LOCAL APPROACH TO RENEWABLE DISTRICT HEATING: CASE STUDY CROATIA

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Abstract – Highly efficient cogeneration and district heating and cooling systems have a significant potential for primary energy savings which are still highly underutilized in most European countries. They can provide significant benefits to the uptake of waste and renewable heat but also help foster the integration of intermittent energy sources for electricity production for example wind and PV through the use of heat storage systems and power to heat technologies. In order to fully utilize, or in some cases even begin the utilization of said potentials, certain parameters have to be met.
District heating and cooling networks are capitally highly intensive projects that present a long term commitment for their utilization. In order to plan, design and implement them in the most cost effective way, spatial distribution of the heating and cooling demands as well as waste and renewable heat sources need to be analysed, mapped and compared to the existing systems. Such an information source enables the optimal utilization of local energy sources and thus ensures the maximum positive impact on both the cost and environmental impact of the heating and cooling sectors.
In order to utilize some sources of waste heat, shallow geothermal sources, heat pumps and other forms of renewable heat sources, conditions in the district heating network have to reach certain parameters. Most district heating systems in Eastern Europe still function in the category of so called second generation, meaning that they utilize pressurised hot water with supply temperatures well above 100 °C making them unsuitable for the exploitation of low temperature heat sources. A coherent refurbishment strategy of both the building stock and the district heating systems is necessary for this to change. In order to do so, elaborate strategies are necessary, not only from the technical perspective but also from the sociological perspective. District heating in certain Eastern European countries has a low public acceptance due to relatively high costs, low efficiency, high energy losses and especially unjust historical payment schemes for the final consumer.
The goal of this work is to demonstrate both sides of the strategies, technical and sociological, with Croatia as a case study example. In order to start heat/cooling demand mapping, project development and implementation, elaborate schemes towards citizen and public authorities are necessary. Second goal of this work is to demonstrate the heating and cooling demand, as well renewable and waste heat source, mapping methodology and to utilize the obtained results in order to model the impact district heating and cooling can have on the penetration of renewable and waste heat utilization in the overall energy system. The impact that urban refurbishment has on the potential uptake of low temperature heat sources has also been presented. The mapping has been done using the ArcGIS tool while the energy planning has been done using EnergyPLAN.

1. INTRODUCTION

Even though there are over 7000 district heating (DH) systems in Europe today, they are distributed in an uneven fashion, resulting in an overall share of district heating systems around 13 % of total European heat supply (Connolly et al., 2014). Potentials for increasing this share on European level are rather big, since heat demands in urban areas are dense enough to utilise DH systems. These potentials will be even bigger in future when the transfer to the 4th generation DH systems (low distribution temperatures, use of renewable energy sources and waste heat, use of large scale heat pumps and thermal storage, etc.) (Lund et al., 2014) is completed, which will also make feasible using DH systems in areas with lower heat demand.

The share of DH in the overall heat supply in Croatia is practically identical to the European average, but although majority of DH systems in Europe can be classified as 3rd generation systems, most Croatian systems are 2nd generation DH systems, using pressurised hot water with supply temperatures well above 100 °C as a heat carrier. Major reason for this is the age of the building stock in Croatia, and the lack of adequate heating insulation, which usually results in heat demands of 150-250 kWh/m^2 annually. When it comes to energy sources used for DH purposes in Croatia, there is almost no renewable sources (only one small geothermal DH plant and one small biomass DH plant), compared to a share of 14 % on European level (Schmidt et al., 2013). Therefore, fossil fuels prevail as an energy source, the most common being natural gas (approximately 80-85 %), followed by fuel oil. There are 3 DH plants that utilize cogeneration, including 2 DH plants in Zagreb, which make the biggest DH system in Croatia, while the rest are heat only systems. All of the cogeneration facilities are using fossil fuels (mostly gas), although an analysis of different cogeneration options for DH system in a midsized town in Croatia showed that using biomass fired cogeneration results in much bigger primary energy savings than using a gas fired cogeneration (Lončar & Ridjan, 2012). A study (Akhtari et al., 2014) showed that incentives from government will be crucial for biomass DH since it is still not as economically attractive as fossil fuels. It has to be pointed out that although there are no such systems in Croatia, there are a growing number of small renewable DH systems in Europe, with Denmark being the leading country in this sector. For example, Marstal DH comprises of a biomass cogeneration, heat pump and more than 30 000 m^2 of solar collectors, combined with seasonal underground thermal storage (Wiltshire, 2015). More examples from Austria, Spain, Poland and Germany are presented in Refs. (Basciotti et al., 2016) and (Bauer et al., 2016).

DH sector in Croatia faces some rather big issues, the biggest being the average age of DH systems, low gas prices for households and as mentioned before, average age and condition of the building stock in the country. Since most of the DH infrastructure in Croatia has been built in the second half of 20th century (e.g. average age of pipes in Zagreb DH is around 30 years (Culig-Tokic et al., 2015)), specific heat losses of these systems are substantial. Heat losses are caused both by the heat transfer between heat carrier and surrounding ground (i.e. high distribution temperatures combined with low insulation protection, as evaluated in (Çomaklı et al., 2004)) and water losses due to damages on pipes which cause leaking. Different designs of pipes can be considered in order to reduce heat losses. Ref. (Dalla Rosa et al., 2011), showed potential for energy savings for new designs of pipes, i.e. twin pipes, double pipes and triple pipes. On the other hand, a study (Lund & Mohammadi, 2016) provided a techno-economic analyses of different insulation standards for pipes in DH systems concluding that the highest insulation standard is currently not economically feasible but has a great potential in future.

All of the above mentioned reasons cause the current situation in Croatia, where the general public has a negative opinion of DH systems, considering them inefficient and expensive, although it was shown in Ref (Gudmundsson et al., 2015) that DH with multiple heat sources is a much more cost-effective way (and more environmentally friendly) of heating than individual heating. Therefore, refurbishment of both the building stock and DH systems has to be carried out to increase the cost-effectiveness of DH system over the individual heating. In Ref. (Pukšec et al., 2013), authors presented different scenarios regarding future energy demand of Croatian household sector, concluding that this sector has significant potentials for energy savings and renewable energy sources (RES) in the future and proposing measures to achieve them.

Concerning the legislative framework for DH systems in Croatia, the heating sector is regulated with a number of different laws and subordinate legislation, the most important being Heat market law, which defined the framework for the heat market in Croatia. Nevertheless, the market is still practically non-existent. Incentives as such are not existent for the district heating sector in Croatia but they can be received for electricity production in the highly efficient cogeneration facilities, therefore also subsidizing production of heat from the highly efficient cogeneration facilities. In order to implement renewable district heating project in Croatia, a large number of administrative documents and permits have to be obtained, therefore making the process rather lengthy. Legal and market framework of Croatian energy sector have been analyzed in more detail in (Banovac et al., 2007) and (Lončar et al., 2009), with special focus on district heating and cogeneration.

In this paper, a step-by-step methodology for implementing renewable DH systems in Croatia will be presented (with a focus on small modular renewable DH systems). Few steps of the methodology will be presented in more detail as case studies of two cities in Croatia.

2. METHODOLOGY

The presented methodology was developed for implementation of small modular renewable DH systems in communities in Croatia. The methodology describes the planning phase of the implementation. All of the presented steps should be followed in order to successfully implement such systems. The main steps are identified as follows:

1. Building political and public support
2. Analysing the framework
3. Mapping the stakeholders
4. Gathering information
5. Analysing information

2.1 Building political and public support

The first step that has to be done in order to implement small modular renewable DH system in a community is to build political and public support. It has been recognized as a vital step that determines how the project will develop. It is very important to receive support from an important local politician who will be responsible for the whole initiative and who will use already existing documents such as Sustainable Energy Action Plans and Energy Visions of the city as the roadmap of the project. After a politician with authority supports the initiative, the next step is to use his authority to gain the support and commitment of all involved areas inside City Hall since this is the key to success.

Citizens should also be included in project activities in order to ensure sustained public acceptance of renewable DH systems. Information events and workshops are great opportunities to promote the project among the citizens and to gather their ideas, suggestions and doubts in the form of a survey. Checking the public opinion and winning public support for the renewable DH system initiative may also contribute significantly in convincing the municipality politicians to give their support.

2.2 Analysing the framework

This part of the methodology should include analysing existing policies or strategies which concern district heating systems such as documents related to climate change, energy, waste, planning etc. Policies that should be analysed are defined on a city scale, regional scale and national scale. That way, the implementation plan can be either underpinned by those policies, or gaps in the policies can be identified in order to propose improvements. A brief analysis of Croatian legislative framework for DH systems has already been made in the introduction.

Number of policies can help in creating a market for smart DH systems: benchmarking and disclosure requirements of building energy performance; incentives for energy efficient renovation and new construction; measures and standards that provide incentives for the electricity produced in district energy systems (e.g. CHP) with clear, consistent rules for connecting to the grid; priority dispatch; licensing exemptions for small scale generators; and policies that open energy markets to decentralized generators and internalize the public benefits of DH systems (net-metering, heat incentives) (Schmidt et al. 2013).

This step should also include defining best practices in the country and analysing them in order to learn from their specific experience and use them as a valid argument when building political and public support.

2.3 Mapping the stakeholders

Table 1. A list of important stakeholders for implementation of small renewable DH systems

Stakeholder	Role
Politicians	Lead strategy
Utilities, energy service companies, network operators	Offer solutions
Construction companies	Construction of power plants, installation of distribution networks, building refurbishments
Citizens	Heat consumers
Industries	Heat producers and/or consumers
Component manufacturers	Technology providers
Renewable energy industry	Energy suppliers
R&D institutes and universities	Consulting services, technology providers
Project developers, designers	Designing distribution networks, connections of buildings to the network, etc.

It is vital for the implementation of small renewable DH systems that stakeholders (organisations and individuals) are mapped as early as possible in the process and that their roles in the planning phase as well as implementation phase are identified. A list of important stakeholders for implementation of small renewable DH systems is presented in Table 1 (Schmidt et al., 2013). Effective engagement and involvement of the stakeholders will be critical to succeed with the process as well as it will be necessary to ensure good communication between stakeholders.

The challenge concerning the stakeholders is in the number of stakeholders that are involved in the planning process with an emphasis on exploiting waste heat potential from industrial sites or including demand side measures in the concept. Increasing the number of stakeholders implies a higher complexity in the planning task, more difficulties to access data and many private economic interests to satisfy so that should be taken into account during the mapping of the stakeholders.

2.4 Gathering information

Gathering the information that is necessary to plan the small renewable DH system in communities is an important step that has to be done in order to analyse that information and propose the best measures to transform the heating system of a city.

Data has to be collected and organised in order to be used in evaluating the heating sector of the city/municipality. Important data for planning small renewable DH systems can be divided into three sets as follows:

1. *Energy data of the city/municipality* which includes heat consumption, energy sources used for heating and domestic hot water preparation, waste heat production, etc.
2. *Climate and geographical/geological data of the city/municipality* which includes wind speeds, solar irradiation, ground temperatures, nearby water temperatures etc. which makes the basis for calculating the RES potentials of the community
3. *Technical data of the city/municipality* regarding heating, which includes current heat production and in-house distribution technologies, level of insulation of buildings, household areas, etc.

Not all data is accessible to planners, so all the stakeholders should be included in providing the data. The official data available on a municipal level will vary depending on the municipality and on the country in question. Disclosure of data may also be possible only at a regional or national level. If so, the use of a top - down approach can help the accounting procedure. As municipality may not have a direct observation of data, energy data can also be provided by some utilities, as formal partners of the project. Not every country has official statistics on a municipal level, but it should be researched what kind of official energy, climate and technical data are available. For example, if a city/municipality has a Sustainable Energy Action Plan, it can serve as a good source of energy data, but the more precise data can be gathered by surveying the citizens of the city/municipality. Since the focus of this paper are small renewable DH systems in communities, i.e. small cities and municipalities, gathering reliable energy data through surveys from citizens is relatively easy, but in large cities this would require a large amount of time, manpower and funds.

2.5 Analysing information

After all the relevant information has been gathered, as described in the previous subchapter, the next step is to analyse this information in order to get a clear picture of the municipality's current heat sector situation and how developed and sustainable it is which gives the basis for proposing the measures that have to be implemented in order to develop the small renewable DH system in a community. This step represents a crucial part of the methodology since the measures and actions are proposed based on the information analysis.

By analysing the heat consumption of end-users, the heat demand mapping can be done. This gives a clear picture of current state of buildings as well as of the end-user behaviour. Also, this locates areas with highest potentials for DH systems as mentioned before.

By analysing climate information on RES, potentials for their utilization can be determined. For better analysis, the gathered RES data should be put on a map by the means of GIS tools. The locations of potential plants can then be much easier determined. Data of excess heat production in the municipality should also be mapped for the same reason. Also, the assessment of land (public or private) that is available for installation of DH system should be made.

By analysing technical data of the municipality's heating system, as well as the municipality's energy data, current state of the heating system is determined. This defines households which already have a suitable heating system for connecting to a DH system, which significantly decreases the investment for the end users (i.e. households which would only have to pay for connection to the grid and substations). Level of insulation of buildings, as well as household areas, are both used as a valuable data for heat demand mapping.

In this step, after all the data is analysed, it is also important to make models of current system and develop different scenarios for the small renewable DH systems in order to determine what are the best, most cost-effective measures that have to be implemented. Different tools for analysing integration of RES into current energy systems have been presented in Ref. (Connolly et al., 2010). Feasibility analysis of different scenarios (i.e. different measures and actions being implemented) has to be done in this step of the methodology. The capital, operational and maintenance costs, along with likely revenues from heat, cooling and electricity sales, should be roughly estimated at this stage. This will help to establish whether the proposed scheme is economically viable, and affordable for customers.

3. ANALYSING BUILDING STOCK AND PUBLIC OPINION ON SMALL RENEWABLE DH SYSTEMS IN A COMMUNITY IN CROATIA

3.1 Methodology

Data has been gathered by implementing a door-to-door in a small city in Croatia. The city is situated in the western part of continental Croatia, close to the border with Slovenia. The survey was conducted on a sample of 391 households, which is around 17 % of the total number of households in the city (Ostroški, 2016). The survey was made in order to receive data of energy use for heating and cooling, the condition and type of households, technical data of heating systems in use and to gather public opinion on small renewable DH systems. Data received by the survey will be further used for planning of a small renewable DH system in this community.

3.2 Results

Some of the main results of the survey will be presented in this paper. Since the city in which the survey has been carried out is a small city in rural part of Croatia, most people live in houses rather than apartments (Fig. 1), in average 3-5 people per household. This fits well with the data provided by Croatian Burreau of Statistics (Ostroški, 2016) and is characteristic for small rural towns in Croatia.

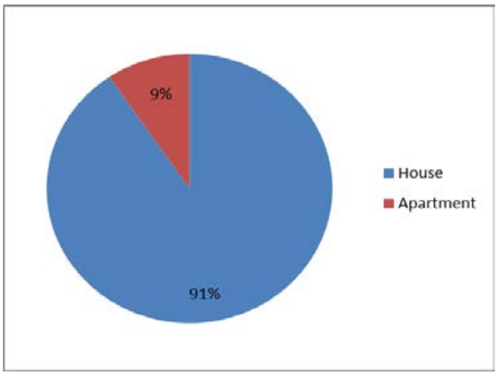

Fig. 1. Types of households in the surveyed city

Concerning the condition of buildings, around 35 % of buildings have insulation on the outter walls. Practically the same share of buildings have insulation on the roof. The situation is slightly better when it comes to types of windows that are used on the buildings, where almost 50 % of windows are made of polyvinyl chloride (Fig. 3).

Most buildings have been built in period 1960-1980 as expected, which means that the average age of buildings is 40 years, as shown in Fig. 2. These results prove general assumptions provided in the introduction, that buildings in Croatia have high annual heat demands.

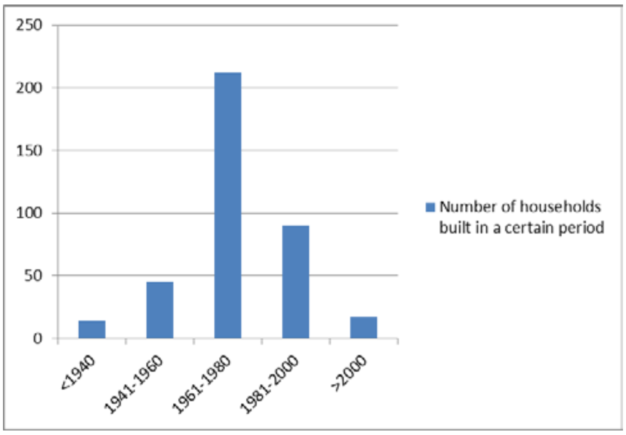

Fig. 2. Construction period for households

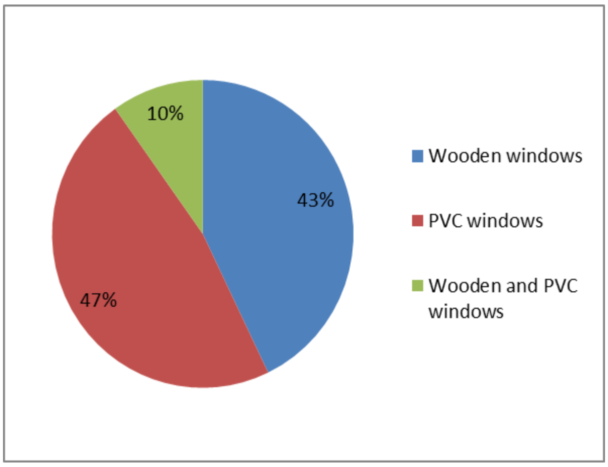

Fig. 3. Types of windows used on households

Since the surrounding area of the surveyed city is covered with forests, the majority of households use wood as an energy source for heating. Another reason is that there is no city wide natural gas grid. Almost 15 % of surveyed citizens own a part of the forest so they supply the fuel themselves and therefore pay only transportation costs. This can present both the advantage and disadvantage for DH sytems. Since they currently have no costs, those citizens will not want to connect to a DH system and pay for connection and heat. On the other hand, this can be tackled by enabling citizens to provide their biomass to the DH system in exchange for lower heating bills.

Energy sources used for space heating are presented in Fig. 4. These figures roughly correspond to those presented in Sustainable Energy Action Plan of the city (Domac et al.). On the other hand, most of the surveyed citizens do not use cooling at all, with only 34 % of people using some kind of cooling, mostly split system air conditioners. An interesting parameter when planning DH systems is a type of heating system that people have in their households. Results showed that majority of surveyed citizens (84 %) already have centralised radiator systems on the dwelling/apartment level, which significantly decreases initial investments for citizens. Data on heat consumption received by the survey will be used for mapping of the heat demand on the individual dwelling scale.

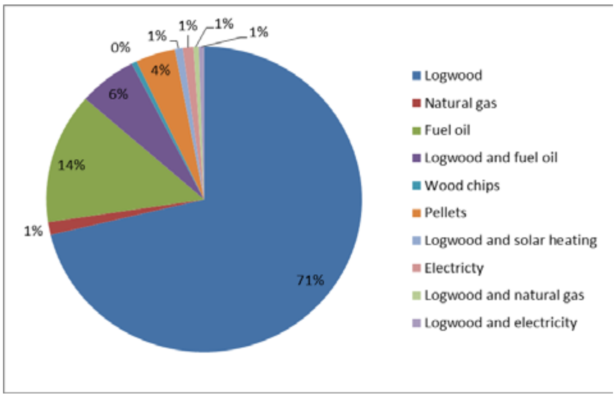

Fig. 4. Energy sources used for space heating

Another important goal of this survey was to check the public opinion on small renewable DH systems. As mentioned earlier, citizens in Croatia in general have a negative opinion on DH systems. The survey presented citizens with some of the most significant advantages of small renewable DH systems in order to analyse which of these advantages do people care about the most. The results showed that 54 % of surveyed citizens would be willing to connect to a DH system, while there are two main reasons why people would not want to connect to a DH system, as shown in Fig. 5.

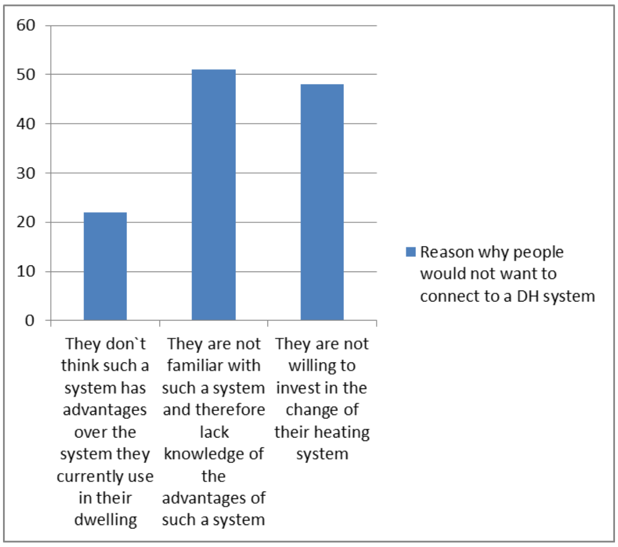

Fig. 5. Main reasons for citizens not to connect to a small renewable DH system

The fact that people lack knowledge of such systems can be tackled by implementing information events in communities or by setting up information panels in different parts of community, which would also promote energy efficiency measures, different renewable energy technologies, etc. The fact that people are not willing to invest in the change of their heating system is specific for the rural small cities in Croatia since older, retired citizens prevail and the standard is low.

Concerning different advantages of small renewable DH systems which were presented in the survey, citizens found the ones related to the economy the most important ones i.e. that economic feasibility for the user is much better than for individual heating systems and that these systems increase local economy and enhance local employment and security of supply. On the other hand, the least important advantages were defined by citizens as elimination of security risks due to fuel combustion in dwellings and increased comfort for the users. These results show which advantages the future activities should focus on.

4. MAPPING THE HEAT DEMAND IN A MID-SIZED CITY IN CROATIA

Heat demand mapping, which is a part of the presented methodology for implementing small renewable DH systems in Croatia, will be presented in this chapter for a mid-sized city in Croatia. The city in question is located in central part of Croatia, close to the capital.

4.1 Methodology

The methodology can be divided into four steps. In the first step, data from an online building census (rooftop areas and locations of buildings) is used in order to create an initial matrix of existing buildings in the city. In the second step, data on the number of floors of every building have been gathered. Since the building census did not contain this data, it had to be gathered manually using Google maps street view. Initial matrix of buildings was than color-coded depending on the number of floors of each building. This data is used in order to calculate total gross area of each building by multiplying rooftop area with the number of floors. Due to the fact that data on number of floors had to be gathered manually, this step was the most time consuming step in the methodology.

The third step included classification of buildings into 6 categories, depending on their age and type. These categories are: old house, new house, old apartment building, new apartment building, industrial facility and skyscraper. This step was actually done parallel to the second step since this data was gathered in the same way. The type of building criteria determined specific heat demand. Total heat demand was then calculated by multiplying total gross areas of buildings with specific heat demand of different types of buildings. Specific heat demands used in this method are empirical values received from analysing Croatian building stock, as was shown in previous chapter. This data was then utilized in ArcGIS software in order to create a 100x100 m heat demand map of the city.

4.2 Results

Mapping of the heat demand on a scale of 100x100 m for the mid-sized city in Croatia has been presented in Fig. 6.

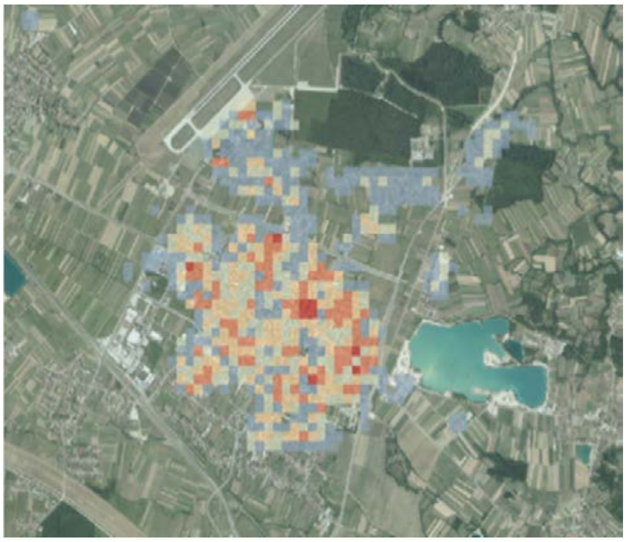

Fig. 6. Heat demand mapping of a mid-size city in Croatia

The results show that the highest heat demand occurs in the city centre, while the lowest heat demand occurs in the surrounding areas of the city. This way, the most attractive areas for DH utilisation. are pointed out. For better analyses, more layers should be added, including gas networks, DH networks (if existent) and potential waste heat sources, which will be done in future work. That way, different heat production technologies and distribution grids can be analysed in order to find the optimal solution. Future work will also include comparison of 2 mapping methodologies for small cities, the one presented in this chapter and the one which uses data gathered by surveys for mapping on the individual dwelling scale.

5. CONCLUSIONS

This paper presented a step-by-step methodology for implementing small renewable DH systems, which consists of 5 general steps. This methodology will be used for future planning and implementation of such systems in Croatia. Analyses of building stock and public opinion regarding small renewable DH systems was also carried out, based on a survey which was conducted in a small city in Croatia. The results of the survey confirmed general thesis that buildings in Croatia have high annual heat demands because of their age and poor insulation standards. The survey was also used as one way of informing people about benefits of small renewable DH systems and to gather their doubts, ideas and general opinion. Received information on public opinion will be used for better planning of future public related activities. At last, heat demand mapping methodology was presented with an example from a mid-sized city in Croatia, giving expected results of highest heat demand in the centre of the city and lowest heat demand in the surrounding areas of the city.

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