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HOW PUBLIC INTERVENTIONS IN BUILDINGS ENERGY EFFICIENCY AFFECT THE ECONOMIC FEASIBILITY OF A DISTRICT HEATING NETWORK– A CASE STUDY FOR VIENNA

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A techno-economic model for the integrated analysis of the development of the buildings' heat demand, the energy carrier mix to supply this demand and the resulting effects for an existing district heating network up to 2050 is developed. An exemplary case study for Vienna is conducted, where two scenarios, differing in the assumptions regarding subsidies for thermal refurbishments and investment-subsidies for heating systems, are analysed and the effects of the decrease in the heat demand on the economic feasibility of an district heating network and the expansion plans are pointed out.

1. INTRODUCTION

1.1 Motivation and Research Question

An urban district heating network represents an energy efficient way to supply the cities heating demand. The extension of district heating and the increase of it's share in heat supply allows replacing ecological inefficient heating technologies. The economic feasibility of the extension and expansion and the operation of a local district heating network is a major issue. Hence the investment decision of a district heating company is influenced by the current and future installed capacity for heat generation, the trend of energy prices, as well as the development of the regional heat density. Apart from production and distribution, it's also necessary to consider the society's attitude toward heat supply by district heating. Without heating related investments like the investment in new heating systems of the building owners no increase in the share of district heating is possible.

The focus of this paper is to develop a methodological framework to answer the following research question:

"What are the impacts of heating related investment decisions in the building sector and the resulting decrease in the buildings' energy demand on the existing district heating network?"

The aim is to point out the future potential of district heating due to the development of the buildings heat demand and these investment decisions up to 2050. This potential is influenced by public interventions like subsidies, directives and legislatives on national and European level. The scope of this work is to illustrate the impacts of the variation in the subsidies for thermal refurbishments and investment subsidies for heating systems. The usage of an optimization model allows to determine possible future extension and expansion plans for district heating network from an economic point of view as the different model-based scenarios for the development of the heat demand are considered.

1.2 State of Art

This section outlines shortly the already existing models and methods to answer the formulated research questions or parts of it. There are some models which focus either on the development of the buildings' heat demand or on the optimization of the expansion of an existing district heating network. The model described in [Blesl 2002] analyses the expansion and extension in grid-bounded energy supply for low-temperature heat demand. The author formulates a time-discrete, mixed-integer optimization model to determine the optimal investment strategy in heat generation technologies, distribution and buildings' heating technology. The spatial information is displayed similar to a network flow model. The model uses different types of settlement to determine the costs of a change of the energy carrier and the required connection length to the existing grids. The types of settlement are determined by the urbanistic appearance of regions. This method is also used in various other works, like in [Neuffer and Witterhold 2001] or [Hausladen and Hamacher 2011], since interdependencies between the type of settlement and the heat supply exists, as shown in [Roth and Häubi 1980]. [Hensel 2013] compares three different optimization models to examine the expansion of the existing district heating network for each single street of houses, whereas the existing grid for gas supply is considered as well. This method provides results in reasonable time for parts of cities. These approaches are suitable for expansion planning of areas like districts of cities. Another approach is described in [Nielsen and Möller 2013], where the future potential for district heating in Denmark is considered. The methodology is based on the danish heat atlas with all the buildings and their heat demand. The economic feasibilty of a connection to the existing district heating network considers costs for heat generation, transmission and distribution costs. In addition, the model Invert/EE-Lab [Müller 2015] which is integrated in this approach focuses on the development of the buildings heat demand explicitly under consideration of the building owners decision behaviour in heating related investments. For detailed description see section 3.1 or [Müller 2015]. In contrast to the used methodological framework in this paper, the focus of the above mentioned works is either the detailed analysis of the development of the buildings heat demand or the economic expansion planning of gas and district heating grids.

2. METHODOLOGICAL FRAMEWORK

The methodological framework consists of two parts: The simulation-module for the future development of the buildings' heating demand of a city or a region considering the building owners heating related investment decisions. Additionally, an optimization-module for the determination of future investments in expansion and extension of the existing district heating network and the evaluation of the economic feasibility is used. An overview about the methodological framework is shown in figure 1.

The whole model uses two different data aggregation levels. The simulation model aggregates the buildings in segments by area of settlement, usage of building, building size, construction period, envelope quality and installed heating system. The usage of different types of areas of settlement, also used in [Blesl 2002], [Neuffer and Witterhold 2001] or [Hausladen and Hamacher 2011], allows to use different costs for the connection to the existing district heating network for buildings dependent on their location. For all segments the share of buildings, which invest in a change of their heating system and thermal refurbishments is determined. Since the model can not offer the information about the development of the heat demand and the according heat system for one single building, a regionalisation is conducted: All buildings are assigned to a building block and are grouped by areas of settlement, usage and construction period and the average development of the district heating related demand is assigned to these building. Section 2.2 describes the methodology in detail. This regionalisation is the input for the optimization-module.

2.1 The Development of the buildings' heating demand

For the simulation of the buildings' heating demand dependent on thermal refurbishments and investments in the buildings heating technology the existing techno-socio-economic bottom-up modelling tool Invert/EE-Lab is used (a detailed description of the model can be found in [Kranzl et al. 2013] or [Müller 2015]). The model

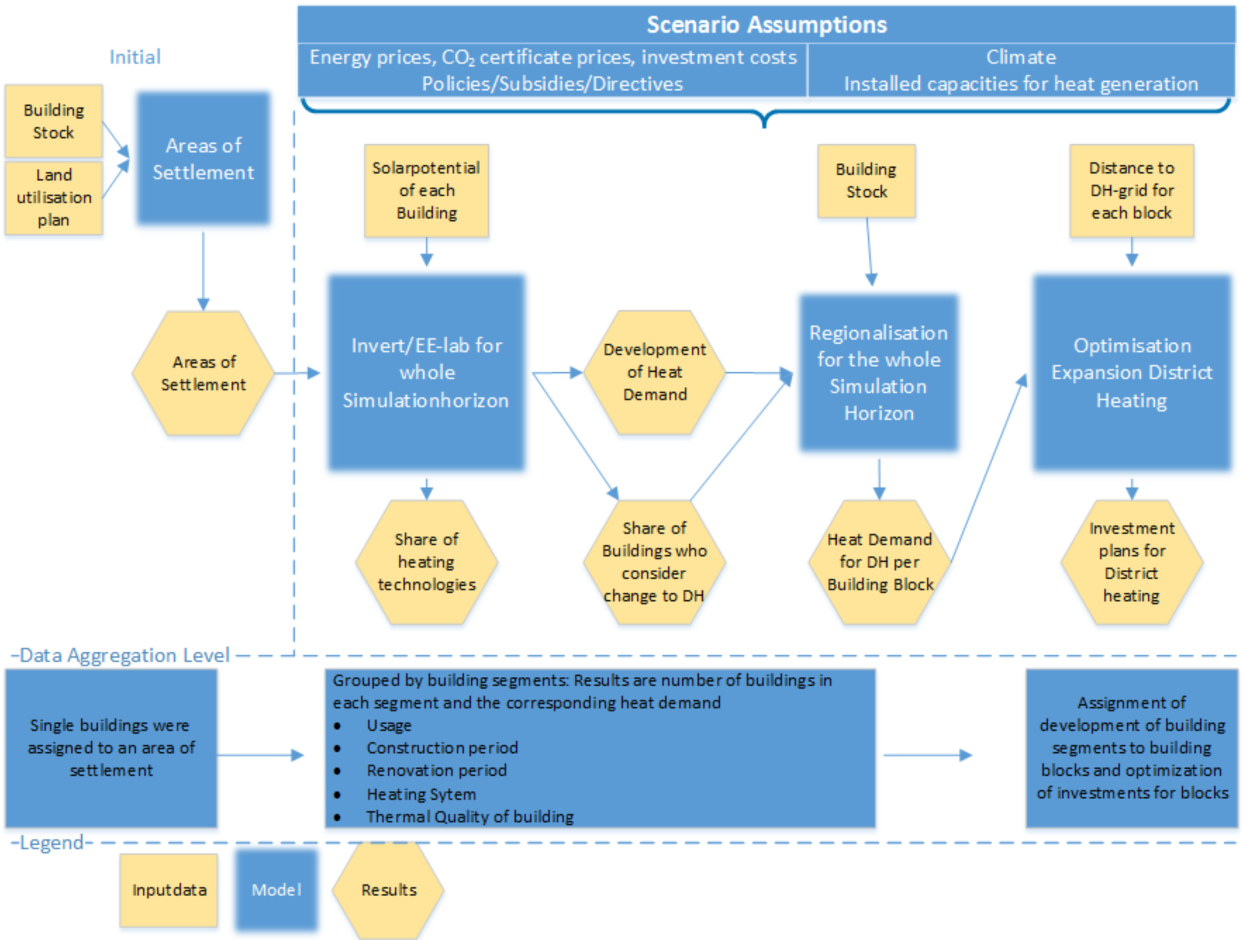

Fig. 1: Overview methodological framework

describes the future energy needs and final energy demand for space heating and -cooling (FED), as well as for domestic hot water based on an enhanced monthly energy balance approach. The consumers decisions for a specific heating system depends strongly on the costs of a technology which cover energy prices as well as connection costs for grid-bounded heating systems without existing connection. These cost based decisions are endogenous modelled with a nested logit approach. The buildings in the modelling tool Invert/EE-Lab are grouped as follows:

—building category: distinction in primary building types, like single family houses, apartment buildings, schools

—building classes: distinction i.a. in different construction periods, building geometry, building envelope and user profiles

—building segments: distinction i.a. in energy carrier regions, used heating systems or installation period of heating systems

Based on the characteristics, each georeferenced building is assigned to a specific building segment and thus to a building class and category. The assignment to a building segment requires the knowledge of the type of settlement the building is located. This information allows a classification in energy carrier regions, which

describe the current share of district heating and other existing heating systems in the region.
The outcome of the simulation-module is the share of buildings within each segment willing to connect to the existing heating network, the share of the other heating technologies and the development of the buildings heating demand. The economic optimization-module, described in 2.3, then is used to determine the actual newly connected buildings, respecting the heating demand, the demand-related costs for heat generation, the connection costs dependent on the distance to the existing network and the reinvestment costs.

2.2 Regionalisation

The regionalisation of the District heating related demand is necessary for an expansion planning of the existing grid to consider the location of the building and the distance to the grid as well as the available capacities of the grid. The District heating related heat demand is defined as the demand, which is already connected to the existing grid in the base year or the demand, where the owners consider a change to district heating and are willing to invest in district heating technologies. For the base year of the calculation the already connected buildings are determined, as well as the final energy demand for space heating and domestic hot water of these buildings. These calculations are conducted for groups, grouped by areas of settlement, usage and construction period. Furthermore the change in the final energy demand $FED - FED_{\text{previous}}$ is determined for all simulations years. This change is influence by efficiency measurements like thermal refurbishments and investments to replace an old heating system. Depending on whether the reduction due to refurbishments or the increase due to investments to connect to district heating technologies dominates, these change in the final energy demand has to be splitted to the building blocks.

—positive change: The possible new gross floor area for connection has to be split to the non-connected building $nbNonDH$ within this group. Therefore the ratio for each building (block) is calculated $\frac{FED-FED_{\text{previous}}}{nbNonDH_{\text{group}}}$

—negative change: If the owners decide to invest in another heating system, although they were connected to the district heating network or the reduction in the final energy consumptions dominates, it's necessary to subtract the resulting reduction dependent on the share of connected buildings. The required reduction is determined and the blocks in each group are weighted with their connected final energy demand. This reduction is then subtracted from each single building in this block and group.

As a result of the regionalisation the development of the district heating related demand, as well as the corresponding gross-floor area and heating load for all blocks over time are determined.

2.3 The Investment Optimization Model

The Optimization Model for investments in the existing district heating model is formulated as a mixed-integer optimization model. The dynamic model considers several investment periods with the objective to maximize the heating network operators' profit Π. The costs for the grid extension/expansion c_{Inv} and the costs for heat generation c_{g} are considered, as wells as the capital costs c_{cap} and operation costs c_{op}. The revenues R_{tot} respect the base price p_{base} dependent on the blocks heat load in MW and the demand charge p_{dc}, which arise from the heat demand in MWh. The objective function is formulated in (1), where r is the interest rate, T the considered horizon, P_b the connected heating load in MW of the building block and $D_{b,t}$ the heat demand in MWh per block.

$$\max_{x_{b,t}} \Pi = \sum_{t=1}^{T} \frac{R_{\text{tot},t} - c_{\text{tot},t}}{(1+r)^t}$$
$$R_{\text{tot},t} = \sum_{b \in B} (p_{\text{base},t} + p_{dc,t}\, D_{b,t} + p_{base,t}\, P_b)\, x_{b,t}$$
$$c_{\text{tot},t} = c_{\text{cap},t} + c_{\text{op},t} + c_{\text{Inv},t} + \sum_{m=1}^{12} c_{\text{g},m,t} \tag{1}$$

Due to cost variations within the year for the heat generation costs c_{g}, these costs are calculated on monthly base. The decision, whether a block is connected to the district heating network or not is formulated as a binary variable $x_{b,t}$, see (2). This binary variable also indicates blocks, which are already connected to the existing heating network.

$$x_{b,t} = \begin{cases} 1, & \text{if block } b \text{ is connected in period } t \\ 0, & \text{else} \end{cases} \tag{2}$$

A block either can be connected in one of the simulation years except it's already connected in the base year. In this case the block remains connected as long as the blocks demand district heat A connection is possible, if the new heat demand for the connection of district heating is greater than zero. Opposite, if the heat demand of a connected building is lower or equal zero, the building has to be disconnected in this simulation year. So the according constraints for the development of the connected heat demand for all blocks b are stated in the equations (3)-(6), where the prefix In indicates Input variables from the simulation-module and the prefix var stands for decision variables.

$$var.D(b,t) \geq 0 \quad \forall b, t \tag{3}$$
$$var.D(b,t) \geq var.D(b,t-1) + In.D_{neu}(b,t)\, var.x(b,t-1) \quad \forall b, t > 1 \tag{4}$$
$$var.D(b,t) \leq var.D(b,t-1) + In.D_{neu}(b,t)\, var.x(b,t) \quad \forall b, t > 1 \tag{5}$$
$$var.D(b,1) = In.D_{ang}\, var.x(b,1) + In.D_{neu}(b,1)\, var.x(b,1) \quad \forall b, t = 1 \tag{6}$$

As mentioned, the heat generation costs are computed on monthly base. The installed capacities for heat production $cap_{s,m,t}$ are defined and the required heat $Q_{s,m,t}$ is assigned to the available sites S, see (7). The required heat arise from the monthly heat demand $D_{b,m,t}$ of the already connected and actual newly connected blocks b and considers the heat losses $l_{b,m,t}$, as stated in (8). The demand-related costs c_{g} are determined with the monthly energy prices $c_{\text{fuel}_{s,m,t}}$ related to the sites, see (9).

$$Q_{s,m,t} \leq cap_{s,m,t}, \quad \forall s \in S, \forall m \in M, \forall t \tag{7}$$
$$\sum_{s \in S} Q_{s,m,t} \geq \sum_{b \in B_{DH}} D_{b,m,t} * x_{b,m,t} * l_{b,m,t}, \quad \forall m \in M, t \in T \tag{8}$$
$$c_{\text{g},t} = \sum_{s \in S} \sum_{m \in M} c_{\text{fuel}_{s,m,t}} * Q_{s,m,t}, \quad \forall t \in T \tag{9}$$

2.3.1 Economic Evaluation. The economic evaluation is conducted by calculating the Net Present Values of the future Cash Flow. As the model considers changes in the buildings' heat demand over the time as well as changes in the costs for heat generation, the given period T consists of two parts, the investment period T_{Inv} and the payback period T_a. The investment period T_{Inv} consists of pre-defined time-steps, where investments in the extension/expansion of the heating work are allowed. In the payback period T_{a} the investments have to be recovered and no new buildings are connected. The Cash Flows in this period consist of the revenues and the costs for operation and demand whereas the future heat demand and the change in the heat demand is given by the simulation-module. The optimization-model determines the buildings, which are profitable to be connected to the existing district heating network in the Investment period T_{Inv}. Hence the objective function can be reformulated:

$$\max \Pi = \sum_{t=1}^{T_{\text{Inv}}} \frac{p_{\text{tot},t} - c_{\text{tot},t}}{(1+r)^t} + \sum_{t=T_{\text{Inv}}+1}^{T_{\text{a}}} \frac{p_{\text{tot},t} - c_{\text{op},t} - c_{\text{g},t}}{(1+r)^t} \tag{10}$$

The yearly newly investments are restricted with a maximum amount, as depicted in

$$var.cInvNeu_t \leq In.maxInvestments_t, \qquad \forall t \tag{11}$$

In the current version, the district heating price for consumers, the base price $p_{base,t}$ and the demand charge $p_{dc,t}$ is exogeneously given.

3. APPLICATION AND CASE STUDY

The case study is conducted for Vienna with a time horizon up to 2050. This means, that the development of the buildings' energy demand is simulated up to 2050, due to an 15-year amortisation horizon investments in the extension of the district heating network are possible up to 2035. The step size of the investment optimization model are 5 years, starting with 2015. The focus of the analysis of all scenarios is on the actual building stock. New buildings due to the increase in population are neglected. However, buildings newly constructed due to demolition are included in the case study

3.1 Data Description and pre-analysis/modification

The main databases for the model is the "Heat registry of Vienna"(Wiener Wärmekataster, called WWK in the following), provided by the Viennese municipal departmen 39, (Wiener Magistratsabteilung 39), and the data provided by the Statistik Austria regarding the building stock and the used heating systems ([Statistik Austria 2004], [Statistik Austria 2009]). In WWK, a table data set, Vienna's buildings are displayed with further information about their construction year, actual calculated energy demand with focus on demand for space heating, and its geometry like total gross floor area, ground area, number of floors, etc... The base year of the WWK is the year 2008, whereas the data are calibrated to the year 2013 with the data from Statistik Austria.

All the analysis in this thesis are conducted with the following changes in the WWK:

—Filter of buildings, which are categorized as 'other buildings'. These buildings do not come with space heating

—Correction of obvious data errors (e.g. number of floors is zero)

—Calculate the proper ground area (Area of the basement ceiling in the WWK) for each single building. Some attached buildings are grouped together for the heat demand calculations. This is necessary to receive the geometry of each single building, because the grouped buildings can differ in their usage. In this case, the conditioned gross floor area of each single building, and the cumulative gross floor area of all attached buildings is given. The conditioned gross floor area is defined as the area, which is thermal conditioned and which is enclosed by the gross volume (for detailed description see [Pöhn 2012]). The segmenting of the basement ceiling requires to know the share of each single building of the whole basement ceiling. With the presumption, that the proportion of the individual conditioned gross floor area is the same as the proportion of the basement ceiling and that the gross floor area for each floor is the same, the gross floor area per floor of each building is calculated and the share of the cumulative gross floor area per floor is determined.

—Calculate the additional required geometrical information (length, width of building). The WWK contains besides the area of the basement ceiling information about the ceiling's perimeter. If multiple buildings are combined, the length and width of all buildings are calculated, as mentioned. The division is conducted as mentioned above.

Additional the buildings are classified by their usage (single family houses, small/large apartment buildings, small/large offices, offices in apartment buildings).

Based on the information about the building stock in year 2001 and 2011 ([Statistik Austria 2007] and [Statistik Austria 2013]) the share of buildings for each usage is interpolated for the year 2008. Since the WWK doesn't distinguish the different sizes of residential buildings, a classification in single family houses, small or large apartment buildings and offices in buildings is done.

Detailed information about the number of buildings in each of these classifications per registration district is just available for the year 2001, for the year 2011 the information is just available for districts. It's assumed, that the ratio from 2001 to 2008 is the same within all registration district of one district in Vienna. In addition the residential buildings are sorted by it's size to be able to determine the share of each usage, which is specified by the data of Statistik Austria.

To distinct the costs for the connection of the buildings to the existing district heating network, the method of areas of settlement is introduced (see e.g. [Blesl 2002], [Blesl 2002]). Therefore the registration district in Vienna are classified in the following areas of settlement, displayed in table I, whereas the classification except for settlement type ST 12 is adopted from [Blesl 2002]. Based on the classification in [Blesl 2002], an analysis of the number of houses per usage (single family house, apartment buildings, etc.), the average ground floor of the houses, average number of floors, ratio between built area and usable area in the registration district is conducted and each registration district is assigned to one area of settlement.

Table I. : Areas of settlement

Name	Description	Number of registration districts
ST 1	low housing density, primary single family houses	4
ST 2	settlements with single family houses	71
ST 3	old center of village, higher housing density than in ST 2	30
ST 4	serial houses	1
ST 5a	settlement with small apartment buildings	28
ST 5b	settlement with small and medium apartment buildings	23
ST 6	settlement with large and high apartment buildings	15
ST 7a	settlement with low buildings blocks density	6
ST 7b	settlement with high buildings blocks density	29
ST 9	history city centre	7
ST 10a	public special buildings	not whole registration districts, just single buildings in each district
ST 12	settlement of small garden plots	14

With this classification and the cost data from [Lutsch et al. 2004], p. 99 and p. 159, the average connection costs for buildings within different settlement areas can be used for the simulation of the buildings heat demand and the investment decisions in heating systems.

3.2 Development of the heat demand and Regionalisation

As mentioned in chapter 2.1, the model Invert/EE-Lab is used for the simulation of the development of the buildings heat demand. The main parameters are taken from the project [Kranzl et al. 2014], where the development of the Austrian heat demand was analysed. The model is parametrised with the building stock data described in 3.1. In addition, the different areas of settlements are introduced, the single buildings assigned to the appropriate settlement type and the costs for the house connection within the different areas of settlement are used (taken from [Lutsch et al. 2004]). The simulation models Invert/EE-lab simulates the building owners decision behaviour, which is mainly influenced on the long run marginal costs. These costs include the consumption dependent, the consumption independent annual costs and the levelized investment costs (detailed description in [Müller 2015]). The actual economic reasonable buildings for the connection to the existing district heating model are determined with the investment optimization model (see also 2.3 or 3.3)

The analysis of the effects for different policy frameworks on the development of the buildings heat demand for district heating and the resulting economic feasibility of the district heating network is based on two different scenarios. The scenarios in [Müller 2015], based on those in [Müller and Kranzl 2013] are adapted for this analysis for the building stock in Vienna. It's important to mention, that these scenarios just cover some implemented and contemplated measures and don't describe the actual subisidies and policies in detail, especially not for Vienna. The focus on this paper is to analyse the effects of different measures on the economic of district heating and demonstrate the methodological framework. For detailed description of Scenario 1 and Scenario 2, see [Müller and Kranzl 2013].

—Scenario 1 - WEM (With existing measures): This scenario framework considers the adapted policy framework conditions which where implemented in spring 2012.

—Scenario 2 - WAM (with additional measures): This scenario framework deals with the policy measures which are considered to be implemented in Austria.

Both Scenarios, Scenario 1 and 2 consider investment subsidies for heating systems and for building refurbishment. In contrast to Scenario 1, in Scenario 2 higher financial budgets for refurbishments are assumed, as well as higher refurbishment standards after 2020.

Based on the number of buildings already connected to the existing district heating network in 2013, the buildings, where the building owners consider a change to district heating for the different scenarios are displayed in figure 2. In addition the development of the final energy demand for space heating and domestic hot (FED)[1], which can be supplied by district heating, is shown. Although there is an increase in the number of buildings willing to connect to district heating, the final energy demand decreases after an initial increase up to 2030. This is the result of the building owners investments in thermal refurbishments, the resulting decrease in the specific heat demand of the buildings and the fact, that the number of buildings who consider a change increases less rapidly. Due to the additional buildings, which can be connected, the decrease in the final energy demand for district heating is lower than the decrease for all energy carriers after 2030. This is displayed in figure 3. The results show, that the trend in number of buildings and final energy demand is the same for both scenarios, the WEM and WAM scenario. This can be explained with the definition of the scenarios, which just differs in the quality of the thermal refurbishments and the amount of the investment subsidies.

The following example should point out the regionalisation, which is calculated for all building blocks in Vienna. Assuming a building block consisting of 10 apartment buildings, built in 1944, 3 apartment buildings

[1] In the following if final energy demand is mentioned the demand for space heating and domestic hot water is meant

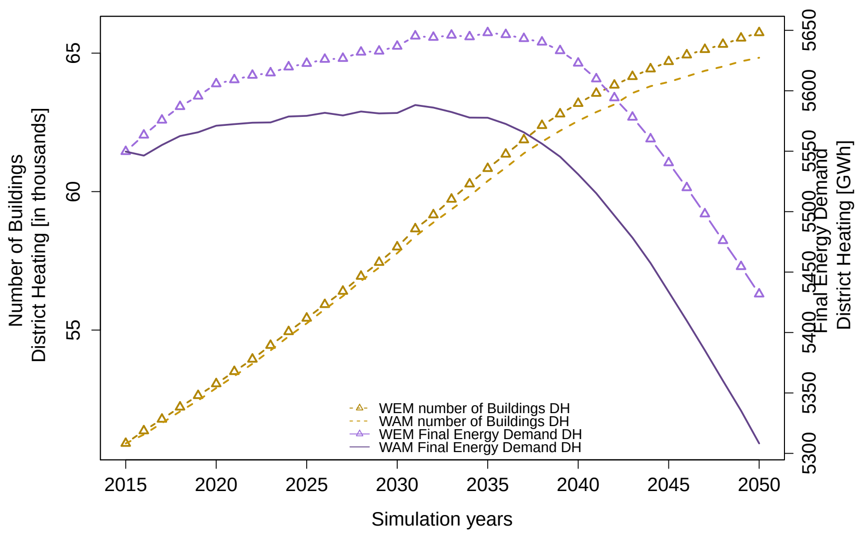

Fig. 2: Results of simulation model: comparison number of buildings willing to connect and development of final energy demand for district heating

built in 1918 and one office building built in 1998. 9 of the apartment buildings are connected to the existing district heating network with an initial final energy heat demand in the year 2015 about 1970 MWh.

Table II. : Regionalisation: demonstrating example

Simulation Year	WEM: Increase/Decrease [MWh]	WAM: Increase/Decrease FED [MWh]
2020	16.49	10.17
2025	15.04	2.39
2030	-7.38	-7.1
2035	-17.31	-65.45
2050	-346.15	-493.09

In Table II the change in the final energy demand for district heating for the different scenarios is displayed. These changes are influenced by the renovation rates for office and apartment buildings as well as the number of building owners, willing to connect to district heating.

3.3 Investment Optimization

The following general assumptions, displayed in Table III for the investment optimization model are made.

Table III. : General Assumptions

interest rate	6 % per year	yearly price increase	2 % per year
Amortisation Horizon	15 years	Demand price customer	49.18 €/MWh
Biomass fuel	30 €/MWh	base price customer	69 437 €/MW
Gas price	22 €/MWh	CO_2-Emission factors taken from	[Büchele 2013]
Electricity	32.91 €/MWh	CO_2-Emission costs	5.75 €/t

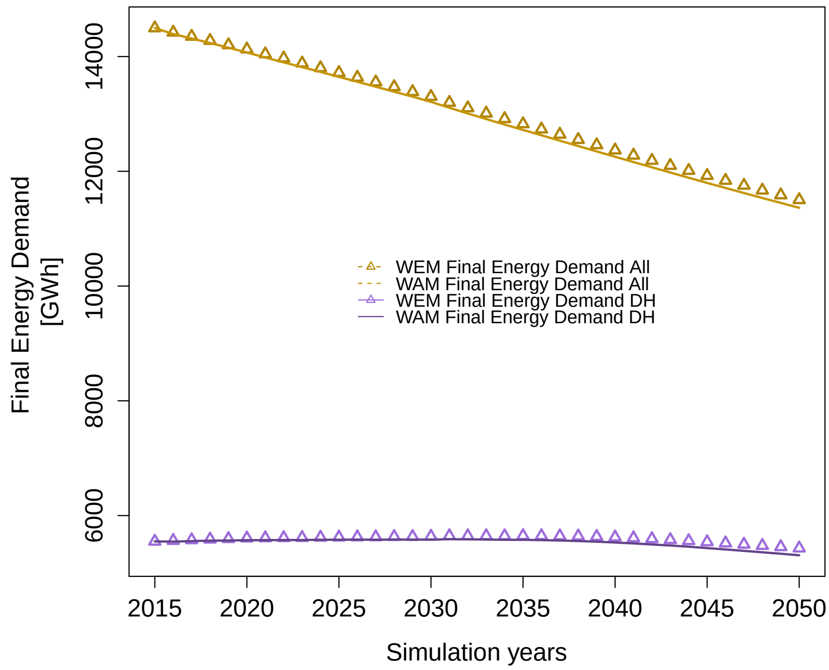

Fig. 3: Results of simulation model: development of final energy demand for district heating and development of final energy demand all energy carriers

It's assumed, that the installed capacity will be the same as in the base year 2013, that means 242 MW installed capacity for incineration plants, 37 MW for a biomass CHP, 173 MW waste heat from industry, 1370 MW heat from fossil fuel power generation and 1464 MW from fossil fuel sites. The cost allocation of fuel costs and CO_2-emissions to heat and power in CHP plants is done with the market based method, see [Holmberg et al. 2012], p.617. .

In the present work, the investment costs and capital costs are combined as distribution capital costs c_{dcap}. Based on [Persson and Werner 2011] the distribution capital costs are formulated as shown in (12), where C_1 indicates the construction cost constant in €/m, C_2 is the construction cost coefficient in €/m^2, d_a the average pipe diameter in m and L the total trench length in m.

$$c_{dcap} = (C_1 + C_2 * d_a) * L \tag{12}$$

It is necessary to group the building blocks b by their energy carrier region, because the cost coefficients C_1 and C_2 differs dependent on the plot ratio and the pipe diameter d_a differs dependent on the heat transfer in the sections of the heating network. The total trench length L is derived by summation of the individual buildings connection length l_b, see (13). Since every building is assigned to a specific energy carrier region the average connection length for the energy carrier region can be used[2].

$$L = \sum_{b \in B} x_{b,t} * l_b \tag{13}$$

3.4 Results

This exemplary Case Study for Vienna should show, how the methodological framework can be used to derived results and conclusions for the development of the future district heating network and the economic feasibility of this. The main differences in the two scenarios are in the development of the buildings heat demand as described in section 3.2. Thus, the development of the final energy demand actually supplied by district heating has the same trend for both scenarios. In figure 4 the trend for different settlement types is shown for the WEM scenario. There is no difference in the trend for the settlement types, since the subsidies in the scenarios concern all building categories. In comparison to the results from the simulation module, the increase for the demand supplied by district heating is lower, see figure 2, although the same trend with an initial increase up to 2030 and a decrease afterwards can be seen. This is explained by the low energy demand of the buildings in comparison to the distance to the existing district heating network, where the owners are willing to connect.

Since the focus of the analysis is on the existing building stock and newly built areas are excluded from the analysis, there is no real expansion of the district heating network, the main reason for the initial increase in the demand supplied by district heating is due to the extension of the network. The extensions is the additional connection of buildings within blocks already connected to the network. This also results in no difference in the trend within the settlement types. In the current work it's assumed that this buildings can be connected without any additional costs for the network operator, because the building owners pay for the house connection. The efficency scenario WAM has 14 % less newly connected building blocks in comparison to the WEM-scenario.

Concluding, the Net Present Value, the main indicator for this analysis, worsen for the WAM scenario by 4 % in comparison to the WEM scenario.

4. CONCLUSIONS AND PROSPECTS

This exemplary case study should demonstrate the model framework for the integrated analysis of the development of the buildings heat demand, the energy carrier choice of the building owners to supply this demand and the resulting consequences for the existing district heating network.

It could be shown, that the decrease in the buildings heat demand worsen the economic feasibility of the district heating network, although the number of buildings, which are willing to invest in the connection to district heating increases. Since the district heating network in Vienna's city center has already a high rate of connected building blocks, less new blocks are connected. This can be explained by the distance of these blocks to the existing network and the associated costs for connection.

One main reason for the little expansion in this Case Study is the exclusion of development areas and the already high share of district heating in Vienna (share of district heating in final energy consumption: 40.6 % in 2014 (Source: [Statistik Austria 2014])).

[2]The distance of each single building to the existing district heating network is provided by Wien Energie

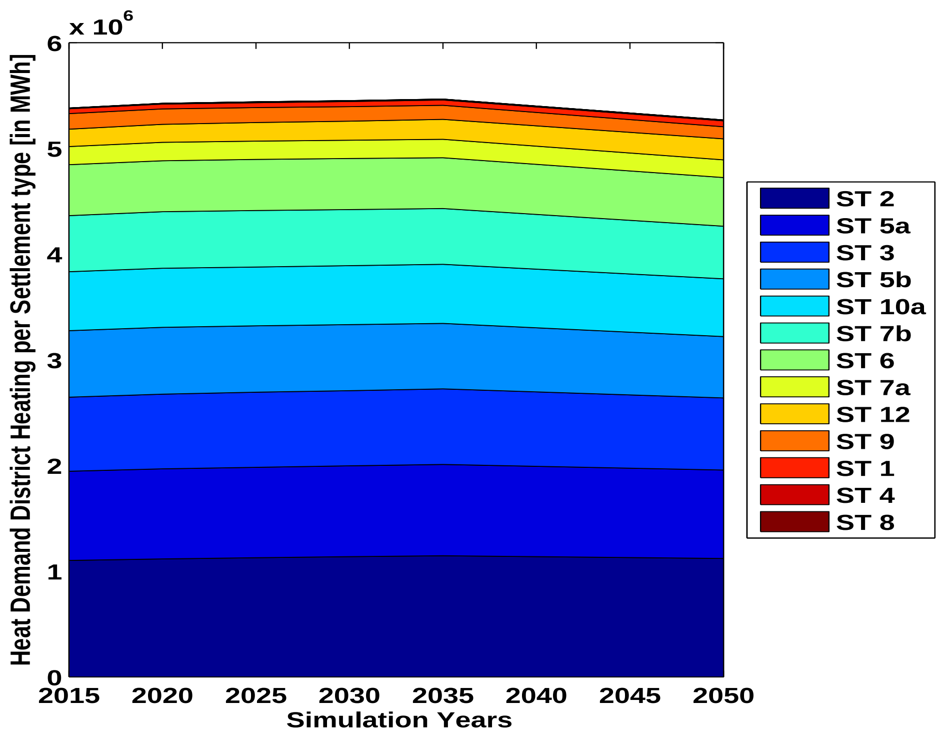

Fig. 4: Results of Optimization model: development of final energy demand actually supplied by district heating for different settlement types

For an established analysis and to deduce reasonable future developments, it's necessary to extend this analysis. This should include a detailed description of the possible future policy frameworks within different scenarios for the city of Vienna, variation in the assumptions for this scenarios and the introduction of indicators to evaluate these scenarios. One possible indicator could be the CO_2 emissions for the supply of the heat demand for the whole city. Therefore it's necessary to include the actual and future installed sites for heat generation.

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