# Evaluating and implementing policies on regional level to ensure renewable heating and district heating in Eastern European countries - The case of Brasov

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## ABSTRACT

In many Eastern European cities district heating systems are in place that could contribute to a $CO_2$ emission reduction which is required to reach the climate protection goals. However, many of these systems face huge problems due to historic reasons and the lack of investments in the past decades leading to now inefficient and outdated networks. Therefore in this paper we want to assess which policies are required and suitable to reduce $CO_2$ emissions and improve the economic performance of especially the district heating supply structure for the case of Braşov. To deal with this question we carry out two key activities which were performed within the Horizon 2020 project progRESsHEAT:

(1) Conduct a broad policy implementation process including a wide stakeholder discussion process where different policy measures, their implementation, findings concerning barriers and drivers, best practice examples and recommendations for a local heating and cooling strategy are discussed.

(2) Implement a policy evaluation process where a modelling framework is implemented and applied to calculate the least cost combination of heat savings and different heat supply options to quantitatively analyze the contribution of different policies to increase the share of renewable heating and especially renewable district heating

The results show that the assessed single policies are hardly able to generate a favorable policy framework but the combination of different single policies to a policy packages can lead to good results regarding $CO_2$ emission reduction and share of renewables without overstressing one single measure.

### Introduction

To reach the climate goals agreed on at the 2015's COP 21 meeting held in Paris it is essential to decarbonize the heating sector. Especially in urban areas district heating (DH) is an important decarbonization option because it is often the only feasible option to integrate large shares of renewable or excess heat into the heating sector (Conolly et al. 2014; Werner 2013, 2017). In many Eastern European cities DH systems already exist, however, at the moment not providing efficient and renewable heat supply. These systems typically were installed in the communist era, without relevant re-investments since that time. Therefore they often still have installed old supply technologies and are based on fossil fuels. High losses due to overdimensioned and old infrastructure and outdated technology make these DH systems economically unfeasible and lead to unreliable supply. At the same time in many areas where DH networks are in place also a gas grid was installed. This led to disconnection of many district heating

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customers, further increasing the inefficiency of the DH systems counteracting the climate protection goals (Poputoaia and Bouzarovski 2010; Iacobescu and Badescu 2011).

Identifying DH as an important means to reduce $CO_2$ emissions especially in urban areas, policy frameworks should be adapted to allow the transformation of these outdated DH systems to economically and ecologically feasible systems which can contribute to a $CO_2$ emission reduction. Therefore assessments are needed to evaluate the effect of different policies on the feasibility of renewable heating and district heating.

So far only few assessments have been published on renewable heating policies in general. E.g. Kranzl et al. (2013) question how various policy instruments could impact the development of renewable heating technologies, Steinbach et al. (2013) analyze different levels of policy harmonization for target compliance and the economics of renewable heating and cooling and Connor et al. (2015) consider the evolutionary process which led to the UK's Renewable Heat Incentive along with the need to consider other elements to work with it.

Even less and very recent articles try to assess the political framework and its influence on the feasibility of district heating systems: E.g. Nuorkivi (2016) discusses district heating and cooling policies for major regions worldwide. Sandberg, Møller Sneum, and Trømborg (2018) compare historical, economic, jurisdictional, political and geographical framework conditions for DH and assess their impacts on the development of DH in the Nordic region. Møller Sneum et al. (2018) analyzes the impacts of taxes, subsidies, and electricity transmission and distribution tariffs and heat storage on the operation and economic feasibility of district heating plants with different flexibility potentials in the Baltic countries. Poputoaia and Bouzarovski (2010) give very interesting additional insights to the work presented here by exploring the legal aspects of post-communist DH reforms in Romania, with the aim of identifying some of the governance challenges faced by state authorities in managing the sector.

In this paper we want to assess which policies are required and suitable to reduce $CO_2$ emissions and improve the economic performance of the heat supply structure for the case of Braşov, a city with around 275 thousand inhabitants and 1760 inhabitants per $km^2$ on average located in the center of Romania with around 3400 heating degree days. To deal with the research questions, we carry out two key activities which can be grouped into a broad policy implementation and an accompanying policy evaluation process both described in detail in the method chapter. All work was performed within the Horizon 2020 project progRESsHEAT and a previous version of this article with less information and not presenting the implementation process was published in Büchele, Kranzl, and Hummel (2018).

## Methods

The two key activities to deal with the research question are not independent of each other and are performed in order to provide a model based *ex-ante* assessment of policy interventions in scenarios up to 2030 together with the authorities and give a quantitative basis for a strategy and policy development with an overall system integrated long-term perspective. The two key activities are:

- A broad policy implementation process including a wide stakeholder discussion process where different policy measures, their implementation, findings concerning barriers and drivers, best practice examples and recommendations for a local heating and cooling strategy are discussed.
- A policy evaluation process where a modelling framework is implemented and applied to calculate the least cost combination of heat savings and different heat supply options to quantitatively analyze the contribution of the different policies to increase the share of renewable heating and especially renewable district heating.

Focus of all the activities presented in this work is on the local and regional level although the whole process also included national level activities which were taken into account into the different steps of the process to consider policy intervention by local, regional and national authorities affecting the local level.

Figure 1 shows the different steps of these key activities including the iterations between the implementation and the evaluation process especially after the first modelling results and the draft strategy based on the evaluation results are available after the first part of the stakeholder discussion, and results and recommendations get further improved for the second part of the stakeholder discussion process.

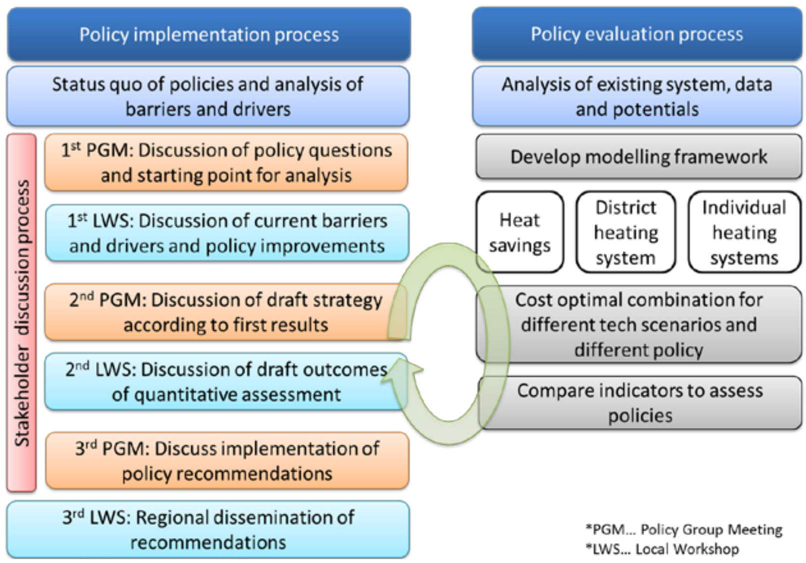


Figure 1. Scheme of performed policy implementation and evaluation process. *Source:* authors. PGM: policy group meeting, LWS: local workshop.

### Policy implementation process

The policy implementation process is mainly a stakeholder discussion process on different levels and is a continuous activity which has to be monitored, assessed and updated permanently to support the local policy makers in the development of local heating and cooling strategies. The objective of the whole process is to develop policies and improved policy packages to be quantitatively assessed within the policy evaluation process and to be integrated as recommendations into a strategy document. The policies and policy packages are developed in close discussion with the policy makers and other relevant stakeholders to assure that particular user needs are considered. Relevant stakeholders, like policy makers, local authorities responsible for urban and energy planning, energy supply companies, industrial demand representatives etc., are included in the different steps in order to allow for the development of strategies with high probability of implementation. The policies developed during this process which are feasible on local level may be implemented directly by the responsible local authorities, whereas the implementation of national or EU level policies needs further steps and cannot be realized during the policy implementation process presented here. To allow this process, the local "Agency for Energy Management and Environmental Protection Braşov" (ABMEE) had a key role establishing contact with the local policy makers and to keep in touch with them throughout the entire policy implementation process, to assure that the developed strategies follow the user needs and will be implemented in the end.

The stakeholder process itself was divided into local policy group meetings (PGM) and local workshops (LWS) with different objectives each, which will be described in the following subsections. The policy implementation process included the assessment of the status quo and current barriers and drivers prior to the stakeholder process. This assessment was important in order to understand the mechanisms of implementing renewable heating and cooling (RES-H/C) policies by:

- Giving an overview of existing RES-H/C policies and related regulations.
- Describing existing barriers for using and implementing renewable technologies.
- Identifying ways to minimize and overcome these barriers.
- Identifying success factors for using and implementing RES-H/C.

**Policy group meetings**

The policy group meetings involved a small group of policy makers responsible for policy development and implementation at the different regional levels, and therefore provided a platform to discuss intensively in detail. Policy makers were defined as high level persons from the public administration or energy agencies with corresponding impact on policy making processes, and at the same time with sufficient experience and know-how regarding technical, economic and energy system aspects. Three policy group meetings were held along the whole stakeholder discussion process:

- The first policy group meeting took place in the beginning of the stakeholder process to gather relevant policy questions and set the starting point for both the policy implementation but also the evaluation process by giving inputs on scenarios that should be evaluated. The involved stakeholder included two deputy mayors of the Braşov municipality, the coordinator of the private sector office, an engineer from the local district heating supplier and two members including the executive director of ABMEE. As the most important points, the potential for renewable energy sources that would optimize the current district heating, the future role of the highly efficient cogeneration, the relevance of heat savings and individual supply options as well as the scenarios and policies presented in the results section were gathered from this meeting.
- The second policy group meeting took place when first results of the evaluation of the policies and scenarios discussed in the first policy group meeting were available. The involved stakeholder included the deputy mayor of Braşov municipality, the director of the local public service for district heating in Braşov newly founded during the policy implementation process, the operations director of the main district heat production utility, a market analyst from the Transformer Energy Supply S.R.L and two members including the executive director of ABMEE. This meeting contributed directly to the development of the draft strategy document by discussing the proposed policies and their effects received from first modelling results.
- The third policy group meeting took place after the final results of the policy assessment were available, and was used to discuss the possibilities of implementation of the policy recommendations. Some of the proposed and assessed policies like the long term loan policy the DH connection subsidy and the RES-DH subsidy could be at least partially implemented by the different local authorities during the policy implementation process. The $CO_2$ tax policy was seen as a very important means for a future decarbonization but an implementation is only possible at national or EU level and regional authorities can only support this claim. Also the zoning was seen as a very helpful and important policy, but this can only be implemented stepwise in the long term by first defining the different zones and then adding the specific rules to the zones.

**Local workshops**

Additionally to the policy group meetings local workshops were carried out. This was on the one hand to discuss the strategy development with a broader stakeholder group than in the policy groups, and on the other hand to share experiences with other municipalities. These workshops in the municipality included around 30 to 50 participants each to support the local policy process by bringing together key actors and stakeholders from the different field of RES-H/C, like policy makers, industry associations, large-scale building owners, craftsmen, etc. This should guarantee that the knowledge acquired will be spread to support the implementation of RES H/C technologies. Two workshops were held within the policy implementation process and a third workshop was held as a dissemination workshop after the stakeholder discussion process had ended:

- The first local workshop was held after relevant policy questions and scenarios had been gathered in the first policy group meeting, to discuss findings concerning barriers and drivers of the different technical scenarios, and to discuss first recommendations for policy improvements. The workshop addressed the current state of policies, barriers and drivers and best practice examples from other case studies, and aimed at reflecting and discussing findings on barriers and drivers and development of ideas for improved and new policy packages. The workshop involved 32 participants including 15 representatives from different departments of eleven municipalities, seven representatives from four different district heating utilities, but also representatives from the Romanian National Authority for Energy Regulation, the Romanian Green Buildings Company, the Romanian Water Administration and the national coordinator of the Stratego[2] project and the head of the Covenant of Mayors office. Regarding technology scenarios for the district heating system, the main outcomes of this workshop were that geothermal heat pumps using the aquifer resources of Braşov should have a major role in a future scenario, that also biomass coming mainly from the near forests should be considered but only with very limited potential, that there is not sufficient excess heat at relevant temperature level because bigger industries closed down after the communist era, and that waste incineration would be an interesting option but will not be enforceable in the near to mid-term. For geothermal heat pumps no authorization from the National Authority for Mineral Resources but only from the National Administration of the Romanian Waters is necessary being only a minor barrier. This was the case in the example of Măgurele, where drilling to 200 m was performed without any impediments from the National Authority for Mineral Resources. Regarding the use of biomass, the attending specialists suggested further investigation regarding the existence of biomass resources in Braşov, estimating the potential of wood resulting just from the cleaning of the forests and green spaces in Braşov to about 10 GWh/year. Although it might be a barrier to find a site for a bigger biomass plant, at least a smaller plant should be considered in the scenarios. Concerning waste, there is currently not enough information on the quality of waste and how it could be used as a RES potential for DH. All in all the future district heating system should use at least 50% renewable energy or 75% from high efficient cogeneration.
- The second workshop was held after the second policy group meeting and dealt with the draft outcomes of the quantitative assessment concerning barriers and drivers. Also success factors for RES-H/C technologies were discussed and presented in the second workshop. This workshop involved 53 participants including 31 representatives from different departments of 19 municipalities, the director of the Association of Romanian Energy Service Companies, the vice-president of the Romanian Geoexchange Society, the councilor of the Ministry of Regional Development, Public Administration and European Funding etc. As a major barrier, the old district heating infrastructure with high losses and the resulting outages leads to disconnection and further economic inefficiencies. This was described as a vicious circle for old DH systems where unhappy clients disconnect due to low quality of supply (outages and unsteady supply) which leads to lower income of the utilities which then leads to higher specific costs per apartment or further decrease in service quality which then again leads to more unhappy clients. On the other hand it turned out that some initiatives providing (smart) energy meters to the clients were

[2] http://stratego-project.eu/

fruitful, allowing the clients to decide when and how much heat they need and to see the relation between consumption and costs.

- The third workshop was not part of the stakeholder discussion process itself but was intended to disseminate policy-recommendations, "lessons learned" and best practice examples to the municipalities which already participated in the previous workshops. Also in this workshop the different departments of the municipalities and regional energy agencies were directly integrated and supported with their experiences in the realization of regional and local policy programs and further disseminated the results through their broad networks.

**Ex-ante policy evaluation process**

To make an ex-ante evaluation of the policies discussed and developed during the policy implementation process, a model based policy assessment framework was developed. Prior to the modelling, information and data on current status of heat demand and supply situation as well as resource potentials for alternative supply were collected. This information was used to implement a model of the current system and to discuss and develop a reference and a desirable alternative technical scenario for the district heating system during the first phase of the policy implementation process. The modelling framework was developed to find the least cost combination of heat savings with either district heating or individual heating for different building groups located in different areas of the municipality, according to their location to a current district heating network for the different technical and policy scenarios discussed in the policy implementation process. The tools and approaches used in the different steps are explained in the following:

**1st Step: Calculation of heat saving potentials and costs**

The costs and potentials for implementing heat savings in buildings of the city until 2030 were calculated using the techno-economic bottom-up model Invert/EE-Lab (Müller 2015; Kranzl et al. 2013).

To do so the current building stock of Braşov, available from a building register, was classified into ten typical building types (small and big SFH, small and big MFH, private offices, public offices, Schools, Wholesale and Retail, Hotel and Restaurants, Health) with three different construction periods[3] (<1945, 1945-1994, >1994). For each of these building classes the necessary investment costs and the resulting reduction in heat demand for ten different renovation levels[4] – including maintenance only (without thermal improvement) – are calculated. Out of the necessary additional investment costs (compared to maintenance only) and the achievable heat demand savings of the different renovation levels, costs per saved kWh are calculated which than can be directly compared to heat supply costs of different technologies. To consider only the share of buildings that will undergo a renovation until 2030 the achievable renovation rate was calculated within the Invert/EE-Lab model resulting in less than 20% of residential buildings and around one third of non-residential buildings renovated within this period.

[3] The definition of the construction periods was done according to time periods with similar specific heat demand

[4] The definition of the renovation levels are based on the current building codes in Romania. The levels were set to (1.9, 1.75, 1.6, 1.45, 1.3, 1.15, 1, 0.85, 0.7) times the transmission coefficient resulting from the current building codes. This means that the worst renovation level achieves a transmission coefficient of 1.9 times the coefficient resulting from the current building codes and the best renovation achieves a 30% lower transmission coefficient then foreseen in the building codes. Six renovation levels achieve transmission coefficients worse than the current building codes and three levels are equal or better than the current building codes in Romania. Additionally the costs of maintenance work without improvement of the thermal quality were calculated and used as reference.

**2nd Step: Geographical zoning of the municipality**

In this step, the municipality was divided into four different types of areas according to the proximity to the existing DH distribution network, resulting in different costs of connecting buildings to the DH system:

- The so-called "DH area" is the area of the currently existing distribution network including the zone of 50 m distance to this network. In this area, it is assumed that additional buildings can be connected to DH without further expansion of network, but by investing only in connecting pipes and heat exchangers.
- The so called "next-to-DH area" is the area within 1 000 m of the current transport network that is not within the "DH area". In this area it is assumed that further buildings can be connected by investing in an additional distribution network plus connecting pipes and heat exchangers.
- The "individual area" is defined as the area outside the "next-to-DH areas" that is not sharing a border with the existing DH area. For buildings located in these areas, it is necessary to invest in transmission pipes, distribution pipes, connecting pipes and heat exchangers to be able to connect to DH.
- Scattered buildings, which are spread across the municipality and not close enough to other buildings, are not considered as possibly connected to the DH system

**3rd Step: Calculation of heat supply with district heating**

The existing DH system and the possible alternative supply portfolios for the future of the DH system until 2030, discussed during the policy implementation process, were modelled in the techno-economic optimization tool energyPRO (EMD International n.d.) to calculate the DH generation costs, $CO_2$ emissions and fuel use of the DH system, and also to obtain the sensitivity of the costs to disconnection or additional customers, based on optimal dispatch of the supply portfolio.

**4th Step: Calculation of heat supply with individual supply technologies**

In this step, levelized costs for the supply of heat with five different individual heating technologies (Air-Source Heat Pump, Ground-Source Heat Pump, Biomass boiler, Natural gas boiler, and Oil boiler) were calculated for the same building classes as the heat saving costs.

**5th Step: Identify least cost combination for all policies and scenarios and compare indicators**

For all building classes and all areas within the municipality, the cheapest combination of heat savings and heat supply was calculated for all technical scenarios and all policies developed during the policy implementation process. For all these combinations of technical scenarios and policy settings, following indicators are calculated and compared to evaluate the policy:

- Total useful energy demand for heat, which is defined as the total useful energy demand for space heating and domestic hot water within the municipality.
- Total $CO_2$ emissions for heat, which is defined as the total $CO_2$ emissions arising from heat supply with district heat and with individual technologies within the municipality. For electricity used in heat pumps or electric heating the $CO_2$ intensities[5] of the Romanian power sector according to EU reference scenario (European Commission 2016) are used. For district heating, the specific $CO_2$ emission is a result of the techno-economic model depending on the unit dispatch for each scenario.

[5] The EU reference scenario gives emission factors of (2014=600g/kWh; 2030=270g/kWh; 2050=90g/kWh) for the Romanian power sector)

- Total costs of heat supply and heat savings, which is defined as the total system costs of heat supply and costs of implemented renovation measures minus transfer payments occurring due to policy interventions.
- Share of renewables, which is defined as the share of total useful heat demand supplied by renewable energy. For electricity the renewable share[6] is calculated according to the net power generation from RES for Romania according to EU reference scenario (European Commission 2016). For heat pumps, additionally to the renewable share of the power input also the ambient heat is renewable. For district heating the renewable share is a result of the techno-economic model depending on the unit dispatch for each scenario.
- Share of district heating, which is defined as the share of total heat demand supplied by district heating.
- Difference in total system costs, which is defined as the difference in total costs of heat supply of the different policy scenarios compared to the no policy scenario.

## Results

### Results of policy implementation process

The policy implementation process led to the definition of a technical reference- and alternative scenario and to five different single policy measures, five combined policies and one policy package. The combined policies each includes the long term loan policy described below plus one of the other policies described below. The policy package includes the long term loan policy plus the RES-DH subsidy plus the expected $CO_2$ tax level from the emission trading scheme which are all described below. Each of these policy or combination was evaluated according to its influence on the least cost combination of heat savings and heat supply and the resulting indicators of the technical scenarios.

### Current status, reference and alternative scenario

The status quo of the current heat supply in Braşov is, that from a total building related heat demand of almost 1 400 MWh, around 95% is covered by individual natural gas heat-only boiler, around 4% is supplied by district heat and less than 1% is supplied by individual biomass boilers. This results in $CO_2$ emissions of more than 330 kt per year, a renewable share of 0.2% and annual total costs of heat supply of almost 80 MEUR which would rise to more than 130 MEUR until 2030, assuming an energy price increase according to the EU reference scenario (European Commission 2016). The district heat is currently mainly purchased at fixed rate from an external heat supplier, producing heat with highly efficient combined heat and power natural gas engines. The current district heating network has a length of around 36 km of transport and 70 km of distribution network, whereof 13 km (36%) and 16 km (23%) respectively have been renewed within the last 10 years. Still, big parts of the network are outdated and inefficient, leading to heat losses of more than 50%.

In the reference scenario, the current supply structure of the district heating system remains as it is, and the heat is mainly purchased from the external heat producer at a rate increasing by 2% p.a. until 2030. As a main investment the replacement of 50% of the old parts of the district heating network (not renewed within the last 10 years) is included in the calculation to reduce the current heat losses to 20%.

In the alternative scenario, also 50% of the old parts of the network get renewed, but additionally investments into renewable heat supply units are made: in the different parts of the network a 0.5 MW biomass boiler, a 9 $MW_{th}$ heat pump and 2 000 m² of solar thermal collectors get installed.

[6] The resulting renewable shares of Romanian electricity according to the EU reference scenario are: (2014=0.396; 2030=0.455; 2050=0.498)

**Long term loan policy**

Profit-oriented investors usually calculate their investments with return rates above socio-economic interest rates and with depreciation times well below the technological lifetime of the investment. This is a main barrier for investments into long term infrastructure with high upfront costs. Therefore, this policy instrument aims at providing low interest rates and long depreciation times for investments made into district heating infrastructure. It can be implemented either by giving long term loans from a public fund to a private operating company or by fostering ownership structures that allow investments with low interest rate and depreciation times in the order of the technical lifetime. These ownership structures could be public services or consumer owned cooperatives both not aiming at generating profit. For the calculation of the effects of this policy, the interest rate is set to 1.5% (compared to 4% without this policy) and the depreciation time is set to 40 years (compared to 25 years without this policy) for investments into network infrastructure and to 20 years (compared to 15 years without this policy) for investments into supply units.

**$CO_2$ tax for individual end-consumer**

Currently, fossil fuels for individual consumers are not taxed in Romania. The not included external costs caused by damage due to the use of fossil fuels may be a barrier for the implementation of alternative and renewable technologies. Therefore this policy instrument reflects the implementation of a tax on $CO_2$ emissions caused by burning fossil fuels in individual heating technologies. Two different price levels are considered:

- The same $CO_2$ price per ton as it is expected for the emission trading scheme according to the EU Reference Scenario 2016 (European Commission 2016) for the year 2030 (31.5 €/t) and
- a price level that is needed to reach an impact with $CO_2$ tax as a standalone policy.

**DH connection subsidy**

The connection of a household to a district heating network generates costs for the end consumer, which may be a barrier for higher connection rates. Therefore this policy instrument supports the connection of buildings to the district heating network for the occupants/owners of all types of buildings by covering the connection costs. The costs per dwelling in apartment blocks are in the range of 700 € to 1 200 € depending on the size of the building. These costs only refer to the costs arising from the connection of apartments to an existing network in the district heating area. Network expansion costs are not included here but affect the levelized costs of heat from district heating in next to district heating areas where there is no existing network. These costs have to be paid either by a municipal, regional or national subsidy or by the utility or a public service as a promotion to gather customers. Therefore this policy generates transfer costs which are deducted from the total system costs. This results in different decisions of the end-consumer because they see a lower district heating price, but this subsidy is not included in the total system costs.

**RES-DH subsidy**

Due to lower market penetration and a lower number of units, renewable DH heat supply technologies often have higher upfront investment costs than established fossil fuel technologies, which may be a barrier for utilities to invest into renewable heating supply. Therefore this policy reflects investment subsidies of 45% of eligible costs for investments into renewable heating technologies in DH systems. Also these costs have to be paid by a public authority and therefore are treated as a transfer payment not affecting the total system costs. This means that the costs for subsidies of almost 2.6 Mio EUR for the investments into renewable technologies in the alternative scenario are included in the total system costs.

**Zoning with forbidding of gas**

Building owners usually can freely decide on the heating supply and often choose the supposedly cheapest solution, which can lead to double infrastructure and suboptimal utilization of existing infrastructure. Especially district heating networks get specifically cheaper with higher linear density[7] which means higher connection rates. Therefore, identifying areas with high heat densities and other prerequisites for efficient district heating and defining resulting zones where buildings have to connect to district heating unless there is a more efficient solution can lead to lower overall costs. Therefore this policy reflects implementation of GIS based heat planning, resulting in different zones for certain energy carriers to avoid double infrastructure and to ensure a high connection to DH. For the case of Braşov this policy means that within the area defined as district heating no individual natural gas boiler can be installed when the heating system is replaced. This policy of course has to be implemented stepwise by giving the municipality a legal framework to apply spatial energy planning and define energy zones where different energy carriers are preferred against others.

**Results of policy evaluation process**

Figure 2 shows the model results of the policy evaluation process. Along with the status quo, the results of the least cost combination of heat savings and heat supply for the different technical scenarios and policy settings are shown. For all scenarios, the energy demand supplied by the different technologies, the resulting share of renewables and district heating and the costs and $CO_2$ emissions relative to the current situation are shown. The status quo shows the current situation of heat supply in Braşov in 2014 and the resulting relative costs and emissions when using the energy prices and emission factors for 2030. The total costs for heat supply would increase by 73%, while the $CO_2$ emissions would only decrease by 2.7% due to assumed higher efficiencies of individual natural gas boilers in 2030.

In all other scenarios it can be seen that a reduction of the total heat demand of around 250 GWh (18%) can be achieved by implementing the cost optimal combination of heat savings and heat supply. This demand reduction is very similar in all scenarios due to three main reasons. First, the heat saving costs in the Romanian building stock are relatively low due to low average thermal quality of the current building stock and high achievable savings at moderate costs of working force. As a result the deep renovation levels are cost effective[8] leading to a low difference in heat demand of renovated buildings. Second, in all the scenarios the cost optimal combination between heat saving level and the cheapest heating system is chosen. As a result the next-best heat supply system is chosen when heat supply costs of a certain heating system increases due to a policy measure and as the most heating systems have similar heat supply costs the supply system changes rather than the heat saving level. And third, the achievable heat demand reduction is limited by the achievable renovation rate until 2030 accounting only for 30% of the heat savings that could be achieved until 2050.

[7] Linear density is the sold heat per meter of network [MWh/m]

[8]The chosen heat savings in combination with the cheapest heat supply system is for all building classes within the four highest renovation levels achieving between 1.15 and 0.7 times the transmission coefficients from the building codes

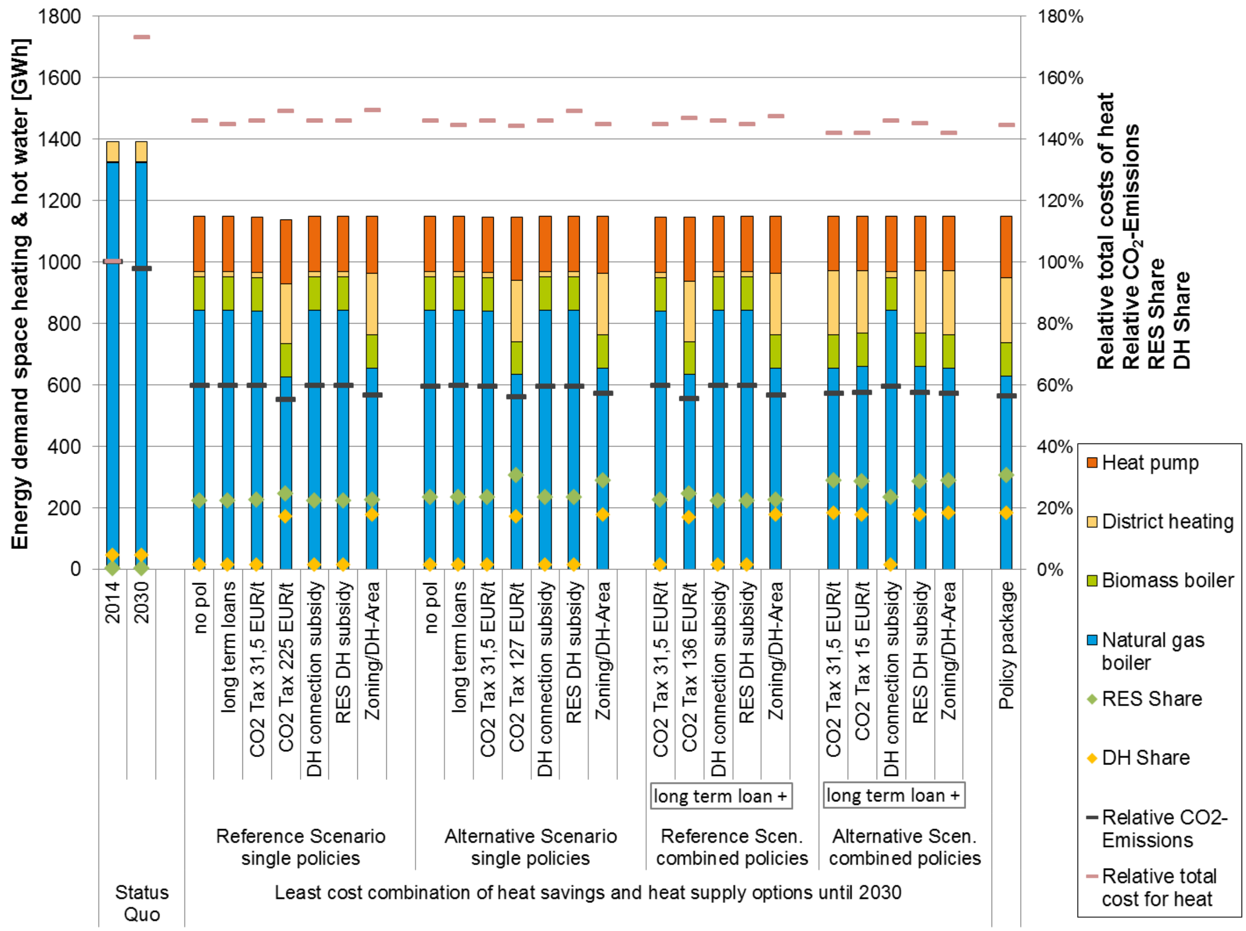


Figure 2. Results of policy evaluation process. *Source:* own calculation.

Assuming no additional policy, but that all consumers apply the cost optimal combination of heat savings and heating supply for their building, the DH system would decrease its share to only 1.5% of the overall heat demand for both the reference and the alternative scenario. According to this assumption, most detached single family houses would switch to air source heat pumps after renovation, resulting in almost 16% of the demand supplied by this technology. Other single family houses and row houses would switch to individual biomass boilers as the cheapest option after renovation, resulting in more than 9% of the heat demand supplied by biomass. Restrictions like the availability of biomass or consumer preferences are not reflected in the modelling framework but probably would inhibit the expansion of biomass to this extent.

Comparing the different standalone policies for the technical reference and alternative scenarios, it can be seen that most of the assessed policies alone do not affect the results regarding the cheapest heat supply combination. Only a high $CO_2$ tax on fossil fuels would increase the cost for natural gas to an extent so that individual heat pumps become cost effective in more buildings and that DH would become competitive for most of the larger buildings within the "district heating area", where no additional network has to be built. When $CO_2$ tax is applied as a single measure, a tax level of 225 EUR/t$CO_2$ is needed in the reference scenario and a level of 127 EUR/t$CO_2$ in the alternative scenario to reach the point where DH gets cheaper than individual natural gas boiler within the district heating area. As another single policy, the regulatory measure of forbidding natural gas boilers in the designated "DH areas" would also enforce most of the buildings within this area to switch to DH leading to a DH share of almost 18%.

In the scenarios with two combined policies, where the long term loan policy is combined with each of the others, higher RES and DH shares can be achieved with not too strong additional policies. For example an additional $CO_2$ tax of only 15 EUR/t$CO_2$ or the supposed investment subsidies for RES in DH could result in a RES share of around 28% and a $CO_2$ reduction by 40%. Alternatively, banning natural gas from the DH area allows reaching similar shares.

Applying the suggested policy package, the highest share of more than 30% RES for heating and a $CO_2$ reduction of almost 44% can be reached with a moderate $CO_2$ tax level as it is expected for the emission trading scheme and without the strong regulative measure of forbidding natural gas within the "DH area". Therefore, combining different policies leads to similar shares of RES and DH without overstressing single measures.

Regarding the total costs of heat savings and heat supply all scenarios are in the same range. The costs vary from 108 MEUR to 114 MEUR which means an increase by 42% to 49% compared to the current system costs or a decrease by 14% to 18% compared to the status quo situation with energy prices of 2030. The results also show that from a climate policy point of view it only makes sense to force increased shares of DH when the DH system is transformed to include higher shares of RES. When DH is forced in by zoning and the prohibition of gas but the DH system stays with the fossil reference supply there is no positive effect on the $CO_2$ emissions.

## Conclusions and discussion

Although the proposed approach is not capable to fully reflect the real behavior of all actors, and certain barriers like comfort or consumer preferences couldn't be integrated in the modelling framework, the impact of different policies on decisions based on a least-cost-approach could be assessed. The assessment showed that not all but only selected standalone policies are able to generate a favorable policy framework for economically and ecologically efficient DH, however, these policies would have to be rather strong. For example, the introduction of a $CO_2$ tax in general was advocated within the policy discussion process, but the implementation on national level was seen as very difficult especially in view of the required level. Also the implementation of zones where no natural gas boilers are allowed was considered only as a long term option with stepwise implementation.

In contrast, integrated policy packages combining different policy measures but at lower intensities would lead to even stronger effects on RES and DH shares as well as $CO_2$ emission reduction. Following this it is more efficient to combine different policies to ensure a modernization of the old DH system and to bring back consumers. To ensure the modernization it is crucial to trigger investments in the outdated network infrastructure and in renewable supply. A favorable policy framework to enable this could include the proposed long term loan policy and the investment subsidies for renewable heat supply units. On the other hand it is essential for the feasibility of a DH network to share the infrastructure costs amongst as many customers as possible. To enable this, a favorable policy framework could include measures that make DH economically more attractive compared to fossil supply, like the connection subsidies or taxes on fossil fuels, or by a stronger planning approach in terms of strategic local and regional heat planning by defining zones where certain supply technologies are preferred.

However, these policy measures will not guarantee that end-consumers decide 100% economically rational, applying the least cost combination as implemented in the modelling framework resulting in a 100% effective policy. To reach a better compliance of the end-consumers decisions with the intentions of the policy measures, further research is needed, especially regarding the efficiency of the policies and the effect of information campaigns. Still, the close cooperation of the modelling and the implementing process performed in this work facilitated the possibility of implementation of the policies and the compliance due to the wide integration of very different stakeholders.

In the case of Braşov, due to this close integration of policy assessment and policy implementation, some of the discussed policies could be implemented during the presented process.

Most importantly, the long term loan policy was implemented by establishing a local public service which will use generated profit continuously for new investments into the district heating system, and only incorporates these investments and running costs to calculate the price of heat for the citizens and already includes the costs of connecting to the DH system. Therefore this new local public service comprises the DH connection subsidy. Furthermore the intent of this local public service is to identify funds, such as structural funds or funds for governmental programs, needed to support the district heating sector, but also to make provisions in the public budget to reduce the losses in the system. Therefore also the RES-DH subsidy policy was implemented to the extent of the availability of these subsidies.

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