D6.3 Heating and cooling strategies for pilot cities – Bistriţa

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The Hotmaps project

The EU-funded project Hotmaps aims at designing a toolbox to support public authorities, energy agencies and urban planners in strategic heating and cooling planning on local, regional and national levels, and in line with EU policies.

In addition to guidelines and handbooks on how to carry out strategic heating and cooling (H&C) planning, Hotmaps will provide the first H&C planning software that is

- **User-driven**: developed in close collaboration with 7 European pilot areas
- **Open source**: the developed tool and all related modules will run without requiring any other commercial tool or software. Use of and access to Source Code is subject to Open Source License.
- **EU-28 compatible**: the tool will be applicable for cities in all 28 EU Member States

The consortium behind

Scientific partners

Pilot areas for developing and testing the tool

Bistrita Municipality

Executive Summary

In the course of the Horizon 2020 project Hotmaps, a database and toolbox for strategic heating and cooling planning has been developed. Also, strategic heating (and cooling) planning in 7 pilot areas has been performed using the developed Hotmaps toolbox to demonstrate its usability in the strategic planning process.

This document presents a heating strategy for the city of Bistriţa developed within the Hotmaps project. This strategic planning document has been derived following a commonly defined strategy process and using the Hotmaps toolbox for quantitative scenario analysis. The strategy process hereby included the following steps: an analysis of barriers and drivers, a stakeholder analysis, the mapping of the existing heat demand and available resource potentials, the development of scenarios for heating demand and supply in the city in the year 2050 and the discussion of these steps and their outcomes with relevant persons in the city. The outcomes of this process are described in this document.

Bistriţa is a city of around 75 thousand inhabitants which is located in the northern part of Romania near the border with Ukraine. Currently around 360 GWh/yr of heat is needed for space heating and hot water generation in the buildings of the city. At the moment this demand is nearly entirely supplied with natural gas.

In the course of the analysis, various scenarios for future heat demand and supply for the city have been developed. Hereby the costs and potentials for heat savings in buildings, for decentral heat supply and for the supply of district heating have been investigated. The results of the analyses in these different parts of the heating system have been compiled to consistent scenarios for the entire city.

The quantitative scenario analysis shows that district heating should be considered as a potential future option for supplying remarkable parts of the buildings' heat demand in the city. However, a more detailed analysis of costs and potentials of renewable and excess heat sources has to be carried out in order to deepen the understanding of the district heating potential in the city. Furthermore, for very promising supply options pre-feasibility studies should be carried out. The analysis also has shown that renovation of existing buildings plays an important role in reaching emission reduction targets in the city. A renovation strategy should be developed to analyse which buildings to renovate at which level of ambition. A roadmap of activities and next steps on the way to a low carbon heating system for the city of Bistriţa is presented in the last chapter of the document.

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List of terms and abbreviations

CHP	Combined Heat and Power
CM	Calculation Module (in the Hotmaps toolbox)
COP	Coefficient of Performance
CO2	Carbon Dioxide
DH	District heating
EASY City	“Environmental Sportive Energy City”, the Energy Vision of the city of Bistriţa for the year 2050
EEG	Energy Economics Group (Institute of Energy Systems and Electrical Drives, TU Wien)
Enertile	Model to analyse the energy supply, of the Fraunhofer ISI
EU	European Union
EUCO30	Model for an energy efficiency target of 30% developed by the EU Commission
Fraunhofer ISI	Fraunhofer Institute for Systems and Innovation Research
GFA	Gross Floor Area
GHG	Greenhouse Gas
GIS	Geographic Information System
GWh	Gigawatt hours
Heat demand	Heat demand in terms of useful energy, unless stated differently
HDD	Heating Degree Day
IEA	International Energy Agency
INEA	EU Innovation and Networks Executive Agency
Invert/EE-Lab	dynamic bottom-up techno-socio-economic simulation tool that evaluates the effects of different policy packages on the total energy demand, energy carrier mix, CO2 reductions and costs for space heating, cooling, hot water preparation and lighting in buildings.
LCOH	Levelized costs of heat
MFH	Multi-family houses
MSW	Municipal solid waste
MWh	Megawatt hours
PP	Power Plant

PRIMES	partial equilibrium modelling system that simulates an energy market equilibrium in the European Union and in each of its Member States
SDI	Sustainable Development Initiative
SEAP	Sustainable Energy Action Plan
SECAP	Sustainable Energy and Climate Action Plan
SET-Nav	EU Horizon 2020 co-funded project "Navigating the Roadmap for Clean, Secure and Efficient Energy Innovation"
TU Wien	Technische Universität Wien

1 Introduction to Bistriţa

Location: South Eastern Europe

Size: 145,47 km2

Population: municipality (inhabitants): 75.076

Population: central area (inhabitants): 67.272

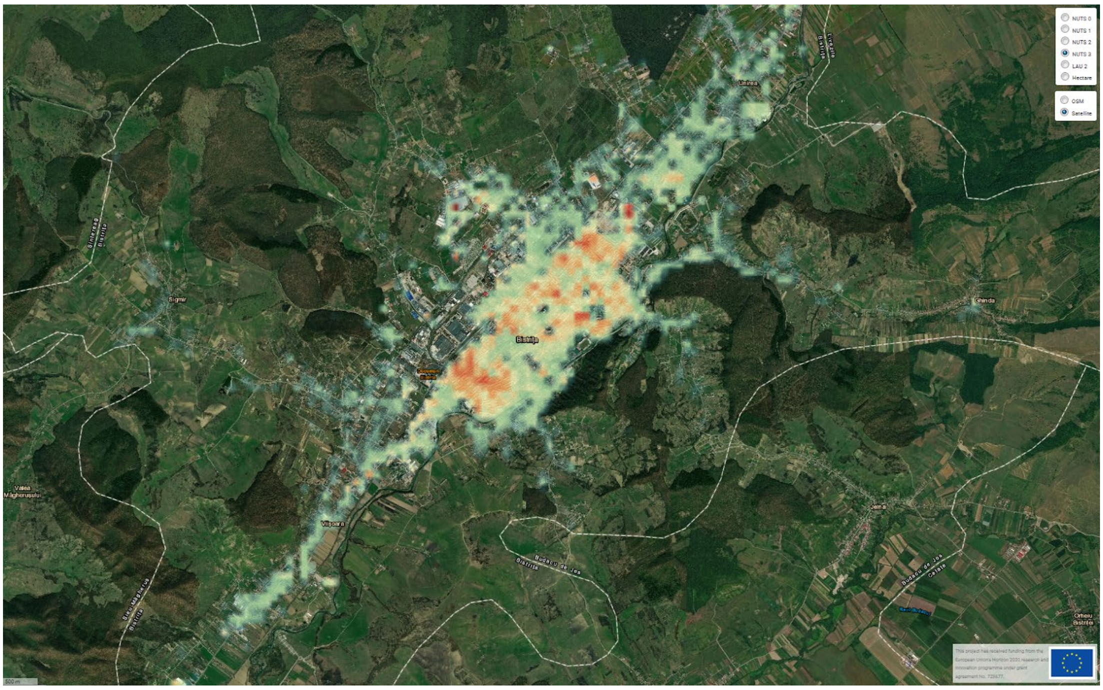


Figure 1: Heat demand density map of Bistriţa (Source: own calculation based on (TU Wien, e-think, 2015), and (Bistriţa, 2018). See description in chapter 4.1.1)

In the national territory framework, the city of Bistriţa is located in the northern part of the country, near the border with Ukraine and at the contact area between the historical regions of Transylvania and Moldova.

In the North-West Region territory framework (Northern Transylvania), Bistriţa municipality is a relatively peripheral urban centre, the fifth largest in the region, being located on the border with the North-East and Central Region.

In the county territory framework, the city of Bistriţa is the capital of Bistriţa Năsăud county, its main urban, administrative, economic, and cultural centre.

The residential areas of Bistriţa Municipality are presented in two hypostases:

- Urban area - with single-family homes, but mainly collective housing (blocks of flats built between 1960-1990)
- New residential areas - The new residential neighbourhoods of Bistriţa Municipality were built after 1990, on the outskirts of the city, mainly to the north, south, and west, being made up almost exclusively of single-family homes. Their density in the heart is relatively low, being similar to that of the rural area, due to the generous gardens that separate the houses. Another explanation is that the development of

these new residential areas was made up organically and often chaotic, especially in the first years after the 1989 Revolution, without clear city planning regulations (the first General Urban Plan came into force in 1993, when already the first villas had appeared and had been updated only twice since then, without keeping up with the city's expansion rate).

The rural area of the municipality - comprises more than 883 hectares within the city (34.5% of the total urban inside area) that are located in the 6 component localities (Ghinda, Sărata, Sigmir, Slătiniţa, Unirea, and Viişoara). Where the first four localities have between 50 and 100 hectares of urban area and under 1,000 inhabitants, Unirea and Viişoara experienced a real estate boom after 1990.

At the municipal level of Bistriţa, there is currently a decentralized heating system mainly based on natural gas consumption. The centralized city heating system was disbanded in 2007, being technically outdated and recording significant losses.

At present, Bistriţa natural gas network is managed by the company E.ON Energie România S.A. and covers 51% of the total of the city's existing streets.

2 Objectives and approach

2.1 Themes to address in the planning process

The solution that is becoming clear for Bistriţa municipality, given the inefficiency of the local heating system on the one hand and, and the experience from European cities that have centralized heating systems, on the other hand, is to develop district heating systems in certain city areas and neighbourhoods concurrently with the punctual existence of the individual heating systems.

As a result, the Hotmaps toolbox becomes extremely useful in the short, medium, and long-term planning process of the city’s heating-cooling system. In this regard we highlight the following:

Priorities for using the Hotmaps toolbox:

- Evaluate the heat demand in the area (city of Bistriţa).
- Visualize the existing data
- If possible, add and visualize consumption data, available excess heat from industry, etc.
- Compare energy demand and economic feasibility of new district heating against individual boilers for specific areas
- Estimate the potential energy savings in buildings
- Assess the impact of deploying renewable energy carriers on CO_2 and energy mix

The citizens are currently not interested in district heating; (partly) due to the experience with the previously existing district heating system that Bistriţa had until 2007 cf. the above-mentioned.

The process should start with addressing political and administrative stakeholders: Major, local council (formed by different political parties), local energy providers.

2.2 Approach

2.2.1 Overall approach for the strategy development

In order to reach the political targets of greenhouse gas emission reduction and energy efficiency at local as well as national and EU level, heating and cooling systems in Bistriţa have to be changed. A strategic analysis is needed to find technically, economically and resource-efficient solutions fulfilling these targets. In the course of the Hotmaps project, a strategy development process for decarbonising the heating system in Bistriţa has been performed, according to the following steps:

1. Description of the city and stakeholder analysis:
    - Definition of local, regional, and national targets for GHG emission reduction and energy (see chapter 3.1)
    - Description of the existing heating and cooling system in the city (see chapter 4.2)
    - Analysis of stakeholders relevant to address when seeking sustainable decisions in heating and cooling transition (see chapter 3.2)
    - Analysis of barriers against and drivers towards a transition of the heating and cooling systems in the city (see chapter 5)
2. Mapping of demand, resource potentials and existing plants:
    - Mapping of the status quo of the heating and cooling system in the city including demand and supply points (see chapter 4.1)
    - Analysis and mapping of resource potentials of renewable and excess heat sources in the city potentially usable in the mid to long term (see chapter 4.1)
3. First stakeholder meeting
    - Held on 10th April 2019
    - 10 participants of Bistriţa Municipality: 2 from the Technical Department, 2 from the Cadaster Office, one from the Chief Architect Department, 2 from the Public Services Department, 2 from the Environment Office, one from European Integration Department
    - Topics discussed at the meeting: bottom-up vs. top-down heat demand calculation for the city, the Hotmaps database and toolbox and its data sources and available calculation modules, method for scenario calculation in the course of the strategy process, potential scenarios and sensitivities to be calculated
4. Setting up scenarios:
    - Compilation of economic input data for the economic assessment of future heating (and cooling) alternatives (see chapter 4.3)
    - Calculation of various potential alternatives for heating (and cooling) demand and supply from renewable and excess heat sources (see chapter 6.1)
    - Assessment of the calculated alternatives regarding costs and emissions (see chapter 6.1)

5. Second stakeholder meeting
    - It took place online, via a Skype video meeting, the 14th of May 2020
    - There were 13 participants: 3 from the Technical Department, 3 from the Cadaster Office, 2 from the Chief Architect Department, 1 from the Public Services Department, 1 from the Environment Office, one from the European Integration Department, 1 from the Buildings Heritage Department, 1 Vice-mayor
    - Topics discussed during the online meeting:
        - The participants were briefly introduced to the project, its objectives and results.
        - Then there was a live demonstration of the Hotmaps toolbox.
        - Finally the potential scenarios for Bistriţa heating system were presented.
        - After the meeting, the participants got involved, they put questions and prioritized through a google survey the scenarios presented: 1 person for scenario 3, 1 for scenario 4, 2 persons for scenario 2 and 8 persons for Scenario 1.
6. Strategy formulation:
    - Prioritisation of alternatives and development of a roadmap for changes in the heating (and cooling) systems of the city in the next years (see chapter 6.2)

2.2.2 Technical approach to quantitative scenario assessment

To calculate scenarios of potential future heating demand and supply in the city and the relative costs and emissions, mainly modules developed in the Hotmaps project have been used. These calculation modules (CMs) were developed to analyse different parts of the heating and cooling system such as decentral heat supply, district heating distribution costs or district heating supply dispatch. Most CMs developed in the project have been integrated into the online version of the **Hotmaps toolbox** (Hotmaps, 2020). In the course of this analysis, stand-alone versions of all CMs have been used to allow more flexibility in the use of input parameters and automated calculation of a number of sensitivities. Furthermore, one calculation module has been used that is not part of the Hotmaps project development. This module is part of the **Invert/EE-Lab model** (TU Wien, e-think, 2015) and was used to derive cost curves of heat savings for the city. Also, the development of selected parts of the modelling environment used for the analysis has been performed in the course of two master theses at TU Wien. These were performed by Jeton Hasani and David Schmidinger. The corresponding parts of this document are based on (Hasani, 2020) and (Schmidinger, 2020).

Figure 2 shows the different CMs that were used in the analysis and the information that was created from or fed into the CMs.

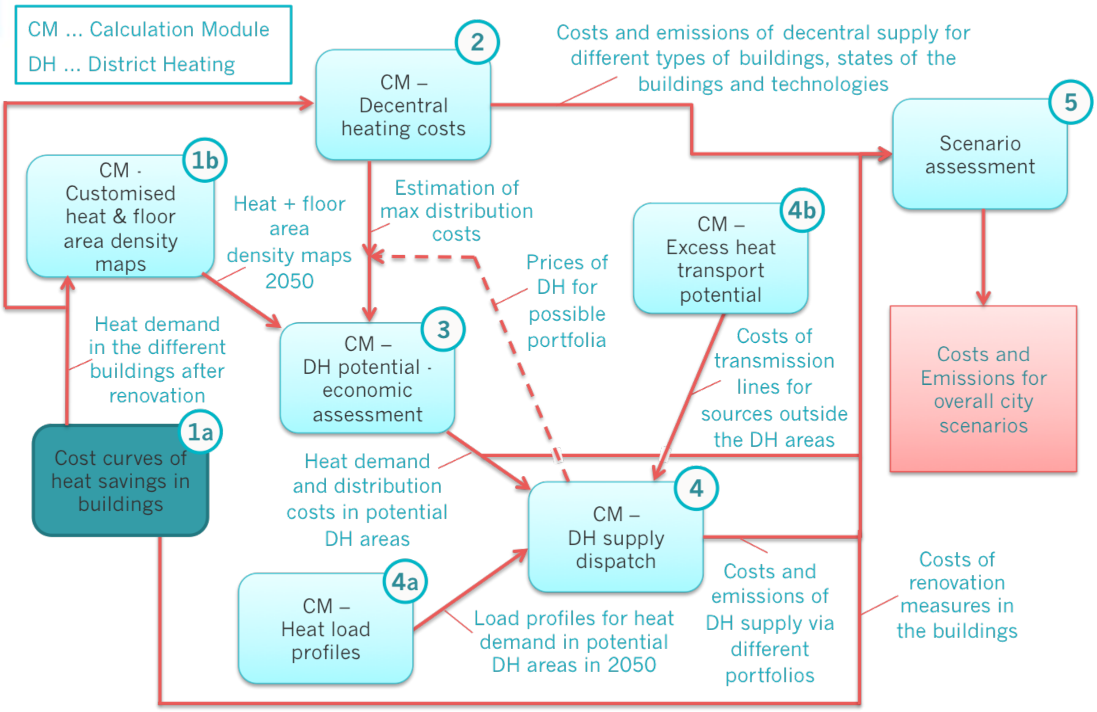


Figure 2: Method for calculating scenarios and sensitivities of heating demand and supply for this strategy process

The first step (1) in the analysis was to generate different scenarios of the state of renovation of the buildings in the city for the year 2050. This was started with setting up a database of the buildings in the city characterising their location, type, age, energy demand for space heating and hot water generation (see chapter 4.1.1 for further description). For all typical buildings in the city, various renovation packages, all reaching different relative savings of heat demand, have then been derived. Based on this data, the cheapest combination of building renovation packages, enabling to reach the 2050 predefined citywide saving targets, has been identified. For this reason, we used the renovation cost curve module of the **Invert/EE-Lab model** (TU Wien, e-think, 2015). Applying these results to the buildings' database of the city leads to different versions of the buildings' database reflecting different saving/renovation scenarios in 2050. A description of the data used for the renovation measures and the methodology applied is presented in chapter 4.3.4 The resulting databases were then fed into the **"CM - Customised heat and floor area density maps"** (Hotmaps Wiki, 2019a) (step 2) to generate heat demand and gross floor area density maps for different heat-saving levels in the city in the year 2050.

These heat demand and gross floor area density maps were further used to analyse the sensitivity of heat distribution costs in potential district heating (DH) networks (step 3). With the **"CM - District heating potential: economic assessment"** (Hotmaps Wiki, 2019b) the costs and location of potential DH networks were calculated for different saving levels, DH market shares, and thresholds for average heat distribution costs. The module hereby derives the size and location of a potential district heating system for a given threshold of average heat distribution costs in coherent areas of the system. The heat demand density map together with the market shares of DH in potential DH areas is the basis for estimating the heat potentially supplied by the DH system. The gross floor area density together with the heat potentially supplied is used to estimate the costs of the grid in the potential DH areas. A detailed description of the CM can be found in the Hotmaps wiki, a description of the data for the investment costs into the network infrastructure is presented in chapter 4.3.3.

With the **“CM - Decentral heating supply”** (Hotmaps Wiki, 2019c) the heat supply costs and related emissions from the application of decentral technologies were calculated for different types of buildings in Bistriţa, the different calculated states of renovation of the buildings and for various decentral technology options in each of these buildings (step 4). These costs have been used to calculate weighted average decentral heat supply costs for the different saving scenarios and a defined mix of decentral supply technologies. Chapter 4.3.1 shows the costs and efficiencies of the decentral technologies applied in the calculations. A description of the methodology for calculating the heat supply costs with the module is presented in the Hotmaps wiki.

The costs of supplying heat into the DH system were calculated with the **“CM - District heating supply dispatch”** (Hotmaps Dispatch Wiki, 2019) (step 5). This CM calculates the dispatch of different technologies installed in a potential DH system in order to reach minimum running costs while covering the heat demand in all hours of the year. For this strategy process, the dispatch and the resulting costs and emissions were calculated for various potential sizes of the DH network and related supply portfolios. A description of the technology data used in the analysis is presented in chapter 4.3.2 and of the modelled DH system sizes and related portfolios in chapter 6.1.2. A detailed description of the overall approach of the dispatch model can be found in the wiki of this model. The applied relation between the temperatures in the DH network, the heat sources and the Coefficient of Performance (COP) of different heat pumps are described in (Gumhalter, 2019).

An important input for the calculation of the DH dispatch is the load profile of the heat demand representing the heat demand of all consumers in the DH system for each hour of the year. These profiles are foreseen to change with decreasing heat demand for space heating due to renovation activities. Load profiles for future DH systems have been calculated with the **“CM - Heat load profiles”** (Hotmaps Wiki, 2018a) based on heat demand profiles of current DH systems according to the results of the different saving scenarios calculated in the first step of the analysis (also step 5).

In the last step (6) of the analysis, selected calculations of the different parts of the heating system in the city have been combined to consistent citywide scenarios of potential heating systems in the city of Bistriţa in the year 2050. For these scenarios, the following indicators have been calculated, split into different components such as technologies and system parts: the yearly costs of the heating system, the final energy demand, the CO2 emissions and the shares of DH and savings. For this step the **“CM – Scenario Assessment”** (Hotmaps Wiki, 2020)has been used. The selection of the scenarios of the different parts of the heating system is presented together with the resulting indicators in chapter 6.1.2. A detailed description of this CM can be found in the Hotmaps wiki (Various Authors, 2018).

3 Target and policy instruments

3.1 Local, regional and national targets and policy instruments

To successfully implement the Paris Agreement and the European targets for climate and energy for 2020/2030/2050, and further, climate actions need to be improved at all relevant levels of governance.

In Romania and most countries local authorities are the main promoters of energy transition and the fight against climate change at the level of governance closest to the citizens.

The joint actions of municipalities and local actors have a considerable potential to increase energy efficiency and to reduce greenhouse gas emissions in the administrative area of the respective cities.

At the national level, the Integrated National Plan for Energy and Climate Changes 2021-2030 is in the status of analysing the implementation of the European Commission recommendations.

At the county level, the Plan of maintaining the air quality with measures until 2020 is in place. This plan includes measures for the municipality of Bistriţa in transport and mobility, waste, wastewater, working with citizens and also, residential and non-residential buildings.

At the municipality level, this heating strategy is currently not part of an overall energy strategy of the city. However, it is indented to include it into the general urban plan for the city, SEAP 2020 (Municipality of Bistriţa, 2011), SECAP 2030[1](Municipality of Bistriţa, 2019), SDI 2030 (*SDI Bistriţa - Local development strategy 2010-2030*, 2011), Zero Carbon City 2050 Action Plan (“Zero Carbon Cities,” 2020).

Bistriţa has the following **local political targets**.

Reduction in heat demand

Roadmap 2050

Bistriţa City gets engaged for: “Environmental Sportive Energy City 15 MWh” (EASY City Bistriţa) – the city actions for environment protection and energy efficiency to get the 15 MWh target.

This involves promoting sustainable development, restricting the energy consumption increase to 15 MWh, promoting renewable energies and energy efficiency, local energy production from renewable energy and promoting an energy saving slogan for Bistriţa City. Through this strategy, the City of Bistriţa will develop a lot and will be ready for the period when the conventional energy resources will be very expensive.

[1] SECAP 2030 (Sustainable Energy & Climate Action Plan 2030 under EU Global Covenant of Mayors for Climate & Energy)

Use of renewable energy and energy supply

At present, renewable energy is used at a modest level, but the SEAP 2020 & SECAP 2030 include some medium-term actions in this regard.

Through Roadmap 2050, in terms of electricity and gas supply as well as the local and district heating supply, Bistriţa pursues a long-term transition to a supply with renewable, environmentally friendly and resource-friendly energy sources. There will be established a Heat Supply concept and a Power Supply concept for the year 2050.

Reduction of CO2 emissions

Bistriţa has set the following CO_2-reduction targets:

- SEAP 2020: 20% CO_2-emissions reduction until 2020 compared to 2008
- SECAP 2030: 40% CO_2-emissions reduction until 2030 compared to 2008

Lower heat demand in buildings

The Thermal Rehabilitation Program was set out to reduce energy consumption and CO_2-emissions from heating. In 2010 Bistriţa Municipality implemented a local program related to the thermal rehabilitation of apartment buildings. We speak here about the 487 housing blocks built before 1990, which means 23,000 apartments.

By the end of 2019, the thermal rehabilitation works have been completed for a number of 50 blocks (about 11%) and in 2020, 24 blocks more will be completed. (total 16%). The savings for heating energy is 40%.

Covenant of mayors agreement

- In 2009 the municipality of Bistriţa signed the adhesion to the Covenant of Mayors and in 2011 finalized and sent the SEAP to the Covenant of Mayors' European Office. After its approval in 2011, we submitted the monitoring reports, due every 2 years, in 2013 and 2015; measures' plan update in 2016, following in December 2019 to submit the 4 years SEAP monitoring report.
- In December 2019 we submitted for approval in the local Council, the accession' request of Bistriţa Municipality to the Covenant of Mayors for Climate and Energy, together with the concomitant approval of SECAP 2030. The admission of Bistriţa Municipality to the Covenant of Mayors for Climate and Energy is published on the official site of the European initiative.

3.2 Stakeholder Analysis

Important stakeholders in the frame of heating strategy development are described in the following.

Political (Local Council, County Council):

According to the National Institute of Statistics, the number of public buildings in the city is 954, out of which only 200 buildings are managed directly by the Municipality, the difference of 754 being managed by the County Council, respectively by the local institutions (representatives of the ministries in the territory).

As important building owners, political stakeholders should be models for the community; local legislative bodies, which are drafting and adopting energy politics/strategies

Utilities (gas, electricity, etc.):

The liberalization of the market of natural gas and electricity in Romania has provided domestic and industrial users the possibility to choose their utility supplier. Thus, in Bistriţa appeared the following utility providers: EON, ENEL, "Electrica Furnizare Transilvania Nord" - S.A. They are searching for solutions to provide competitive cost energy in order to lower production costs and to resist the competition.

Residential sector - housing blocks' owners associations

According to the National Institute of Statistics, the number of private housing in Bistriţa (single-family houses and multi-family houses) has an upward trend, from a number of 33530 in 2016, to 33892 in 2017, to 34363 in 2018.

Table 1: Overview of stakeholders

Name	Category	Interest /Impact	Power/ Influence	Needs	Contributions	Blocking risk	Engaging strategy
Local Council	Political/ local authority	High	High	Getting cheap heating for own public buildings; community model	local legislative bodies	Composed by different parties and we are in election year	1. Decide and adopt executive departments' implementation and monitoring. 2. Include this strategy into the city strategic documents
County Council	Political/ local authority	Medium	Medium	Getting cheap heating for own public buildings	Promotion as good practice example for county's 3 main cities and other counties	Composed by different parties and we are in election year	Keep satisfied
EON, ENEL, SC ELECTRICA FURNIZARE	Energy suppliers	High	High	Providing cheap energy to lower production costs and be more competitive	Support in implementation	Financial reasons	In choosing the right scenario(s) for different areas/ the city
Residential sector - housing blocks' owners associations	Final energy consumers	High	High	Getting cheap heat for own household	Support in implementation	1.Financial reasons. 2. Citizens currently not interested in district heating	Public debate

Table 2: Visual map of Stakeholders

	High Interest/Impact	Medium Interest/Impact
High Power/Influence	• LOCAL COUNCIL • EON, ENEL, SC ELECTRICA FURNIZARE • Residential sector - housing blocks' owners' associations	
Medium Power/Influence		County Council

4 Description of energy demand and supply

4.1 Mapping of demand, resource potentials and existing plants

4.1.1 Energy demand in buildings

The basis for the bottom-up estimation of heat demand and the development of a heat demand density map for the municipality is a database of the buildings in the area. The database of the building stock is hosted by the Cadastre service and Real Estate Claims Department of Bistriţa Municipality and was provided for the work within this project. Hereby an extraction of the database from March 2019 has been used.

The building stock database exists in the form of a GIS shapefile containing polygons of 24,028 buildings in the municipality. Various attributes of the buildings are linked to the building shapes. However, not for all buildings in the municipality, all attributes are available in the database. The following Table 3 shows, which building attributes have been used for the analysis and to which degree data (values) have been available in the database.

Table 3: Description of building attributes used for the bottom-up calculation of the heat demand and the heat demand density map for the municipality

Value	Description
Building footprint (FP)	- available for all buildings - used for cross checking
Number of floors (NF)	- used for cross checking - > 0 for 98% of buildings
Gross floor area (GFA)	- available for all buildings - GFA = FP * NF for 98% of buildings
Type of building	- used for estimation of type of building according to Invert/EE-Lab classification - 3 different classifications for type of building are available in the DB with different nr. of types; the most detailed is used
Construction Year	- used for allocation of demand values - for 51% of the buildings value in DB is 0
State of the building	- used for filling in missing construction year values
Number of inhabitants	- not used

In a first step, a consistent dataset containing information on type, size, age, and location of each building has been derived from the original database. This has been done according to the following procedures and assumptions:

- Allocation of the type of building used in the further calculations (see structure, and type descriptions in Table 4) to each building based on the two most detailed classification structures contained in the database

- Estimation of missing values of construction years according to the following approach: if buildings with the same cadastre number have a construction year, the average year is allocated to the other buildings with the cadastre number; for all other: the median construction year of the same building type and the same building status was allocated; the database hereby distinguishes 8 different statuses of buildings

Figure 3 shows the distribution of gross floor area (GFA) of buildings with relevant heat demand in the municipality. Multifamily houses (building category 5) show to be the main part of the building stock with 46% of total GFA in the city (residential and service sector). A large share of the buildings was constructed between 1990 and 2018. This share is especially high for multi-family buildings. Wholesale and retail (building category 10) is the most relevant type of service building with a share of 38% of GFA of service buildings in the city, public and private offices together account for 27% of GFA in the service sector.

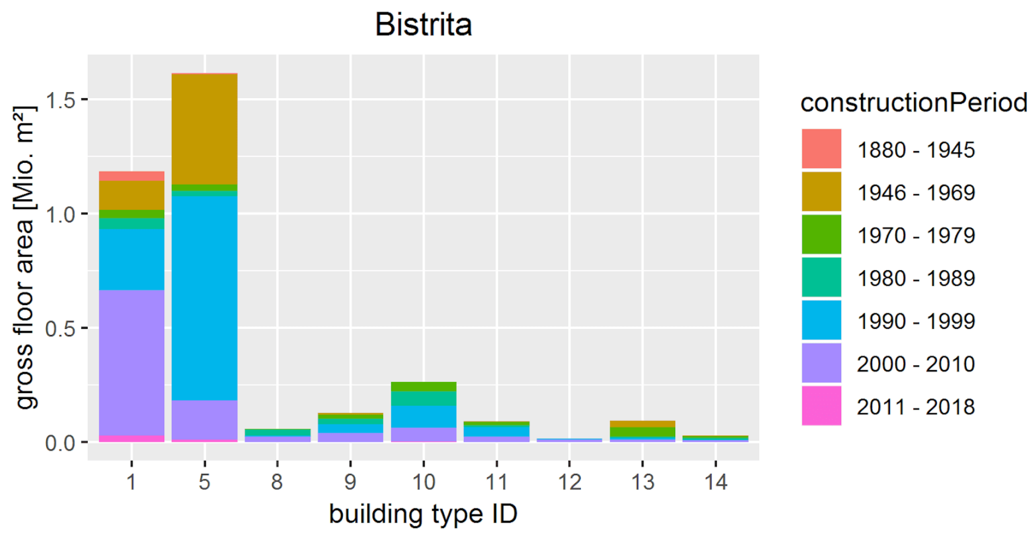


Figure 3: Gross floor area of buildings with relevant heat demand in the municipality of Bistriţa differentiated between building types and construction periods (Building type ID 1 and 5: single family and multifamily houses, other IDs: non-residential buildings, see Table 4 for more details). (Source: own calculations based on (TU Wien, e-think, 2015), and (Bistriţa, 2018))

In a second step statistical energy demand values per gross floor area (GFA) for space heating and hot water generation have been joined with the resulting building dataset. These energy demand (per GFA) values were taken from the database of the Invert/EE-Lab model[2]. The values reflect the energy demand for space heating and hot water preparation of typical types of buildings from different construction periods in Romania and are calibrated on the national building stock and the national energy balance. Before joining with the dataset of buildings in Bistriţa the demand (per GFA) values were climate corrected from the average Romanian climate to the climate in Bistriţa. For this reason, the values of the heating degree days (HDD) from the Hotmaps database were used and elasticity of 60% was assumed. According to this

[2] The Invert/EE-Lab model is a bottom-up simulation model of the energy demand for heating and cooling (H/C) in buildings. It calculates the energy demand based on detailed data of the buildings like dimensions, u-values of the buildings' envelope, climatic conditions and user profiles. Future development of the building stock is derived by simulating investment decisions in H/C relevant equipment like insulation, windows or heating and heat distribution systems. The model has been developed and applied in national and international research and consulting projects in Europe for over a decade. More information can be found on https://www.invert.at/.

approach the heat demand in buildings in Bistriţa is around 18% higher compared to the national average.

From the Invert/EE-Lab database we use the values of useful energy demand effective for the analyses. These values for space heating reflect the energy needed to keep the indoor temperature of the buildings at a certain set temperature and take into account various factors of user behaviour like higher indoor set temperatures for better-insulated buildings or that parts of the buildings and flats are not heated such as pantries or staircases.

Table 4: Number of buildings, gross floor area and useful energy demand for space heating and hot water generation for buildings in Bistriţa separated for different building categories (Source: own calculations based on (TU Wien, e-think, 2015), and(Bistriţa, 2018))

		number of buildings [-]	Gross floor area [m²]	useful energy demand [GWh/yr]	
				space heating	hot water
1	single family houses	9,003	1,186,766	78	20
5	multi family houses	1,973	1,615,566	130	27
8	public offices	141	59,938	9	0
9	private offices	224	130,427	24	1
10	wholesale & retail	555	264,073	43	3
11	hotels & restaurants	143	90,559	13	1
12	health	19	14,350	3	0
13	education	138	105,465	9	0
14	other	71	32,730	5	0
Residential		10,976	2,802,332	209	47
Non-residential		1,291	697,542	105	6
Total		12,267	3,499,875	314	52

In Table 4, the results of the bottom-up calculation of heat demand for space heating and hot water generation are summarised. It shows the large share of residential and especially multi-family buildings on the gross floor area as well as the heat demand in the city: Multi-family buildings account for 42% and single-family buildings for 28% of total heat demand for space heating and hot water generation in the city. Wholesale and retail is the most relevant part of the service sector of the capacity both in terms of gross floor area and in terms of heat demand. The totals for the residential as well as non-residential sectors match very well with estimations of useful energy demand in the city based on the consumption of gas, oil, and electricity for heating and hot water generation (see chapter 4.2).

The resulting heat density map of the city is shown in Figure 1 in chapter 1.

4.1.2 Power and CHP plants

In the city of Bistriţa currently, no Power Plant (PP) or Combined Heat and Power (CHP) plant is in operation. A waste incineration plant also does not exist. Therefore, no related potential supply points currently exist in the city.

It is considered as an interesting future option to build a waste incineration plant in the mid to long-term near the city to burn the municipal solid waste (MSW) of the city. Therefore, in several scenarios of a potential district heating system for the future, such a supply option has been taken into account. Further details on the potential capacity of such a plant are described in chapter 4.3.

4.1.3 Industry

In the city of Bistriţa, no large industrial plants are located. Industry plays a minor role in the city with only some plants of the wirings and car batteries industry. Regarding those plants, no data on energy demand nor potential excess heat amounts were available for the analysis. However, the amounts of excess heat from industrial plants potentially usable for district heating are considered negligible.

4.1.4 Individual heating

In the current situation the demand for space heating and hot water generation in Bistriţa is mainly supplied by natural gas with an estimated share of 95% (see also chapter 4.2). The other 5% is supplied by electricity or biomass. Due to this very high share of natural gas, the entire city area is considered to be currently connected to gas.

4.1.5 Existing network infrastructure

As written before, the main part of the current heat demand is supplied by natural gas. Therefore, nearly the entire city territory is covered by a natural gas network operated by E.ON Gaz Romania. Although there was a district heating system in place in the past, this was shut down in 2007 due to a strong disconnection and decreasing efficiency and reliability of the network. The infrastructure of the old district heating grid is not usable for potential new installation.

4.1.6 Local renewable energy resources

A low-carbon heating and cooling system is based on the use of renewable energies, available excess heat sources as well as the incineration of waste. For this strategy, potentially available amounts of these energies have been estimated based on existing information from the city. These estimations are described here below.

A resource potential of high interest for the heat supply in Bistriţa could be a waste incineration plant that might be built in the proximity of the city. Currently the municipal waste from the city and the region is disposed in a landfill around 20 km outside the city. Due to EU legislation the landfill has to be closed down in the near future. Therefore, the waste of the county Bistriţa-Nasaud could potentially be used for generating heat and electricity. A location for a potential waste incineration plant is also available north of the city. A rough estimation of the heat generation potential of such a waste incineration plant based on currently existing plants in other cities and the number of inhabitants yields around 300 GWh/yr. Assuming around 6000 full load hours a year this equals a potential of 50 MW thermal. Due to a potential generation of electricity in the plant a maximum potential of 20 MW thermal is used in the calculations.

As described before, currently no relevant industrial plants are located in the city and thus no related excess heat streams are available. However, there are the following heat sources that could be used in a potential district heating system by applying large scale heat pumps: the heat contained in the cleaned wastewater of the city, and the heat contained in the river water that runs through the city. Based on measurements of wastewater treatment plant outflow temperatures in other places in Europe and information from the plant in Bistriţa it is assumed that the temperature of the outflow will vary between 9 and 24°C over the year with an average of 15°C. Based on the study of the potential of heat in the outflow of wastewater treatment plants in Frankfurt (ECO.S and Fraunhofer ISE, 2018) a potential of available heat for heat pumps of around 20 MWth in the plant in Bistriţa is estimated. However, for the calculations in the course of this strategy a maximum potential of 10 MW thermal is assumed in the calculations. For the heat capacity that might be used of the Bistriţa River no estimations exist. It is assumed that around 10 MW of thermal output power in a large-scale heat pump might be available. However, this potential is only used in the calculations reflecting very low heat savings in the city.

Local biomass from surrounding regions could be also a possibility to supply the heat demand in the city. However, there is no analysis of the potential of biomass from the region around Bistriţa available. A wood chip boiler is used as peak technology in the calculations of the dispatch of potential district heating systems in the city. In the calculations it is assumed that wood chips for a maximum of 25 MW thermal output from a wood chip boiler could be available. However, further analysis is necessary in order to assure this assumption. In the calculations various different sizes of district heating systems as well as portfolios to supply the heat are used in order to see the effects on resource needs and costs. The results are presented in chapter 6.1 and recommendations also related to the use of biomass are drawn in this chapter.

North of the city of Bistriţa a potential area for a solar thermal collector field is located. It is estimated that around 1 ha of collectors could be installed there to feed into the district heating system. This could lead to a potential of 15 GWh/yr. At the same time, it is assumed that the installation of solar thermal collectors on the roofs of the buildings can be an interesting option in the city of Bistriţa. In the scenarios of decentral supply for the buildings in the city a potential of around 5 Thousand m² of collector area in the roofs is assumed.

For the scenario calculations we selected different technology combinations for decentral and district heating supply. A description of these technology combinations is given in chapter 6.1.

4.2 Description of existing heating and cooling

The demand for heating in the city of Bistriţa is dominated by space heating and hot water generation in residential and service buildings. Around 95% of this demand is supplied by natural gas. In the years 2008-2009, an average of 49 Million m³ of natural gas have been consumed in the city, 56% of this in residential buildings, and another 30% in service buildings(Municipality of Bistriţa, 2011). Thus, only 16% is consumed in the industry. This gas demand corresponds to 275 GWh/yr in the residential and 138 GWh/yr in the service sector. Assuming that around 5% of the heat demand is not supplied by natural gas, the overall final energy consumption for space heating and hot water generation in residential and service buildings is estimated to 435 GWh/yr, 290 GWh/yr in residential buildings and 146 GWh/yr in service buildings.

Gas consumption in Bistriţa, in the buildings managed by the municipality and in the residential sector, has a downward trend. On the one hand, due to the thermal rehabilitations carried out in buildings, on the other hand, because some categories of citizens prefer a minimum thermal comfort in homes in favour of economies to their family budget, this making it even more important to secure a cheap and reliable heating supply for the inhabitants in Bistriţa.

Residential sector gas consumption:

- 279,192 MWh/yr; (26,627,750.964 Nm^3) in 2017;
- 269,550 MWh/yr; (25,708,130.931 Nm^3) in 2018;
- 269,162 MWh/yr; (25,671,130.672 Nm^3) in 2019.

Municipal buildings gas consumption (including schools):

- 20,887 MWh in 2012;
- 18,622 MWh in 2014;
- 15,160 MWh in 2018;
- 15,129 MWh in 2019.

As described before the entire demand for space heating and hot water generation in the city is supplied by decentral technologies, no district heating system is currently in place.

4.3 Data for economic calculation

The economic calculations for this heating strategy reflect socio-economic criteria: the depreciation time was set to the lifetime of the technologies and an interest rate of 3% was used. This interest rate includes inflation on the one hand and also a supplement for the risk of losing the investment on the other hand.

In the following, we describe the relevant data of costs and prices related to the heating system, which are used in the calculation of the scenarios presented in chapter 6.

4.3.1 Data for decentral heat supply technologies

In order to calculate the costs of supplying space heating and hot water in the buildings via decentral supply technologies, the following data are used: investment costs as a function of the device size (larger devices usually have lower costs per capacity - due to economy of scale), fixed operation and maintenance (O&M) costs, thermal efficiency and lifetime of devices, and the price of the energy carrier used by the device. The following Table 5 shows these data for the different technologies taken into account in the analysis except for the energy carrier prices. Those are described in chapter 4.3.5.

Table 5: Investment and O&M costs, thermal efficiency and lifetime of decentral heat supply technologies applied in the scenario calculations (Source: Invert/EE-Lab database for Romania (TU Wien, e-think, 2015))

	power [kW_{th}]		invest [EUR/kW_{th}]		O&M fix	thermal	LD [yr]
	from	to	from	to	[EUR/kW_{th}*yr]	efficiency [-	
Oil boiler	10	200	326	134	7.1	0.97	20.0
Natural gas	10	200	206	85	4.5	0.98	20.0
Biomass_Automatic	10	200	707	208	9.0	0.98	20.0
Biomass_Manual	10	200	524	155	10.0	0.93	20.0
Wood stove	10	200	524	155	10.0	0.93	20.0
HP Air-to-Air	10	200	496	276	15.8	3.41	12.0
HP Air-to-Water	10	200	725	397	15.8	3.41	18.0
HP Brine-to-Water	10	200	1307	708	11.9	4.59	20.0
Solar thermal	3	200	646	411	7.1	1.00	30.0
Electric heater	10	200	29	29	0.7	1.00	30.0

4.3.2 Data for district heating supply and storage technologies

Table 6: Investment and Operation and Maintenance (O&M) costs, thermal and electrical efficiency and lifetime of district heating supply and storage technologies applied in the scenario calculations (Source: own calculations based on experiences in various projects)

	invest [EUR/kW_{th}]	O&M fix [EUR/kW_{th}*yr]	O&M var [EUR/MWh_{th}]	efficiency		lifetime [yr]	Minimum Output Power Factor [0-1]	Cold Start Costs [EUR/Start)
				th	el			
Biomass Boiler	600	18	0	0.85	-	20	0.05	1000
CHP Back Pressure Biogas	1530	46	0	0.58	0.20	15	0.05	1000
Heat Pump Wastewater	750	34	0	2.8 - 4.2	-	20	0.05	1000
Waste Inceneration	1960	54	0	0.8	-	20	0.05	1000
Heat Pump Riverwater	580	34	0	2.8 - 4.2	-	20	0.05	1000
Natural Gas Boiler	60	4	0	0.95	-	20	0.05	1000

	invest [EUR/MWh]	O&M fix [EUR/yr]	O&M var [EUR/MWh_{th}]	hourly heat storage losses [-]	lifetime [yr]	Storage Capacity [MWh]	maximum loading/unloading power [MW]	loading/ unloading efficiency [-]
heat storage	2500	-	-	0.01	25	2800	28	0.97

Table 6 shows the costs, efficiencies, and lifetimes of district heating supply and storage technologies applied in the scenario calculations with the district heating supply dispatch module. The data are based on experiences in past projects performed by TU Wien and e-think.

4.3.3 Costs of district heating network construction

Besides the costs for the supply of heat to the district heating grid, the costs for the distribution of heat via the grid have to be calculated for determining the overall costs of heat supply via district heating. The costs for the heat distribution mainly consist of the investment costs for the network infrastructure. For calculating the investment costs in the network the Hotmaps **"CM - District heating potential: economic assessment"** (Hotmaps Wiki, 2019b) builds on a concept developed by (Persson and Werner, 2011) as well as (Persson et al., 2019). The concept is based on the following relations: 1) a relation of the effective width with the plot ratio, 2) a relation between the effective width, the distributed heat demand and the average pipe diameter, and 3) a relation between the average pipe diameter and the overall investment costs in the network construction. These relations have been derived based on the analysis of a number of existing district heating projects around Europe. A detailed description of the CM for assessing the heat distribution costs and how these relations are used in the module is given in (Fallahnejad et al., 2018).

For the analyses in Bistriţa the relations are used as given in (Persson and Werner, 2011) as well as (Persson et al., 2019). The following figure shows the resulting investment costs per meter of trench length (flow and return pipes) for the range of heat demand density relevant in Bistriţa and for different plot ratios e. Plot ratio hereby is defined as the fraction between building gross floor area (GFA) and corresponding land area (LA) in a defined raster element, both measured in [m²]. In the calculations for this strategy a raster element is defined as a land area of 100 x 100 m.

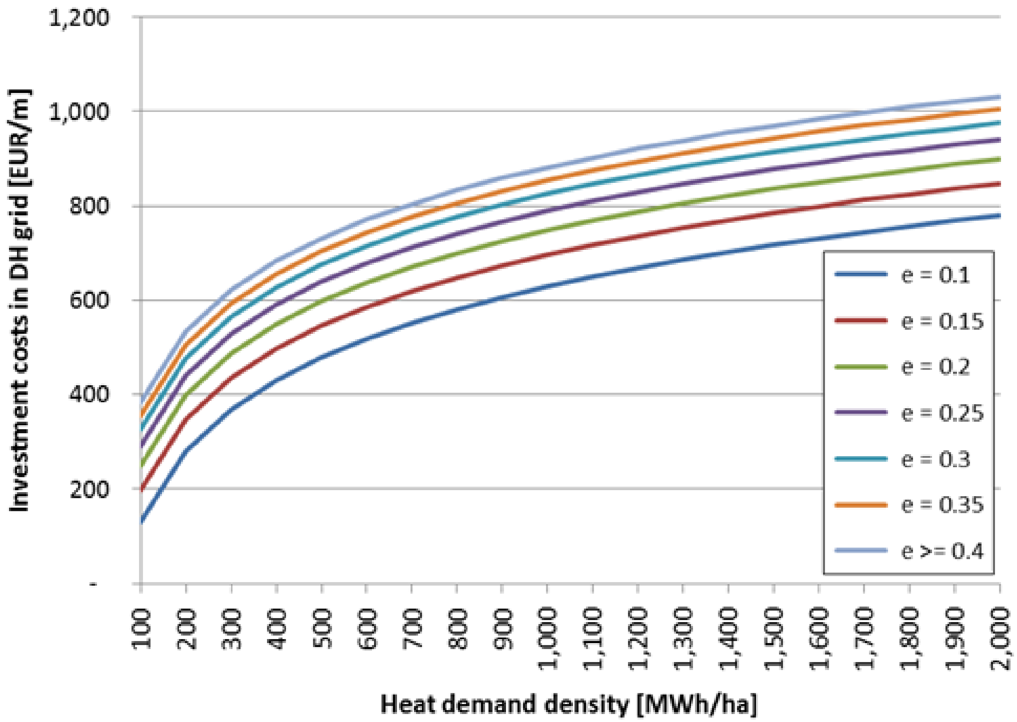
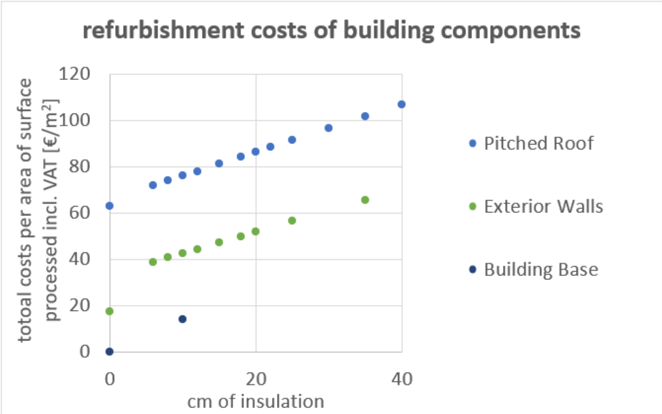


Figure 4: Investment costs in network construction per meter of trench length (flow and return pipes) for different plot ratios e in relation to the heat demand density to be supplied (Source: own calculations based on (Persson et al., 2019))

4.3.4 Costs of renovation measures in buildings

The costs and effects of applying renovation measures to the existing building stock in the city are calculated using the Invert/EE-Lab model. For each typical building currently existing in the city (see chapter 4.1.1 for a description of the current building stock) a set of 9 renovation packages is developed. Each renovation package hereby leads to different relative savings and consists of a combination of the following single measure: roof insulation, exterior walls insulation, basements insulation, and change of windows. While to reach ambitious savings, measures on each part of the building are required, packages for less ambitious savings only consist of selected measures. The compilation of the packages is done by identifying the combination of single measures with the lowest investment costs to reach a certain saving target for the building.

The following figures show the investment costs for renovation measures on the different parts of the building surface depending on the thickness of insulation and the u-value of the windows, respectively. The basis of the values is a detailed analysis of past renovation projects in Germany. The data sample of the German study was high enough to derive cost functions for the different measures showing the correlation between ambition of the measures and the related costs. These values have been recalculated to the Romanian situation using the difference in the construction cost index between both countries.



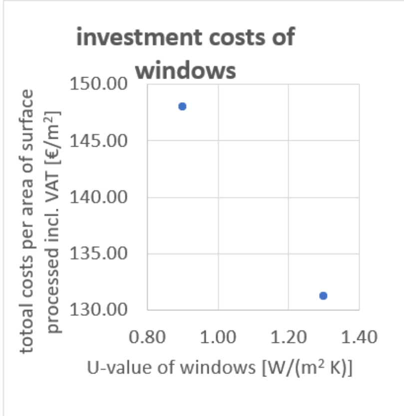


Figure 5: Investment costs for renovating different parts of the building surface depending on the thickness of insulating and u-value of windows respectively (Source: own calculations based on (BMVBS, 2012))

A more detailed description of the approach of compiling the renovation packages can be found in the article "The costs and potentials for heat savings in buildings: refurbishment costs and heat saving cost curves for 6 countries in Europe" (Hummel et al., 2020).

The costs and effects on the heat demand of all different renovation packages in all different typical buildings are used for the identification of least-cost combinations of renovation packages in the buildings of the city to reach certain predefined saving targets. Hereby the additional costs are taken into account, which is the difference between the costs of the renovation measure and the costs of only maintaining the selected part of the building surface. The results of this calculation are presented in chapter 6.1.2.

4.3.5 Prices of energy carriers and CO2 emission allowances

In order to calculate the cost-effectiveness of different alternatives for heating supply and demand reduction, the prices of energy carriers play an important role. For the calculations in the course of this strategy process, we use price data from the Horizon 2020 SET-Nav (SET-Nav, 2020). These data form also the default data on energy carrier prices of the Hotmaps database (Hotmaps Wiki, 2018b).

In the project SET-Nav, scenarios of the entire European energy systems for the years 2030 and 2050 have been developed, which are in line with the long-term European climate targets. This included modelling of the heating and electricity systems in Europe as well as the transport grid for heat and electricity.

While prices for fossil energy carriers were taken from the IEA World Energy Outlook 2016 (the IEA 450 ppm scenario) (IEA, 2016), the hourly prices for electricity were derived with an electricity market model, Enertile (Fraunhofer ISI, 2020) for 4 different settings regarding political and regulatory framework conditions. The price scenarios were calculated using a cap for the carbon emissions from electricity and district heating generation based on the PRIMES EUCO30 scenario from the European Commission 2016 (734 Mt in 2030, 146 Mt in 2040 and 60 Mt in 2050)[3].

Table 7: Overview of the four different price scenarios (Source: SET-Nav project (Resch et al., 2019))

Scenario name	description
Directed vision	EU/state directed shared vision strong EU policy framework
National champions	utilities & incumbents regulatory capture low transition costs
Diversification	heterogeneous actors coordination (beyond markets) digitalization (diverse heterogeneous actors) regulatory change disrupt incumbents
Localization	local resources resistance to big infrastructure developments experimentation & diversity (many niches) digital winners-take-all

The following figures show the average yearly retail prices for electricity, solid biomass, and natural gas for end consumers as well as the hourly electricity wholesale prices in the four scenarios both for the year 2050.

Table 8: Average yearly retail prices for end consumers of relevant energy carriers in the year 2050 in Romania, including taxes, excl. VAT (Source: SET-Nav project, (SET-Nav, 2019))

Energy Carrier	Retail price [EUR/MWh]
Electricity	133.4
Biomass solid	19.3
Natural gas	38.7

[3] A detailed description of the scenarios can be found in (Resch et al., 2019)

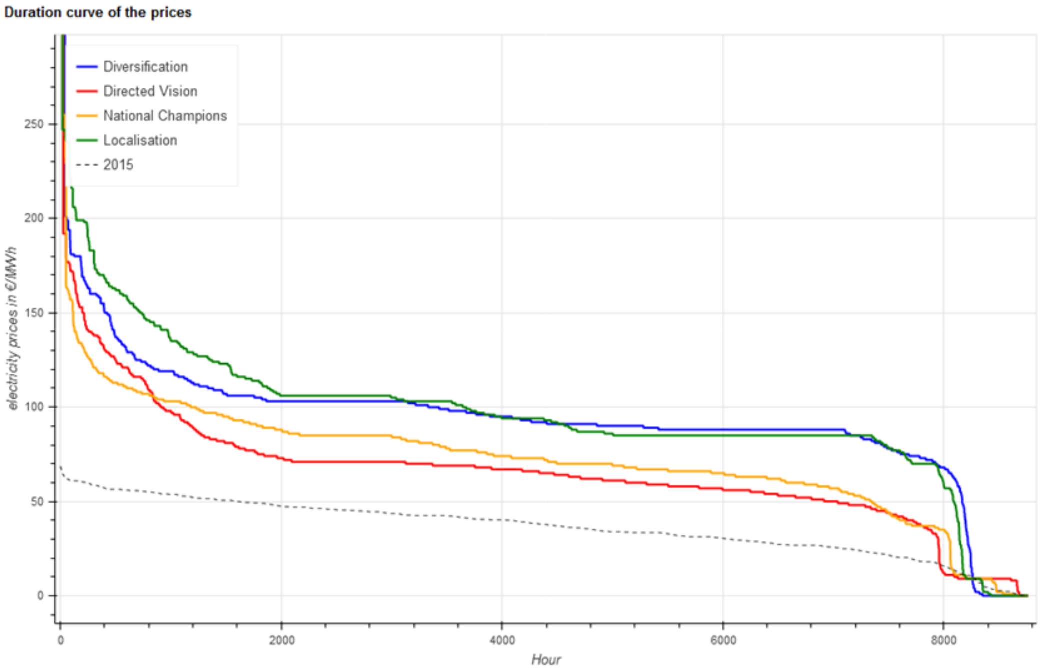


Figure 6: Duration curve of wholesale electricity prices for 4 scenarios for 2050 and historic prices in 2015 for Romania used in the scenario calculations (Source: Enertile (Fraunhofer ISI, 2020), SET-Nav project (Resch et al., 2019))

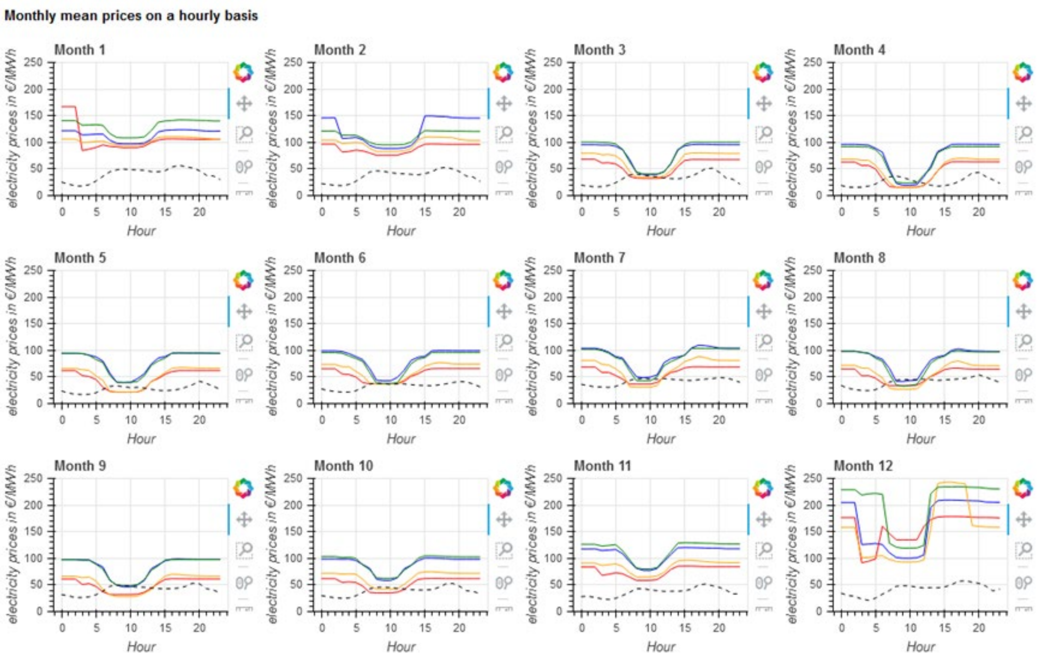


Figure 7: Monthly mean prices on hourly basis of wholesale electricity prices for 4 scenarios for 2050 and historic prices in 2015 for Romania used in the scenario calculations (Source: Enertile (Fraunhofer ISI, 2020), SET-Nav project (Resch et al., 2019))

The electricity wholesale market prices do not include charges for the electricity grid. Therefore, in the calculations, we add 40 EUR/MWh of grid charge on top of the prices.

The following Table 9 shows the mean electricity wholesale prices as well as the CO_2 shadow prices[4] in the year 2050 in Romania for the four electricity price scenarios as described before. The CO_2 shadow price is used in the calculations for Bistriţa for determining the costs of CO_2 from fossil emissions.

Table 9: Mean electricity wholesale prices and CO2 shadow prices in the year 2050 in Romania for the four electricity price scenarios (Source: SET-Nav project (Resch et al., 2019, p. 7))

Scenario	Name	Mean electricity price [EUR/MWh]	CO2 price [EUR/tC02]
Price 1 (P1)	Directed Vision	65.85	183
Price 2 (P2)	National Champions	71.83	139
Price 3 (P3)	Diversification	93.37	199
Price 4 (P4)	Localisation	96.74	296

5 Drivers and Barriers

In this chapter the barriers against and the drivers towards the goal of decarbonising the heat sector in Bistriţa are described.

5.1 Drivers

The city of Bistriţa has already moved a few steps in the direction of the sustainable energy transition, and there are several reasons to continue on this path.

Organizational and administrative actions have been taken to monitor the energy consumption in public buildings, such as designating an energy responsible in each of the managed buildings, and starting a monitoring and evaluation process in public buildings through the IT application “Energy Management System”.

Besides, an information and awareness campaign for children and young people on energy saving in buildings and promotion of renewable energy sources has been carried out.

The Bistriţa Local Council Decision no 170/2015 has established incentives for improving energy performance and aesthetic appearance of collective housing buildings by granting an exemption from housing taxes to the owners of apartment buildings, who proceeded to thermal rehabilitation works on their own expenses in the period 2014-2020.

[4] The shadow prices of CO_2 are the result of the optimisation calculation with the Enertile model. For the different framework and technology settings different CO_2 prices result from the calculation.

Renewable energy is promoted also with regards to the legal framework: the “Green House” Programme co-finances the installation of solar panels and geothermal heat carried out by private citizens and small business.

Additional drivers for further reducing energy emissions can be seen in the growing potential of solar thermal energy, adopted by more and more individual homeowners, and in the availability of the Hotmaps tool, which offers comparative scenarios regarding the potential DH systems in Bistriţa and analysis of the related technical and economic-financial aspects.

5.2 Barriers

The adoption of low-carbon technologies, especially in the field of energy, is however hindered by a few barriers:

- Infrastructural, as the transport and distribution network must be built from scratch because the old DH network was devalued.
- Financial, as DH suppliers face investment restrictions with regards to the transport and distribution networks.
- Socio-cultural, as the previous experience left a lack of trust in district heating systems.

The decentral heating system has the advantage of giving household owners control over their comfort temperature and consumption level, but little incentives to reduce consumption. Citizens have a strong preference for having control over thermal comfort, especially due to the lack of confidence in a centralized heating system as a result of serious malfunctions of the DH system in Bistriţa, dismantled in 2007.

However, the municipality believes that DH should be promoted in certain areas of the city, as the right solution for the urban population. The issue is to convince citizens to return to a centralized DH system, by increasing awareness on the adverse climate impact of decentral heating. Currently, no regulations impose a defined heating system: also legal restrictions could be conceived at individual, building, at the district level.

In addition, local sources of excess heat are limited:

- Renewable energy sources are limited due to specific geographic location,
- No geothermal survey prospects have been carried out,
- Excess heat from industrial processes could be used, but it has a strong geographic connotation, which limits its potential to the surroundings of the source.
- Also sewage water heat could be captured through heat exchangers and reused for district heating.

6 Local heating and cooling strategy

6.1 Assessment of scenarios

In order to identify technically and economically sound solutions for future heating systems in Bistriţa, a set of scenarios is calculated and assessed regarding costs and CO_2 emissions. The outcomes then form the quantitative basis for formulating a heating strategy for the city. In the following chapters, the scenarios, as well as the results of the different analysis steps, are described. The method for the development of the scenarios is described in chapter 2 of this document.

6.1.1 Definition of scenarios and sensitivities

For a first analysis, various sensitivities are calculated for each of the different parts of the heating demand and supply systems in the city:

- Six different levels of savings in demand for space heating via virtually applying different renovation packages to different buildings in the city.
- 198 different sensitivities for the expansion of the district heating grids in the city varying the following input parameters: heat demand density maps (developed in the previous step), share of heat demand connected to district heating in the regions where district heating is available, grid cost ceiling of district heating (= the maximum distribution costs in each of the connected regions)
- Six different sensitivities of decentral supply costs in the city varying the following input parameters: heat savings in the buildings according to the saving scenarios developed in the first step
- Five different portfolios of a potential district heating system for the city based on different renewable energy sources, excess heat, waste incineration and natural gas boilers. Different portfolios are compiled for different sizes of potential district heating networks. These are calculated for 4 different electricity and CO2 price scenarios and three different temperature levels in the supply line of the heat distribution grid.

All sensitivities are calculated for the year 2050. The citywide scenarios are then compiled from a selection of those sensitivities.

The following table gives an overview of the sensitivity calculations in the course of the strategy development and it shows the parameters and range in which these have been varied in the different modules.

Table 10: Overview of sensitivities calculated with the different modules in the course of the strategy process

Main parameters varied	*range of variation of parameter*
Energy demand for space heating and hot water generation	
target of savings in heat demand for space heating	10% - 60% in steps of 10%
Decentral heating supply costs	
savings in heat demand for space heating	10% - 60% in steps of 10%
District heating (DH) distribution costs	
savings in heat demand for space heating	30%, 50%, 60%
share of heat demand connected to DH in areas with DH grid	50%, 70%, 90%
maximum grid costs [EUR/MWh] in regions connected to DH	9 - 30 in steps of 1 EUR/MWh
District heating (DH) supply costs	
total heat demand supplied by DH	70, 100 and 170 GWh/yr
capacities of installed technologies	5 different portfolia; see respective chapter for more details
electricity wholesale and CO_2 prices	4 different prices scenarios, see chapter 4.3.5
supply line temperatures in the district heating grid	3 different temperature profiles from 55 - 86 °C (median Temperature)

6.1.2 Scenario results

6.1.2.1 Heat demand density maps 2050

A heat demand density map for the city's current situation has been developed based on the data of the building stock in the city and building type-specific demand data from Invert/EE-Lab (see chapter 4.1). Potential changes in the heat demand density in the city have been developed by virtually applying different renovation measures to each of the buildings in the city of Bistriţa. These heat-saving measures have been chosen in a way that the overall costs of renovation towards a predefined overall saving target for the city were minimised, i.e. buildings providing cheaper renovations are renovated first and more ambitiously. In the following figure, the heat demand density map of the current situation is shown together with heat demand density maps for three different saving scenarios: 19%, 36%, and 50% savings of heat demand in the city.

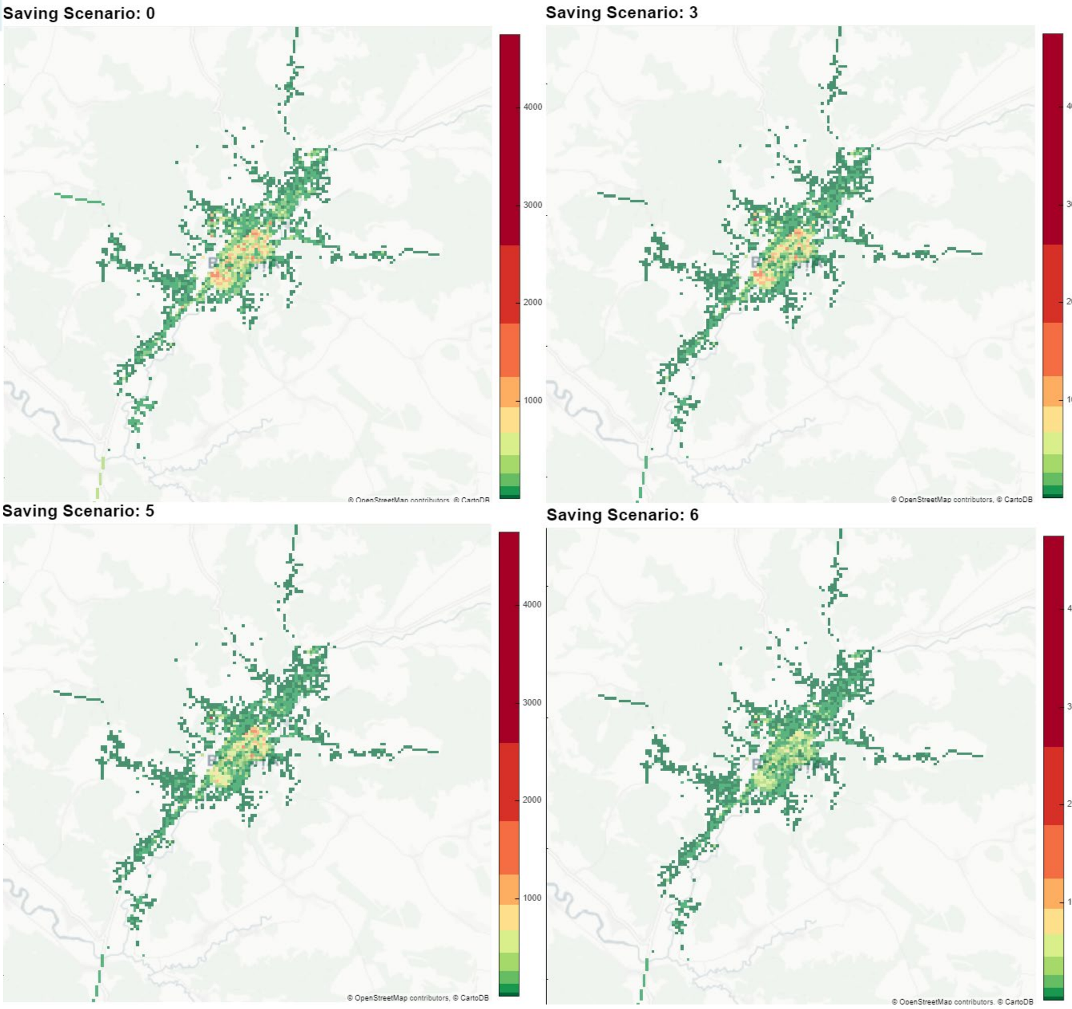


Figure 8: Heat demand density maps of Bistriţa for 2017 (top left), 2050 with 19% savings (top right), 2050 with 36% savings (bottom left) and 2050 with 50% savings (bottom right) (Source: own calculations)

Currently, the useful energy demand for space heating and hot water generation in residential and service buildings in the municipality of Bistriţa is 365 GWh/yr [5]. The average heat demand density in the city is currently around 154 MWh/ha*yr, and the highest heat demand density in the city center is 4,755 MWh/ha*yr.

As can be seen in Figure 8, the application of renovation measures in the city would lead to decreased heat demand densities especially in the central parts of the city. In the surroundings of the city, the heat demand density is already low in the current situation. In the three saving scenarios shown in the figure, mean (and maximum) heat demand density decrease to 124 (and 4,755) MWh/ha*yr, 99 (and 2,850) MWh/ha*yr and 77 (and 2,850) MWh/ha*yr.

The following Figure 9 shows the costs of reaching different levels of heat savings in the buildings of the city of Bistriţa. For different levels of overall savings, between 6% and 50%, the annualised investment costs per MWh of saving and the total annual investment costs in MEUR/yr are shown. The figure shows that the average costs per savings (blue line) increase only slightly until savings of around 36% of the overall heat demand, which would cost around 50 EUR/MWh. Reaching savings of 50% of the overall heat demand, becomes remarkably more expensive at around 150 EUR/MWh. This gives an indication that an economically

[5] See details on the bottom-up estimation of heat demand and heat demand density in chapter 4.1.1

interesting level of heat savings might be in the range of 30 - 40% of total heat demand. However, which level of heat saving is meaningful, depends not only on the costs for the savings, but also on the costs for heat supply and on the availability of resources. Such a comparison is done in the scenario assessment section in 6.1. In this comparison the total annualised costs of heat saving are used to calculate the overall costs occurring in different scenario settings. In the figure these values are shown in the orange line.

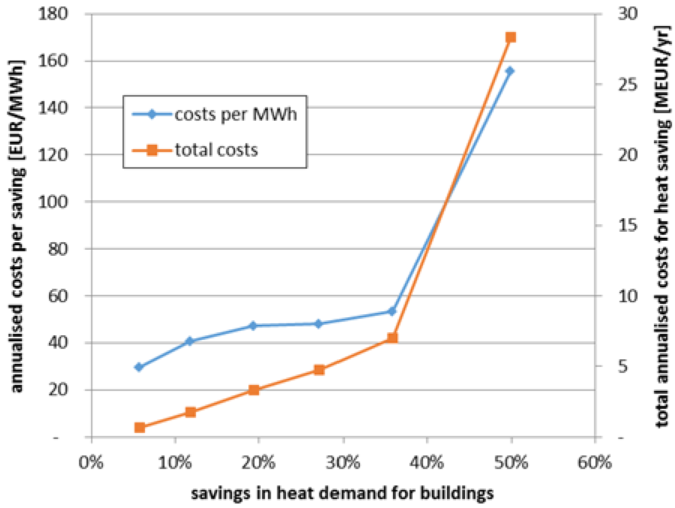


Figure 9: Annualised investment costs per saved heat (left axis) and total annualised investment costs (right axis) for reaching different overall savings of heat demand in building in the city of Bistriţa (Source: own calculations)

As already described in chapter 4.3.4 and 6.1.1, different renovation targets are calculated. However, these refer to the total heating demand and still have to be adjusted for the additional hot water production. The following table shows the relationship between a renovation scenario, the calculated savings and the savings that can be achieved by considering space heating and hot water production.

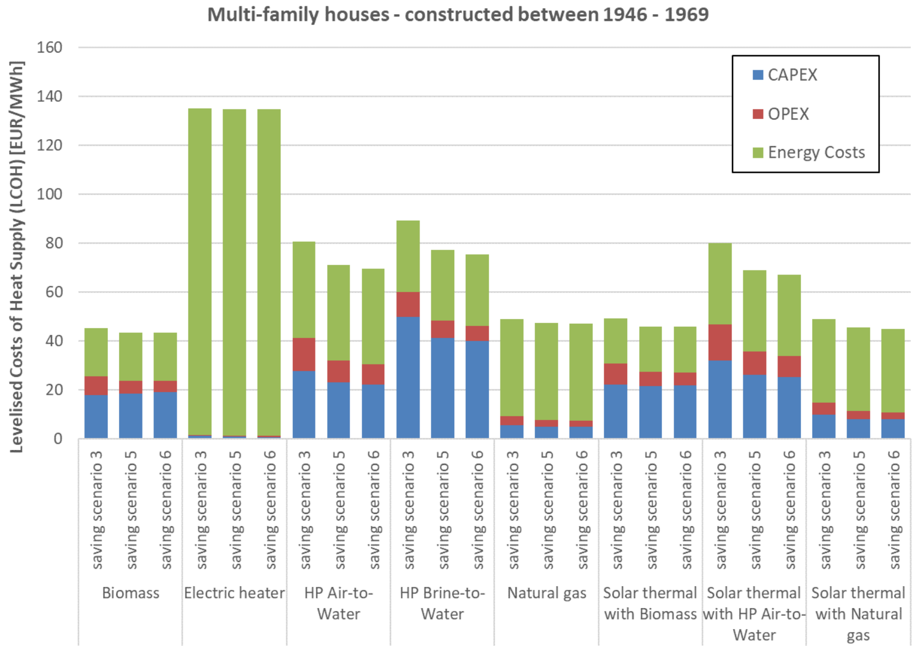
Table 11: Savings in demand for space heating and savings in total heat demand (space heating + domestic hot water) for the calculated renovation-scenarios. (Source: own calculations)

scenario name	savings in demand for space heating	saving in total heat demand (space heat + domestic hot water)
renovation scenario 1	9%	6%
renovation scenario 2	20%	12%
renovation scenario 3	30%	19%
renovation scenario 4	38%	27%
renovation scenario 5	46%	36%
renovation scenario 6	59%	50%

In order to reach 19% of savings (at lowest costs), 42% of buildings gross floor area are renovated in the calculations, to reach 36% of savings, 73%, and to reach 50% of savings, all buildings are renovated. To reach the 19% of savings, only single-family buildings, offices and educational buildings are renovated in the model, all of these buildings with measures below the standards for renovation. To reach savings of 36% also multifamily buildings, wholesale and retail and hotels and restaurants are renovated. Then to reach 50% of savings, all buildings have to be renovated and also the ambition of the measures increases. At the same time the costs for the measures also increase remarkably.

6.1.2.2 Costs of decentral supply

The costs of heat supply (Levelized costs of heat - LCOH) via decentral technologies have been calculated with the **"CM - Decentral heating supply"** (Hotmaps Wiki, 2019c). For each building type and construction period distinguished in the calculation of the current heat demand (see chapter 4.1), heat supply costs in the year 2050 have been calculated. Hereby, costs have been calculated for different levels of refurbishment in these buildings according to the saving scenarios developed in the first step of the analysis (see description of methodology in chapter 6.1.1).



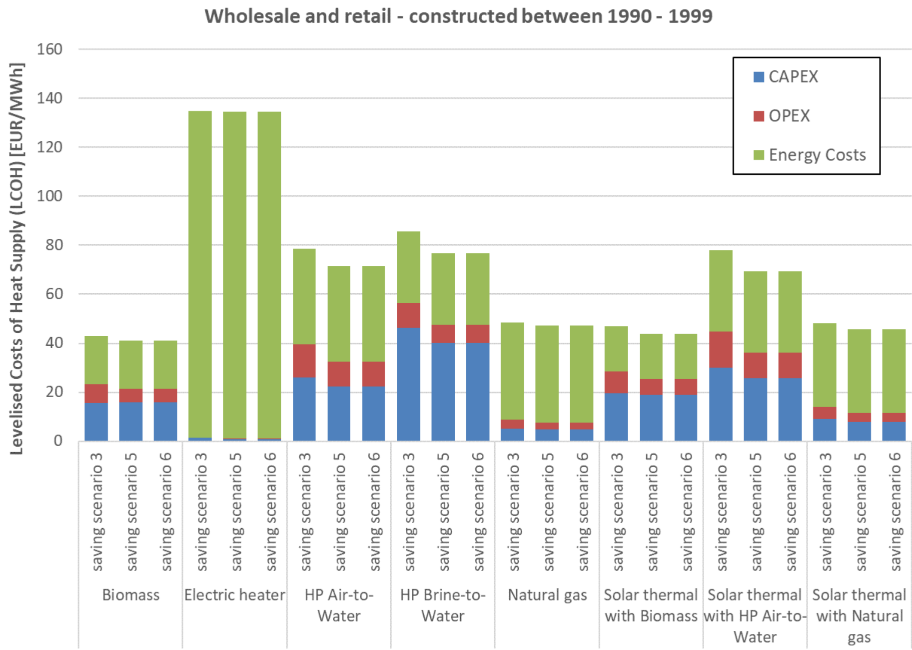


Figure 10: Levelized costs of heat supply from decentral technologies in 2050 for three different scenarios of heat savings in the buildings (19%, 36% and 50% savings in overall heat demand), left side for multifamily houses constructed between 1946 and 1969, right side for retail/shops built between 1990 and 1999 (Source: own calculations)

Figure 10 shows the LCOH for heat supply from different technologies for three saving scenarios (19%, 36% and 50% savings in overall heat demand) for two exemplary building types and construction periods: multi-family houses (MFH) constructed between 1946 and 1969 (top) and wholesale and retail buildings constructed between 1990 and 1999 (bottom).

Most buildings in the construction period between 1946 and 1969 are economically feasible to renovate in many heat-saving scenarios. Decreasing heat demand in buildings, affects the heat supply costs: smaller device capacities usually lead to higher specific investment costs and many technologies have a certain minimum capacity available on the market. This often leads to increased LCOH with decreased heat demand in the buildings, especially for small buildings or flat-wise heat supply. However, it is also possible that LCOH decrease with decreased heat demand. This is the case when the maximum needed power decreases strongly after renovation. In the figure, this effect is shown for both Multi-family houses and retail buildings. LCOH for heat supply from decentral technologies in Multi-family houses constructed between 1946 and 1969 are calculated to between 43 and 135 EUR/MWh, with biomass boilers being the cheapest supply option and electric heaters being the most expensive. The supply with heat pumps leads to LCOH around 70-90 EUR/MWh in those buildings. For retail buildings constructed between 1990 and 1999 LCOH between 41 and 135 EUR/MWh have been calculated. This is very similar compared to the costs in Multi-family houses.

The LCOH for each building type, construction period, and supply technology is used to calculate the average cost of decentral heat supply in the different heat-saving scenarios. For this, the overall heat demand and related supply costs in all buildings of the city are calculated. The following mix of technologies has been assumed: 70% heat pumps, 10% electric heaters, 5% solar thermal, and 15% biomass. This results in weighted average costs of decentral supply in the year 2050 for the different saving scenarios at 89 (no savings), 96 (21% savings), and 98 EUR/MWh (39% savings).

6.1.2.3 Sensitivity of economic district heating expansion

With the **"CM - District heating potential: economic assessment"** (Hotmaps Wiki, 2019b) several scenarios for the expansion of district heating (DH) in the city have been calculated. The module calculates the location, the investment, and the heat distribution costs as well as the delivered energy of a potential DH system under different technical and economic framework conditions. The following figure shows the annualised investment costs into the DH grid over the average grid costs per distributed heat (left side) and the share of DH on the overall heat demand in buildings over the average grid costs per distributed heat (right side). Scenarios have been calculated for various different levels of heat savings in the buildings, different shares of heat demand connected to DH in DH areas, and different maximum grid cost ceilings.

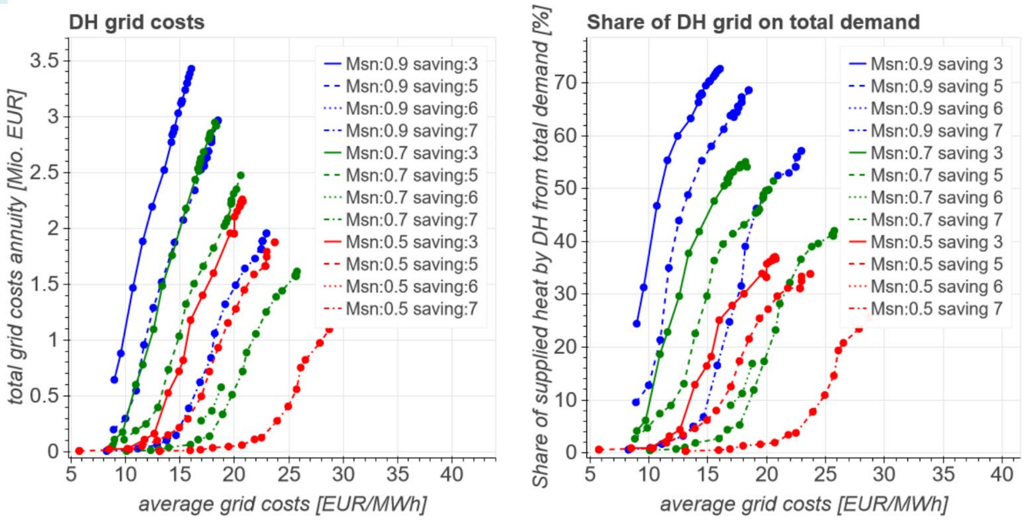


Figure 11: Annualised investment costs into the district heating (DH) grid (y-axis) over the average grid costs per distributed heat (x-axis) (left side) and share of DH on overall heat supply in the city (y-axis) over the average grid costs per distributed heat (x-axis) (right side) for several scenarios with different levels of heat saving [6] in the buildings, different shares of buildings' heat demand connected to DH in DH areas (Msn) and different maximum grid cost ceilings (Source: own calculations).

The figure shows the high sensitivities of the average grid costs per distributed heat [EUR/MWh] to the heat demand density/amount of heat savings in the city (solid vs. dashed vs. dotted lines) and to the share of heat demand that is connected to DH in areas where a DH grid would be built (red vs. green vs. blue lines). Assuming e.g. savings in the heat demand of buildings of 36% (savings 5) and that district heat should be supplied at heat distribution costs of 15 EUR/MWh on average: in case that 50% of the heat demand is connected in areas where a DH grid is constructed, that would lead to a total share of 6% DH in the city, while if 90% of the heat demand in DH areas is connected, this would lead to a share of around 58% of total heat demand to be supplied by DH. This shows the remarkable importance of increasing the share of buildings connected to DH in areas where DH networks are constructed to decrease the costs of DH distribution.

The right side of the figure also shows that the increase of the share of heat demand supplied by DH with increasing average grid costs per delivered heat is not linear: starting from very low average grid costs the curves first have a low gradient, which is increasing and after a break-over point, the gradient decreases again. When looking up the same curves on the left side of the figure, which shows the total annualised investments in the grid, it is visible that the gradients of the curves do not decrease for high average grid costs as much as is the case on the right side of the figure. The reason is that in the areas with higher heat demand density already a district heating grid is constructed and with the same amount of investments only smaller shares of heat demand can be connected. This change in the gradient of the curves on the right side together with potentially feasible average grid costs per delivered heat serves as an indication for economically interesting scenarios of DH expansion in the city.

[6] See chapter 6.1.2.1 for a description of the different heat-saving/renovation scenarios and especially Table 11 for the share of heat savings in the related renovation scenarios 3, 5, 6 and 7

6.1.2.4 District heating portfolios and related costs

For the supply of district heat in the city of Bistriţa, a number of different technologies could be used. According to the estimation of potentially available resources, the following technologies have been taken into account in the compilation of district heating (DH) portfolios: a heat pump in the outflow of the wastewater treatment plant, a potential waste incineration plant outside the city at a distance of around 15km, a heat pump in the river water, a back-pressure biogas CHP, a heat storage, as well as biomass or natural gas boilers to cover peak load. These technologies have been combined with different capacities to different portfolios.

Table 12: Overview of portfolios of district heating (DH) supply calculated for the city of Bistriţa (Source: own assumptions)

Portfolia	Installed capacity [MW]	Yearly Supply [GWh/yr]
Portfolio 1: - Heat Pump in the waste water treatment plant - Biomass boiler for peak load	 10 0.9	30
Portfolio 2: - Waste incineration plant - Biomass boiler for peak load	 10, 10 14.3, 24.4	70, 100
Portfolio 3: - Waste incineration plant - Biomass boiler for peak load - Heat Pump in the waste water treatment plant	 10, 10 4.3, 14.4 10, 10	70, 100
Portfolio 4: - Waste incineration plant - Natural gas boiler for peak load	 10, 10 13.5, 23.6	70, 100
Portfolio 5: - Biogas back-pressure CHP - Heat Pump in the waste water treatment plant - Heat Pump in the river water - Waste incineration plant - Heat storage	 10 10 10 20 28	170

Based on the analysis of the costs of potential DH systems in the city and eventually meaningful amounts of heat supplied by DH, four different sizes of heat networks have been modelled: 30 GWh/yr of total heat to be supplied by all devices, 70 GWh/yr, 100 GWh/yr and 170 GWh/yr. Table 12 shows the compilation of the different technologies for the different sizes of the network.

A small DH system of 30 GWh/yr could be supplied with a heat pump in the outlet of the wastewater treatment plant plus a boiler for peak load supply (Portfolio 1). To supply larger DH systems, a potential waste incineration plant might be used (Portfolio 2). Adding the heat pump in the wastewater treatment plant would decrease the need for biomass in the peak load boiler (Portfolio 3). To supply a large DH system of 170 GWh/yr, additional technologies would be needed. A combination of several technologies has been modelled for this case (Portfolio 5).

For all portfolios, different sensitivity calculations have been performed. This includes three different temperature profiles of the district heating distribution grid (supply line temperature[7]) and four different price scenarios for the electricity wholesale and the CO2

[7] For a description of the modelled supply line temperatures in the district heating grid please refer to the Annex of the document

price. The following figure shows the Levelized Cost Of Heat supply (LCOH) for three different portfolios under different scenario settings.

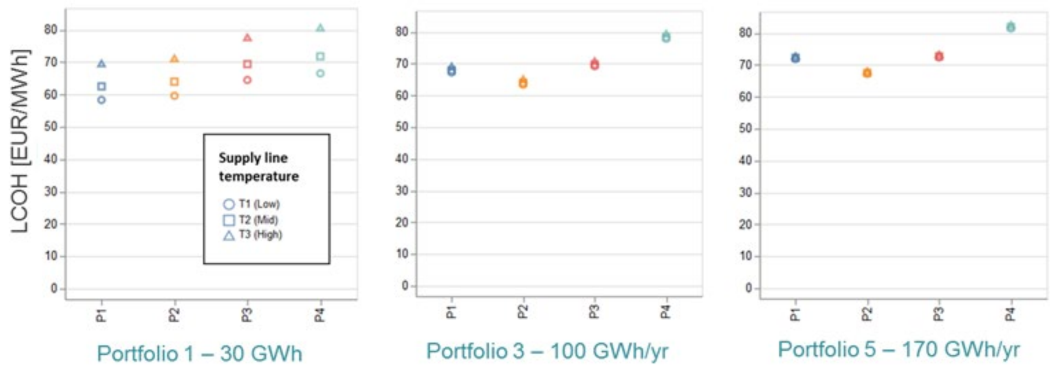


Figure 12: Levelized costs of heat supply to the district heating grid in [EUR/MWh] for three different portfolios, different scenarios for energy and CO2 prices (P1 - P4)[8] as well as supply line temperatures (T1 - T3)[9] (Source: own calculations)

The figure shows that the future electricity wholesale and CO2 prices have a remarkable influence on the LCOH of DH in the modelled portfolios. In Portfolio 1, an increase of LCOH from the lowest electricity prices (P1) to the highest electricity prices (P4) can be observed. For the medium supply line temperatures in the DH network, the range of the LCOH for different price scenarios is between 63 and 72 EUR/MWh. For the portfolios 3 and 4, the lowest LCOH can be observed for the P2 price scenario (see also chapter 4.3.5). The P2 scenario shows the lowest CO2 prices of all 4 price scenarios. Portfolios 3 and 4 are mainly based on a waste incineration plant, which is not generating electricity, but a price for the emitted CO2 has to be paid. This leads to the lowest LCOH for these portfolios in the P2 price scenario. The resulting range of LCOH due to different future electricity and CO2 prices for Portfolio 3 is 65 to 80 EUR/MWh and for Portfolio 4 it is 68 to 83 EUR/MWh. It can also be observed in the figure that the impact of the temperature of the DH supply line is negligible in Portfolio 3 and 4, while in Portfolio 1 it is remarkable. The reason is that in Portfolio 1, a relevant portion of heat is supplied by the heat pump in the outlet of the wastewater treatment plant, while in the other portfolios, the share of heat supplied by heat pumps is remarkably lower with a maximum of 10% in Portfolio 3. In Portfolio 1, the effect of different supply line temperatures leads to differences in the LCOH from low to high between 11 and 14 EUR/MWh depending on the price scenario. Overall the figure also shows that the LCOH for supplying 30, 100 or 170 GWh/yr is in a similar range between 60 and 80 EUR/MWh.

The following figure shows the load duration curves for Portfolio 3 and Portfolio 4. It shows the differences in necessary peak power (maximum values on the start of the x-axes) and the split of capacities used in each hour of the year ordered by the total power needed in each hour.

[8] See chapter 4.3.5for a description of the energy carrier and CO2 prices in the price scenarios P1-P4.

[9] See the Annex of the document for a description of the assumed supply line temperatures T1 to T3.

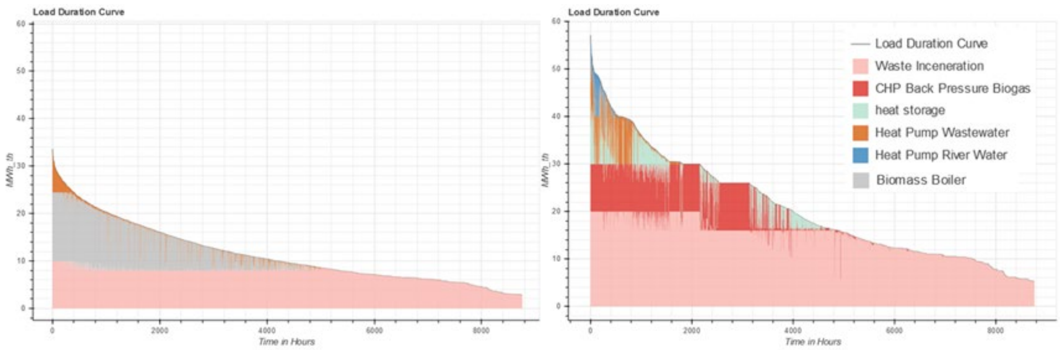


Figure 13: Load duration curves for portfolio 3 (left side) and portfolio 5 (right side) - split into the different supply technologies (Source: own calculations).

The figure shows the different peak powers and overall heat demands needed as a result of the different sizes of the district heating systems (Portfolio 3 supplies 100 GWh/yr and Portfolio 4 supplies 170 GWh/yr). Also, it shows the different technologies that are used in each hour of the year according to the dispatch calculations. In Portfolio 3 and 4, the baseload (lower part of the curve) is supplied by the waste incineration plant. However, in Portfolio 4 a larger capacity of the waste incineration plant is assumed than in Portfolio 3. Large parts of the peak load in Portfolio 3 (left side) are supplied by a biomass boiler and only a small share of the heat is supplied by the heat pump in the outlet of the wastewater treatment plant. The use of the biomass boiler could even be further decreased by adding a weekly heat storage into the portfolio. This would also increase the use of the heat pump. In Portfolio 4 (right side) the biogas back-pressure CHP is used to supply a relevant share of the medium loads. The heat storage included in the portfolio increases the use of the CHP and also the use of the heat pump in the wastewater. The heat pump in the river water is only used in times of very high heat demand.

Although the calculations cover different sensitivities for different combinations of technologies, different temperatures in the supply line of the network and different electricity and CO2 prices, other main influencing parameters have not been varied over the scenarios as e.g. the future development of biomass prices and the investment costs of the technologies. This has to be taken into account in the interpretation of the results.

6.1.2.5 Overall city scenarios

Based on the analyses of the sensitivity of costs in the different parts of the heating demand and supply system, a set of scenarios has been selected to compare indicators for the entire city. One main scenario has been selected that seems interesting as a basis for more detailed analyses in the future. Further scenarios have been defined in order to visualise the effects of different changes to the main scenario on the overall city-wide indicators. The following table shows the definition of the main as well as of the different sensitivity scenarios.

Table 13: Overview of scenarios in the different calculation modules combined with overall city scenarios and sensitivities (Source: own assumptions)

Scenario nr.	1	2	3	4	5	6	7	8
Scenario Name	Main scenario	Low savings of heat demand	High savings of heat demand	Low District Heating connection rate	High District Heating connection rate	Low District Heating share	Natural gas and Waste incineration in DH	High Electrictiy and CO2 price
Savings in heat demand of the buildings	36%	19%	50%	= main scenario	= main scenario	= main scenario	= main scenario	= main scenario
Decentral supply	default technology mix, no CO_2 prices paid	= main scenario	= main scenario	= main scenario	= main scenario	= main scenario	= main scenario	= main scenario
District heating network	70% connection rate, 41% DH on total	70% connection rate, 53% DH on total	70% connection rate, 4% DH on total	50% connection rate, 27% DH on total	90% connection rate, 58% DH on total	70% connection rate, 9% DH on total	= main scenario	= main scenario
District heating supply	Waste incineration, HP in waste water, Biomass boiler, medium distribution temperature, medium prices	= main scenario + HP in river water, heat storage and Biogas CHP	= main scenario without waste incineration	= main scenario	= main scenario	= scenario 2	= main scenario, no HP waste water and natural gas boiler instead of biomass boiler	= main scenario with high prices

The following figures show important indicators for the entire city for the different scenarios considered. These indicators are total annual heating system costs [MEUR/yr], total annual CO2 emissions [tCO2/yr], final energy demand [MWh/yr] and shares of district heating (DH) and heat savings [%].

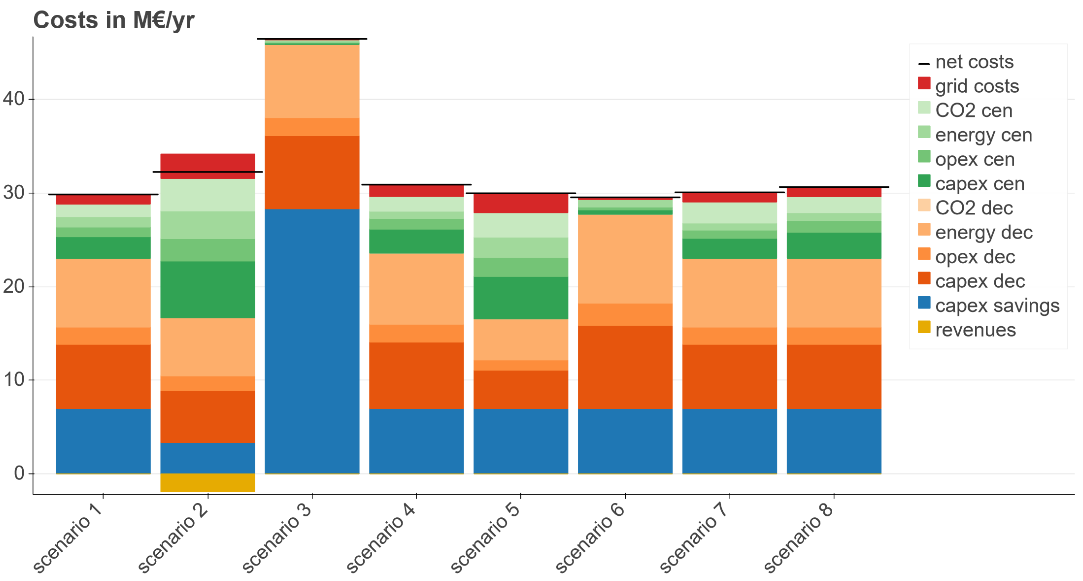


Figure 14: Annual heating system costs for the city of Bistriţa in 2050 for the defined scenarios split into costs for heat savings (savings), decentral supply (dec), district heating supply (cen) and district heating grid (grid) as well as revenues from electricity generation (revenues) (Source: own calculations).

It is visible that scenario 3 has by far the highest annual costs for the overall heating system in the city of Bistriţa. This is due to the very high costs of measures to reach savings of 50% of the heat demand in the buildings of the city compared to the costs of lower savings (see also chapter 4.3.4). Lower differences in the overall costs can be found for the other selected scenarios showing effects of lower and higher market shares in the district heating system, lower and higher shares of district heating in the city and differences in the portfolios or prices scenario assumptions. However, the differences still lie in the range of some million EUR per year.

The following figure shows the fossil CO_2 emissions in the different scenarios considered. The highest amount of emissions can be found in scenario 7. The source of emissions in this scenario is the natural gas boiler in the district heating system, which has been inserted instead of the biomass peak boiler in this scenario in order to see the effect of changing the biomass peak supply with natural gas peak supply. When looking at the overall costs of scenario 7 vs. scenario 1 (see Figure 14) it can be seen that no remarkable cost savings might be expected when using natural gas instead of biomass. At the same time, the emissions would increase remarkably when using natural gas for peak load supply. In the other scenarios, the fossil emissions nearly only result from waste incineration. Thus, a further analysis of which emission factors would be meaningful for waste in the year 2050 and a discussion of the weight of the emission factor compared to resource usage has to be taken in the future.

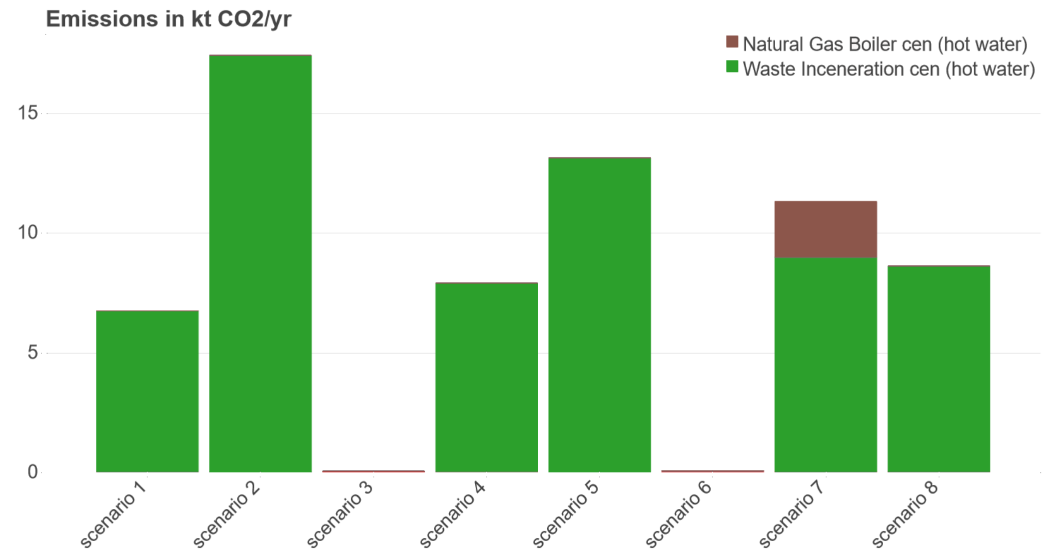


Figure 15: Total annual CO2 emissions for the city of Bistriţa in 2050 for the defined scenarios distinguished between the different supply technologies (Source: own calculations).

The following Figure 16 shows the demands for energy carriers in the different calculated scenarios. For decentral heat supply these reflect energy carriers used in the buildings and for district heating supply these reflect the energy carriers used in the supply plants of the district heating systems. Solar thermal energy and ambient heat used in heat pumps is not reflected in the figure. Remarkable differences between the different calculated scenarios can be observed. High shares of energy carrier demand in the city would be composed of municipal waste and biomass in many scenarios. Lower amounts of energy carrier demand are visible in the scenarios with lower shares of district heating. This is due to the fact that a high share of heat pumps is assumed for decentral heat supply and the ambient heat that is used in the heat pumps is not reflected in the values for energy carrier demand.

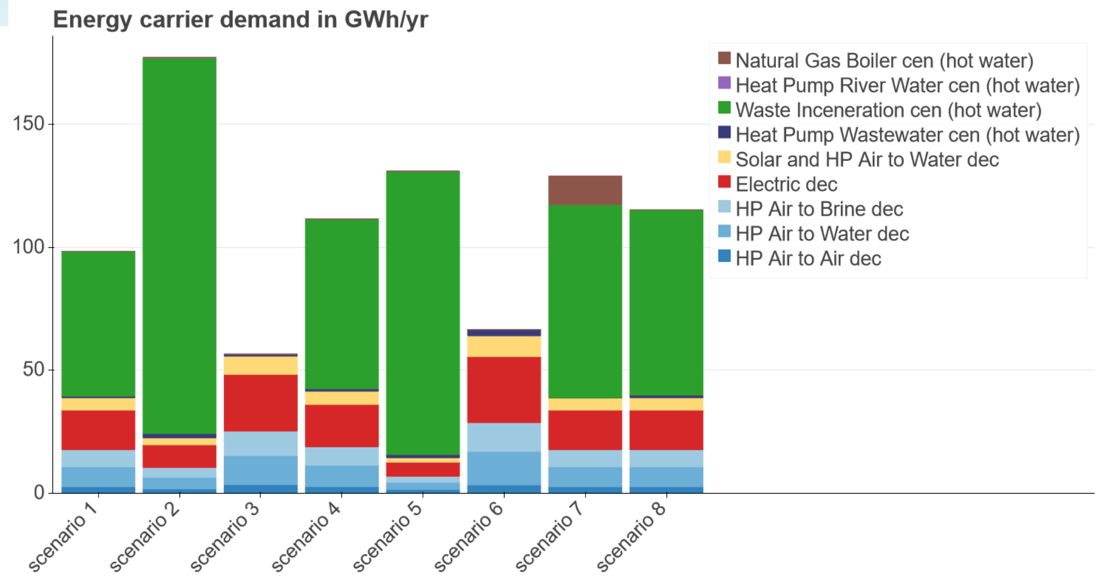


Figure 16: Total energy carrier demand for space heating and hot water generation (energy carriers used in the buildings plus energy carriers used in the district heating supply plants) in the city of Bistriţa in 2050 in the different scenarios distinguished between the different supply technologies (Source: own calculations).

The following Figure 17 shows the shares of heat savings through renovation of buildings (on the total heat demand for space heating and hot water generation) and the share of district heating on the overall heat demand in the buildings. It shows the broad range of settings in the different scenarios.

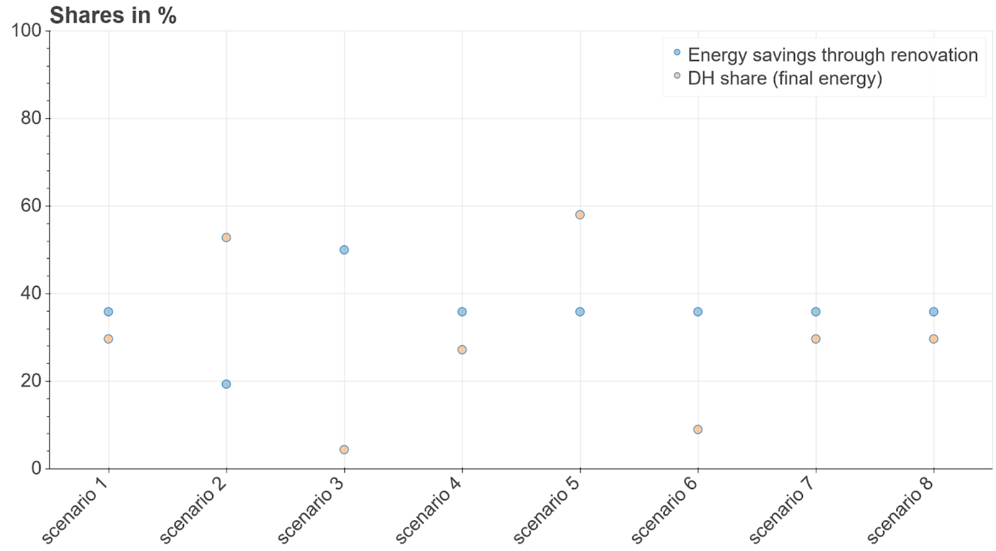


Figure 17: Shares of district heating (DH) and heat savings in the city of Bistriţa in 2050 in the different scenarios (Source: own calculations).

The following figure shows the areas in the city where district heating (DH) would be economically feasible when saving 36% of the overall heat demand in buildings. On the left side (in green) a market share of 70% of DH in DH areas and maximum allowed values of DH distribution costs of 17 EUR/MWh are assumed. On the right side (in red) a market share of 50% of DH in DH areas and maximum allowed values of 20 EUR/MWh DH distribution costs are assumed. The resulting economically feasible district heating grid on the left side in green covers a larger share of the area of the city compared to the grid on the right side in red. At the same time, the average distribution costs of the larger grid are lower than those of the smaller grid. The main reason is the different share of heat demand in the area that is assumed connected to the grid. This illustrates the strong influence of the market share of DH in DH areas on the economic feasibility of DH grid expansion.

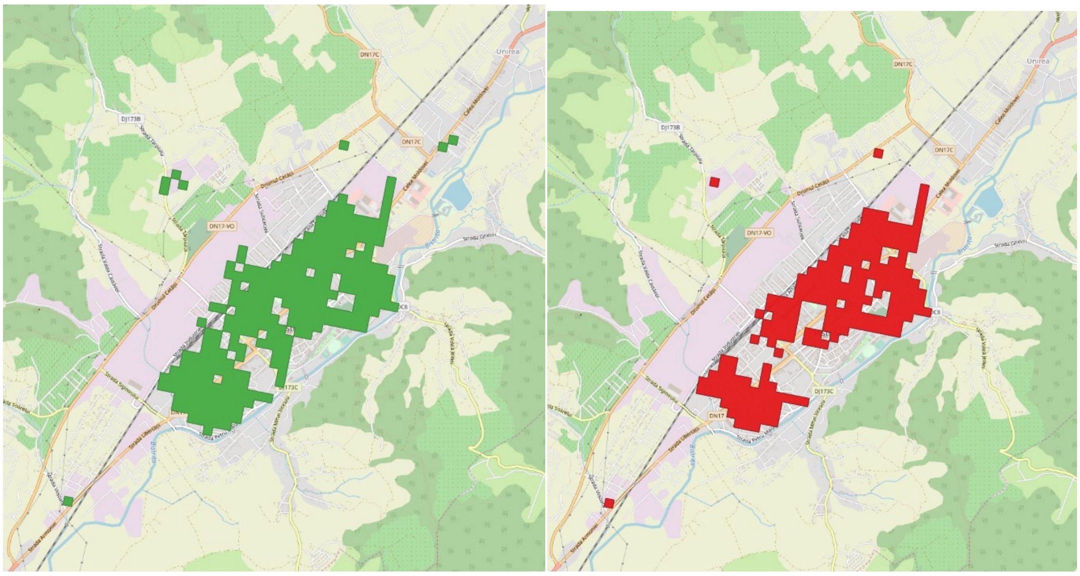


Figure 18: Identified district heating areas in the city of Bistriţa in two scenarios (left side: 41% of total heat demand in the city delivered by DH, 70% delivered by DH in the green area, distribution costs of 17 EUR/MWh on average; right side: 27% of total heat demand in the city delivered by DH, 50% delivered by DH in the red area, distribution costs of 20 EUR/MWh on average) (Source: own calculations).

6.1.3 Conclusions and recommendations from the scenario assessment

In the course of developing this strategy, a high number of calculations has been performed. This included the collection of a remarkable number of input parameters and the variation and combination of various of them. The results of the different analyses have been presented in the previous. Based on these calculations the following conclusions and recommendations are derived.

Achieving a low carbon heating system in the city of Bistriţa is based on two important pillars: the reduction of heat demand in buildings and the supply of the remaining heat demand with energy derived from renewable or excess heat sources. Thus, the availability and cost of different options in these two fields are crucial.

The results have shown that the level of heat savings targeted in the city has a high influence on the overall costs of the heating system. Savings of around 30 - 40% of the overall heat demand in the buildings (space heating plus hot water generation) in the city seem to lead to the lowest overall system costs. In order to reach such levels of savings around 70% of the entire buildings, gross floor area has to be renovated.

To supply the remaining heat demand, a number of different scenarios have been analysed. The results have shown that a variety of different supply scenarios lead to similar overall system costs for the heating system of the city. Therefore, it is essential to develop a clear picture of the availability of resources as a basis for further calculations. Apart from energetic potentials, this includes associated costs and prices like e.g. expectable biomass prices.

The costs calculated for decentral supply and the costs calculated for supply via district heat (heat generation + heat distribution) are in a similar range for most scenarios. Therefore, the meaningful share of district heating in the city is not clearly identifiable based on the calculated scenarios, being also very sensitive to several input parameters. Such game-changing input parameters are e.g. the following: energy prices, losses in the district heating grid as well as available resource potentials and related costs. Further analyses are necessary in order to derive the meaningful share of district heating in the city.

The results of the district heating grid cost analysis show a strong sensitivity of the costs to the share of buildings connected to the grid in areas where district heat is available (market share) and the amount of heat savings in the area. Thus, in case a district heating system is constructed, measures to reach a high share of buildings connected to the grid should be foreseen and prioritized.

As written before, the meaningful share of district heating in the city largely depends on the available energy from renewable and excess heat sources. The results show that different sizes of the district heating grid (between 30 and 170 GWh/yr) might supply heat at similar costs between 60 and 80 EUR/MWh depending on the scenario settings. Hereby, the resulting costs in all modelled portfolios are affected remarkably by different price assumptions for 2050. However, many important input parameters have to be further discussed like the estimated costs, prices and CO2 factor for a potential waste incineration plant and its transmission line to the city, the availability of biomass and possible future price developments for a peak load boiler, or the availability of biogas for a biogas CHP as modelled in the largest district heating system. Furthermore, also the scenarios modelled for small and medium-sized district heating systems including a heat pump should be further analysed regarding the meaningfulness of integrating a biomass CHP instead of a biomass boiler. This could allow for benefiting from times with low as well as times with high electricity prices over the year. However, it has to be taken into account that the operation of a biomass CHP also involves constraints like high cold start costs and upfront costs that need to be taken into account in the analysis.

In general it is recommended to base the heat supply on a diverse portfolio of technologies in order to mitigate potential fluctuations in fuel, electricity or CO2 prices or shortages in specific energy resources.

Many sensitive input parameters have been varied in sensitivity analyses. However, a remarkable number of input parameters has not been varied in the calculations and are based on estimations and experiences from other cases and countries. Therefore, further analyses have to be undertaken in order to strengthen the conclusions. A summary of which parameters should be included in further feasibility studies is given in chapter 6.2.

The calculations in this strategy have been performed with an interest rate of 3% and a depreciation time equal to the lifetime of each technology and component. This reflects socio-economic calculations and lowest costs mean lowest costs for the general public. Based on socio-economically meaningful scenarios business cases have to be developed in which potential investors could find economically interesting investment opportunities.

6.2 Heating and cooling strategy roadmap

After the quantitative and qualitative analyses and the discussions with the stakeholders this chapter presents the main pillars of the resulting strategy for decarbonising the heat sector in the city of Bistriţa. The primary goal on this way is the planning and installation of a district heating system for the city based on technologies with low CO2 emissions. On main steps (milestones) on this way are the following:

- 2030 - Completing the activity of identifying the potential of local renewable energy sources and planning a possible feasible DH system in accordance with the identified resources
- 2040 - Connecting to district heating 50 % of the municipal buildings of the city central area
- 2050 - Approximately 20% of the blocks of flats in the city should be connected to district heating (90 % of the buildings built before 1990 rehabilitated and 20% connected to district heating)

The most important barrier on the way to a low CO2 heat sector in the city of Bistriţa are the citizens experiences with previous district heating systems and the reaction towards benefits of district heating based on excess heat and renewable energies.

The next steps on the road to a low carbon district heating system for the city are the following activities:

- Develop a **renovation roadmap for the buildings** in the city including the following content: distinction between buildings that have already been renovated and which have not, including the status of renovation in the buildings database of the city, plan for financing / financial assistance in the renovation activities of public and private buildings, definition of renovation targets for different buildings in the city following the overall cost efficiency of renovation in the city (cost optimal overall heating system searching for the cost optimum between savings and supply)
- **Detailed analysis of the potentials for renewable energy and excess heat** in and nearby the city. This should include the following content: analysis of the excess heat available in the outlet of the wastewater treatment plant, potential of excess heat in the river water, potential and feasibility of the installation of a waste incineration plant near the city, potential for excess heat in small industries and the service sector (e.g. super markets, data centres, etc.), potential for forest and agricultural biomass usable from nearby the city, potential for solar thermal collector fields, potential location for a weekly and/or seasonal heat storage
- Detailed (pre)**feasibility study of a potential district heating system** with more focus on the following aspects and input parameters: more cost details related to the different technologies potentially used in the system (based on cost sheets of companies active in the area), inclusion of technical barriers as analysed in the potential analyses (step before), analysis of sensitivity to different energy price developments and assumptions (prices for energy carriers in the buildings (decentral use), biomass prices, price of municipal waste in case a waste incineration plant makes sense to install near the city including a first idea of a transmission route, realistic network construction costs in the city (based on companies active in the city / region).

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8 Annex

In this section we present assumptions on input data used in the calculation of the scenarios that are not described in the other parts of this document.

8.1 A1) Temperature sensitivity of heat pumps

As described in chapter 2.2.2 the modelling of the generation of heat in the district heating systems takes into account the sensitivity of the COP of heat pumps towards changes in the temperatures of the heat source, the flow and the return of the district heating system. This sensitivity is based on the formula and values described in (Totschnig et al., 2017) and (Gumhalter, 2019). The following table shows the values used for the different modelled heat pump systems together with the fade out and shut off temperatures, the source temperatures and the nominal temperatures for flow and return.

Table 14: Specifications of heat pumps as used in the district heating supply dispatch model (Source: (Totschnig et al., 2017) and (Gumhalter, 2019))

	COP source tempe-rature sensitivity (1/°C)	COP flow tempe-rature sensitivity (1/°C)	COP return tempe-rature sensitivity (1/°C)	min shutoff source tempe-rature (°C)	fade out tempe-rature where power reduction starts (°C)	source tempe-rature (°C)	nominal flow tempe-rature (°C)	nominal return tempe-rature (°C)
HP – River Water	0.0578	-0.0247	-0.0136	3	6	10	70	50
HP – Waste water	0.0578	-0.0247	-0.0136			10	70	50
HP – EH Servers	0	-0.0247	-0.0136			30	65	45
HP – Industrial HT EH	0	-0.0247	-0.0136			80	100	70
HP – Industrial LT EH	0	-0.0247	-0.0136			40	65	45
HP – near-surface Geothermal	0	-0.0247	-0.0136			15	65	45

HP ...... Heat Pump
HT ...... High Temperature
LT ...... Low Temperature
EH ...... Excess Heat
COP ...... Coefficient Of Performance

The technology (type and working medium) of the heat pump for each of the sources as defined in the table is chosen based on the temperatures in which the heat pumps should operate. The operating points of each of the heat pumps are defined separately for each of the sources and for each flow and return temperature scenario of the district heating systems (see chapter 8.2). This is done using median values of the yearly flow and return temperature profiles.

8.2 A2) Flow and return temperatures in the district heating system

For the district heating system three different flow and two different return temperature scenarios are calculated to investigate the influence of these temperatures on the COP of the heat pumps and subsequently on further indicators of the heat supply to the district heating system and the entire heating system in the city. The following figures show the modelled flow and return temperatures in function of the ambient temperature in the city.

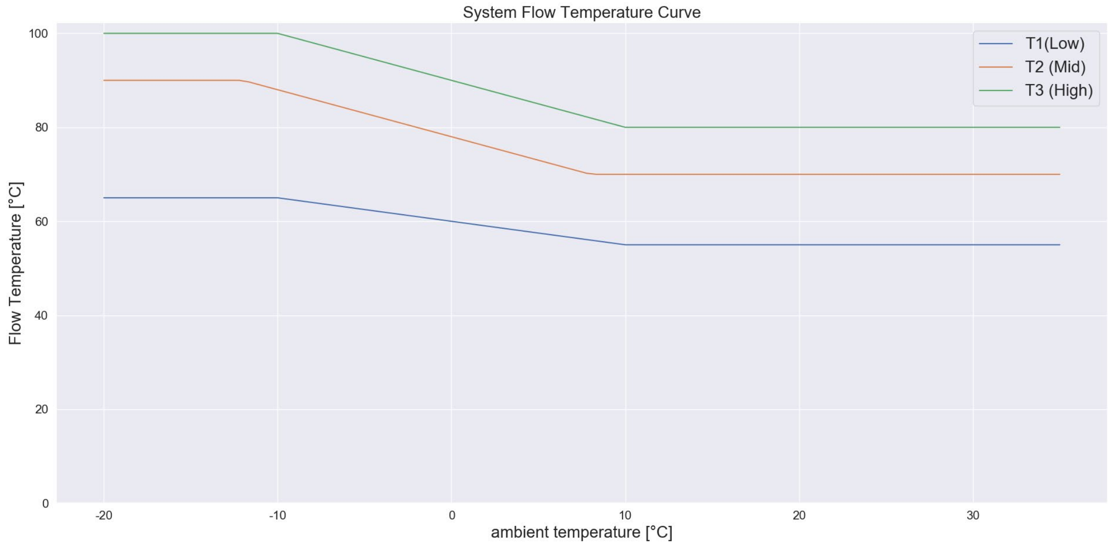

Figure 19: Flow temperature in the district heating systems in function of the ambient temperature used in the dispatch model

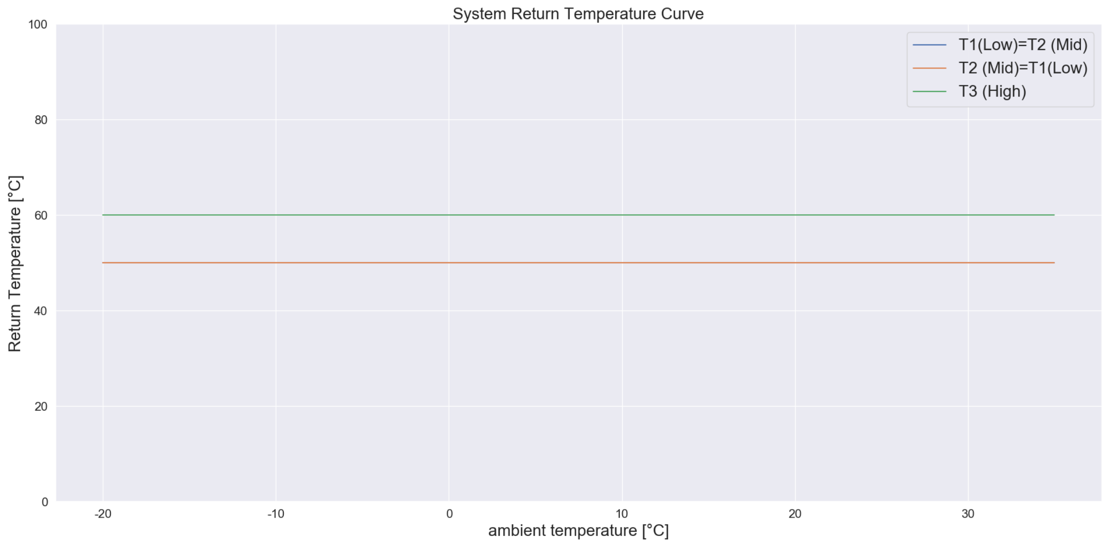

Figure 20: Return temperature in the district heating systems in function of the ambient temperature used in the dispatch model

These relations together with the hourly profile of the ambient temperature (see chapter 8.3) are used to calculate the hourly temperature profiles of the district heating flow and return lines.

8.3 A3) Temperature and solar irradiation profiles

In order to derive the hourly temperature profiles of the district heating flow and return line the ambient temperature for each hour of the year in the city is needed. These data as well as the hourly solar irradiation data have been taken from (EU PVSEC, 2017) for the location of Bistrita. Furthermore, hourly temperatures of the river water as well as of the outlet of the wastewater treatment plant were needed to model the sensitivity of the COP of the heat pumps. These data have been taken from (GDB, 2020) and (ECO.S, 2018). The following figures show these values for each hour of the year.

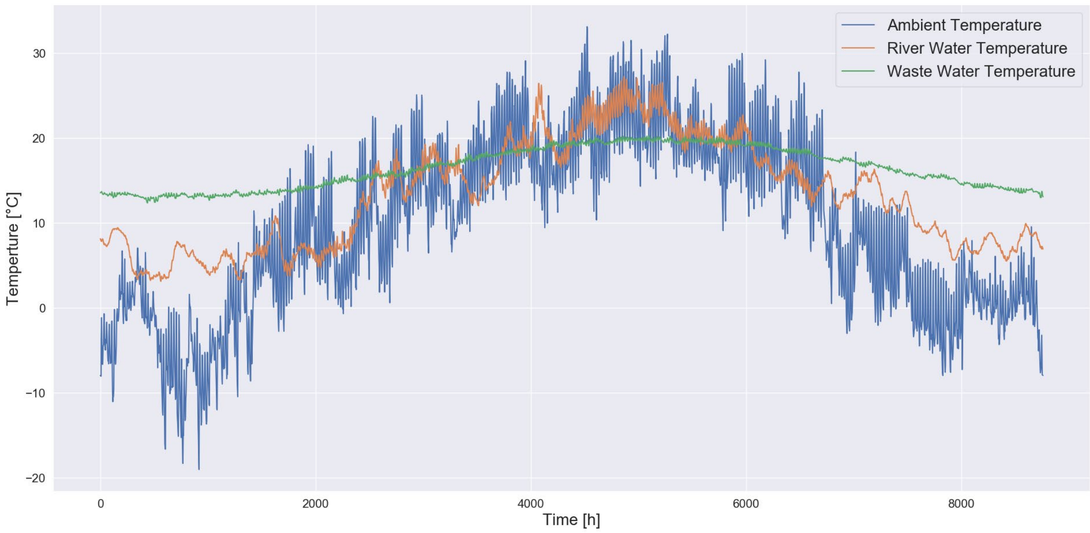

Figure 21: Temperature profiles for ambient air, river water and the outlet of the wastewater treatment plant used in the dispatch model (Source:(GDB, 2020), (ECO.S, 2018), (EU PVSEC, 2017))

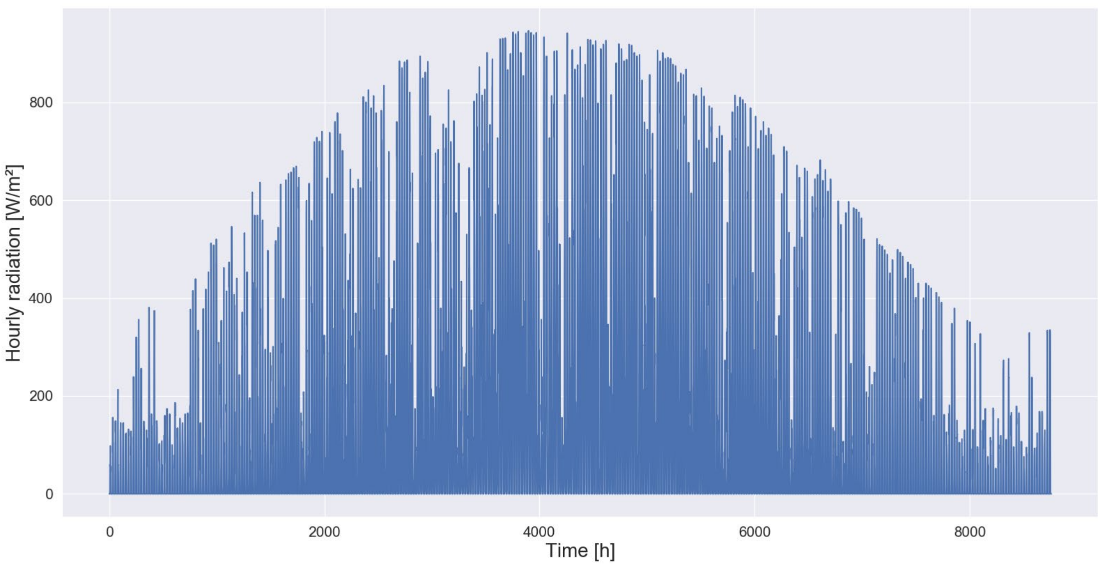

Figure 22: Solar irradiation profile used in the dispatch model (Source: (EU PVSEC, 2017))

8.4 A4) Load profiles of the district heating system

An important input parameter for the calculation of the heat supply to the district heating system is the projected hourly demand profile of the system. For the calculations described in this document the following methodology has been applied: The basis are hourly profiles of space heating demand and hot water demand in the respective NUTS3 region from the Hotmaps database (Fallahnejad, 2019). These profiles are scaled to fit the space heating and hot water demands in the different scenarios using the overall heat demand defined to be supplied to the district heating system in the different scenarios and the split of space heating vs. hot water demand derived in the respective heat saving scenario. With this approach it was possible to account for the change in the characteristics of the load profiles of district heating supply with decreasing share of space heating on the overall load. The following figure show the resulting load duration curves for the overall heat demand (space heating plus hot water) for the calculated sizes of the district heating systems.

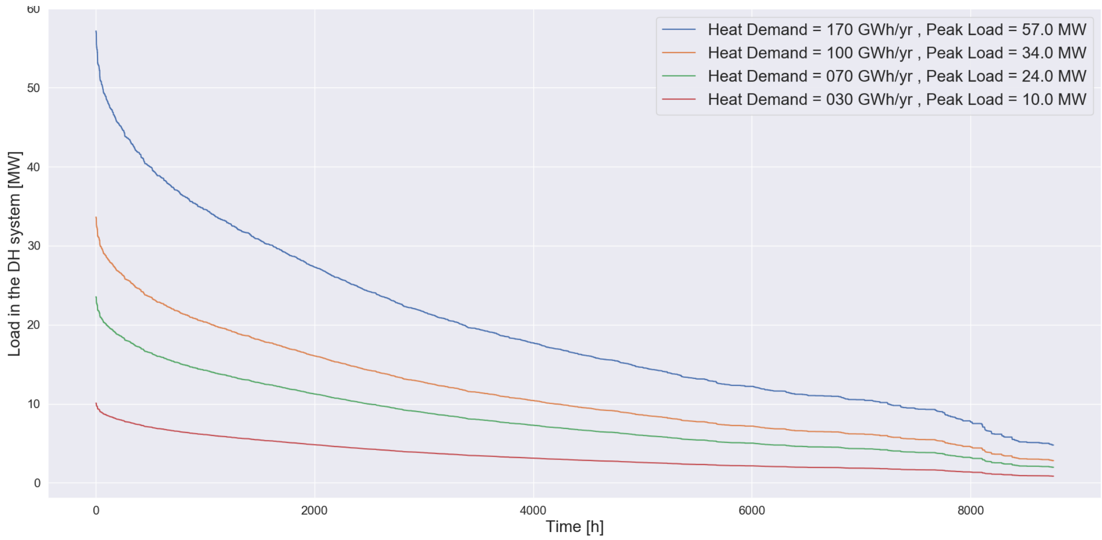

Figure 23: Load duration curves of the district heating system for the different total heat demands supplied by the DH system used in the dispatch model (Source: own calculation based on data from (Fallahnejad, 2019))