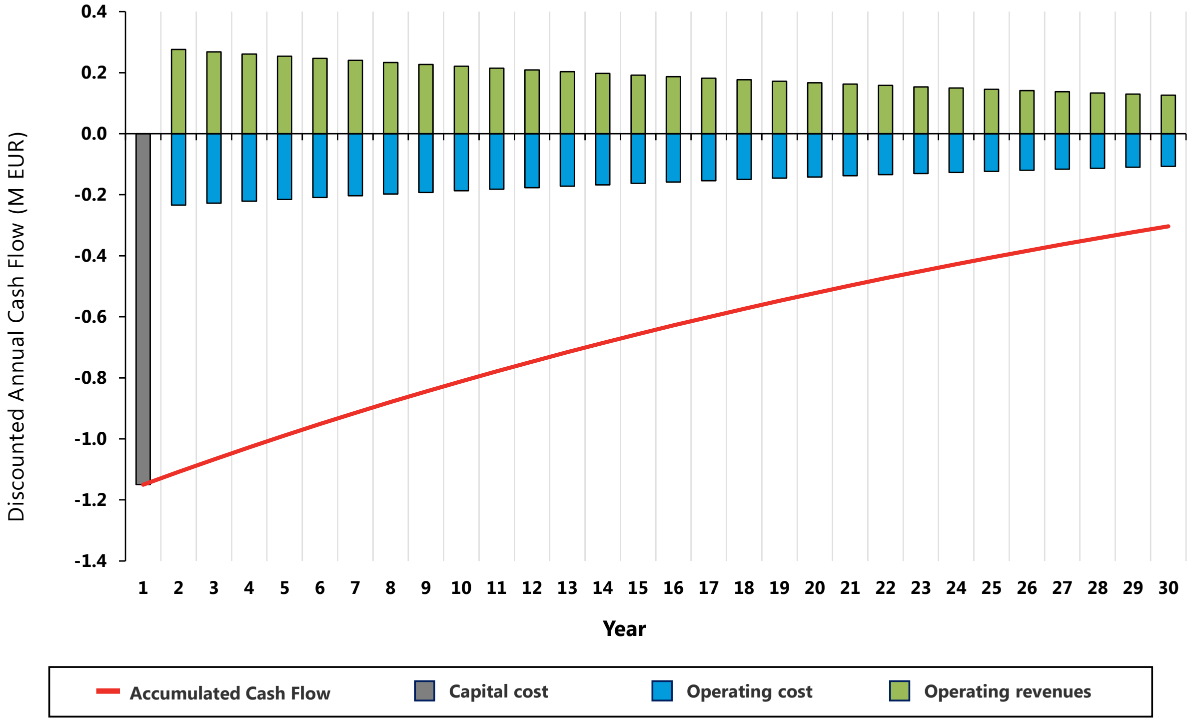

Figure 6-6. Cash flow of Cascais´ case study

6.5 Conclusions and next steps

6.5.1 *Status quo* of the case study

This project represented an early approach to district heating and cooling infrastructure for a residential area. The area was chosen due to its potential for growth associated with nearby infrastructures (both existing and planned).

The network´s economic feasibility could justify a pipework expansion beyond the initially required set of demands. This network expansion would only consider the pipework, as the heat supply has already been built and is still capable of providing heat for the new demands. This would allow to increase the number of network users, thus increasing both revenues and network efficiency.

A model was created in THERMOS in order to evaluate the feasibility of this project. For it, a lower heat tariff was tested, providing a less network dispersion but only covering three optional buildings. The reason behind it was that by reducing the tariff, the operational revenues are also reduced and thus the economic feasibility when including new buildings is stricter. For example, in this test, due to the low number of connected demands, the project was deemed economically unfeasible.

As data regarding heating and cooling parameters becomes more accessible and consistent, a new THERMOS model could be developed. If this new model is considered reliable enough, the Tool could be used in the short to medium-term planning of district heating and cooling networks.

6.5.2 Challenges

The main challenge faced at this stage was the lack of information for new urban buildings. This was mainly due to the low expertise on heat network design, as well as the inexperience of the municipality when dealing with this kind of developments.

There might be some data available as planning areas (implementation area) but there is no information regarding particular capacity and energy demands according to physical parameters, such as the different uses and population served. Also, regarding other development parameters like pipe costs or connection costs, it was complicated to obtain the needed data to perform the characterisation.

6.5.3 Future outlook

On one side, different stages of district heating and cooling solutions could be assessed in collaboration with the local stakeholder liaison group with the full deployment in a given urban area as the final objective. On the other side, THERMOS allows the user to rapidly model or modify a district heating and cooling project based on own considerations.

Hence, more liaison meetings are envisioned, where stakeholders could be trained while, at the same time, they include their technical expertise in the models. This can be achieved both in urban development projects and energy efficiency (also exclusively for DHC) solutions.

Cascais is currently sharing the use of the THERMOS Tool in climate and energy themed conferences and seminars when invited as guest speakers. The project has become a good example on how cities can help the market to strive innovative solutions towards climate and energy goals.

Simultaneously, with the local liaison group, we have achieved a new dialogue with spatial development and urban project promoters to include district heating and cooling as a possible infrastructure in their projects. Despite the early stage of these discussions, the interest has been rising and an increase of assessments in different urban projects is foreseen.

7 Granollers

7.1 Specific energy planning goals

The European Green Deal is the roadmap for achieving economic sustainability in the EU. It envisions turning climate and environmental challenges across all policy areas into opportunities, assuring that this transition will be just and inclusive for all.

Granollers will also implement actions to contribute to the National Integrated Energy and Climate Plan 2021-2030, the National Pact for Energy Transition in Catalonia and the European Commission's initiative "Clean Energy for all Europeans".

7.1.1 Qualitative objectives

Sustainable energy planning started in Granollers last century with the approval of the first local agenda (1999). Energy efficiency and the promotion of renewables continue to be key goals for the city through Local Agenda 21 (2009) and nowadays, the transition of local Agenda 21 to the 2030 agenda keeps those objectives along with the sustainable development goals, which are the blueprint to achieve a better and more sustainable future for all citizens.

The four-year programme (PAM) that Granollers' local government approves periodically after elections, includes the actions that will be promoted with the objective of addressing the sustainable development goals. Even though until now the PAM was focused on more qualitative objectives, at the present time each implemented action will be linked to quantitative objectives for the sustainability of the city in the long run.

7.1.2 Quantitative objectives

Energy planning towards an energy transition in the city has been a goal for Granollers since the city committed to the Covenant of Mayors in 2008. In 2009, the city approved its SEAP and, in 2016, Granollers accepted a wider scope of commitments. Also, that year, the city approved its SECAP providing adaptation measures for these commitments.

Sustainable energy goals

The original SEAP, approved in 2009, settled for a 20% increase in energy efficiency, as well as another 20% increase in the use of renewable energy sources. These goals should be achieved by 2020.

GHG reduction goals

The original goal, set by the SEAP, was a 20% reduction of the GHG emissions. Furthermore, the new SECAP, implemented since 2016, goes further by aiming to reduce them by 40% in 2030.

In 2017, several sectors reached the planned reduction in emissions, specially the tertiary and industry sector which reduced their emissions by 30%. The fact that 98,875 tons of CO_2 (2017) come from the industrial sector makes necessary projects such as the EcoCongost, a district heating project in the industrial aimed at reducing GHG emissions, producing and using heat with local renewables and boosting of circular economy.

Transport sector did not show a satisfactory evolution and that is why new measures will be needed in the Sustainable Urban Mobility Plans to reach more ambitious goals in this sector for the future.

Climate action goals

Nowadays, the opportunity to produce biogas has increased and new options are discussed among the cluster of facilities treating organic matter and producing renewable energy in the industrial area. Therefore, a strategic energy action for Granollers is to be able to test different alternatives and analyse what those sources of renewable energy mean for local energy transition.

7.2 Overview of the local case study analysed with THERMOS

7.2.1 Introduction to the case study

In recent years, funding was awarded to Granollers municipality through the European Regional Development Fund (ERDF). The reason for the deployment of this resources was to build two district heating networks for public buildings, the Xarxa (network) Nord and the Xarxa Sud. The Xarxa Nord (completed in early 2020) counts with a 0.5 MW energy supply plant and a known energy demand of 755 MWh/year. Xarxa Sud, which is planned to be built in late 2020, will have a 1 MW power plant that will exceed the initial demand of 705 MWh/year.

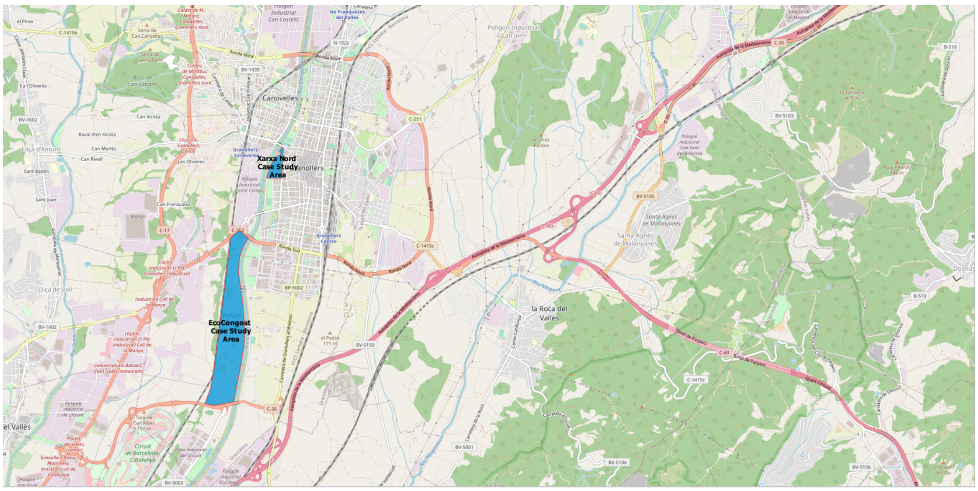

Figure 7-1. Location of the case study's area

Both of these public networks are part of a project financed by Granollers municipality, the Deputation of Barcelona, and the ERDF. The project is referred to by the name of BIOenergia case study.

The Xarxa Nord was tested with THERMOS to check its economic feasibility and GHG emissions impact by comparing the district heating solution with the existing individual heating systems.

BIOenergia's main goals are to reduce the fossil fuel consumption and reduce GHG emissions. Therefore, for Granollers municipality, it is crucial to use the THERMOS Tool to optimise the network design, in order to study the outputs and obtain the most efficient parameters. The network main users are public facilities and other factors besides NPV optimisation were considered when deciding if the network should be developed or not, such as CO_2 emission reductions and energy efficiency improvements.

7.2.2 Key objectives of developing the analysis

Figure 7-2. BIOenergia network elements

The local BIOenergia case study includes two district heating networks using local biomass energy sources. The main goals of BIOenergia are:

- Increase biomass as a source of renewable energy for thermal uses in the municipality of Granollers, considering different criteria, like energy efficiency, energy security and energy diversification towards renewables.
- Increase the use of biomass to develop and consolidate the local sector. This would have positive impacts in the community such as economic growth and job creation.
- Reduce GHG emissions and improve energy efficiency.

In addition to the objectives strictly related to bioenergy and energy planning, the implementation of both district heating networks will also have additional goals, such as:

- Reduction of air pollution emissions
- Contracting model innovation and development of sustainable environmental and social criteria
- Creation of reference documentation
- Establishment of an action program for optimizing the use of biomass
  - Promotion of local biomass from forests with sustainable forest management
  - Involvement of all agents in the economic sector

The main achieved goals testing Granollers's first public network, Xarxa Nord, with the THERMOS Tool, were:

- Learn how to feed the THERMOS Tool with actual mechanical and civil networks costs that the construction of the network had in Granollers and test how the tool compares the solution with individual systems

- Better understand the supply parameters required to introduce in THERMOS
- Incorporate the CO_2 emission parameters based on a given supply fuel mix
- Include other air pollution parameters
- Compare the option of using individual heating systems versus already installed ones

The total demand to be satisfied has been calculated using real consumption data for the individual systems already in place. The value of the total demand is about 755 MWh including 6 equipment buildings, 4 schools and 1 cultural centre. The main characteristics of the demand are illustrated in the table below.

	Demand
# of buildings involved	5 users (even though, there are six buildings involved)
- Schools	4 (5 buildings)
- Cultural centre	1
Tot. energy demand	755.7 MWh
- Schools	708.5 MWh
- Cultural centre	47.2 MWh

Table 7-1. Main characteristics of the demand

The supply is a new energy plant with a boiler (Heizomat with a high efficiency and low emitting technology) of 0.5 MW that allows fuel diversity. The fuels used are woodchips, as they come with high quality certification and are locally produced. There are individual boilers as a backup system as well as to cover peak demands that the network will not be able to supply. The only implemented data in order to account for this was the emission factor for CO_2, which was included in the supply parameters. The main characteristics of the supply are:

	Supply
Technology	Boiler
Fuel used	Biomass (woodchips)
Maximum capacity (MW)	0.5 MW
Fixed cost	66,500 €
Capacity cost	267.6 €/kW
Annual cost	8.2 €/kW
Supply cost	2.6 €cent/KWh
CO_2 emissions	23.7 g/kWh
$PM_{2.5}$ emissions	120.8 g/kWh
NO_x emissions	321.5 g/kWh

Table 7-2. Main characteristics of the supply

The emissions of CO_2 were estimated taking into consideration the assumption that the Xarxa Nord claims in its proposal report that biomass is "carbon neutral". Therefore, the emissions of CO_2 come from the use of electricity for the pumping system and from the gas used to supply thermal energy when the biomass boiler is not able to do so.

The rest of emissions are also estimated according to the percentage of heat supplied by the biomass boiler in a year (90.6%).

Also, in Xarxa Nord case study, it was considered to modify the economic values to consider the cost reduction produced by the grant awarded by the European Regional Development Fund (ERDF). This grant has meant the co-financing of 50% of the cost (VAT not included), allowing the municipality to perform the development.

The main characteristics of the supply are thanks to the grant are listed in the table below.

	Supply
Technology	Boiler
Fuel used	Biomass (woodchips)
Maximum capacity	0,5 MW
Fixed cost	39,000 €
Capacity cost	157 €/kW
Annual cost	4.1 €/kW
Supply cost	2.6 c€/kW
CO_2 emissions	23.7 g/kWh
$PM_{2.5}$ emissions	120.8 g/kWh
NOx emissions	321.5 g/kWh

Table 7-3. Main characteristics of the supply

7.2.3 Involvement of local stakeholders

Identification of the stakeholders

To envision BIOenergia as a tool for local development in the most accurately way possible, several stakeholders have been enrolled within the project. Aiming to ensure the quality of both the supply and the used renewable energy source, Granollers municipality has organised several meetings with the Catalonia´s Bioenergy Cluster. Another positive impact, other than the implemented technological solutions, has been the development of an innovative procurement model, which means an improvement of the public-private business processes.

Different actors from the bioenergy sector have been involved throughout the whole development process. An example of this would be the Catalan Energy Institute (ICAEN), which is the Catalan Government´s entity in charge of elaborating and carrying out the Catalan energy policy. This entity focuses specially in the improvement of energetic savings and energetic efficiency, as well as renewable energies' development. Also, Granollers had several meetings with Climate Action Area and the Fire Prevention Office of Barcelona's Deputation.

Catalonia's Bioenergy Cluster is the organisation which is helping Granollers to promote BIOenergy project and through them Granollers was able to meet the main private companies from the biomass sector, such as facilities enterprises and associations of forest biomass producers and owners.

Engagement of the stakeholders

Engagement of the stakeholders has been of the upmost interest and productiveness for both sides. The main reasons were in one hand the opportunity to develop a model that could be replicated in other cities, and in the other the business opportunity, especially for plant developers as well as forest biomass producers and owners.

As of right now, both public and private stakeholders have enrolled with the next meeting that will be organised in collaboration between Granollers municipality and the Biomass Cluster in November 2020.

Stakeholders diversity allows Granollers to have a wider perspective about the bioenergy sector, considering it as an option to achieve energy self-sufficiency.

7.3 Case Study information and data

7.3.1 Data preparation

For the BIOenergia case study, Granollers started by uploading the local geometry regarding the urban area using multipolygon files. Even though this had been tried before and it did not work, this time it did due to new Tool features implemented in recent updates.

The Open Street Maps information on the Granollers residential and commercial areas is in general better than in the industrial area, but the uploading of local information via GIS has helped to compare local estimations with the default ones generated by THERMOS.

Furthermore, the energy demand needs were also calculated outside the THERMOS Tool, using both estimated and real values for the different building uses and types.

After the first optimisations using THERMOS, Granollers decided to use simple polygons to upload the model to THERMOS. This was decided because having multiple polygons would not allow to have different parameters, such as demands or tariffs, for each independent building. This change meant that the whole geometry would need to be fixed on GIS, as well as the demand data, which would need to be adjusted to the new distribution.

Geographical data	
Buildings	• Origin: Own data • Source: GIS service Granollers Town Hall, QGIS • Type: Public
Paths	• Origin: Own data • Source: GIS service Granollers Town Hall, QGIS • Type: Public
LIDAR	• No
Demand data	
Buildings	• Origin: Real data • Source: Granollers Town Hall • Type: Both public and private
Cost data	
Tariffs	• Origin: Own estimations • Type: Private
Pipe cost	• Origin: Real data • Source: Granollers Town Hall • Type: Both public and private

Table 7-4. Data information

Also, regarding the Xarxa Nord's design, there were some paths added to the original graph. This decision was made because the Tool recommended that the pipelines were built under the street´s pavement. By adding new paths, the civil costs were reduced. This was due to the fact that the path´s new outline would go through softer ground, using the inner patios of the buildings to be connected, thus diminishing the civil works needed.

7.3.2 Issues faced

Barriers

The first barrier faced when testing Xarxa Nord in the THERMOS Tool was the difficulty to translate other goals, such as environmental objectives, into the Tool´s economic optimisation. In Granollers´ case, the economic feasibility was not the main goal when planning the network, focusing more on the sustainable energy goals and GH emissions´ reduction.

Another barrier faced with the Xarxa Nord ´s test was that the geometry uploaded had five separated buildings, but the real project had six final users connected, as one school has two separated heating boilers for two different buildings. This barrier was easily overcome, drawing a new building with the feature the THERMOS Tool has.

The last barrier was how to compare emissions caused by individual systems and emissions the new network causes. Granollers focused Xarxa Nord test on this barrier and thanks to air pollutant emission inventories, this comparison came out from the Tool.

Recommendations

If the local user does not want to upload their own information, the Tool allows users to change the energy demand estimated by THERMOS, building by building and it is feasible to draw new connection paths and new buildings or supply buildings if needed. That makes easier to start making network simulations without the need to work with different files and estimates that must be uploaded later into the Tool.

In order to take emissions into account, the Tool allows an emissions comparison between individual systems already installed and the new district heating network. If a user wanted to compare those values, the only thing to do would be to introduce emission factors when defining the new supply and alternative individual systems, as well as when implementing pumping costs. Once this is performed the tool will automatically generate the aforementioned comparison in the "Emissions" tab of the results section.

Furthermore, if the user wanted the tool to take the environmental parameters into account, it could be accomplished by assigning a cost to the emissions. This way the Tool will be considering the economic impact of the emissions, thus becoming a defining parameter to the model. Great research and tool parameter refinement is needed in order to achieve this, as the relationships will be non-linear, and the implementation of this parameters might end up being counterproductive.

7.4 Results

7.4.1 Network topology

Granollers compared the emissions from individual systems with the estimated emissions the final network built has. The economic values were also compared with the real figures of actual mechanical and civil networks costs. The pipework solution costs (according to the Tool estimations) are about 138,280 €, whereas the final construction project has spent over 117,113€. This difference is due to the fact that most of the network has been built over soft surfaces which reduce the average cost of the distribution network.

The seven buildings connected to the existing network were required to be included in the solution of the Tool, and the new paths (different to the surrounding streets coming as a default for the tool) were also selected as requirement. The real connection costs were included for each building (38,562€). The specificities of the project (public network for public utilities, that keeps the existing individual boilers as a backup system), and the priorities of the city in Xarxa Nord, drove Granollers to maximise the whole system in the THERMOS Tool with the following network solution:

Pipework solution	
Length	591.4 m
Linear Cost	233.8 €/m
Total Cost	0.14 M€
Demand solution	
Total Undiversified[11] Peak Demand	0.56 MW
Total Demand	866.2 MWh/year
Conn. Cost	0.04 M€
Revenues	0.044 M€/year
Supplies solution	
Total Capacity Required	381.4 kWp
Output	960.7 MWh/year
Capital Costs	0.17 M€
Capacity Costs	0.05 M€
Heat Production Costs (fuel)	0.026 M€/year

Table 7-5. Network solution

The pipe work solution has similar length of the final path built and it was a proof to use the same variables defining the costs to test the tool again with Xarxa Sud, given that the results were not far from actual market values. There was doubts of how to introduce in the optimisation the co-finance by the European Regional Development Fund, ERDF and Diputació de Barcelona, but for now, the main objective was the emission and real cost comparison for civil works and engineering with the Tool. The consistent results are useful for Granollers to analyse alternatives of a further expansion to be studied in Xarxa Sud with the Tool.

[11] This value represents the sum of the peak thermal energy demand of each building in the solution. However, since the peak demands of a set of buildings are unlikely to occur at exactly the same time, the total capacity required by the supply is considerably less that this value.

Figure 7-3. Solution presentation of the Xarxa Nord

Granollers, thanks to the THERMOS Tool was able to compare the CO_2 emissions saved, to evaluate different scenarios to locate the energy supply and to compare different routes for the district heating distribution network for the Xarxa Nord project.

At this moment, with all the training done and the available information collected to test the THERMOS Tool, Granollers will easily be able to create different feasibility studies to connect possible users in nearby areas for the Xarxa Sud urban public district heating system, that is going to be built between 2020-2021.

7.4.2 Economical results

	Capital cost	Operating cost	Operating revenue	NPV
Pipework	0.14 M€			-0.13 M€
Heat supply	0.17 M€	0.43 M€		-0.52 M€
Demands	0.04 M€		0.65 M€	0.49 M€
Emissions				
	0.34 M€	**0.43 M€**	**0.65 M€**	**-0.16 M€**

Table 7-6. Economic solution summary – operating costs and revenues are considered over 15 years

Xarxa Nord has been tested also with the second economic objective that the Tool provides, which is to maximise whole-system NPV. The goal is to choose how the heat will be supplied to the buildings in the problem (or abate demand), at the minimum overall cost. This makes sense because the main users are municipal schools. The Tools solution still leaves out of it the two buildings that the previous optimisation did not considered (even they were settle as required candidates) and shows that keeping two individual systems, for two of the candidates, is the best wholes-system NPV choice.

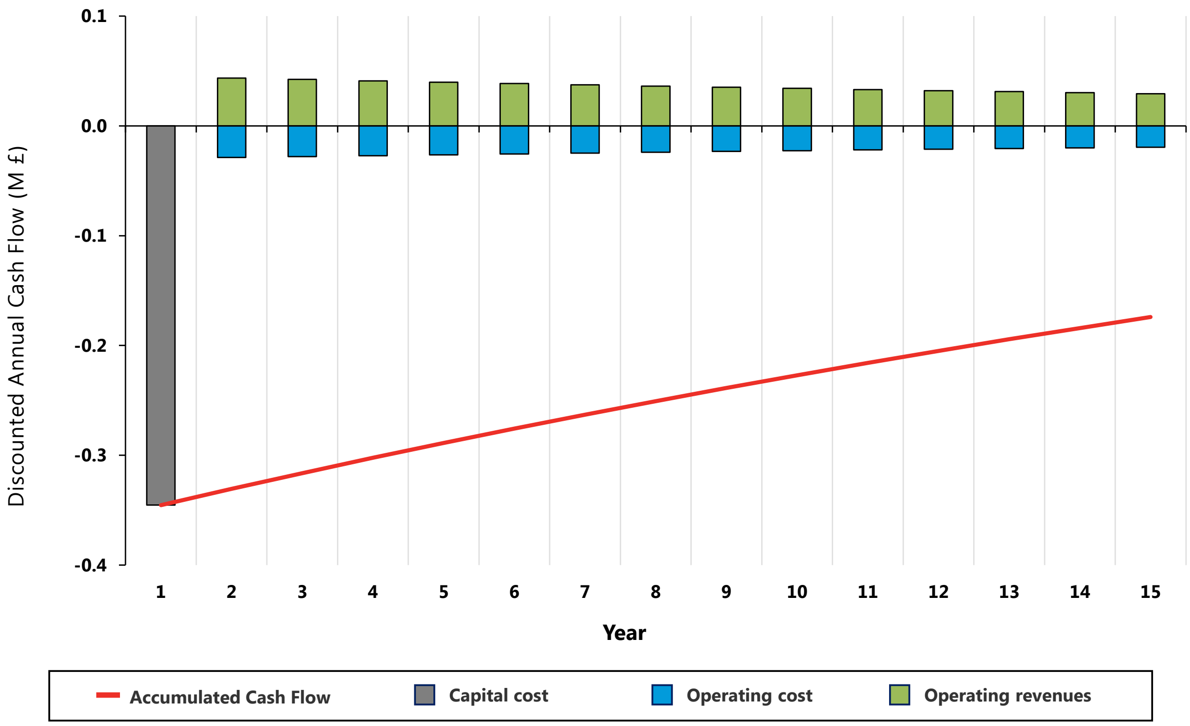

Figure 7-4. Cash flow Granollers of Granollers´case study

Thanks to the guidance to prepare national emission inventories published for the Environmental European Agency, Granollers also tested the results of network emissions for $PM_{2.5}$ and NO_x. The results show an increase of emissions for $PM_{2.5}$ and NO_x with the network over individual boilers. Even so, it is most likely that these figures have been overestimated somehow, since the emission factors used from the EMEP/EEA air pollution emission inventory guidebook, even though they are technology specific factors, do not match the biomass boiler technology used in Granollers' network. This may occur because this technology might be most accurately represented by the lower value in the confidence interval of the mean emission factor published.

	CO_2	$PM_{2.5}$	NO_x
Network (heat)	23.0 t/year	0.116 t/year	0.308 t/year
Network (pumping)	2.3 t/year	--	--
TOTAL	25.3 t/year	0.116 t/year	0.308 t/year
Business as Usual	218.3 t/year	0.0017 t/year	0.228 t/year
Net balance	**-195 t/year**	**0.1143 t/year**	**0.08 t/year**

Table 7-7. Emissions comparison

This has been calculated under the assumption that biomass power generation is "carbon neutral", according to the memorandum of the Xarxa Nord. There is somehow a controversy about this assumption, but if we assume that biomass is carbon neutral, the emission factor used included for the network, only the % of energy that is planned to be provided with natural gas.

7.5 Conclusions and next steps

7.5.1 *Status quo* of the case study

The fact that most of the cost in the case of BIOenergia Xarxa Nord has been financed with grants from ERDF and the Barcelona's Deputation, makes it difficult to analyze using the THERMOS economic optimisation. The reason behind this is that the THERMOS optimisation is established as a private development, considering tariffs as benefits and costs as loses. As of right now, there is no functionality to implement any subsidies or financing schemes into the model, even though it is planned for future updates, but if the user wanted to take them into account it could be done manually. Anyhow, this adds a layer of complexity to the problem.

Furthermore, many of the users (four out of six) are municipal consumers and therefore the subject who has built the network, the local authority, is the same that pays the energy bills. As these bills are also subsidised this could be another reason explaining the economic results' imbalance.

The development of this case study helped Granollers to learn how to feed the THERMOS Tool with actual mechanical and civil networks costs by doing, as well as testing how the Tool is able to compare the solution with counterfactual individual systems.

Thanks to the network parameters of the given supply fuel mix (biomass and gas) the optimisation could incorporate the CO_2 emission parameters and see the net balance of emissions the network causes. The Tool has proven to be useful when comparing the option of using individual heating systems already installed versus connecting to the network.

7.5.2 Challenges

The emissions comparison between individual and network energy production systems has raised some issues over the technology and how the reduction of emissions is estimated and addressed. This was because, even though CO_2 emissions were reduced, NO_x and particulate matter increased slightly.

Granollers is located in an area specially affected by high concentrations of atmospheric particulate matter and nitrogen oxides. The population often feels the effect on air quality of implementing specific energy generation systems (such biomass burning boilers) and there is a need for scientific evidence and clear figures to report those effects.

That means that energy goals to address climate challenges might be in accordance with other environmental challenges and goals across all policy areas, aligning the objectives of the transition for all of them.

7.5.3 Innovative results

The optimisation of emissions could be an innovative objective to include in energy planning goals. Very often the energy policies and air quality policies take different objectives as the goal of the projects and it will be helpful to calculate reductions of GHG emissions at the same time that the tool accounts for other pollution emissions to decide with a multicriteria information beyond economic figures.

Smart control systems are also necessary for the correct generation and distribution of hot domestic water (exhaust pipes, circulation pumps and others) as well as the regulation, control and monitoring of the networks. BIOenergia networks will communicate with a SCADA web application, connected to the SENTILO open data platform of the Diputació de Barcelona. The energy indicators and the emission savings will be publicly displayed to inform citizens and users of the facilities connected.

7.5.4 Future outlook

In a medium term, Xarxa Nord has no other analysis to make but possible suppressions of individual systems already installed in the buildings. Anyhow, this does not seem to be a matter of interest nowadays.

8 Islington

8.1 Specific energy planning goals

In June 2019, Islington Council declared a climate emergency, setting an objective of being a net zero carbon borough by 2030. A zero-carbon strategy that sets out how the borough can be decarbonised by the target date is currently being drafted.

8.1.1 Qualitative objectives

The strategy is currently in draft format. It envisages gas heating being replaced by a combination of individual heat pumps and district heat networks, in which the heat is also supplied by heat pumps, ideally using waste heat.

Currently there are two heat networks in Islington; the Bunhill Heat and Power Network run by Islington Council and the Citigen Network run by E.On.

The Bunhill network serves four council estates, two private blocks of flats, two leisure centres and a primary school. It has two energy centres, one based on a gas CHP unit and another on a heat pump using waste heat from the London Underground.

Citigen supplies commercial buildings only. There are also around 50 communal heating systems on council housing estates, supplying around 4,300 properties.

8.1.2 Quantitative objectives

Sustainable energy goals

The council's current objective is to achieve a net zero carbon borough by 2030. In addition to promoting heat networks, the strategy also includes an ambition to phase out gas boilers in the council's own new build properties by 2025.

Previously Islington Council had a target of achieving a 40% reduction in carbon emissions (for the whole borough) between 2005 and 2020. Although figures are only available up to 2017 (they are published two years in arrears by central government), the latest data showed the reduction was 39.8%.

There are also targets for energy performance in the council's planning policies, which developers of new buildings have to meet. For major developments, the targets are a 30% reduction compared to the 2010 national building regulations or a 40% reduction if connection to a local district heating network is possible. If they do not meet these targets, they have to pay into a Carbon Offset Fund, which the council uses for delivering carbon-saving projects.

Islington is not a signatory of the Covenant of Mayors.

8.2 Overview of the local case study analysed with THERMOS

8.2.1 Introduction to the case study

Islington began operating the Bunhill Heat and Power Network in late 2012. It was built to connect three council estates (around 600 homes) and two leisure centres, with an energy centre ('Bunhill 1') on Central Street consisting of a 2.2 MWth gas CHP unit and 115m^3 thermal store. The three estates connected already had communal heating, and the existing boilers at each site (and the leisure centres) were retained to provide backup and peak load. In the first four years of operation, the network was expanded to add two private blocks of flats with around 220 homes.

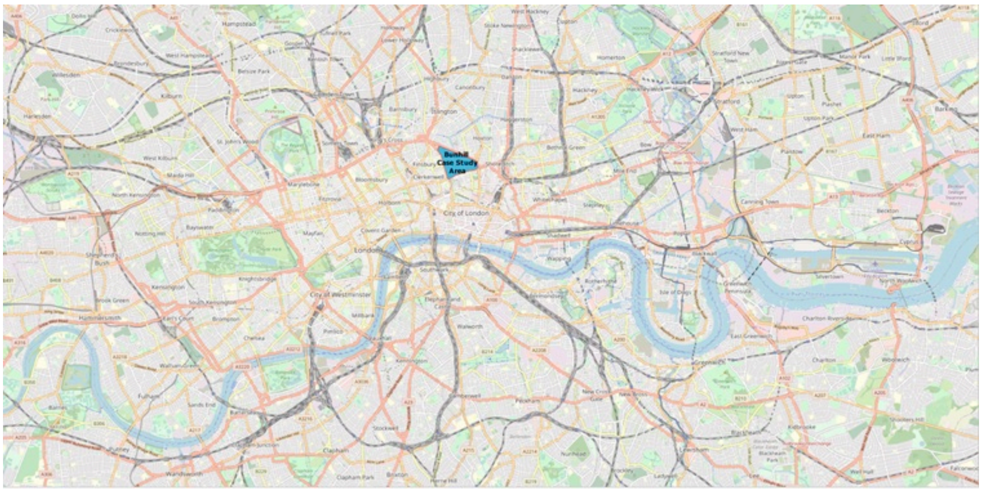

Figure 8-1. Location of the case study's area

In 2016 work began on a significant expansion, with a new energy centre ('Bunhill 2') based around a 1.0 MW heat pump using waste heat from the London Underground tunnels extracted through a ventilation shaft. The new energy centre also has two small gas CHP units with a combined capacity of around 750.0 kW_{th} and a 70m^3 thermal store. As the network was expanded to the new energy centre, an additional council estate with over 500 homes and a primary school were also connected.

The expansion was planned with significant spare capacity for additional connections, allowing the network to grow in future years.

Figure 8-2. The original energy centre of the Bunhill Heat and Power Network

8.2.2 Key objectives of developing the analysis

Although there is the potential to connect new private developments in the area, the council has also considered expanding the network to the closest council-owned housing estates with communal heating systems. These include the Brunswick and Finsbury estates to the west of the network, and Braithwaite House, a large tower block located to the south of the network. In addition, a council-owned museum and library next to the Finsbury estate could also be connected to the network.

A feasibility study was carried out on the westwards expansion in 2016 and funding was requested from central government to proceed with the project. However, the funding bid was unsuccessful.

Another feasibility study was carried out in 2018 on building a new energy centre adjacent to a data centre on the same street as the Bunhill 2 energy centre. The study found that it was technically feasible and financially attractive. However, at the time we did not have the required heat demand necessary to justify proceeding with building the energy centre.

This case study uses THERMOS to model the potential expansion of the network using the additional council connections and the new energy centre. The existing network has been replicated in the model, with the new energy centre and potential connections added as 'optional' in the model run. The total demand to be satisfied for the three residential sites and the library/museum is 6.6 GWh. The main characteristics of the demand are:

	Demand
# of buildings involved	9
- Residential	3 estates (8 buildings in total)
- Commercial	1 library/museum
Tot. energy demand	6,658 MWh
- Residential	6,498 MWh
- Commercial	160 MWh

Table 8-1. Main characteristics of the demand

The supply is a combination of the spare capacity in the existing system, and a possible new energy centre based on a heat pump that will also supply cooling to a data centre. The main characteristics of the supply are:

	Supply
Technology	Gas CHP, heat pumps
Fuel used	Gas, electricity
Maximum capacity	Existing: 4MW, potential: 1MW
Fixed cost	Existing: £0, potential *[confidential]*
Annual cost	16-128 £/kW
Supply cost	-2.2-1.3 p/kWh

Table 8-2. Main characteristics of the supply

8.2.3 Involvement of local stakeholders

The potential heat supply connections are all council-owned sites, so no external stakeholder engagement is required, although Islington would have to carry out engagement with residents of the estates being connected to make them aware of the construction works (the estates are communally heated, so residents would not see any major changes in how their heat is delivered).

If the new energy centre were to be built (supplying cooling to the data centre), the data centre would be a key stakeholder in the project.

8.3 Case Study information and data

8.3.1 Data preparation

All the data needed was available from the existing district heating network or communal heating systems (which give us real gas or heat consumption) and feasibility studies.

Geographical data	
Buildings	• Origin: OpenStreetMap • Type: Public
Paths	• Origin: OpenStreetMap • Type: Public
LIDAR	• No
Demand data	
Buildings	• Origin: Real gas use data • Source: Gas bills • Type: Private
Cost data	
Tariffs	• Origin: Calculated based on cost of supply • Source: Gas, maintenance, and management costs • Type: Private
Pipe cost	• Origin: Real pipe costs • Source: Recent project • Type: Private
Others	• Estimated new energy centre cost from feasibility study • Connection cost from feasibility studies

Table 8-3. Data information

The data for the pipe costs and connection costs needed to be calibrated for the Tool's method of input. We had pipe costs for a range of diameters and created a 'best fit' calculation to the THERMOS methodology. Similarly, we had costs for a range of connection sizes, and worked out the average cost per kWp.

8.3.2 Issues faced

Barriers

The most common barriers for local authorities wanting to progress district heating systems in the UK are:

- A lack of internal expertise on heat networks: Few councils have officers with experience of building or managing heat networks. This can mean they are reliant on external consultants and do not have the expertise to challenge proposals made by the private sector, which sometimes fails to understand the differing priorities of the public sector (for example, councils are often more interested in supplying cheaper heat to address fuel poverty than a return on investment). The lack of officers familiar with heat networks may also reduce senior management confidence in the ability of their organisation to manage high-cost projects and the systems once they are built.

- Business case: Due to the relatively low cost of gas in the UK and high cost of heat network build (particularly in London), it can be challenging to make a business case for heat networks that connect existing properties without increasing heating bills. With fuel poverty in mind, many local authorities will expect residents' heating costs to fall as a result of connection to a heat network, meaning heat prices have to be lower than that of a gas boiler.
- Lack of data: Although local authorities will have heat consumption data for their own properties, it can be challenging to find data for potential private connections, who are often unwilling to share or simply unwilling to engage in data sharing activities.
- Opposition from residents: The legal mechanism for funding upgrades to communal heating in buildings means that although tenants pay for it as part of their rent, leaseholders are only charged when the upgrades occur, which may only be every 20-30 years, at which point they are presented with a cost that they view as excessive (even if it is cheaper than a gas boiler when spread over the relevant time period). As a result, leaseholders frequently call for communal systems to be scrapped or request that they be disconnected. Local authorities creating heat networks based on retrofitting communal heating to existing individually-heated housing estates are likely to see opposition by leaseholders based on this experience.

Recommendations

Regarding recommendations for future case study developers, the most important ones found were:

- If unable to obtain heat data for other public sector sites, publically available DECs can be used. These give figures for annual heat use in kWh/m^2/year and a total floor area, from which a total annual heat consumption figure can be calculated. These also state the heating type.
- Local authority officers can also access the national EPC database that holds EPCs for all properties in the UK (currently around 19.m domestic EPCs and 900,000 non-domestic EPCs). Individual EPCs hold data that can be used to approximate heat consumption for residential properties, such as currently heating type and annual cost.

8.4 Results

8.4.1 Network topology

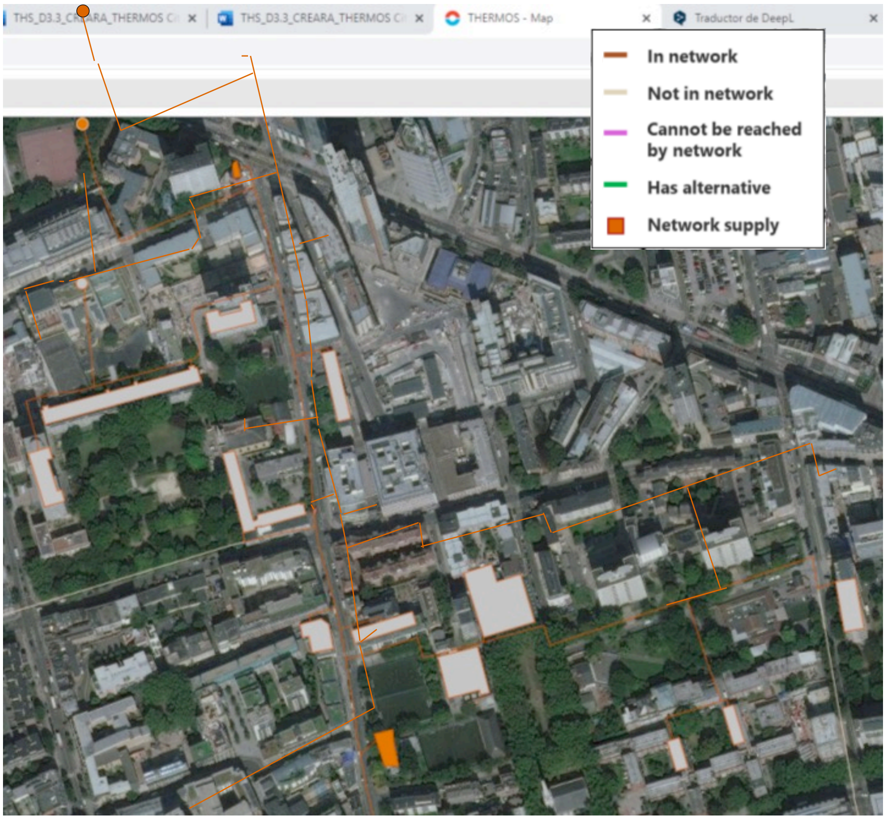

Figure 8-3. Model results

Of the four potential connections, the model results suggested that only two (Brunswick Estate and Finsbury Estate) should be connected. These were by far the larger of the two proposed connections, with annual demands of 2.6 and 3.1 GWh a year, respectively. The smaller sites – Finsbury Library/Museum (160MWh) and Braithwaite House (825MWh) were not connected. It is not clear whether this is due to insufficient capacity or it not being financially viable, as the combined capacity of the energy centres in the results is around 240kW below the highest possible figure (both of the excluded sites have peak demands of 300kWp or higher).

Pipework solution	
Length	2,510 m
Linear Cost	79.1 £/m
Total Cost	0.20 M£
Demand solution	
Total Undiversified[12] Peak Demand	6.1 MWp
Total Demand	11,798 MWh/year
Revenues	0.41 M£
Supplies solution	
Total Capacity Required	4.1 MWp
Output	12,414 MWh/year
Capital Costs	1.9 M£
Capacity Costs	0.2 M£
Heat Production Costs (fuel)	0.12 M£/year

Table 8-4. Network solution

8.4.2 Economical results

The economic results of Islington's case study, are presented in next table. The capital costs (2.1M) are associated with the pipework and the heat supply. The revenues are related to the operating revenue results accounted for the network. Considering this information, the model shows a negative NPV of k£269,6.

	Capital cost	Operating cost	Operating revenue	NPV
Pipework	0.198 M£			-0.19 M£
Heat supply	1.9 M£	13.19 M£		-9.19 M£
Demands			16.5 M£	9.12 M£
Network	**2.098 M£**	**13.19 M£**	**16.5 M£**	**-0.26 M£**

Table 8-5. Economic solution summary – operating costs and revenues are considered over 40 years

[12] This value represents the sum of the peak thermal energy demand of each building in the solution. However, since the peak demands of a set of buildings are unlikely to occur at exactly the same time, the total capacity required by the supply is considerably less that this value.

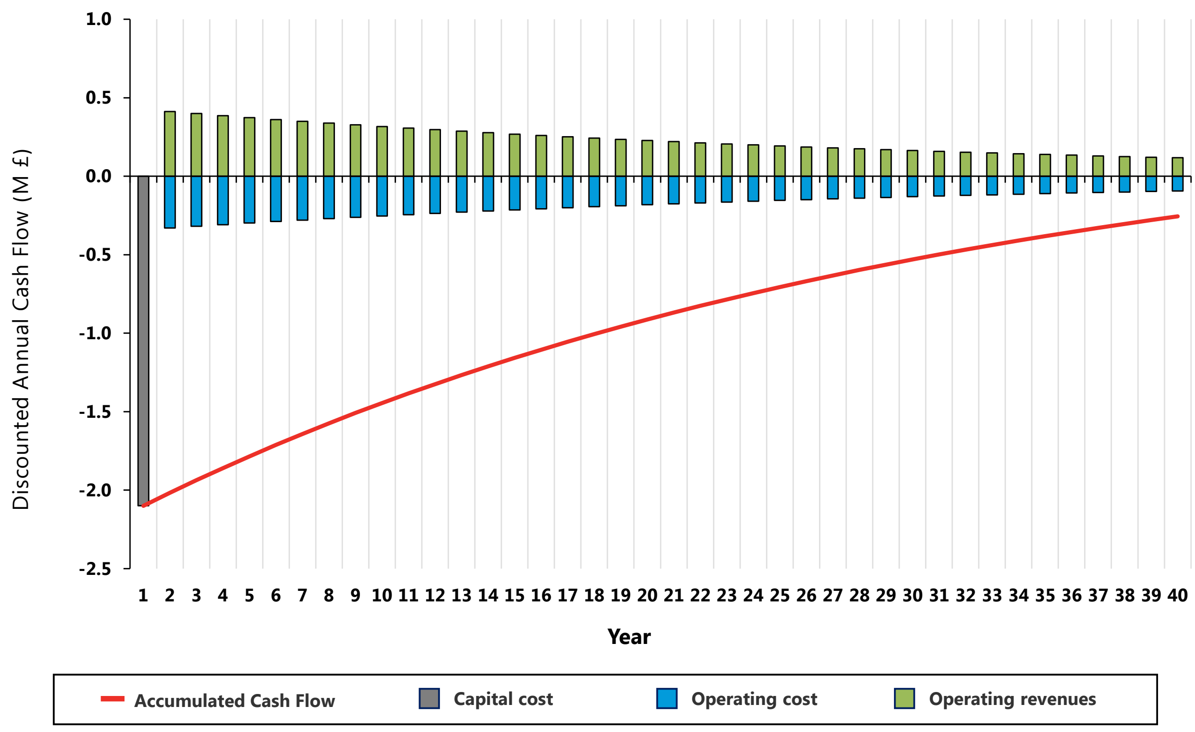

Figure 8-4. Cash flow of Islington's case study

8.5 Conclusions and next steps

8.5.1 *Status quo* of the case study

The proposals detailed in the modelled scenario – i.e. expanding the system to the Brunswick and Finsbury estates and building a new energy centre were looked at in recent years. However, after a funding bid for the expansion to Brunswick and Finsbury network was unsuccessful, the proposal was mothballed.

Similarly, the new energy centre was not advanced due to there being no current requirement for additional capacity on the existing network. This will be revisited if any potential new connections arise.

8.5.2 Challenges

We have two major challenges in developing heat networks in Islington:

- The excessive costs of building heat networks in inner London makes it difficult to create a business case in which heat can be delivered for a lower cost than existing systems. In addition, the most recent expansion of the Bunhill heat network was significantly over budget, meaning the (already high) estimated costs are likely to be even higher in reality.
- There are very limited funding opportunities. Although there is a central government fund for heat network development, Islington's not-for-profit model does not appear to fit with the government's drive for networks that provide a return for investors. Both funding bids we have made have been unsuccessful.

However, we still view THERMOS as a useful Tool for examining potential new heat networks or the expansion of existing heat networks.

8.5.3 Future outlook

Currently the UK has around 14,000 heat networks (most of which are communal networks) and around 450,000 of the UK's 28 million homes are connected to heat networks of some kind. Central government is supportive of heat networks, having created a £320m fund for the development of new or expanded networks.

Islington's net zero carbon strategy identifies heat networks as a key part of delivering the carbon reduction required. However, the main issue to overcome will be funding; creating a business case that meets both the needs of residents (in terms of reduced bills) and government funders (return on investment) will be a major challenge.

If we were to progress, the next stage would be a detailed design study that would look more closely at the costs, capacity, and pipe routes.

9 Benefits of using THERMOS to achieve energy planning goals

9.1 THERMOS and the local thermal planning objectives

The use of modern district heating systems in cities is considered one of the most economical and efficient solutions to reduce GHG emissions and primary energy demand. It also allows cities to play a major role in the energy transition. Furthermore, these systems are increasingly low-carbon and cost-effective as they combine heating and cooling networks with elements such as cogeneration, renewable energy, thermal storage, and heat pumps.

The European Union commitments have required local governments to promote the development of energy projects with high efficiency in order to achieve the objectives of affordable energy supply, reduction of import dependence and optimisation of energy supply. In addition, a side benefit resulting from energy planning processes is the reduction of emissions.

In this regard, THERMOS is key to develop a well-designed energy system planning and to facilitate the development and efficiency improvement of district energy systems. It creates holistic planning processes including new heat/cooling sources on a local level by optimising the use of local resources.

Thanks to the THERMOS project, the participating cities have carried out a deep, quick, and efficient analysis of their local energy needs on a broader perspective, considering energy supply and demand for the different economic sectors residential, commercial, and industrial.

Cities have concluded that their experience with THERMOS case studies has led to a faster process of identifying and subsequently proposing possible solutions for different types of district heating and cooling systems. City planners have found that it is easier and significantly faster to investigate district heating and cooling market potential with THERMOS, assessing in which areas it is feasible to expand or build a network.

9.2 THERMOS and the Sustainable Energy Climate Action Plan

Cities signatories of the Covenant of Mayors on Climate and Energy should develop and implement sustainable energy and climate action plans (SECAPs). These SECAPs must contain a clear outline of the strategic actions of the local authorities regarding energy efficiency, renewable energy generation, fuel switching and smart local heat and cold production in order to reach their commitments. This is the reason why district heating and cooling play an important role on cities mitigation efforts.

From the perspective of local policy development, THERMOS has positioned itself as a useful instrument in contributing to the development of SECAPs in local governments. THERMOS provides a tool to evaluate and design district heating projects to be contained in local policies that promote sustainable solutions and that could be translated into mitigation actions to reach their local energy and emissions reduction objectives. In addition, THERMOS can also help cities to identify new local sources for potential heat and cold production or recovery options that have not been evaluated before.

Several cities such as Alba Iulia and Jelgava have confirmed that their experience working with THERMOS case studies has provided them with the necessary knowledge of the tool to use it when defining their new goals defined in their SECAP.

9.3 THERMOS and the scale up at the city level

The THERMOS Tool can be used not only on a specific case study like the ones presented by the cities and local authorities participating in the project, but it is also an effective tool for assessing the feasibility of district heating networks for the entire city.

Pre-feasibility studies for thermal networks are expensive, take time, and rely on uneven approaches, leading public authorities to face growing challenges to effectively manage their energy planning tasks. All these barriers are overcome with THERMOS. Specifically, the THERMOS Tool is designed to consider four main use-cases which should cover the needs of most cities:

- Expansion of existing district heating and cooling networks to find the best buildings, streets, or neighbourhoods to bring into the network
- Identifying local energy demands for known energy sources and finding the best route for the pipework
- Optimising networks between known energy sources and demands. An optimal network solution is sought that matches up available energy sources and demands
- Identifying optimised heating and cooling solutions when considering energy demand reduction, networked and non-networked system measures

The use of THERMOS for the energy planning at city level will provide a better network design on a prefeasibility stage that integrates local (low carbon) energy sources to local thermal networks. It will also help the city to promote the energy efficiency and meet local sustainability goals, such as energy, GHG emissions and air pollution reduction goals.

10 Annex: Granollers – EcoCongost

Granollers is also developing a further case study focused on a heat network conveying high temperature vapor for industrial applications, a design option that is currently not supported by the THERMOS tool. We include its description here in order to provide a collection of initial insights, with the intention of covering the full case study in future THERMOS publications.

10.1 Overview of the local case study analysed with THERMOS

10.1.1 Introduction to the case study

The EcoCongost project is focused on two industrial areas in the Granollers municipality where the energy efficiency and renewable energy implementation is managed and optimised individually by each company, rather than at global level. The district level approach proposed by EcoCongost will increase economic feasibility due to economies of scale, organisational and technical aspects that will help to optimise the efficiency of energy distribution and generation. The project not only aims to increase the competitivity of the industries thanks to the offer of heat at a competitive and stable price, but also to facilitate the reduction of their CO_2 emissions by offering a renewable alternative to their main primary energy source: natural gas.

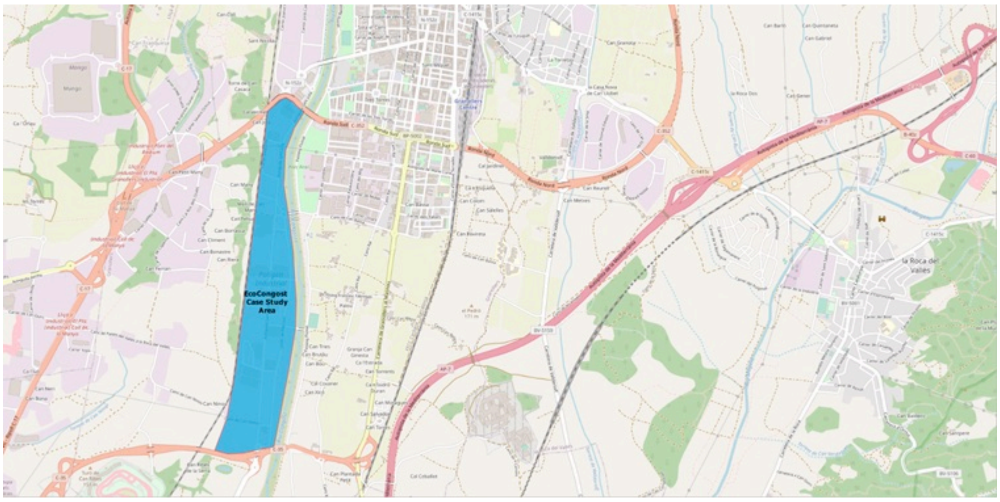

Figure 10-1. Location of the case study's area

Nowadays, industrial companies have internal objectives in order to be climate neutral or to reduce significantly emissions and the substitution of natural gas is one of the most challenging objectives and one of the most necessary to guarantee business in the coming future.

The original EcoCongost project was aimed to develop an industrial network to supply steam for a industrial demand of 167 GWh/year. This network, that was estimated to have a seven-year payback period for the first phase of development, needed a plant of 20 MW according to different feasibility studies done by the Granollers city council.

Initially, the objective was to make a pre-feasibility study for the early stage planning of a DH network given an available energy source based on natural gas, biogas, and biomass. The biogas can be sourced from the nearby anaerobic digester of a composting plant that had a consistent biogas production surplus. In addition, different contacts and meetings were made with local producers of biomass, to guarantee local provision of the resource, increasing the sustainability of the whole project.

During 2019, the improvements planned by the organic matter treatment facilities consortium in the area have led to a potentially much higher local generation of biogas. In addition, it was established that waste thermal energy could be available as well.

At present, no date is established to start the deployment of the project. Several network managers of district heating networks in Spain have shown interest to finance the project and Granollers has applied to European funds to finance part of it. As discussed in the next pages, preliminary studies about the design of the energy production plant and the first stage of deployment have been realised.

10.1.2 Key objectives of developing the analysis

The main objectives of the THERMOS case study of the EcoCongost project are:

- To make a pre-feasibility study for an early-stage planning of a DH network, given the available energy sources;
- Evaluate an industrial heat network as a solution to achieve GHG reduction towards energy transition in industrial areas;
- Compare the emissions reduction between the individual heating systems and common centralised generation with renewables and collective heat distribution;
- Determine construction costs for the available routes in order to compare the original considered path with other alternatives;
- Evaluate different primary energy sources to compare the emissions reduction against the economic feasibility;
- Analyse connection cost estimates for each of the industries involved;
- Analyse and evaluate the expansion of the network, supplying energy to more industries and industrial areas.

Given the current THERMOS tool limitations described above, so far it has only been possible to estimate the best location of the energy supply plant and the cheaper network design between alternative available routes.

10.1.3 Involvement of local stakeholders

Identification of stakeholders

The Ecocongost project has several stakeholders that can be classified depending on their relationship with the project:

- Customers: basically, all those companies located in Granollers industrial areas that could be connected to the heat network in order to cover part of their heat demand. Individual industries and the industrial park business association are directly involved providing information (in case of industries) and spreading word about the project between the member companies

- Energy providers: in order to exactly define the existing local energy supply potential, different stakeholders were contacted, enquiring them about generation profiles, energy transport and storage specifications, primary energy costs and the relation with fossil fuel prices.
- Public authorities: different kind of public stakeholders were contacted in order to obtain information in benchmark ratios and values, future energy cost predictions, replicability and financing opportunities.
- Private promoters and developers: in order to validate the project concept and some of the underlying economical assumptions several private specialised companies were contacts. At the same time, visits wer done to existing heat networks in order to exactly understand them and to engage local industries
- Private financiers: in order to overcome the barriers related with the economic aspects of the project, private financers were approached to help understanding the existing financing alternatives the of the local authority and the connected risks.

Engagement of the stakeholders

Every group of stakeholders request different actions to engage them. In case of public authorities, energy providers, private promoters and financiers, bilateral meetings and direct contacts are in general enough to obtain the needed information.

However, industries need more actions to be involved: meetings, visits to their industrial sites, organising external visits to other heat network projects (to overcome doubts related, for instance, with technical reliability and supply guarantee) and invitations to public meetings presenting the project evolution.

Finally, organising specific meetings focused on the involvement of politicians is crucial due to the importance of the enrolment of local, regional and national authorities to the project. To this purpose, EcoCongost has been presented in several meetings with other municipalities, thanks to Diputació de Barcelona. The project was presented because of its impact in terms of environmental benefits and local economic promotion.

10.2 Case Study information and data

In order to achieve the emissions reduction that the companies and Granollers are pursuing, the original project considered two different renewable energy sources and natural gas as primary energy.

- **Biogas from organic waste treatment plant**: less than 2 km from the EcoCongost industrial area lies a waste treatment plant with an anaerobic digestion process that produces 2,700,000 Nm^3/year of biogas. Currently, part of this biogas is being used to produce electricity and to feed the biogas digesters. Due to legal and technical limitations not all the biogas can be directly used, so the excess could be used the EcoCongost generation plant with a potential of up to 16.7 GWh/year.

- **Biomass**: in order to define the biomass needs Granollers considered:
  - Sesonal heat demand and peak demand
  - Boiler requirments
  - Biogas availability

  The result of the analysis is that two local biomass production zones could provide the needed amount of biomass (18,000 Tn/year).

- **Natural gas**: in order to meet the peak demand and to increase the flexibility of the plant, the system should also include two high efficiency gas boilers as a backup. Natural gas will enable the plant to reach the peak demand of 22.5 MW.

The project started with nine industrial buildings with industrial processes that used high amounts of heat. Eight of those companies are using steam and the other one superheated water. The total demand of those nine companies is 102.5 GWh/year, obtained from monitored data of the natural gas consumption of individual systems. To estimate the heat demand of the rest of the companies located in the same industrial area, the municipality used:

- The main production processes: based on the activity code and other information.
- The area occupied by the industry, clearly differentiating between the industrial plot, the total building surface area and the surface areas with specific heating demand or industrial processes.
- National benchmarks ratios and regionals ratios that allow to estimate the industrial and space heating demand due to the relevant industrial process.

As it was defined previously, the generation plant was initially designed to comprise 3 different boilers:

- **1 biomass and biogas boiler**: a 10 MW boiler that enables to supply the baseline demand. This boiler will be operating 100% of the year and will only be stopped for maintenance purposes.
- **2 natural gas boilers**:
  - A 10 MW boiler that will enable to supply the peak demand of the network. This boiler will be operating less than a 25% of the year.
  - A second 10 MW boiler used as a backup in order to produce energy when the biomass boiler is in its maintenance periods.

In order to represent this plant as a generation unit in THERMOS, a single boiler with a total capacity of 20 MW was considered. The capacity, annual and supply costs were estimated according to the total number of hours that each boiler should run, considering just one of the natural gas boilers and the biomass/biogas boiler. The same methodology was used for the emission values that are defined as a mix, based on the total yearly working hours.

	Supply
Technology	Boiler
Fuel used	Biogas + Biomass + Natural gas
Maximum capacity	20 MW
Fixed cost	1,729,000 EUR
Capacity cost	219.5 €/kW
Annual cost	0 €/kW
Supply cost	2.8 c€/kW
CO_2 emissions	0 g/kWh
$PM_{2.5}$ emissions	0 g/kWh
NOx emissions	0 g/kWh

Table 10-1: Main characteristics of the planned ECOCONGOST supply

10.2.1 Data preparation

Heat demand estimation

Real consumption values sourced from direct monitoring or calculated using natural gas bills are the most accurate method to define the heat demand of a given industrial facility. For EcoCongost, 9 companies have provided such values and the original project was designed considering this data. In order to enlarge the original project, increasing the number of connected companies some approaches should be done:

- Space heating demand: heat demand estimations done by THERMOS tool should be reviewed because of the majority of industrial buildings are not heated.
- Process heat demand: different benchmark ratios, based on industrial surface, exist that allow to calculate a process depending on the national economic activity code of the industry. Some aspects should be considered before use those ratios:
  - National activity code: industries could have more than one code assigned and not all the processes related to those codes may take place in a given location. It is important to know exactly which industrial process is carried out in a given location and, in that case, the correct ratios can be used.
  - Industrial surface: the benchmark ratios do not take into account warehouses and other surfaces unrelated to the production process. In order to correctly apply the benchmark ratios, we should not consider those buildings that are not dedicated to the industrial process.

Topology

Unfortunately, the freely available Open Street Map information for Granollers cannot be used, as the geometry of most industrial buildings is currently missing, and other public facilities are not well defined either. The local geometry was therefore elaborated in GIS and later uploaded in the THERMOS tool.

In order to upload demand and building information to the THERMOS tool, it is necessary to assign a single energy demand (accounting for space heating, sanitary water and industrial process needs) to a building with all the information variables placed in it (name of enterprises, type of activity, etc.).

There were two solutions found during this process:

- When several buildings belong to a single user, the whole demand should be assigned to a single building to be considered by the tool. The building chosen should be the one where the energy generation equipment is located.
- In case more than a one user is located in a building, the heat demands should be summed.

Additional local information dealing with possible network paths such as train tracks, river basin and others was prepared in GIS and uploaded to THERMOS in order to evaluate the possibility to build the heat network not only on local streets or roads.

10.2.2 Other issues faced

Industries engagement

Several industrial companies consider heat demand values as confidential data that should not be shared with other local industries. A confidentiality agreement was signed in order to access those values, with the provision that results cannot be shared or published. Furthermore, for some companies, energy consumption is not a priority due to the current low primary energy prices. Other arguments such as environmental impact, economy decarbonisation or the economic promotion of the industrial park helps to engage with such actors.

It is recommendable to contact with industries with the most heat intensive processes such as those from the textile, chemistry and food sectors. Those industries will represent a large share of the heat demand of the industrial park.

Other actors' engagement

Other actors should be involved in the project development such as energy providers, local authorities, financiers, promoters and developers. The enrolment of the public authority responsible for the biogas production was the greatest barrier in these cases. Since the biogas production consortium is composed by different municipalities, each of them has different objectives which are very difficult to harmonize.

10.3 Results

10.3.1 Network topology

Figure 10-2 – A possible EcoCongost network layout

Thanks to the work made with the THERMOS tool in the industrial area, Granollers has now:

- Better maps with estimates of thermal energy demand for the industrial sector considering industrial process heat, space heating and hot water demand;
- An evaluation of different alternatives to locate the energy supply plant;
- A design of an energy supply plant with biogas, biomass and natural gas;
- A pre-feasibility study to build a network only for space heating supply;
- A pre-feasibility study to build a network for industrial heat demand in order to reduce industrial emissions.

10.3.2 Emissions results

Due to the temporary limitations of the THERMOS tool already mentioned, the analysis so far has been done in order to compare the emissions of individualised systems and centralised systems.

The benefits in terms of CO_2 emissions can be appreciated in the following table. Such results could be increased if the share of biogas is further raised. On the other hand, the use of biomass as a primary energy source triggers a significant increase of particles and NOx emissions. Such repercussions should be considered especially by those cities that, like Granollers, have environmental problems linked to particles emissions due to transport. An existing option to reduce those values is to increase the investment and operation costs by adding specific filtering systems to the plant.

	CO_2	PM 2.5	NOx
Network (heat)	5,200 t/year	5.31 t/year	55.03 t/year
Network (pumping)	--	-	--
TOTAL	5,200 t/year	5.31 t/year	55.03 t/year
Counterfactual	27,450 t/year	0.11 t/year	17.43 t/year
Balance	-22,250 t/year	+5.20 t/year	+37.60 t/year

Figure 10-3 - Preliminary EcoCongost emission results

10.4 Conclusions and next steps

10.4.1 *Status quo* of the case study

The main conclusions so far are related to the lessons learnt in estimating industrial heat demand: the benchmarks used by Granollers based on Spanish economic activity codes (CNAE are not reliable enough to be used with no further processing.

Such benchmarks need to be adjusted and complemented with more specific information from each company. Nevertheless, it is useful for the city to study the users and get in touch with them in order to detect the most intensive industrial energy consumptions in their area.

In terms of space heating demand, the estimations based on building volume, are adequate for offices and similar uses, but they overestimate most industrial buildings (such as warehouses) that only in few cases are heated. Space heat demand of warehouses or manufacturing areas should usually not be considered. In order to simplify the approach, when estimating energy demands for space heating or cooling, it is be more accurate to only consider office buildings.

The case study for the industrial areas is undoubtedly a key local project to reduce GHG emissions and Granollers will analyse different additional industrial heat network opportunities in the next years.

10.4.2 Innovative results

The steam distribution network with locally generated renewable energy will represent an innovation for Granollers industrial areas, not only because it will use the best available innovative technologies to lower emissions, waste processing and energy consumption, but also because it will boost local collective energy actions that will be managed in a community energy group.

10.4.3 Challenges

Since the steam network could not be optimised and evaluated with the THERMOS tool so far, there is another approach to be taken. Granollers could analyse a network for space heating demand estimating as an energy source the condensates return of a steam network.

Before adopting this approach, Granollers could establish a cost for those condensates based on the increase or reduction of the boiler efficiency and quantify more precisely the availability and quantity of the condensates. In the medium term, Granollers could also open up the analysis to surrounding industrial areas with commercial buildings by exploiting the condensates or the heat coming from nearby cogeneration plants.

This is an important challenge, because in order to use the heat coming from existing cogeneration plants in waste treatment facilities, the cost of supplying this heat should be previously agreed with the organic waste composting and the wastewater treatment plants. There are many other agreements that could benefit the local industrial sector and Granollers has already evaluate collective energy actions to be organise in a community energy group.

10.4.4 Future outlook

As discussed, there is a great opportunity to use local renewable resources in the industrial network and that is because in the near future there will be more biogas production from local organic waste treatment plants in Granollers.

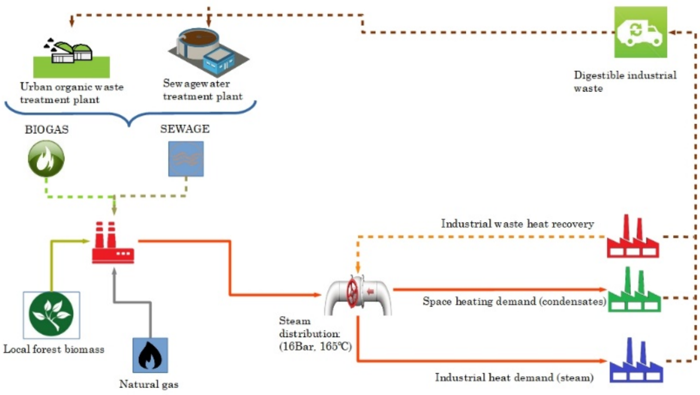

Figure 10-4 -EcoCongost model

On one hand, when EcoCongost was initially analysed a production of 1.5 Mm^3/year was available from the composting plant, but now this has increased to 2.7 Mm^3/year, corresponding to a potential production increase from 9.3 GWh/year up to 16.7 GWh/year. Additional developments currently on the table would make it possible to further increase the biogas production up to 11.4 Mm^3/year, 70% of which could be dedicated to cogeneration and the rest for heating and upgrading purposes.

On the other hand, the wastewater treatment plant will produce further 1.3 Mm^3/year of biogas (for cogeneration and upgrading) and will feature a new burning sludge and biomass facility to treat the solid organic waste from the sewage plant.

These opportunities could boost the city's sustainable energy and climate action processes for the industrial sector that is currently responsible for 30% of GHG emissions in Granollers.

Granollers will wait further progress of the THERMOS tool to be able to study the remaining open questions and showcase the EcoCongost case study and discuss alternatives with local authorities, industrial stakeholders, and waste treatment facilities.