AALBORG UNIVERSITY
STUDENT REPORT

Competitive potential of district heating over individual solutions: a case study of Onești.

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MSc Sustainable Energy Planning and Management

Spring semester 2016
Master's Thesis

Synopsis

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Program: Sustainable Energy Planning and Management

Semester: Spring 2016

A B S T R A C T

The past two decades have shown great influence upon the landscape of the Romanian heating system. Having been divided into both collective and individual solutions, it has the purpose of delivering heating services to consumers which inevitably choose the safest and most affordable alternative. However, recent requirements enforced by the EU have put the matter of choice under question and account for the uncertainty addressed by the research presented in this paper. On this topic, the investigation approaches qualitative and quantitative methods of research and incorporates the use of interviews, study case and scenario design. The study highlights the benefits of using energyPRO as a tool in analyzing the input data and obtaining preliminary results to be later approached in the sensitivity analysis. The latter is presented in brief as the feasibility of the investigated scenario shows high sensitivity to slight changes that would otherwise render it unfeasible. Based on the final results, the conclusion reflects upon the mentioned suggestion and accounts for individual solutions as the most feasible choice seen from a consumer point of view. As for the proposed alternatives, the closing chapter cannot account for a viable solution for their implementation.

Table of Contents

List of figures

List of tables

List of abbreviations

ACER	Agency for the Cooperation of European Regulators
AIPPIMM	Medium and Small Enterprise Project and Programme Implementation Authority
ANRE	National Energy Regulatory Authority
ANRSC	National Heat Sources Regulatory Authority
CHP	Combined Heat & Power
DH	District heating
ENTSO-E	European Network of Transmission System Operators-Electricity
ENTSO-G	European Network of Transmission System Operators-gas
ErP	Energy related Products (Directive)
EU	European Union
IEA	International Energy Agency
IH	Individual Heating
IR	Interest Rate
NEEAP	National Energy Efficiency Action Plan
NPV	Net Present Value
NREAP	National Renewable Energy Action Plan
NYP	Net Yearly Payment
O&M	Operation & Maintenance
OPCOM	Romanian Electricity and Gas Power Market Operator
RES	Renewable Energy Sources
SEPM	Sustainable Energy Planning and Management
TEP	Third Energy Package

Acknowledgements

The following thesis has been written by 4th semester student of the Masters programme "Sustainable Energy Planning and Management" at Aalborg University. Sincerest regards go to Peter Sorknæs, the thesis supervisor, for supplying the necessary information, guidance as well as encouragement throughout the thesis writing process.

Special regards are addressed to Mr. Liviu Tarola, Mrs. Magda Chiper and Mr. Nicolae Balas for the valuable information and input much needed in order to carry out the analysis.

At last, great deal of thanks go to colleagues Bart Bakker and Heinz-Uwe Lewe for their unconditional support during this time.

1. Introduction

1.1. Romanian energy system – short description

Romania, a Latin language and culture country located on the banks of the Black Sea, is the largest country in south-eastern Europe and the twelfth-largest in Europe (Colesca, Ciocoiu 2013). The country is rich in terms of energy sources, compared to other European countries, which is directly reflected upon the significant share of fossil fuels in the total primary energy supply. A closer look into statistics registered by the International Energy Agency reveals fossil energy production (heat and electricity) with a total contribution of 13,813 GWh and 9,255 GWh for gas and 7,726 GWh respectively 16,954 GWh extracted from coal in 2013 (IEA 2013).

Balancing the system in terms of consumption is partially accounted for buildings, which constitute the largest energy consumer in Romania. As illustrated in Figure 1, this sector consists of the residential and tertiary subsectors (consisting of offices, retail premises and non-residential buildings) and account for 46% of the total energy consumption at a national level.

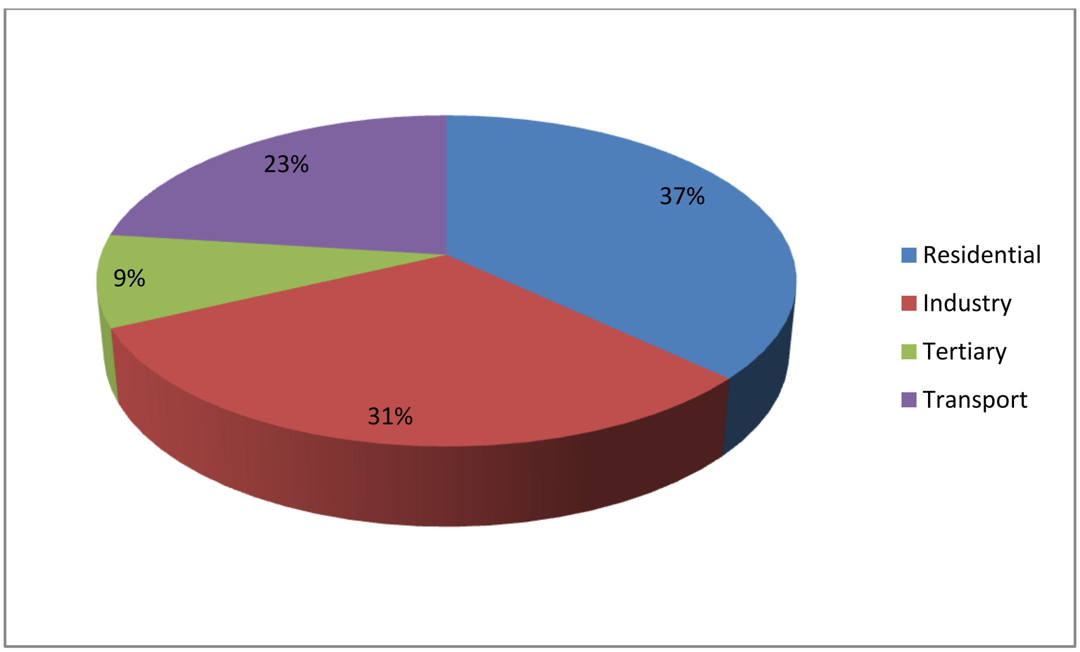

Figure 1: Romanian energy consumption by end use

The Romanian residential sector accounts for 86% of the building floor area and is represented by more than 2,720,000 million housing units built in between 1960 and 1990 with low thermal insulation and a yearly energy consumption of 250 – 400kWh/m^2. In urban areas these units are grouped in blocks of flats (with an average of 40 apartments per block) out of which 19% are connected to the DH grid. The DH system of Romania stands as a major European market: 9th place in total heat delivered and represented the most commonly used technology for hot water and heat delivery since the intense development of Romanian industry in the 1960's (EUROHEAT & POWER 2012). The grid is mainly focused on delivering to residential consumers (91% of the heat) but also reaches public buildings (business area, trade services and industry) with an overall capacity of delivering 60,000 TJ (in 2008). Nevertheless, improvement and development needed to maintain capacity of the system are uncertain. The "District Heating 2006 -2015/Heat and Comfort" program promoted by the Romanian government which allocated funds for modernization of boilers, steam turbines and CHPs (belonging to DH systems) and building rehabilitation would have been an efficient initiative if further support from authorities was given. In its absence, household owners chose to opt for alternative heating solutions, such water boilers, to ensure secure supply of heat and hot water of their homes. This will ultimately lead to a major change in regards to consumer preferences or choice towards the two heating systems.

1.2. History of the heating system – District heating

District heating accounts for a share of 31% of the heat market at a national level and more than 57% in large cities and towns-about 68 are still connected to such a system. Most of these grids are supplied for by CHPs, found predominantly in large areas but also heat-only plants that are owned by the local municipalities (Frunzulica, Damian 2008). This capacity is represented by plants running on coal (45%), gas (45%) and oil (10%) build in between 1960 and 1970. More than 50% of the heat generation is represented by CHPs with current low thermodynamic efficiency, reaching end consumers through a 7,611 km long grid of DH (Colesca, Ciocoiu 2013). Seen as a legacy of the former political regime, the Romanian DH system is an important step of urban planning that can be traced back to 1960. Industrial development was in need of sustaining capacity that ultimately led to construction of numerous power plants (electricity and steam) which successfully provided heating for the blocks of apartments slowly rising up across the entire country. From an architectural point of view, the new cities fulfilled the technical criteria needed for DH to function in optimal conditions. Most important: suitable number of connections (high density of consumers on a relatively small area) and low grid losses due to the vicinity of the heat source.

With the instauration of the new political system following the civil revolution of 1989, the situation of the industry sector is no longer clear. Bankruptcy of important industrial consumers causes a direct decrease in demand (for steam) which ultimately leads up power plants ceasing production because of economical reasons. Remaining units are also affected because of their high capacity that cannot be matched by need required from the DH system. Artificially low set price of gas at the time, cause massive disconnections of the end consumers from the DH grid in areas in which heat is supplied from plants fired by coal and oil, thus rising the costs for remaining end users. Additionally, owners of the DH system (mostly represented by municipalities) are also affected and struggle to maintain the feasibility of the investment.

Further on, the unstable characteristic of the economy and political environment threatens the future development of DH and stands out as a turning point leading to decline, prior to the many disconnections that continue happening in the late 1990`s. The following 10 years register further decommissioning of CHPs across the country (about 3,000 MW) and seals the fate of a large number of units affected by the still decreasing demand and soon outdated technology. Disconnections from the heating system begin as the early 2000's and by 2008 their number rise up to a total of 500,000 with 70 DH stations remain operational out of a total of 352 built by the former political regime (Leca 2008).

1.3. Current state of the heating system: transition towards individual heating solutions

Decline of DH in Romania continues along with the economical crisis of late 2008 which is a significant drawback affecting the purchasing power of average consumers as well. Lack of policy framework and schemes promoting DH make it difficult for companies to fulfil their financial commitments towards the banks and can no longer finance further investments for maintaining the grids. Considering the low income level of the population, less and less customers maintain their connection to the grid and choose to invest in individual heating (water boilers) considering the rising costs and losses of the old alternative. They think of DH as an outdated system that cannot guarantee security in supply, they are not satisfied by the impossibility of metering the heat that is consumed and thus fear of having to pay more than they actually should. Without proper conditions of tariff (to help owning companies deal with unstable economical situation of their clients), subsidies and aids from the government, DH loses its competitive advantage to the individual heating solutions and only few remain "faithful" to the grid constrained by their modest financial condition.

In absence of official figures or studies regarding the total number of the existing water boilers, online publications quoting active boiler retailers on the Romanian market (i.e. the Italian corporation Ariston Thermo – one of the major retailers of thermal equipments active on the Romanian market) give an estimation of how spread water boiler have become. Therefore, according to their own conducted studies, there are more than 1.52 million apartments equipped with an individual heating system. Moreover, yearly sales are claimed to reach beyond 150,000 units while disconnections from the centralized heating system continue to date, making water boilers an appealing solution to more and more consumers.

Nonetheless, feasible examples of collective heating systems as the one managed by the Municipality of Bucharest are proof that under circumstances of suitable planning and strategic investments, DH proves to be an efficient alternative for the production of heat and an affordable connection for the consumers. The capital's heating system-RADET is the largest in the country in terms of capacity, providing for about 1.24 million consumers for which the value of the heating bill is among the lowest in the country (Gandul.info). On the other hand, RADET is proof of an adapting administrative DH framework which has proven successful in the large cities of Romania; twenty nine out of a total sixty one remaining other municipalities have ownership rights over the local DH networks for which the price of heat proves to be competitive compared to the individual solutions. This is a result of the strategic initiatives taken by the government in order to tackle the phenomena of disconnections which, however, has not benefited from a good timing in regards to the smaller municipalities managing smaller DH grids. Nevertheless, current national strategies have regained the presence of DH on the political agenda of the government which aims to invest in revitalizing the system at national level. A descriptive example is a recent report of 2015- **"**Report on the assessment of the national potential to implement high-efficiency cogeneration and efficient district heating and cooling" carried out by the Ministry of Energy in which strategic planning aimed towards the heating sector is presented.

1.4. Impact of EU regulations

As of 2007, Romania officially became a Member State of the European Union which attracts benefits and of course, obligations of complying with existent and/or future EU regulations. Responsibilities in this sense reflect upon the Government as well as upon the general population. In regards focus is put on the share of consumers dealing with a connection to an individual solution which is consequently put under the question of further affordability.

Firstly, a recent EU directive focusing on energy related products-ErP Directive has "gained" responsibilities and obligations for those owning an individual heating system. This is transcribed by a set of regulations focused on space heaters and water heaters that establishes minimum requirements for efficiency and demands certain technology in boilers with the aim of minimizing operating fuel costs and consumption. As a result, replacement of traditional boilers can only be done with new, condensing water boilers that thus have a higher efficiency and lower level of gas consumption. Traditional boilers, bought before the official enforcement of the ErP directive in September, 2015 which have yet to overcome their technical lifetime are not banned. Instead, harsher technical inspections are imposed, which can result in expensive fines for owner and/or the inspection responsible person which do not comply. Costs are, therefore, higher and in most of the cases additional equipments need to be replaced (i.e. old radiators need replacement with new, compatible ones).

Secondly, earlier in 2009 the EU adopted the 3rd Energy Package (TEP) which is a set of directives (2009/72/EC on electricity and 2009/73/EC on natural gas) and regulations (713, 714 and 715, all of 2009) meant to create a common European energy market. The aim of this initiative is to protect consumers and ensure an optimum use of resources by setting up new institutions such as the Agency for the Cooperation of European Regulators (ACER) or the European Network of Transmission System Operators (ENTSO-E, ENTSO-G) for both electricity and gas. This energy market model, promoted by TEP, pursues to strengthen the independence of national regulators and phasing out of the price regulation for energy, which has yet to be successfully adopted within the framework of the Romanian energy market. The political affiliation of ANRE – the National Energy Regulatory Authority (in Romania) delayed suitable planning of adopting new prices for energy (in accordance with the European level) of upmost importance given the social of energy poverty which is affecting 40% of the Romanian consumers. The elimination of regulated energy prices continues for household consumers, which according to planning will be finalized in December, 2017 (Leca et al. 2014). Unlike tariffs for industrial consumers, which have already been liberalized by 2013, energy prices for the population continue to increase until 2018 and will thus reflect on a higher value of the energy bill. Seen from this perspective, one can account for the profitability of a condensing gas boiler which in this case can be affected by the increased price of fuel.

2. Problem formulation

The EU emphasizes on the technological advantages of condensing water boilers (efficiency and low level of emissions) by setting them as standards enforced by the ErP Directive. However, disadvantages may arise in regards to the average Romanian consumers which are thus confronted with the higher price of the equipment compared the traditional boilers and modest financial possibilities. Given the timeline of disconnection from the DH system parallel to a constantly increasing number of consumers opting for individual solutions, a large share of old technology water boilers have reached or are soon reaching the end of their technical lifetime, requiring immediate replacement. Apartment owners are thus facing make new investments to which future increases of gas price should also be considered (due to the energy market liberalization process scheduled until 2018).

On the other hand, DH is actively promoted by the EU's agenda and if benefiting from proper technical/administrative planning and implementation, could potentially account for a competitive heating alternative. Additionally, rehabilitation of DH is prioritized on the political agenda of today and shows signs of promising initiatives.

Given the above mentioned facts in regards to the current situation of the heating sector, its evolution and future perspectives, one could account for the necessity of determining a suitable economical choice for the Romanian consumers. Consequently, the project approaches the problem by analysis with a proposed methodology oriented to establish the feature of the considered alternatives in this sense. The study is therefore led by the following research question:

Can DH provide an affordable alternative for consumers in Onești given the competitive case of the current individual solutions?

To properly account for the validity of the assumed hypothesis, the study narrows down the research to the small city of Onești. A former industrial centre located in the eastern part of the country, part of the county of Bacău and home to approximately 40,000 inhabitants. The reason for choosing Onești as a case study can be argued by the history and evolution of its heating system as representative for the overall situation of other regions of the country in which DH was part of their heating system. Since the industrial development of early 1960's, the city of Onești is born along with a DH system supplied for by the industrial group of Borzești – a petrochemical platform located conveniently close, providing the grid with waste heat. Additionally, security in supply would be assured by a peak solution represented by thermal plant which is later decommissioned in favour of a new project, suitable for the needs of the consumers.

The industrial decline of early 1990's is a reality with significant consequences for the welfare of Onești, similar to the situation happening at a national scale in that particular time. The DH networks designed to cope with the surrounding industrial activity can no longer cope with the changes and their reliability is no longer certain in the eyes of many consumers which eventually opt for the alternative given by gas boilers. However, much like in Onești, small income and overall weak financial situation does not allow all apartments to be equipped with such a system. In Onești, for example, 200 apartments from a total of 10,500 were still connected to the DH grid, according to a local online publication of December, 2014.

2.1. Approach

In the light of these events, the municipality has taken initiatives to adapt the system and ensure its survival have been taken by applying for funds from the central budget for new investments and repairs (as is the case of other municipalities of Romania during the same period). Unfortunately, their efforts have not benefitted from a suitable timing of policies in favour of DH which has proved of significant influence in the development of this sector. Without specific strategic planning and regulation of the energy prices which, at the time, were inclining the balance in favour of the individual solutions, the concept and benefits of individual gas boilers have taken over the market and brought changes in the DH landscape.

In this regards, the presented study sets out to establish and compare the price of both technologies in terms of costs paid by the consumers and determine which of the two maintains its feasibility, given current regulations concerning their role as heating alternatives. The proposed methodology aims to determine the current important factors and policies with regulatory power over individual and district heating, propose relevant alternatives to be further analyzed/compared from a consumer perspective and conclude by presenting the results along with brief recommendations.

3. Methodology

The aim of this chapter is to present an overview of the methods considered to approach the above mentioned research question. A quantitative method has been applied by using the software EnergyPRO which is briefly explained further on and additionally, the subchapters include a description of the scenario designs and a summary of conducted interviews as well as theoretical concepts associated with the topic of the study.

3.1. Case study

For this specific research paper, a case study has been selected as a suitable methodology in order to investigate the hypothesis expressed by the research question. According to Flyvbjerg's "Five Misunderstandings about case-study research" a common misunderstanding about the concept relates to it as often portrayed to be a subjective and unreliable source of information which is not scientific and therefore, cannot be tested or generalized. His article later contradicts this idea by emphasizing on the knowledge of specific case studies as being essential to understanding situations at hand. Flyvbjerg believes that the outcome of a well chosen case study will lead the reader to achieving competence and true expertise, unlike a general study which will only leave the readers' level of knowledge in a shallow, beginner state. Apart from that, Flyvbjerg thinks about generalization as being overrated and in the context of science referring to one expanding his knowledge, generalization is just one of the many ways to do so. The absence of generalization in the detailed investigation of a study case proves of value as it has often achieved, in the past, to cutting "a path towards scientific innovation" (Flyvbjerg 2006). On the other hand, refers to the ability of a case study to be generalized which is increased by the user's ability to choose a suitable strategic case. Regarding the type of case presented in the study, it identifies with one particular type found in the examples given by Flyvbjerg's article: critical cases. As described, the intended purpose behind this case is "to achieve information that permits logical deductions of the type" (Ibid.). In regards to the case that the study chooses, if the heating alternative proves feasible and competitive (from a technical perspective), then it is likely that the same can occur in other areas of the country as they are under the governance of same administrative context. One could thus account for the validity of the concept of a study case as a suitable approach to understand the relevance of the study's result in the context of other areas the city of Onești resembles to. Contributing to the methodology assumed by the case study are also interviews that have brought forth stakeholders in the city of Onești, method of which the next subchapter will further discuss in the following section.

3.2. Interviews

Considering the type and quality of the needed information in order to further address the topic formulated by the research question, structured and unstructured interviews with relevant actors on the local DH scene represent a suitable methodology of obtaining first hand information which in this case account for a valid source of essential technical information as well as providing a broad and clear overview that would otherwise not be facilitated by online research or existent literature.

"The structured interview is one of the two main ways of administering a survey research instrument (Bryman 2008). The other method is represented self-completion questionnaires in which "respondents answer questions by completing the questionnaire themselves"(Ibid.). It thus not engages in face-to-face conversation which is an important aspect for which interviews are considered as methodology for this matter. The interviews are designed on the basis of closed questions which offer a significant advantage facilitating the processing of information to be obtained. When conducted, structured interviews are useful given the type of data that is needed in the context of this study: quantitative data. According to Byrman, open questions give incentive to less structured replies that may come in several sentences which then need to be "sifted and coded in order for the data to be analyzed quantitatively".

On a similar note, semi-structured interviews are approached as method. Unlike the case of a structured interview, the latter "is able to vary the sequence of questions" while still relevant in referring to a schedule. Questions obtain a more general approach and the interviewer has the possibility of pursuing other questions "in response to what are seen as significant replies" (Ibid.).

In order to collect the relevant information in this sense, a visit to Romania has been planned and done. And along with the visit, an interview based research was carried out with different actors relevant to the study. Further on, this subchapter will develop towards the understanding of how the discussions were thought according to the role of the interviewee they each would address. In this regard, three different actors were considered relevant to be interviewed:

- The administrator of the local utility company Termon-Mr. Liviu Tarola. The interview aims towards information about: status of utility company, status and technical specifications about the heating system, insights into potential future planning of the system;

- The general manager of the local Ferroli branch in Onești-Mrs. Magda Chiper. In this case, the interview seeks information about: technical/economical data and experience about condensing boilers (equipment sizing and coverage over dwellings in Onești)

- The secretary of the owner's association Nr.10, one of the 25 existing in Onești-Mr. Nicolae Balas. The interview aims to reveal information about: influence of owners' association as actors, consumer's stand/opinion about the DH system.

For example, one of the main important aspects pursued by meeting Mrs. Chiper was to obtain technical data and price estimates to be later on used in the scenario design phase which means that the course of the interview was thought to be led by precise questions, on the spot, aiming for numbers and technical experience (i.e. technology and type of customer preferred boilers). Also, the purpose of the interview is to test theories regarding consumer preferences and statistics to foresee their behaviour in the future, which categorizes it as a quantitative, structured interview. Same approach can be observed in regards to the meeting with the local utility company administrator-Mr. Tarola. The conversation aims to reveal technical facts and future planning of the heating system in Onești, hence the quantitative type of the interview.

On the other hand, while meeting the secretary of owners' association Nr. 10-Mr. Balaș, the dialogue was designed to focus more on understanding personal opinions and requirements of consumers in regards to the heating system they are connected to. The interviews are thus qualitative, aiming to empathize with their pains and engage in a less structured conversation focused on words and not on numbers. The threat of the conversation is led by few specific questions as to maintain the course of the interview but in order to obtain a deeper understanding of the participants' perspective, the dialogue would often give incentive for the interviewee to contribute and direct attention upon personal experiences.

In order to obtain a better understanding of the discourse that led to this situation, attention has been directed towards the Municipality's administrative council. Unfortunately, none of the requested appointments were given a positive response.

3.3. Scenario design-theoretical aspects

A starting point in developing on the reason for choosing the method of scenario design can be found if considering Go and Caroll's paper-"The blind man and the elephants: views on scenario-based system designs".

"A scenario is a description that contains actors, background information on the actors and assumptions about their environment, goals or objectives" (Go, J.M. Carol 2004). As further described by Go and Caroll in their quoted paper, scenarios are presented in many forms and approaches of which four are specifically considered to be:

- Strategic planning
- Human-computer interaction
- Requirements engineering
- Object-oriented analysis

Out of the mentioned approaches and in the case of the study's topic, emphasis is put in the object-oriented analysis-a methodology of constructing a model based on the idea of objects described by data structure, class hierarchy and behaviour (Go, J.M. Carol 2004). Much like the methodology approached to addressing this paper's research question (which assumes the use of different technologies to account for a given heat demand), similarities between the approaches can be identified in terms of the characteristics of different components as criteria relevant to the process of choice and decision. With reference to the quoted statement above, a scenario is (considered) a description that, in this case, contains technologies, background information in the technologies and assumptions in how their objectives (i.e. efficiency, compatibility with a given energy system) could help in achieve the final goal. This can furthermore account for the choice of the scenario approach within the context of the presented paper.

In order to address the issue presented by the research question, the process of scenario design starts by investigating three heating alternatives that will ultimately be compared in order to establish their affordability seen from a consumer point of view. Differences in analyzing the three alternatives will slightly differ depending on the source and overall framework of the system.

"Scenario types and techniques: Towards a user's guide" written by L. Börjeson, M. Höjer, K-H Dreborg, T Ekvallc and G. Finnvedena, places scenario methodology as often encountered as a mean used with the purpose of the "user's need to know what will happen, what can happen, and/or how a predefined target can be achieved". The study distinguishes three main categories of scenarios based on principal questions one may want to pose about the future: "What will happen?", "What can happen?" and "How can a specific target be reached?". Furthermore, each type is defined by two sublevels characterized by different angles of approach on the defining categories, as shown by the figure below.

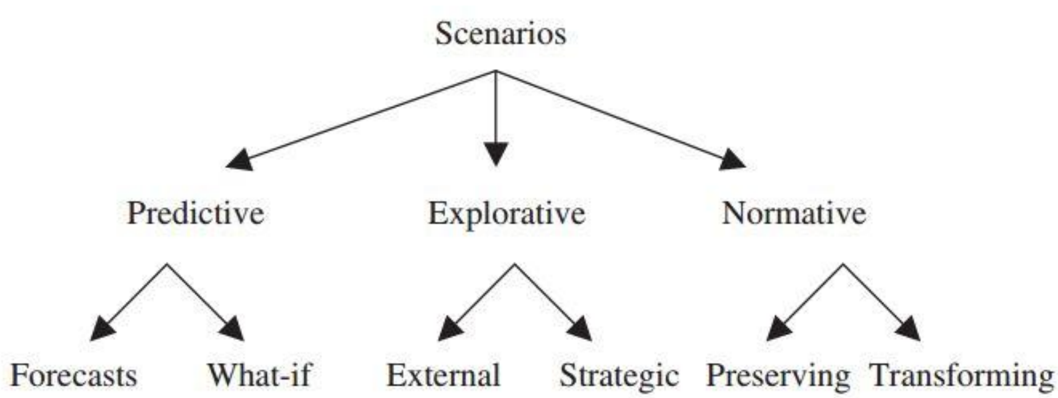

Figure 2 Scenario typology (Börjeson et al. 2006)

"What will happen?" is given response by predictive scenarios which, furthermore, distinguish between "forecasts" replying to "What will happen, on the condition that the likely development unfolds?" and "what-if" scenarios corresponding to "What will happen, on the condition of some specified events?". Considering this structure, it can be noticed that this particular method does not match the structure approached in the presented study.

When considering explorative scenarios, it is shown how they "can be useful in cases when the user may have fairly good knowledge regarding how the system works at present, but is interested in exploring the consequences of alternative developments" (Börjeson et al. 2006). At a first glance, this scenario associates with the research of investigating the use and development of different heating alternatives in an existing and thus familiar system with the purpose of establishing the consumer affordability of the consequences, which in this case, are represented by changes. But what the purpose of the investigation is aiming for is not just to observe and conclude on this basis. It aims to determine and technically implement which does not associate with the type of scenario any more. Following the thread illustrated in the figure above, it can be noticed the explorative scenarios' further division into external scenarios which, in principle, deal with handling "factors beyond the control of the relevant actors" and "are typically used to inform strategy development of a planning entity"(Ibid.). This coincides with the role of relevant actors within the analyzed framework of DH which is not related to the technical planning approach but to ways of sustainable exploitation of the planning's result instead.

Additionally, explorative scenarios further divide into strategic scenarios which imply incorporating policy measures in order to cope with the issue at stake. Their focus relates to policy analysts and research groups which is not the case when considering the application of the scenario design in the process of investigating and comparing technological alternatives within this step of the analysis.

Lastly, the reference article discusses normative scenarios in which "focus of interest is on certain future situations or objectives and how these could be realised" (Börjeson et al. 2006). If the goal is to reach these objectives within a prevailing structure of the system thus aiming towards its optimization, preserving scenarios (subdivision on the bigger normative category) fit as appropriate methodology. However, given the instance of the presented paper, transforming scenarios actually represent and identify more with the chosen method of investigation. Transformative scenarios assume that "target seems to be unreachable if the ongoing development continues" which in case of analysis, relates to an affordable but different heating solution not being reachable in the context of Romanian consumers' income (Ibid.). The presented study basically sets out to determine how a specific target-affordable heating solution can be reached and in order to do so, given alternatives are put forward to investigation while maintaining or optimizing the existing system. There is no interest in maintaining a certain structure or framework of the system but rather, the interest is aimed towards determining the existence of an available alternative considering certain criterion, disregarding changes that may occur as long as they help achieve the goal. Lastly, following the threat of the structure presented in Figure 2, one may conclude the specific type of scenario approached by the methodology which is identifies as a normative transforming scenario.

3.3.1. Scenario 1: Individual heating (condensing gas boilers)-reference scenario

The main input data for this scenario was obtained from one the interviews the author has conducted during his stay in Romania. This scenario reflects the situation in which the heating alternative for consumers in Onești is represented by condensing gas boilers. The importance of investigating this particular technology is mainly accounted for the ErP Directive of September, 2015 enforced by the EU.

The individual heating scenario investigates the possibility of exploiting the benefits of a condensing gas boiler, sized according to information obtained from the interview with Mrs. Chiper. Accounting for the reliability of the data is a 19 year long activity on the local market which has enabled a total coverage of 70% of the gas boiler sales since their establishment as a thermal equipment distributor. In order to do so, the profile of an average apartment in Onești is "sketched" based on the technical experience of the given information. In this sense, the scenario considers an average apartment size of 60 m^2 and an average state of the insulation which "allows" yearly losses ranging 15-40%. Considering a 250kW/m^2 specific consumption of the apartment, figures lead up to a maximum of

21 MWh/year for less insulted houses but can also reach as low as 17.25 MWh/year when dealing with a better overall insulation of the apartment. Subsequently, in order to cover the specified heat demand, a 24kW condensing boiler is considered. According to the information provided by the interview, this capacity is enough to provide the needed flow of domestic hot water for use and space heating needs.

3.3.2. Scenario 2: District heating with CHP (gas)

Frequently related to DH, the concept of CHP is a simple solution which can be considered in order to minimize the use of fuel in the production of electricity and the utilization of resulted heat for DH purposes. In this regards, the second scenario enlarges the scale of the project and considers the construction of a gas CHP plant, designed to cover the heat demand of the total number of apartments in Onești-10,500. To do so, the CHP will be combined with a heat only boiler fuelled by gas, considered as a peak solution and a large scale hot water tank which will be further analyzed with the help of the EnergyPRO software. A proposed layout of the site is included in a graphical representation showed by Figure 3.

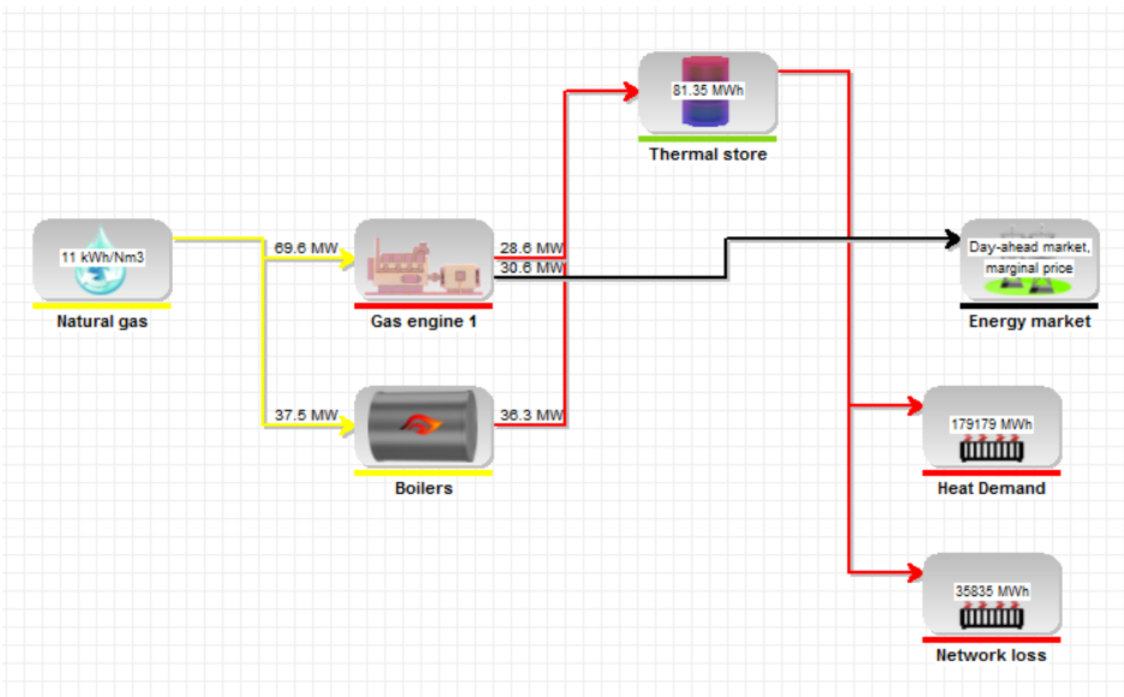

Figure 3Graphical representation of the gas Scenario 2 analyzed in EnergyPRO. Includes technical data describing the capacity of the system's different components, heat demand+losses, fuel heat value and shows distribution of produced energy

Sizing the capacity of the plant along with the additional equipments was made through iterative software simulations considering a total demand of 179,179 MWh and grid losses accounting for a 20% share of this value-35,835 MWh in order to account for the minimum size of the system's components. The model takes into account an already existing pipe grid in Onești, designed for the previous collective heating system, which has had thorough repairing and maintenance operations between 2014 and 2015 (Tarola 2016). In this regards, losses are generated in the form of an additional heat demand-Networks loss. Results to be presented further on in the following chapter have been obtained from simulating the following input values: the scenario considers a CHP gas plant with an overall efficiency of 85% and a heat output efficiency of 41% (according to the technological data sheet (Danish Energy Agency 2012)) which gives a capacity of 28.6 MW (heat) which will "work" together with the 35 MW capacity of the DH gas-fired boiler to deliver the needed peak heat demand throughout the year. It should be mentioned here that a general rule of thumb has been assumed in the process of sizing a suitable capacity for the CHP plant: the sizing of up to 50% of the peak demand the system registers in a given day, will ensure that at least 80-85% of the head demand throughout the year is successfully covered.

A thermal storage with a volume of 2000 m^3 is "linked" to the grid which will partially account for ensuring the demand in times of high prices of the fuel that makes usage of the other two units cost expensive. As shown in Figure 3, the electricity efficiency of the CHP plant gives a total capacity of little over 30 MW which will be exploited by feeding the electricity production into the grid with the aim of obtaining additional revenues. In order to account for the daily price variation of the Romanian electricity market, an hourly price time sheet has been imported into EnergyPRO and used as a time series function which helps in calculating the amount of income generated at certain hours during the whole year. In this regards, a limitation is identified by the price sheet which only represents hourly electricity prices from the year 2015. As for the consumption of gas, reference price given published by the National Energy Regulatory Authority (ANRE) is considered at a certain value in accordance with the yearly used amount of gas. The lifetime of the project is set to 25 years in accordance with the technological data sheet which also includes prices corresponding to investment and O&M of the system's components.

3.3.3. Scenario 3: District heating with CHP (biomass)

When aiming to provide for a given heat demand, the overall efficiency of a biomass fuelled CHP motivates its consideration for the analysis. In this case, biomass is specifically represented by wood chips with high calorific value of 5.5 kW/kg (UK Government). Particularly, flue condensation technology gives a total heat efficiency of 77% compared to a usually otherwise encountered value of 64%. Consequently, electrical efficiency drops considerably to 28%. A similar time series function is included in the design of the scenario in order to account for the potential revenues obtained from selling electricity output. On the other hand, a price per ton is considered for biomass consumption by doing a brief research of the available biomass products retailers which offer different price values according to quantity and type. In this regards, wood chips reach a price range of 133-156 €/ton for which an intermediate value of 140 €/ton has been chosen in order to calculate fuel consumption costs. Same price of gas is maintained for the consumption of the boiler which, in this case, is sized to a capacity of 37.2 MW. Unlike the previous scenario, in which both units were running on natural gas, in this scenario a new type of fuel is declared to account for the CHP's own fuel consumption for which wood chips calorific power is considered (as mentioned above). Nevertheless, the change has no effects on the final output of the simulation but is just a mean of differentiating between the two types of fuel. A graphical representation of the new site layout is shown in Figure 4.

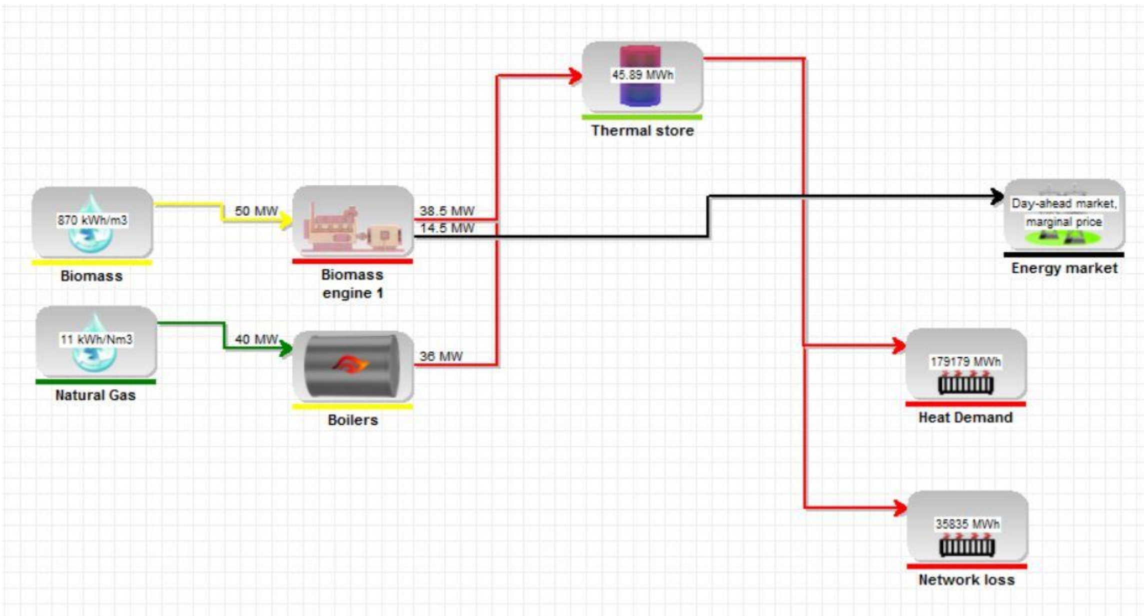

Figure 4 Graphical representation of the Scenario 3 analyzed in EnergyPRO. Unlike the gas CHP scenario, a new type of fuel is declared-biomass

Specific investment, O&M costs for the biomass CHP are considered according to the same source (Danish Energy Agency 2012). One of the main reasons for choosing biomass conversion technology is accounted for the fact that, in Romania, it biomass benefits has a higher potential for heat and electricity purposes compared to geothermal, solar or wind energy to which one should also consider the amount of revenues obtained by selling electricity to the grid and thus benefiting for a production bonus (same value that is used in the gas CHP scenario).

3.4. EnergyPRO

The software EnergyPRO is a tool created by the Danish company EDM International A/St consisting of a modelling software package for combined techno-economic design, analysis and optimization, of both fossil and bio-fuelled cogeneration and trigeneration projects, as well as wind and other types of complex energy projects which was introduced to SEPM students during the course "Sustainable Energy System Analysis" (Connolly et al. 2009). The specific design of EnergyPRO of investigating a single thermal or CHP plant is one of the reasons why it has been chosen in order to simulate two of the proposed scenarios. For the goal of this project, the software analyses yearly data (heat demand) and considers both technical and economical planning aspects along with levels of investment in order to determine costs directed towards the consumer. The investigation is aimed towards the analysis of district heating as an alternative to the proposed reference scenario as to determine the operational feasibility of the systems' different components, task in which EnergyPRO proves to be a valuable tool.

The software interface directs attention towards three main working areas: a general overview area of the site in which images corresponding to fuel types, production units and demands will be shown and further given possibility to be linked with each other in order to establish their relationship, a data input area in which the user declares and identifies features of the system's components, location and costs and lastly, the report area from which descriptive graphs and tables corresponding to system simulations are generated in order to describe the overall performance and costs of the system.

The software allows for custom simulations of the analyzed system according to the needs and goals of the user. In this regards, EnergyPRO distinguishes between two different operation strategies in which a certain priority of the production units can be defined by the user. "Minimizing Net Production Costs" strategy considers all economic aspects related to each production unit in order to determine the least cost for covering the demand. This relates to the consideration of an hourly spot market price for electricity which can be manually imported (as the software is preset to load Nord Pool Spot market) in order to identify the unit which is less or more economical to run over a certain period of time. In order to account for a flexible and cost economical production over the year, the study assumes the minimising net production strategy. Additionally, EnergyPRO allows for a "User Defined Operation Strategy" which in essence assumes that one unit can maintain priority in use over other existing units regardless of their profitability.

Once the operational strategy is defined, particular time series-corresponding to a 2015 online database used by EnergyPRO can be set up which are represented by hourly ambient temperatures for the region of Onești and market electricity prices, set by the Romanian market operator-OPCOM. Electricity prices are defined hourly and accessed from the OPCOM online database for 2015, for the entire year.

By setting an hourly ambient temperature within the temperature time series, EnergyPRO is able to create a heat load profile in order for the simulations to consider a realistic demand over the year. This profile is based on these values in contrast with a preset indoor specific temperature- which in this case is set at 19°C and in order to do so, the software uses the "degree days method" (Bliuc et al. 2007). It begins by determining the amount of degree hours per hour by subtracting the ambient temperature from the value of the indoor temperature (which are summed up according to the total 8760 hours in a year). Separately, it identifies the total space heating demand which is then divided by this amount of degree hours to calculate the required kWh per degree hour and this is then multiplied by the amount of degree hours in that particular hour (calculated previously). In addition, heating demand is needed for domestic hot water is calculated per hour. Set to 30% of the total heat demand (assumed it is equally distributed over the year) the value is divided by 8760 and added to the required kWh of heat needed to space heating.

The "economy" subsection offers the used flexibility when declaring the level of prices for fuel, O&M, investment for the system components and sales of heat and electricity. In this regards, the former are set to "constant" level, while the latter are linked to the spot market related time series which had previously been declared.

Consequently, simulation results are shown in different formats, meaning they can be generated in graphs or tables containing values set to a particular time unit (daily, weekly, monthly, yearly). On a closer analysis, these results reveal the strategy of the software in the way generation units are put to use according to, for example, fuel prices. This way, the user has means of reference on the basis of which sensitivity analysis can be done.

4. Technologies

As mentioned by the research question, the study aims to determine the most affordable heating solution, seen from a consumer point of view. Technical advantages of DH have already been exploited in the past and as a result, the Romanian DH market is ranks 9th on a European level according to the amount of the delivered heat (EUROHEAT & POWER 2012). However, IH has also proven of being a suitable and affordable solution for the Romanian consumer and thus scenarios can be considered to demonstrate which of the two considered alternatives maintains its feasible applicability given the European context of regulations and directives.

4.1. District Heating (DH)

DH is represented by a system distributing heat (that is generated) to consumers in the form of steam of water through an underground pipeline infrastructure. The source providing for a DH system is usually a CHP plant which can be categorized by two types: centralized and decentralized. It can be distinguished among the two in terms of size and specific location. Usually, centralized CPHs are considerable larger than decentralized plants which are also, located in small cities (Danish Energy Agency 2014).

In theory, DH systems are compatible with any type of energy source. Fossil fuel generation can include "renewable" generation from sources such as biomass, wind energy, solar energy, waste heat, the latter being part of the initial DH design that was developed in Romania in the early 1960's.

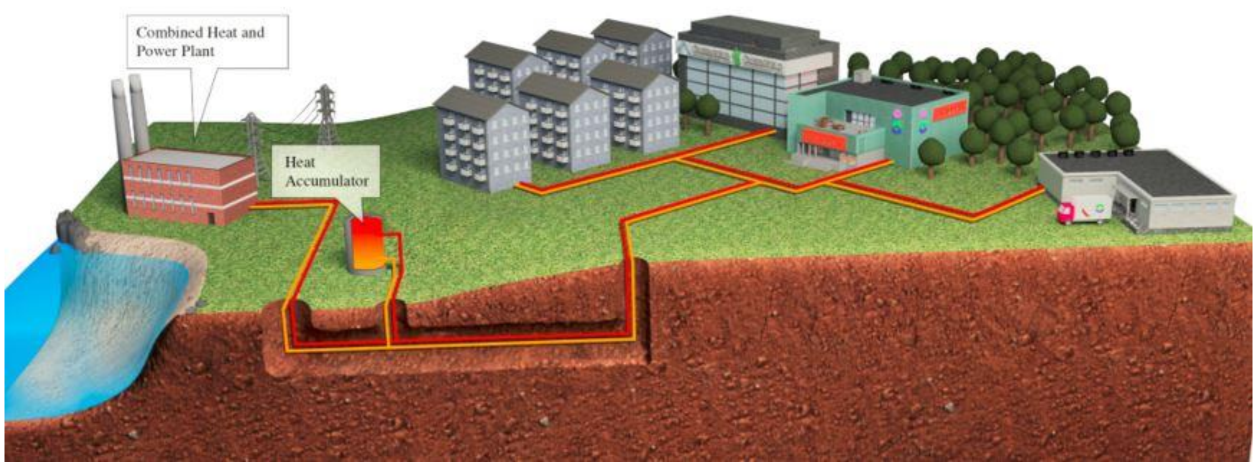

Figure 5 DH system with CHP (author's own research)

Figure 5 illustrates a DH network in combination with a CHP plant and it corresponds to one of the considered scenarios. The red colour pipes carry heated supply to the consumers where hot water is needed for use and space heating. The return and thus, cooler water is directed back to the plant through the yellow colour pipeline. There is also the possibility of carrying steam instead of water which is mainly used in industrial applications where a higher temperature is needed. Nevertheless higher losses are registered when steam is carried through to the consumer compared to water in the transmission pipes (Danfoss 2015).

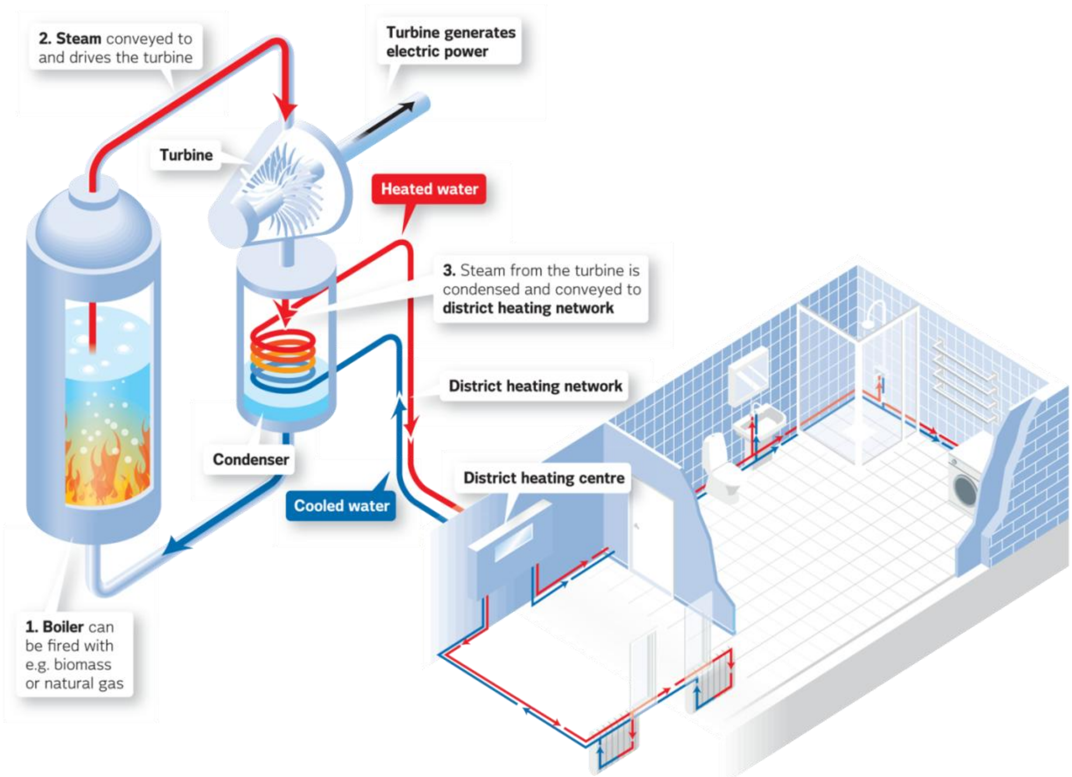

Figure 6 Household connection to DH network (Vattenfall)

Figure 6 describes in detail a household connection to DH network. Basically, the fuel firing the boiler increases the temperature of the water inside and the generated steam will later on provide energy for the turbine (which generates electricity). Subsequently, the steam reaches the condenser where heat is transferred to the cooled water coming from the household. Hot water then reaches its destination through the underground pipeline and is used in usage and heat generation through radiators. The water then completes the cycle (return water) returning to the CHP plant with a lower temperature value.

Heating in Romania was mostly performed by the DH scheme supported by a rapid industrial development in the early 1960's. However, serious alternative is "obtained" with the development and market penetration of alternative individual solutions starting early 2000's. Individual heating consists of gas boilers, installed right on the apartment level which attracts consumers because of their flexibility in use and security of supply that no longer characterizing the situation of having a DH connection. Investment costs have also contributed to the practicality of the alternative but attention is now drawn upon the obligations imposed by the ErP Directive which increase the level of these costs (€ 1,940 for an average sized apartment of 60 m^2). In addition, technical services and maintenance costs adding up the yearly expenditures, potentially exceeding cost assumed by DH.

Although not equally important to the average consumer, DH provides advantages from an environmental point of view offering greater economic possibilities on adopting technical solutions able to control and regulate environmental pollution (Mustetea 2004).

4.2. Condensing gas boilers

Unlike ordinary gas boilers, condensing boilers illustrated in Figure 7, are designed to recover latent heat from water vapour produced during the combustion of gas. In order to do so, flue gasses are cooled to a temperature which determines water vapours to condense, turning them back into a liquid. By doing this, the boiler recovers (totally or partially) some energy (heat) that would otherwise have been lost with the elimination of the gasses (Danish Gas Technology Centre 2016).

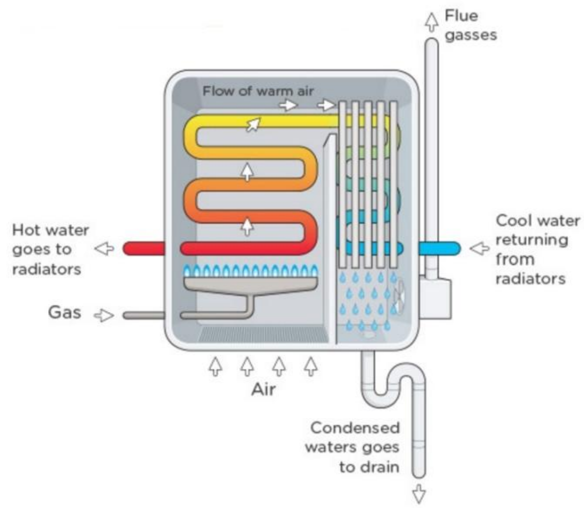

Figure 7 Simplified diagram of a condensing boiler (Danish Gas Technology Centre 2016)

Condensing gas boilers have an advantage of being installed right on the apartment level and in most of the cases they are located on the walls of kitchens or balconies. The general rule of thumb concerns the maximum lengths of the drain pipe which can affect the performances of the boiler if the length exceeds values specified by the producer or installing engineer.

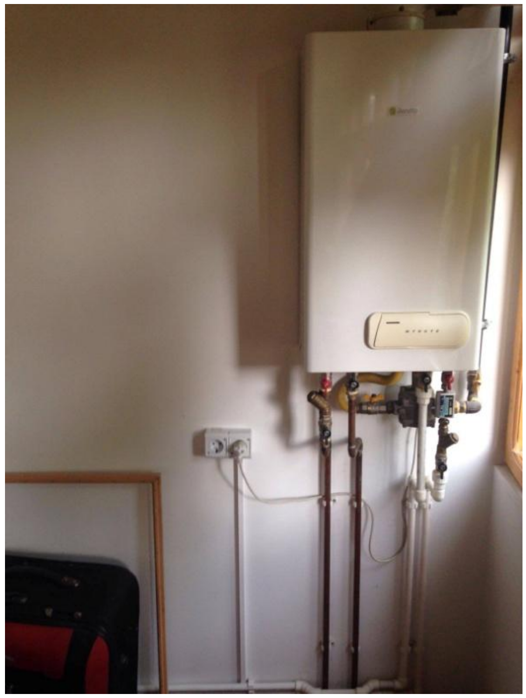

Figure 8 Condensing gas boiler

Considered to be more efficient than the older traditional gas boilers (15-20% higher efficiency), condensing gas boilers are also more expensive (30-45% higher price) and require the additional mounting of a drain pipe to flue gasses. Difficulties may be encountered in the cold season when cold temperatures may cause the pipe to freeze up. It should be reminded that through the pipe, condensate liquid may also be eliminated which is slightly acidic. Therefore, proper positioning and material of the pipe is important to be considered.

A less known or law regulated aspect regarding the positioning of drain pipes (Figure 9, Figure 10) concerns the disappointment of tenants living on the higher floors. They complain that gases eliminated by the drain pipes rise towards the level of their apartments, intoxicating the inside of their own homes. The figure below shows a four floor building in Onești in which condensing gas boilers have been adopted by most of the apartments.

Figure 9 Outside view of the drain pipes (1)

Figure 10 Outside view of the drain pipes (2)

Condensing boilers come as a replacement for the traditional boilers which have been banned from being sold the EU market by the ErP Directive of late 2015. The same regulation requires new boilers to have an annual check-up performed by professional and qualified installers which will reflect as a fraction of the cost for maintenance. The aim of this directive is to improve energy efficiency and environmental protection by regulating electrical appliances that affect energy consumption throughout their life cycle. As for the regulations concerning all space and water heaters, the ErP Directive imposes minimum efficiency requirements in order to meet emission standards at the point of manufacture, known as Ecodesign. In order to distinguish and establish the grade of efficiency, a labelling scheme is considered ranging from A+++ to G to help consumers easily identify the right energy saving product. Energy labels are therefore required for boilers with a rated heat output equal or less than 70kW as well as for storages with an equal or less volume of 500 litres.

4.3. Combined heat and power (CHP)

CHP is the simultaneous utilization of heat and power from a single fuel or energy source, at or close to the point of usage. Given the higher level of losses encountered when transporting surplus of electricity, CHPs should be viewed mainly as a source of heat with electricity as a by-product. They are represented by four main elements: engine (or drive system), electricity generator, heat recovery system and a control system and they are classified according to the type of application, drive system and fuel they use (IEA 2008) (Figure 11). In theory, almost any type of fuel is suitable for CHP. Natural gas is commonly used as well as in new systems, followed by fossil fuels, solid waste or biomass. Nevertheless, some CPHs are designed to use multiple fuel types which allow them to be reliable, flexible and maintain affordability when market prices become higher.

Feature	CHP - industrial	CHP - commercial / institutional	District heating and cooling
Typical customers	Chemical, pulp and paper, metallurgy, heavy processing (food, textile, timber, minerals), brewing, coke ovens, glass furnaces, oil refining	Light manufacturing, hotels, hospitals, large urban office buildings, agricultural operations	All buildings within reach of heat network, including office buildings, individual houses, campuses, airports, industry
Ease of integration with renewables and waste energy	Moderate - high (particularly industrial energy waste streams)	Low - moderate	High
Temperature level	High	Low to medium	Low to medium
Typical system size	1 - 500 MWe	1 kWe - 10 MWe	Any
Typical prime mover	Steam turbine, gas turbine, reciprocating engine (compression ignition), combined cycle (larger systems)	Reciprocating engine (spark ignition) , stirling engines, fuel cells, micro-turbines	Steam turbine, gas turbine, waste incineration, CCGT
Energy/fuel source	Any liquid, gaseous or solid fuels; industrial process waste gases (e.g. blast furnace gases, coke oven waste gases)	Liquid or gaseous fuels	Any fuel
Main players	Industry (power utilities)	End users and utilities	Include local community ESCOs, local and national utilities and industry
Ownership	Joint ventures/ third party	Joint ventures/ third party	From full private to full public and part public/ private, including utilities, industry and municipalities
Heat/electricity load patterns	User- and process-specific	User-specific	Daily and seasonal fluctuations mitigated by load management and heat storage

Figure 11 Applications of CHPs (IEA 2008)

As described by Figure 11, DH plants offer the ownership (private or public-municipalities) the possibility of changing to a different fuel type while working with thermal storage technologies in order to optimize the system and decrease fuel prices. In this regards it should be mentioned that gas and biomass fuelled CHP technology will be further analyzed later on in the scenario design phase, sized to work in connection with a thermal storage and a DH gas boiler in order to ensure peak demand over the year. For the considered heat demand in Onești, the Scenario 2 considers the implementation of a single cycle large capacity plant which offers the advantage of short construction time (compared with steam turbines) and short start up/close down time if needed (Danish Energy Agency 2012). Typically, units as such are fuelled by natural gas or light oil and overall efficiency ranges between 80-85%, respectively 40-41% in regards to the heat output capacity. In regards to Scenario 3-biomass CHP technology, it should be pointed out that while thermal efficiency is increased-64% (compared to a gas CHP-58%) and so are the specific investment costs as presented by the Danish Agency catalogue of 2012. Efficiency performances are increased further if flue condensation technology is considered. The technical lifetime of biomass conversion technology is another slight advantage when comparing to traditional gas-fired plants given the 5 years difference. The alternative scenario "District heating with CPH (biomass)" analyzes a wood chips fuelled plant for which fuel prices constitute an advantage and a capacity of above 10 MW which is a capacity range that proves less cost effective if not exceeded.

4.4. Industrial gas boiler

The core of an industrial boiler is represented by a hot water or steam boiler using a certain kind of fuel (which in this case is natural gas). During the combustion process, fuel is burned in the furnace section resulting in energy which is utilized as a mean of heating a water volume in the boiler section. More precisely, the burner section uses a mixture of fuel and oxygen to provide a platform for combustion. Following the combustion process taking place in the combustion chamber, is a certain amount of heat which is transferred to the water through the heat exchanger. The volume of hot hater produced by the boiler is then pumped sent to destination through a pipeline system.

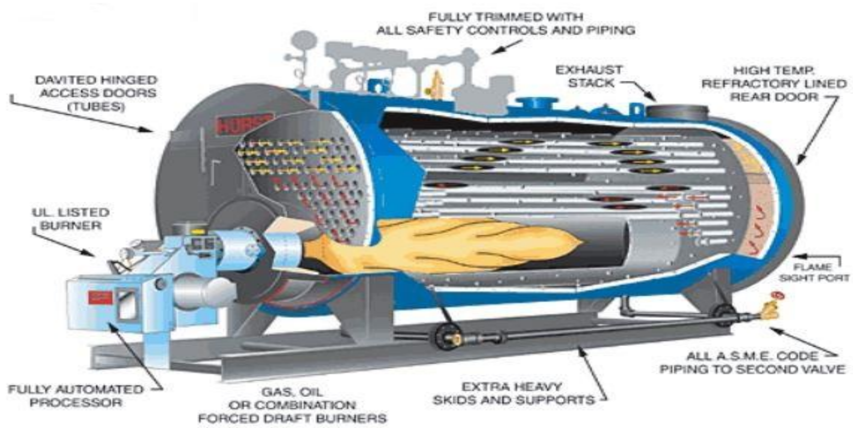

Figure 12 Cut away view of a fire tube boiler (author's own research)

Often, they have been encountered in DH schemes for the past decades while most of the boilers today are used as peak-load solutions, back-up capacity or to balance the electric production at CHP plants in the case of a decrease in electricity prices on the market (Danish Energy Agency 2012).

Based on working parameters such as temperature, fuel type, size and capacity, boiler s are classified into different types. Two commonly encountered types are fire tube (Figure 12) and water tube boilers (Figure 13), which differ from one according to the level of pressure at which they can operate. According to these values, water tube boilers, in which water is flowing inside the tubes and hot gasses resulted from combustion are circulated outside the tubes, can withstand higher pressure values and are commonly used for comfort heating applications.

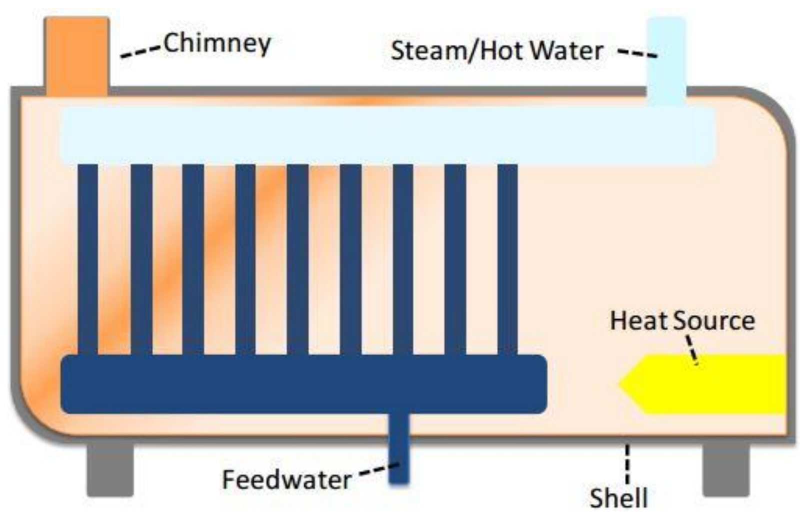

Figure 13 Side section view of a water tube boiler(author's own research)

One of the considered scenarios within the methodology chapter considers exploiting the benefits of DH in connection to a wide spread network of industrial size gas boilers. With capacities ranging from 93 kW to 2,800 kW they are strategically positioned across the city of Onești in order to deliver hot water to surrounding blocks of apartments and neighbourhoods (Figure 14). To the general public, they are known as "neighbourhood thermal plants".


Figure 14 Ferroli industrial size gas boilers (3x2,000kW) (1)


Figure 15 Ferroli industrial size gas boilers (3x2,000kW) (2)

The above shown figure illustrates a thermal unit located in the south-west part of Onești, consisting of three Ferroli 2,000 kW gas boilers meant to ensure the hot water supply for about 250 neighbouring apartments connected to the DH grid. Unlike the scenario in which hot water is provided by a CHP unit or bigger capacity single thermal unit located outside the city limits, "neighbourhood thermal plants" benefit from a convenient positioning within just hundreds of meters from the consumers which allows for smaller losses and lower fuel consumption.

4.5. Storage for District Heating

Storage technology for energy has become widely available and it proves of practical use when, for example, wind production cannot supply because of low of high wind speed. In this case, energy storages can provide for the electricity grid as well as store electricity in times of excess production and demand registers low values. In this project, the "DH with CHP" scenario uses a 2000 m^3 size thermal storage technology to ensure peak supply in times of high enery price. The large scale steel tank, proved to be a stable technology for hot water, is insulated with 2x150mm mineral wool insulation (Danish Energy Agency 2012).

5. Potential of other RES in Romania

Despite a significant renewable energy potential, Romania's "green energy sector" remains poorly exploited with few investments aiming towards its development. Although having a significant potential of RES, the country struggles with a burdening gap between the theoretical potential (on paper) and economical feasibility which leads to a use of the majority of some renewable sources over the others in real life projects.

Biomass

In terms of both theoretical and practical planning, biomass and biogas products account for the dominant RES potential in Romania, adding up to around 65%. In practice, this relates to 135 TWh/year of both electric and thermal produced energy (Grigoras 2015). Its participation is overwhelming compared to wind, solar, micro-hydro and geothermal which are individually represented in Figure 16.

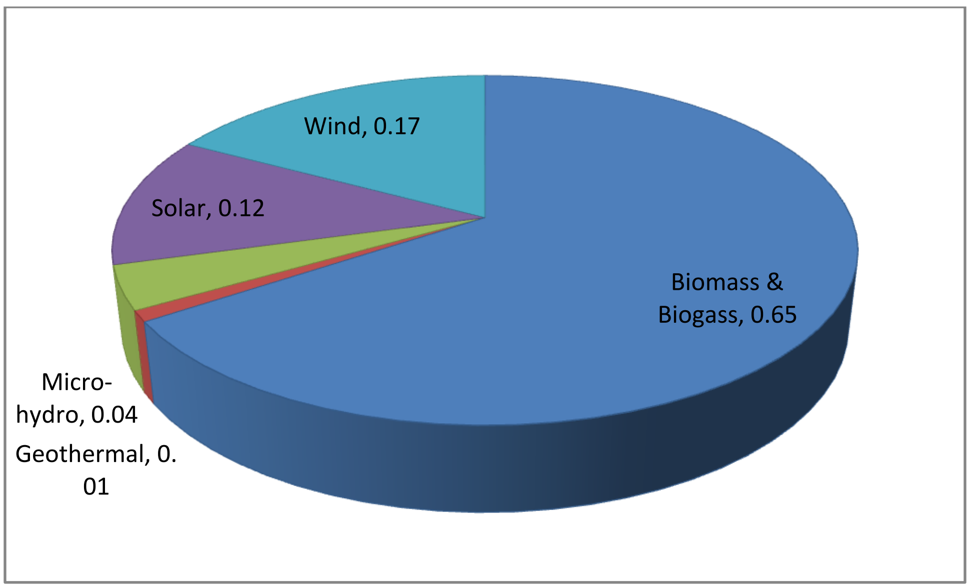

Figure 16 RES potential distribution in Romania

Considering biomass and biogas, statistics estimate the highest potential of green energy production-88.34 TWh/year while about 36% of its potential is supposed to be used at the moment (Grigoras 2015). There is a vast density of forest area which brings optimistic prospects of successful development of the industry. For the moment, its usage is mostly focused by household firewood purposes (about 95%-direct burning, cooking, space heating) while the industrial usage is only estimated to account for a small share-5%. The potential of biomass can be estimated to a significant value when reported to the average primary consumption at a national level-19%, which explains the wide spread usage (Ibid.). Seen from the perspective of its availability, the surface of biomass that has the potential of being used in energy purposes measures 27.3% of the national territory and is mostly located in the central part of the country. This eases and lowers costs of transportation towards the other regions of the country and offers the advantage of industrial development to process different types of biomass fuels which could relate to the creation of jobs and potentially contribute for social development in the rural areas, for example.

Wind

For the time being, wind power attracts the most financial investments in energy projects in Romania compared to other RES but this occurred only in the south-eastern (Figure 17) part of the country where it registers the highest potential. The past decade has reassessed this value and has concluded with average wind speeds of 8-9 m/s, compared to the European average of 6-8 m/s which, at a first glance, theoretical potential estimates an annual production of 23 TWh/year.

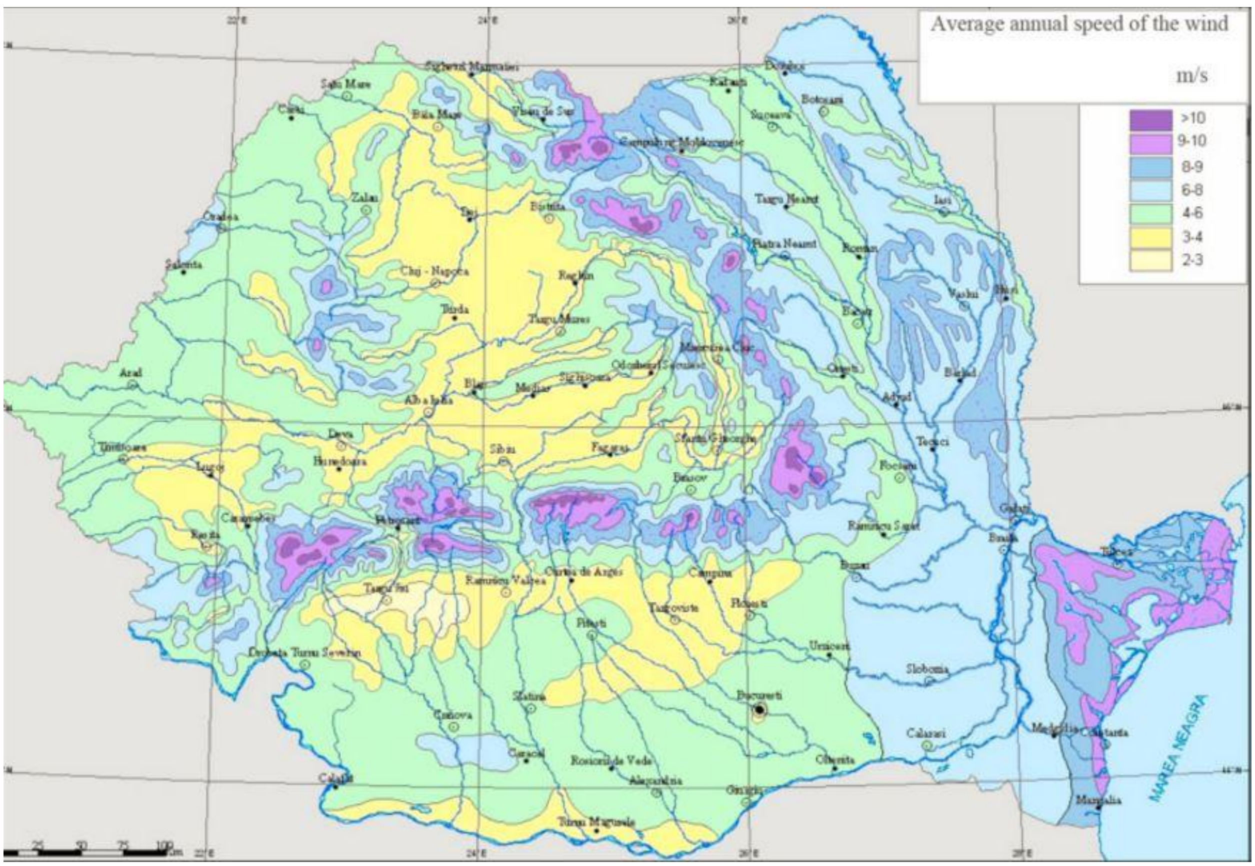

Figure 17 Potential of wind power in Romania (Grigoras 2015)

However, realistic values should be considered according to technical and economic possibilities of exploitation (Grigoras 2015). Additionally, sudden development of wind farms projects between 2010 and 2012 has put the national electricity grid to intense solicitations which has drawn attention upon the poor performance and need of investments in the grid. This has concluded with a significant decrease in the amount of investments announced for wind power projects in Romania and constitutes one of the reasons for which wind power has not been chosen for analysis despite the promising figures shown by its potential.

Solar

Solar energy potential in Romania shows moderate values, the highest of them being rated by the south and south-eastern parts of the country with an estimated yearly production of 1.25 TWh; about 2.5% of the current consumption (Grigoras 2015).

Table 1 below gives a 2005 estimation of the predicted installed photovoltaic capacity by 2020 in contrast with the biomass potential which is estimated for the same period of time.

Table 1 Estimation of 2005 regarding photovoltaic and biomass capacity by 2020 in Romania (Grigoras 2015)

Renewable technologies	Installed capacity [MW]											
	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Photovoltaic	0	0	8	43	78	113	148	183	200	220	240	260
Biomass	0	14	90	165	250	340	425	510	540	565	590	600

Despite the estimations of 2005 (compared to the actual outcome), the year 2014 registers significantly more capacity being exploited in regards to both solar and biomass energy but figures show the influence of administrative and technological barriers in the establishment of both technologies (Pirlogea 2011). On this matter, the solar energy capacity in 2014 only reaches a total of 363 MW compared to 1,056 MW of biomass capacity installed which is one of the main reasons the study chooses to incorporate biomass as a renewable alternative.

Hydro

Hydro power already accounts for a significant share in total energy mix of Romania-28% of the total production. This further relates to an estimated usable power of 36 TWh/year, mostly accounted for the production of plants located on the Danube River, near the Serbian border. Iron Gates I and II are among the biggest hydroelectric plants in Europe summing a total of 30 power generation units placed on the territory of both Romania and Serbia (Wikipedia). Other geographical resources are concentrated into the valleys of rivers emerging from the mountains which are place to 2,500 lakes that sum up to 5.9 GW of power that could be further increased to approximately 8 GW with proper investments (Grigoras 2015). Figure 18 below shows the estimated potential for small hydro power plants, existent and in construction, which accounted for approximately 6.6 GW of power at the end of 2011 (Ibid.).

Figure 18 Potential of small hydro power across Romania (Grigoras 2015)

The hydro potential could be an interesting study case to be considered for with the development in the heating sector and implementation of compressor heat pumps.

6. Results and analysis

This chapter will further develop by presenting characteristic data that has been obtained by EnergyPRO simulations of the technologies presented by the scenario design subchapter of the methodology.
As the study aims to determine the feasibility of the considered different type of heating systems, a yearly heat value expressed in €/MWh incorporating all costs (investment, O&M, fuel, taxes) will be determined for each scenario in order to be compared.

6.1. Results

Scenario 1: Individual heating (condensing gas boilers)-reference scenario
This subchapter develops on the level of costs to be covered by a household consumer should an investment in a condensing gas boiler be considered as a heating alternative. The goal is to calculate a yearly value which represents the fuel consumption needed to cover the heat demand throughout the year to which the value of the boiler investment will be added and presented in different payment plans. The difference is accounted for the payback durations which, according to online bank research, provide with the lowest available interest rates (IR) (Conso.ro).
First, technical features and economic values of a condensing gas boiler sized according to the apartment dimensions and demand (mentioned in the scenario design chapter) are presented in Table 2 as a starting point for the analysis.

Table 2 Technical and economic specification of the condensing boiler.

Condensing boiler		
	Value	Unit
Power	24	kW
Efficiency	90	%
Fuel	Natural Gas	
Heat value of fuel	11	kW/m3
Technical lifetime	10	years
Gas grid O&M	10	€/year
O&M service	50	€/year
Investment cost	2,000	€

As shown, a technical lifetime of 10 years (given by the manufacturer) has been chosen for boiler in the calculation of a yearly value which is to be added to the yearly value of the consumer's heating bill. Gas grid O&M costs represent a cost equivalent which is paid for regular check up visits assured by the gas distributor and is a fixed value throughout the year. O&M service prices are represented by costs equivalent to boiler check up visits made by authorized installing engineers (and required by EU regulations) as well as costs equivalent to minor software malfunctions (which often affect the electronic panel of control found on most of the condensing boilers today (Chiper 2016)). The investment cost reflects the situation, in which the investment considers the purchase of complete system, meaning: a new condensing gas boiler (with a power of 24 kW and efficiency of 90%), radiators and copper piping system, including the installation fee. This enables for an accurate total estimation of the individual heating system which is considered relevant in comparison with an alternative solution.

According to the interview carried out with Mrs. Chiper and the yearly heat demand values of less insulated apartments-Standard Insulation and better insulated apartments-Efficient Insulation, this scenario will account for two final values corresponding to a "low yearly expenditure" and a "high yearly expenditure" matching these two types of apartments. Calculations will be done with a value of the gas price being set to 30 €/MWh, according to ANRE (regulated fixed price for household consumers).

Further on, the cost of the investment in analyzed through the perspective of a bank loan to which three values of the interest rate (IR) are considered according to three loan periods, as previously mentioned. In order to do so, a yearly value of the net payment (NP) is calculated as shown below:

$$NP = \frac{\frac{(LS \times IR)}{100}}{1-(1+(\frac{IR}{100})^{-LP}}$$

in which:

NP=Net Payment (yearly)
LS=Loan size
IR=Interest rate
LP=Loan period

First, the study reveals the yearly net payment which is calculated for a loan period of 10 years, as the cost of heat based on this circumstance will be used as reference for comparison. (Table 3)

Table 3 Net Payment values for different loan periods

IR (%)	Loan Period (years)	NP (€/year)	Low YE (€/year) (19.17 MW)	High YE (€/year) (23.33 MW)
4.5	**10**	**252.76**	**1,025.76**	**1,180.76**
4.0	7	333.22	1,106.22	1,261.22
3.6	5	444.22	1,217.22	1,372.22

Given the interest 4.5 rate and the case of less insulated houses, the net payment value reaches €252.76 for loan period of 10 which assumes yearly expenditures of little over €1,180-High YE for houses with less effective insulation. In accordance to the specific yearly heat consumption both type of insulation assume, a reference price for heat will be calculated to be later compared with the DH scenarios (Table 4).

Table 4 Reference heat price (€/MW) for Scenario 1

Expenditure €/year	State of Insulation -	Heat Price €/MWh
1,025.76	Efficient Insulation	52.26
1,180.76	Standard Insulation	

Scenario 2: District heating with CHP (gas)

As mentioned before in the scenario design, ensuring the coverage of the heating demand with district heating could be done by investing in CHP plant. In essence, Scenario 2 considers the construction of a gas CHP plant for which costs are considered according to the Danish Energy Agency's technological catalogue. The "degree days method" previously mentioned by the Methodology chapter is used to create a heat load profile order to determine the peak capacity according to which the plant has to be sized to. Same chapter mentions a rule of thumb which states that sizing the capacity to 50% of this peak will ensure suitable coverage around the year. Considering the indications, the size of the plant is calculated and shown in Table 5, along with specific economical data. The lifetime of the project is set to 25 years.

Table 5 Technical and economic specification of Scenario 2 components.

	CHP		**Boiler**		**Thermal Storage**	
	Value	Unit	Value	Unit	Value	Unit
Capacity	69.60	MW	37.5	MW	1,950	m3
Electricity ef.	44	%				
Heat ef.	41	%	97	%	95	%
Tech. lifetime	25	years	30	years		
Constr. Time	2	years	1	years		
Nominal invest.	0.7	M€/MW	0.1	M€/MW	200	€/m3
Total O&M	7	€/MWh	5.3	€/MWh		

In order for DH to account for a competitive alternative, the yearly costs that it assumes for one consumer have to be comparable to the yearly costs obtained in Scenario 1. Given the reference price calculated for scenario 1, there is a limit of price for which the yearly costs of having district heating should not exceed a certain limit in order to make the solution interesting for the consumer- 52.26 €/MWh. The inferior limit of the heat price provided by DH is considered according to the reference price approved by ANRE (for which heat can be sold to the consumers which are connected to a DH network, according to Article 22 of the Price Setting Methodology stipulated by ANRE) which is 30 €/MWh. ANRE is also used as source to obtain the price for gas which will be considered as fuel price for the CHP (respectively, 0.33 €/m^3). The simulations will first consider a heat price of 52.26 €/MWh for which the following monthly revenues are obtained:

Table 6 Summary of monthly cash flow Scenario 2 (EnergyPRO)

Calculated Period: 06-2017-05-2018
(All amounts in EUR)

	Total	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Revenues													
Sale of heat	9,370,722	394,191	325,455	341,450	367,958	807,585	873,960	1,194,919	1,399,040	1,215,751	1,110,711	830,813	508,890
Sale of electricity													
Spot	6,655,157	456,564	413,237	425,012	429,225	630,084	623,158	650,796	660,701	587,816	650,796	600,961	526,806
Sale of electricity Total	6,655,157	456,564	413,237	425,012	429,225	630,084	623,158	650,796	660,701	587,816	650,796	600,961	526,806
Total Revenues	16,025,879	850,755	738,692	766,462	797,183	1,437,669	1,497,118	1,845,715	2,059,741	1,803,567	1,761,507	1,431,774	1,035,696
Operating Expenditures													
Fuel costs													
Natural gas	11,632,021	658,336	582,601	601,029	620,386	1,048,155	1,083,054	1,295,468	1,425,463	1,252,367	1,245,795	1,037,096	782,272
Fuel costs Total	11,632,021	658,336	582,601	601,029	620,386	1,048,155	1,083,054	1,295,468	1,425,463	1,252,367	1,245,795	1,037,096	782,272
Operation&Maint.													
Engine1	885,395	59,066	52,586	54,300	55,317	84,823	84,127	87,983	89,910	79,468	87,983	80,753	69,079
Boilers	513,259	14,121	11,971	12,265	13,880	37,846	44,975	74,873	93,891	81,696	66,379	42,740	18,622
Operation&Maint.Total	1,398,654	73,186	64,557	66,565	69,197	122,670	129,102	162,856	183,801	161,164	154,361	123,493	87,702
Total Operating Expenditures	13,030,675	731,522	647,158	667,594	689,583	1,170,824	1,212,157	1,458,324	1,609,264	1,413,531	1,400,156	1,160,589	869,974
Net Cash from Operation	2,995,204	119,233	91,534	98,868	107,600	266,845	284,962	387,391	450,477	390,036	361,351	271,185	165,722

The results in Table 6 show that, without considering investment costs, the system is able to obtain positive monthly revenues. The sums cover monthly fuel and O&M costs which are then subtracted from the total revenues obtained from the sales of electricity and heat and shown in the “Net Cash from Operation” section. Reported to a yearly value, the Net Cash value reaches a total of M€ 2.99.

For the same assumption-no investment costs, a day of operation has been chosen to describe the activity of the system’s different components as shown in Figure 19. This shows the individual level of usage in a 24 hour long interval in for which hourly electricity prices on the Romanian spot market are also considered. This leads to understand the priority of the components within the strategy of minimizing the net heat production which is set before the simulation begins.

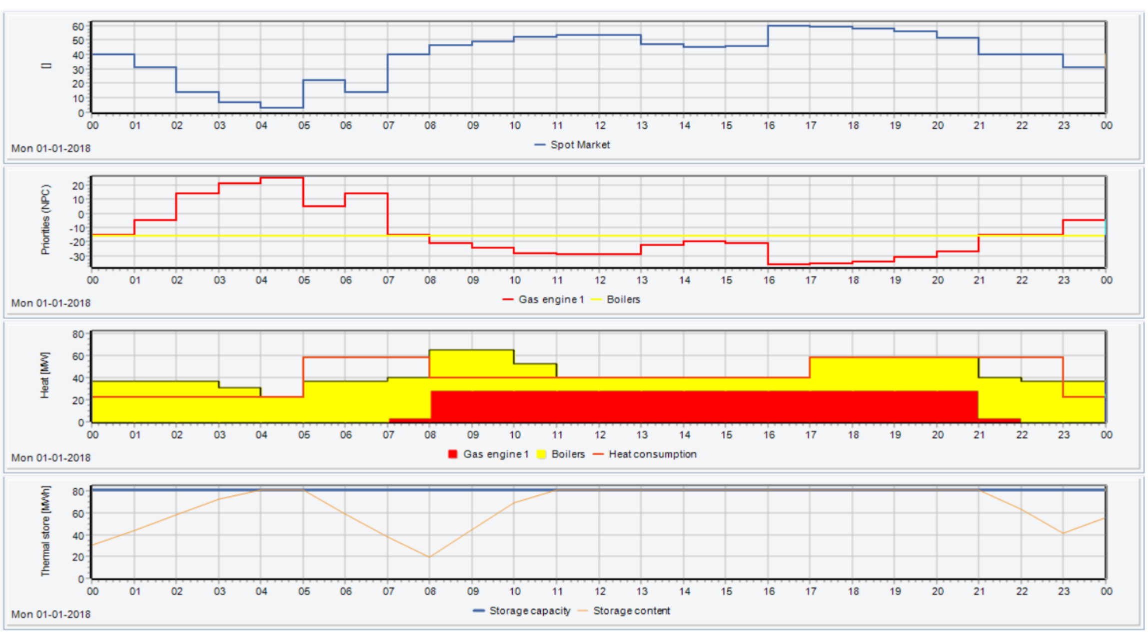

Figure 19 Production graphs of all system components (EnergyPRO, scenario 2)

For this example, the 1st of January has been chosen for simulation. As seen in the first section, the electricity price of the spot market is low in the first hours of the day, time in which production from the gas boiler is preferred over the operation of the CHP which, although obtaining extra revenues from selling electricity, is less profitable to run compared to the gas boiler. This is described by the second section of the graph which, furthermore, shows how priorities change starting 08.00 when the CHP goes into production. The activity of the thermal storage can also been seen in certain moments of the day when the costs of producing heat from the CHP are still relatively high and the boiler cannot account for the entire demand by itself.

The operational advantage of the CHP over the gas boiler can also be seen in Figure 20 which compares the electricity price on the spot market for a cold season month of 2017. The graph shows that for any positive value of the electricity price, the overall revenues obtained by the CHP makes maintains heat production costs at a lower value than those of the gas boiler.

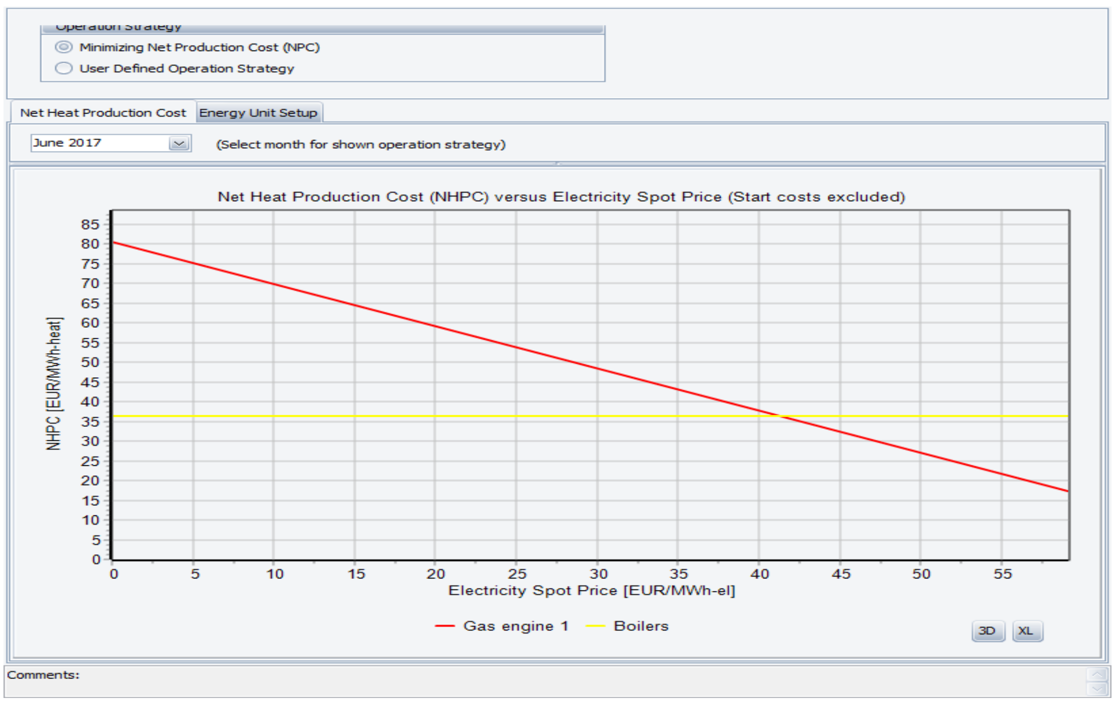

Figure 20 Minimizing net production costs strategy graph (EnergyPRO, Scenario 2)

Further on, the analysis aims to determine if the overall technical setup is able to prove feasibility considering monthly costs in order to cover the loan through which the investment is made. In order to do so, a Net Yearly Payment is calculated which will then be compared with the Net yearly Cash value to determine if yearly revenues obtained by the DH company would be enough to break even. This process implies a payback period of 25 years and an interest rate (IR) of 3.3 that can be obtained in the case of the Municipality (and guarantee from the Government), a according to online bank research. In addition, 6 M€ (non-refundable funding) will be deducted from the final cost. This represents a financial aid provided from both governmental and external sources with the

help of the Romanian agency AIPPIMM – which aims towards the implementation of programs meant to help in developing energy programs and others for companies (Vapo Romania 2015).
The value of the Net Yearly Payment is calculated using the annuity payment method as follows:

$$NYP = 12 * \frac{\frac{(L \times IR)}{100}}{1 - (1 + (\frac{IR}{100})^{-(12*25)}}$$

in which:

NYP=Net Yearly Payment
12=number of monthly payments
L=loan
IR=Interest Rate
25=loan period

In this case, the loan represents the total investment costs of DH system, as listed in the Table 7, below. This excludes the costs for the piping grid as previously mentioned in the methodology chapter (scenario design).

Table 7 Total initial investment costs for scenario 3 (considering funding)

Unit -	**Investment** [M€]
CHP	48.72
Boiler	3.75
Thermal storage	0.39
Total	52.86
Deduction	-6
Total investment cost	**48.86**

The formula concludes a value for the NYP of approximately M€2.75, representing the yearly sum which has to be paid in order to cover for the loan.

Table 8 NYP and Cash Surplus values

IR	3.3	%
Loan	46.9	M€
Loan period	25	years
NYP	**-2.75**	**M€/year**
	+	

Net Cash	2.99	M€/year
Cash Surplus	**0.24**	**M€/year**
NPV	4.18	M€

Further on, the NYP is deducted from the yearly revenues-Net Cash value in order to see if the revenues which the DH would obtain every year are enough to cover the payment towards the bank and have a feasible business. As listed in Table 8, deducting the NYP results in a positive value-Cash Surplus which accounts for a total NPV of approximately M€4.18 thus making the gas fired CHP a feasible case scenario.

Scenario 3: District heating with CHP (biomass)

The alternative proposed by Scenario 3 considers the implementation of a biomass fuelled CHP. Given the technical features of biomass conversion technology, the size of the system's components is as follows (Table 9):

Table 9 Technical and economic specification of Scenario 3 components

	CHP		**Boiler**		**Thermal Storage**	
	Value	Unit	Value	Unit	Value	Unit
Capacity	50	MW	37.2	MW	1,100	m3
Electricity ef.	29	%				
Heat ef.	77	%	97	%	95	%
Tech. lifetime	30	years	30	years		
Constr. Time	5	years	1	years		
Nominal invest.	200	M€	3.72	M€	0.22	M€
Variable O&M	6	€/MWh	5.3	€/MWh		
Fixed O&M	29,000	€/MW/year				

The same fuel price for gas is considered as in Scenario 2 and initial results are given without taking into account investment costs and thus their add on the final value of the heating bill for the consumers. A price of 0.155 €/kg is considered for biomass (Ministry of Economy 2010) which, unlike the previous scenario, registers slightly lower monthly revenues (described in Table 10)

Table 10 Summary of monthly cash flow scenario 3 (EnergyPRO)

CalculatedPeriod: 06-2017-05-2018
(All amounts in EUR)

	Total	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Revenues													
Saleofheat	9,370,722	394,191	325,455	341,450	367,958	807,585	873,960	1,194,919	1,399,040	1,215,751	1,110,711	830,813	508,890
Saleofelectricity													
Spot	2,935,343	137,112	121,276	126,950	132,977	249,879	271,277	373,527	399,390	357,278	344,628	250,400	170,650
Sale ofelectricity Total	**2,935,343**	**137,112**	**121,276**	**126,950**	**132,977**	**249,879**	**271,277**	**373,527**	**399,390**	**357,278**	**344,628**	**250,400**	**170,650**
TotalRevenues	**12,306,065**	**531,303**	**446,730**	**468,400**	**500,935**	**1,057,464**	**1,145,237**	**1,568,445**	**1,798,430**	**1,573,029**	**1,455,339**	**1,081,213**	**679,540**
OperatingExpenditures													
Fuelcosts													
Boiler	1,147,262	51,710	39,996	39,072	44,170	114,309	108,887	115,153	185,374	147,515	117,085	124,611	59,380
BiomassEngine	6,517,389	323,914	291,857	303,482	314,579	542,147	590,408	812,693	871,170	777,466	750,693	542,852	396,130
Fuel costs Total	**7,664,651**	**375,624**	**331,852**	**342,554**	**358,749**	**656,456**	**699,296**	**927,846**	**1,056,544**	**924,981**	**867,778**	**667,462**	**455,509**
Operation&Maint.													
Engine1	261,558	12,999	11,713	12,179	12,625	21,758	23,694	32,615	34,962	31,201	30,127	21,786	15,898
Boilers	196,690	8,865	6,857	6,699	7,573	19,597	18,668	19,742	31,781	25,290	20,073	21,364	10,180
FixedEngine1	1,450,000	120,833	120,833	120,833	120,833	120,833	120,833	120,833	120,833	120,833	120,833	120,833	120,833
Operation&Maint.Total	**1,908,247**	**142,698**	**139,403**	**139,711**	**141,031**	**162,188**	**163,196**	**173,191**	**187,576**	**177,325**	**171,034**	**163,983**	**146,911**
TotalOperatingExpenditures	**9,572,898**	**518,322**	**471,256**	**482,265**	**499,779**	**818,644**	**862,491**	**1,101,037**	**1,244,120**	**1,102,306**	**1,038,811**	**831,445**	**602,421**
NetCash from Operation	**2,733,168**	**12,981**	**-24,525**	**-13,865**	**1,155**	**238,820**	**282,746**	**467,409**	**554,310**	**470,723**	**416,528**	**249,768**	**77,119**

Unlike the previous scenario, the biomass CHP plant has an average higher priority over the gas boiler with a longer overall operation time and its presence in the system's mix is also reflected upon the size of the thermal storage which drops to 1,100 m^3 (compared to 1,950 m^3). Throughout the chosen day of simulation, the gas boiler takes over production between 04-05 a.m. when the spot market price of electricity is at its lowest (Figure 21).

Figure 21 Production graphs of all system components (EnergyPRO, scenario 3)

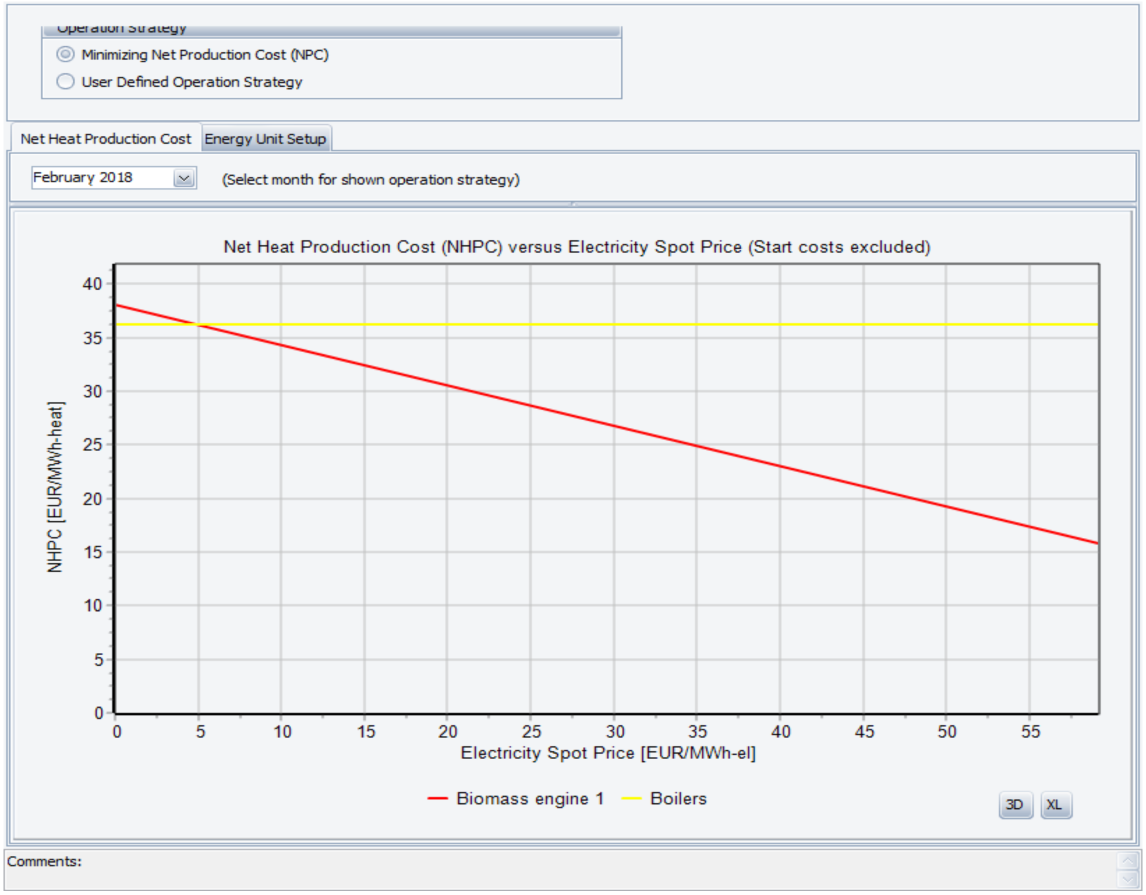

Figure 22 Minimizing net production costs strategy graph (EnergyPRO, scenario 3)

Nevertheless, in order to account for the feasibility of the project, the total investment costs have to be considered and analyzed from the perspective of a loan needed to cover the overall investments. Same conditions applied previously are simulated again but with a different value of the loan. All costs accounting for the total size of the loan are as follows (Table 11):

Table 11 Total initial investment costs for scenario 3 (considering funding)

Unit	**Investment**
-	[M€]
CHP	130
Boiler	3.72
Thermal storage	0.22
Total	200
Deduction	-6
Final cost	**194**

The same formula for calculating the value of the NYP is applied in order to determine the yearly costs which will be further deducted from the yearly revenues (Net Cash):

Table 12 NYP and Cash Surplus values

IR	3.3	%
Loan	194	M€
Loan period	25	years
NYP	**-11.64**	**M€/year**
	+	
Net Cash	2.73	M€/year
Cash Surplus	**-8.91**	**M€/year**
NPV	-126.21	M€

Table 12 shows that for an equivalent heat price to the one obtained in Scenario 1, the yearly Net Cash that the DH company could earn by investing in a biomass CHP plant is not enough to cover the yearly payment needed in order to account for the big size of the loan assumed by the biomass conversion technology. The size of the investment proves of an overwhelming cost compared to the amount of revenues the DH could obtain from its customers. Given that the situation refers to a selling heat price which cannot be exceeded without compromising its feasibility towards the consumers, cost changes would thus have to reflect upon fuel costs, investment and O&M costs or considerable financial support from the Government. In this regards, a further study would be needed to determine the actual factors which could influence the outcome of biomass as fuel prices cost have already been considered to a minimum and investment costs are difficult to be changed.

6.2. Sensitivity analysis

According to the results, the gas fired CHP plant proves of competitive potential against the individual alternative, unlike the biomass CHP plant which is overwhelmed by high investment costs. It is thus interesting to show if different economical factors such as IR, fuel price or reduction in the amount of grid losses have influence upon the technology proposed in Scenario 2 and if so, in what are the outcomes of these changes.

On this matter, the sensitivity analysis sets out to investigate the lowest price for heat which the DH company could sell the good to its customers for and still be able to cover the overall investment of the project, which relates to the NPV≥0. In order to do so, the total revenues that could be obtained by running the plant, represented by the sales of both heat and electricity, should be enough to cover the loan payment to the bank-NYP and the operating expenditures which are accounted for the DH system fuel costs and O&M. The formula to be applied in this case is as follows:

$$R \geq NYP + TOE$$

In which:

R=Total revenues (heat and electricity sales)

NYP=Net Yearly Payment

TOE=Total Operational Expenditures (fuel and O&M of CHP and gas boiler)

Revenues (R) can be further described by the formula:

$$R = HS + ES$$

In which:

HS=Heat Sales

ES=Electricity Sales

Considering that the electricity sales have a fixed selling price (given by the spot market), the minimum heat price for the consumers will be calculated by determining the minimum amount of sales to be obtained from selling heat (which is not fixed yet) which will then be divided by the heat demand (represented by the actual heat demand). The value will thus be calculated with the following formula:

$$MP = \frac{NYP - ES + TOE}{HD}$$

In which:

MP=Minimum Price

ES=Electricity Sales

HD=Heat Demand

The calculation concludes a minimum heat price of approximately 51 €/MWh (NPV of € 27,339) and thus a small difference compared to Scenario 1-1.29 €/MWh. It should also be mentioned that to this point, the analysis did not include additional administrative cost and potential salaries involved in the project.

Further on, the analysis investigates how slight positive and negative variations of the IR reflect on the NPV and show under which circumstances the feasibility of the project can still be maintained (Figure 23).

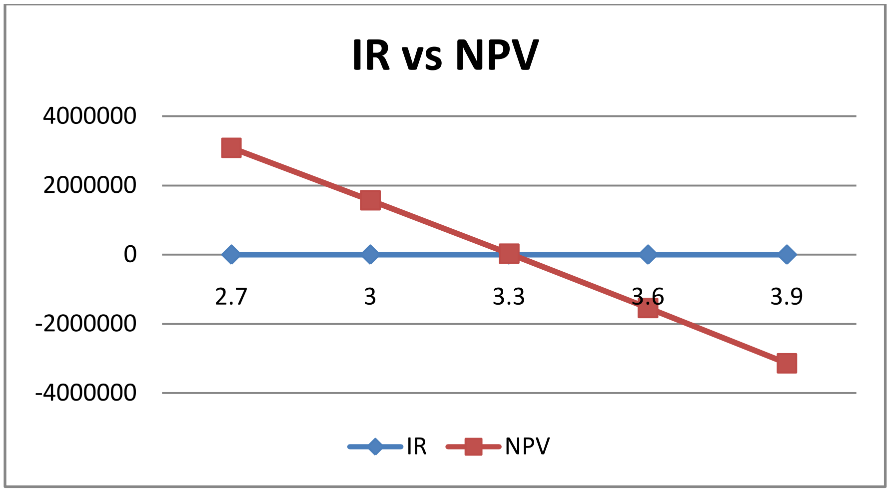

Figure 23 Influence of IR variation on NPV

The graph emphasizes in the importance of the 3.3 IR value upon the feasibility of the project, as the value of the NPV seems to be negatively influenced by slight increases, as shown above. As the overall difference between the minimum and maximum selling price is insignificant, the analysis assumes similar outcome if redoing the calculations for the upper limit of 52.3 €/MWh.

On a different topic, the price of gas accounts as a significant factor which influences the project's NPV. Information in this regards has only been officially announced on a yearly since the total liberalization of gas market whereas before, estimations could have been done for a longer period of time in the future due to the publication of a increase estimation calendar. For the analysis, variation in the price of gas will be considered according to the increases that have occurred in the last years which have ranged between 5 and 18% (Figure 24). The analysis chooses the reference gas price as reference to which it will apply 7% increase and decrease according to 2013-2015 trends (Eurostat 2016).

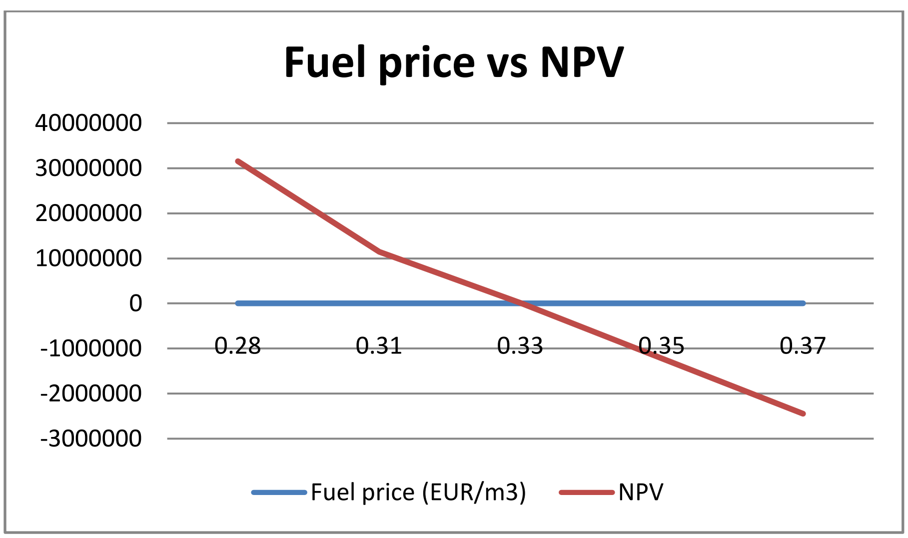

Figure 24 Influence of Fuel cost variation on NPV

The results show that the NPV is easily affected by increasing fuel price fluctuations. Being part of the EU, Romanian energy prices are likely to reach similar values in comparison to the other member countries and based on this fact the changing prices would thus increase the NPV, as shown in the graph.

A late 2015 EU addressed country report, focused on implementing high efficiency cogeneration and district heating in Romania, discusses about main policies and measures which are aimed to improving the overall DH sector. Among others, efficiency measures for 2016-2025 extend over financial aids meant to replace pipe networks and reduce technological leaks in networks to less than 15% (Ministry of Energy 2015).

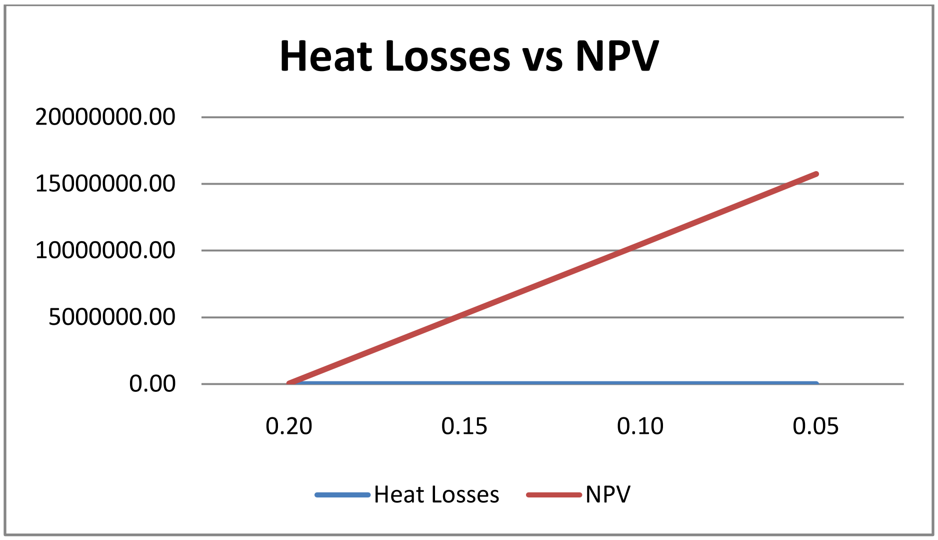

Figure 25 Influence of reducing heat losses upon the NPV

The analysis shown in Figure 25 starts by considering the current value of the system's heat losses-20% of the total heat demand and simulates consecutive reductions of 5% in order to show the influence of the 2016-2025 proposed strategy of the Romanian ministry. As anticipated, reducing heat losses has the potential of increasing yearly revenues the DH company can obtain. Decrease in electricity sales is accompanied by decrease in the total operational expenditures, which contributes to the overall increase of the yearly cash surplus.

7. Overview of the DH framework and actors analysis

The political changes of the Romanian society has shown influence, among others, on the development of a different context concerning the country's heating system in which DH has been "overwhelmed" by the wide spread appearance of other domestic individual heating alternatives. Perfectly timed marketing campaigns promoting the use of such solutions have captivated the public's attention in times of which DH companies' ability to ensure secure supply was doubted by the general public while neither supported by the evolution of energy prices which contributed to a considerable loss of its market share (Poputoaia, Bouzarovski 2010). Additionally, the missing ability of the authorities to adapt and manage the ongoing phenomenon by adopting suitable policy schemes has also contributed negatively on this matter.

Nevertheless, active participation and commitment towards improving security of supply while in the context of addressing climate changes seems to have brought DH back in the agenda of the Romanian officials. Along the national strategic planning included by NEEAP and NREAP which include the national framework of both energy efficiency and renewable energy development and aim to fulfil obligations towards EU policies on the matter, attention has also been focused on the upgrading and expansion of DH in order to regain its competitiveness. More specifically, the initiative addresses the gap created by inadequate attention towards policy reforms with direct influence upon social and economical activities in this domain (Andersen, Lund 2007). A suitable legislation on this matter implies, on one hand, the need of both rights and obligations of relevant actors and stakeholders as well as assessment of procedures and sanctions that can be applied in a framework which is addressed by regulation (Poputoaia, Bouzarovski 2010).

The communist technological legacy of Romania was designed to provide safe and affordable supply in the context of a high industry demand and relevant production capacities, under state ownership exerted by the public company S.C Termoelectrica S.A. The downsizing and migration of major industrial activities away from DH that occurred because of political discourse of events raised the issue of inadequate large capacity to cope with decreasing demand, which is later contributed to by a significant share the population (Romanian Government 2004). This meant that DH companies have been given the responsibility of dealing with over employment cause by the share of 70% of the production costs representing fuel and also salaries and pay-offs (Ibid.). On this matter, constant discrepancy between gas prices for household consumers being lower than the one paid by DH companies emphasizes on the need of coherent policies in this sector (Nuorkivi 2005). One step in regards to this issue that consequently caused continuous disconnections from the system was indeed taken to also counteract the competitive presence of individual gas boilers but not in a positive manner. Instead, imposing additional requirements towards the clients when taken the decision to disconnect has only enhanced the unfavourable image of DH.

7.1. Evolution and structure of the current DH legislative framework

The initiative addressing this situation has later taken the form of policy reforms by strategic planning focused on three main aspects to help reorganize the structure of the DH sector: the creation of DH zones, creation of heat planning and a reform concerning price establishment (regarding the past disadvantaging economical influence on DH competitiveness in this sense).

While further steps of the process concluded with encouraging measures such as the DH Law or the Public Utility Service Law which, among other, was meant to "stipulate the unitary legislative and organizational framework of the public utility service operations", the need of a common responsible body was addressed fulfilled by the establishment of a National Authority for Regulating Public Communal Administration-ANRSC (Matei 2009). The authority's responsibility extends over managing and administrating compliance of operators as well as the issuing of licence for heat only boilers used in DH purposes. In this regards, the prerogatives of ANRSC meet the ones of ANRE, the National Authority for the Regulation of Energy given the regulation and control of cogeneration which, in addition, is in charge of supervising and regulating energy related activities and legislation. Differences between the two can be indentified in terms of the superior authorities of whom they correspond as shown in Figure 26.

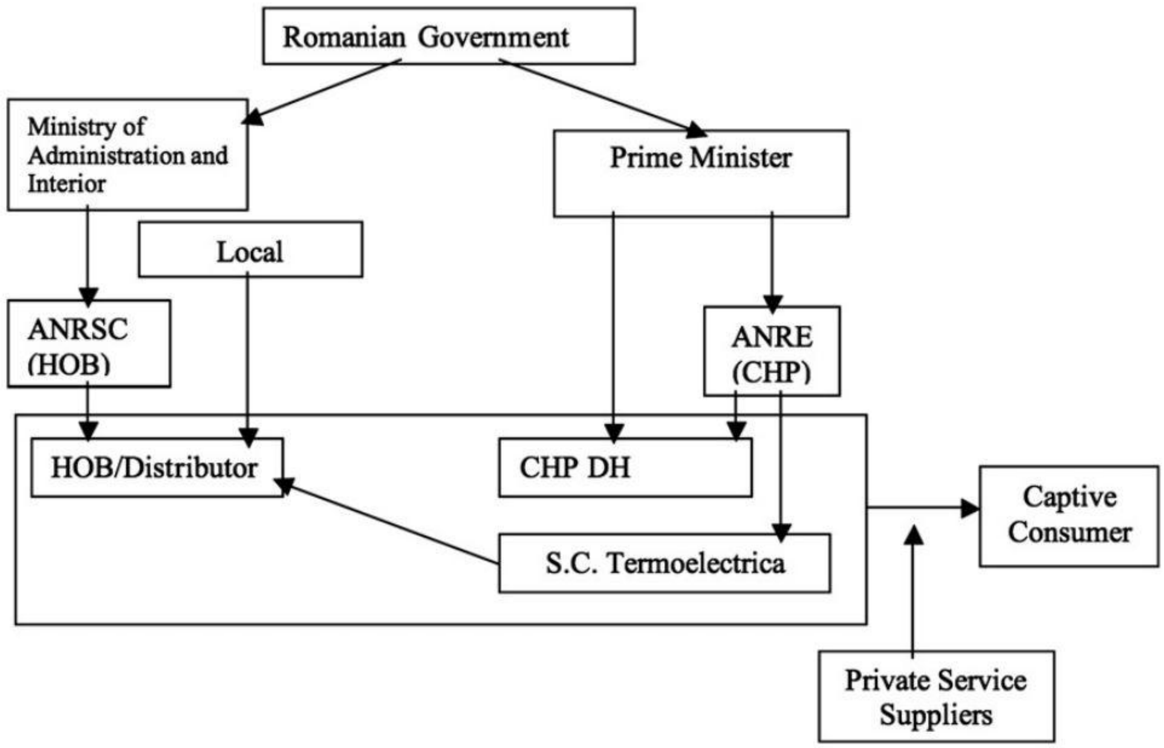

Figure 26 Structure of the DH sector in Romania. Role and administration of ANRSC and ANRE (Poputoaia, Bouzarovski 2010)

Relevant implementation continues but does not benefit from the advantage of good timing when local authorities are transferred ownership of the DH networks in order to ensure their administration and management take place in late 2002 (Grohnheit, Mortensen 2003). This also relates to their responsibility of presenting strategic assessment of their region in regards to the national planning perspective, mandatory for municipalities administrating areas populated by more than 20,000 inhabitants (imposed by The Energy Efficiency Law). The year 2004 follows the "trend" suitable policies by introducing metering of heat, aimed at reducing the amount of losses DH consumers pay for despite of whether they are or not responsible and thus eligible to pay for them. The reason behind the existence of these losses is explained by the "vertical distribution" of collective heating systems typical to previous communist technical planning (Alliance to Save Energy 2007). This measure will later on precede the establishment of "owners' associations" as responsible for providing data concerning heat meters in designated apartment buildings which, among others, account for their importance on the actors list relevant to DH in Romania. Same year reflects rehabilitation of DH in the agenda adopted by the national policy agenda in order to comply with requirements to ease accession to the European Union. In essence, the policies aiming for the development of DH now acknowledge the need of social and environmental protection and act by introducing financial schemes in advantage of the heating sector (i.e. updating The DH Law) (Romanian Government 2004).

But the Romanian DH context is far from regaining competitiveness and attracts consumers to adopt the heating alternative. Complying with EU regulations remains an important issue for outdated technologies which eventually have to shut down because of inadequate efficiencies and contribute to the country's need to import energy. On top of these things, although clearly defined in terms of competences and jurisdiction, poor collaboration between ANRE and ANRSC add to the overall weak "performance" of the newly regulated system which ultimately relates to DH networks' late or insufficient investments for technological update.

In the light of Romania's accession to the European Union, the responsibility of complying with relevant legislation may have a positive impact on rehabilitation of the DH system. EU policies have the potential of triggering implementation of adequate legislation to achieve this goal by attracting considerable funding for infrastructure purposes that can be further directed towards local responsible authorities (Poputoaia, Bouzarovski 2010).

7.2. Actors analysis

Governmental authority

Indirectly responsible for managing both ANRE and ANRSC as well as elaborating strategic energy planning in order to fulfil obligations towards the European Union, the Government is indirectly responsible for the development discourse of DH as well. And as long as it will be maintained and promoted by the European agenda, DH will be a matter of focus on country's agenda and be considered in the decision making process of policy and law formulation, thus placing the Government in an actor" position".

Local authorities

As previously explained, local authorities have been given ownership of DH networks and, implicitly, both managing and administrative responsibility over them. But that is in a rather partial manner as reports of their administrative and managerial actions have to be further approved by the Central Government. This is stipulated by the law which involves them actively in the process of establishing DH zones or regulation of the price and supervision over the implementation of metering for consumers for which collaboration with owners' associations is expected. At a first glance, a considerable and important amount of work which requires an adequate competence is expected from the municipalities. In the light of this matter, difficulties have been revealed by situations which have seems to exceed their abilities. Along with instating their role in the DH sector, specific documentation and/or instructions of how to proceed have failed to be provided to this less competent newly appointed body which is clearly slowed down also because of insufficient level of financial resources (Leca 2004).

The list of responsibilities covers being in charge of maintenance and replacement of meters imposed by the DH Law which expects local authorities to provide with regular data and proposals for metering programs (base on further data obtained from grid operators with whom they have to collaborate in this sense). In regards to operators, authorities approve concession agreement which give the former management rights over the DH services. On a different note, they have the authority of granting access to these operations also to a third party, which is also mentioned in the DH Law as well as the competency of sanctioning any active operator in case of poor performance (Alliance to Save Energy 2007).

Owners' associations

While developing on the responsibilities of local authorities in the Romanian DH sector, the role of owners' associations in mentioned in regards to metering for consumers. In this regards, owners' associations are in charge of signing framework service agreements with DH companies (Poputoaia, Bouzarovski 2010). In essence this means that associations are billed by authorities and are responsible for a certain apartments building in a way that they ensure the value of the bill is covered in accordance with the individual consumption of each consumer (Figure 27).

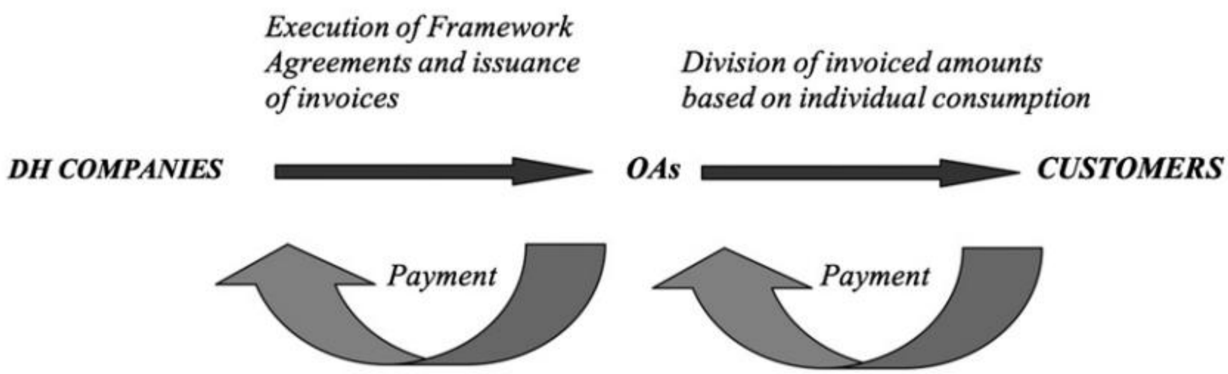

Figure 27 Role of owners' associations in the customer billing process (Poputoaia, Bouzarovski 2010)

Therefore, the role of owners' associations is important in easing this process and ensuring that DH companies receive their payments integrally from the consumers, as well as identifying and carrying out the disconnection for the system of defaulting consumers.

Consumers

In regards to their implication/participation to the administration/management of the DH network in their areas, the consumers are represented by the heads of owners' associations in the Municipality's council meetings. This way, their opinion about local authorities and how they deal with the well being of the heating system is made clear and a mean of communication is ensured between the two bodies. Nevertheless, the communication could be "strengthen" by the consumer's own participation in the meetings which is possible given that, on some of the topics, they are open to the public. In spite of these things, their attitude and almost inexistent presence in these assemblies describes lack of trust consumers have towards the influence of their involvement (Balas 2016).

Although not in a direct regulatory actor position, they have a clear influence in the development of DH landscape, as it has been vividly shown over the past decade. Driven by the heating system's affordability and security of supply, or the lack that it had manifested, consumers have directed their attention towards competitive alternatives which have concluded in a dramatic change with negative influence upon the DH networks around the country. If proven otherwise, one can again account to their influence in revitalizing the system should DH prove to fit within the expectations and needs of consumers.

8. Discussion and recommendations

This chapter follows the logical thread of the presented analysis in order develop on the ideas and methods approached to determine a suitable way of addressing the topic expressed by the research question and implicitly, the conditions assumed the chosen case study-the city of Onești. It is also meant to describe limitations or assumptions which have been made along this process and further present recommendation to support the development of the proposed alternative.

8.1. Discussion

Scenario 1 starts by investigating the competitive potential represented by the current individual heating alternative-condensing gas boilers. The reason for choosing the specific technology is accounted for by the requirement enforced by the EU ErP Directive of late 2015 which introduces one of the issues expressed by the research question as well. Consumers connected to an individual alternative can only opt for the new condensing technology (should they choose to maintain their connection) which in comparison to the previous traditional boilers, assumes a bigger investment and thus relate to a higher heat price for consumers. Within the analysis, this investment is considered from the perspective of a bank loan which according to a given IR (4.5%) sets the final level of the yearly heat price-52.3 €/MWh (including O&M and check up expenditures) which is further on compared with the proposed alternative. To this point, the analysis encounters a limitation regarding the obtained heat price. As the method incorporates the effects of the IR, its absence would assume a much lower price for heat-40.3 €/MWh (per year) for which neither of the proposed alternatives maintain a competitive solution. This is situation can occur if the consumer makes the investment with no bank loan, thus lowering the total eventual costs. Nevertheless, the study addresses the modest financial possibilities of the average Romanian consumer and secondly, considers the added value of a loan in order to highlight the benefits of the alternative provided by Scenario 2.

In order to compare the reference heat price, the analysis continues with the investigation of Scenario 2. In this regards, the proposed alternative investigates the implementation of a DH system comprised of a gas fired CHP plant, a gas boiler and thermal storage. Calculations to determine the heat price assumed in such situation estimate a minimum yearly value of approximately 51 €/MWh, thus a difference of only 1.29 €/MWh. This price is set in the basis of a 25 year long loan for which an IR of 3.3 is considered, according to online sources and bank research. Specific investment costs, O&M, fuel prices and both heat and electricity sales put together in order to determine the DH company's ability to gain revenues by covering the total heat demand, as well as account for the regular payment towards the bank (which is calculated using the annuity payment method). In addition, according to current financial schemes which aim at promoting efficient cogeneration in Romania, a deduction is considered from the total cost of investment representing the equivalent sum that can be obtained from sources providing these schemes on the basis of certain criteria. Based on these assumptions, the heat price is then calculated and compared to the reference value obtained in Scenario 1. Nevertheless, a limitation in this case is revealed by the lack of incorporating taxes on emissions which has not been considered due to insufficient data. According to Romanian legislature, a maximum limit of allowed emission level is set on a yearly basis for different sectors of the industry and then assigned to each sector according to a total number of existing pollutants and new entities which add to this number at the beginning of every year. Exceeding this limit assumes the purchase of "green certificates" from renewable producers which can be bought directly from this source or by bidding on the market of certificates. Unfortunately, the research has not concluded with exact figures to sustain this calculation, however, a remark in this sense may assume that the influence of these taxes on the heat price generated by the scenario would account for a less competitive choice compared to Scenario 1. The price difference between the two 1.29 €/MWh per year, does not allow for a significant margin of additional costs for the case of Scenario 2.

On the topic of the heat price determined by Scenario 2, further mentions extend over the project's NPV. In this sense, the yearly heat price of 51 €/MWh represents the limit to which the investment reaches the breakeven point corresponding to a yearly revenue of just above €1,000. A limitation in this regards is reached as, according to these modest profits, the project cannot cover administrative expenses and salaries or other related costs involved in running the CHP plant throughout the year. This matter requires further investigation as increase in the price of the consumer's heating bill is not a viable option.

The alternative presented by Scenario 3 differs in terms of the fuel used to power the CHP plant-biomass. A widely available and resource that has a cheap price, approaches a renewable heating alternative but does not account as a feasible investment in the context of our case study-Onești. Large investment costs rate high in terms of the annual payment towards the bank which cannot not be entirely covered by the revenues that the DH company can obtain. Nevertheless, encouraging attitude is shown by the authorities in strategic report of late 2015 addressed to the EU which mentions about the "extension and implementation of the programmes for the use of renewable sources and of the production of cogeneration electricity and heat, including in the rural environment" scheduled to happed starting 2019-2030 (Ministry of Energy 2015). In this regards and based on the results obtained in Scenario 3, investigations should relate to the creation of relevant policies and regulation to cope with the obstacles represented by the high investment costs and ways of compensating these prices for the investors. According to the strategy, funding for such projects is already considered but only on a general basis, with no specifications and thus lack of guidelines and eligible criteria or individual financial estimates for that matter.

Based on these results, the sensitivity analysis focuses on presenting how key financial factors as IR value, fuels costs and heat losses influence the outcome of running the gas fired CHP plant. The analysis, therefore, points out the influence of higher values of the IR upon the feasibility of the project which is not maintained if exceeding 3.3%. Fuel prices, on the other hand, show a more favourable study considering trends and potential price changes on the Romanian energy market. As part of the EU, energy prices will reach similar values compared to the other member states, with positive influence on the outcome of the project's yearly revenues. On a similar note, the DH strategy for 2016-2025 proposed by the Romanian Ministry of Energy (which is focused on achieving lower heat losses) could potentially increase the yearly incomes by investments in the replacement of pipe networks and overall "reduction of technological leaks".

8.2. Recommendations

In the light of current regulation, attention is drawn upon the methodology of setting limits of emission to each sector of the industry, which in this regards, should support cogeneration by favourable regulation for development and wider implementation. Unlike the current institutional framework related to the exploitation of wind or solar energy in Romania, the current administrative and bureaucratic system does represent a burden in the process and could be the starting point for a better setup in the future regarding green energy generation.

On a reduced scale, emphasis is put on the faulty implication of important actors and their influence in the DH sector. In Chapter 7, the analysis develops on the topic of DH operation ownership transfer to the local authorities. In this regards, ownership does not assume full control over the local budget (allocated from the central funding) which partially controlled by prefects-meant to act as representatives assigned to supervise that municipality activities, in this sense, meet the government's objectives. The fault along this process is accounted for political affiliation of the prefects which, eventually, reflects on the faulty attribution of the funding or even the possibility of it not being granted to the municipality on the basis of irrelevant reasons. Recommendations, therefore, suggest thorough analysis and re-evaluation of the prefect's position and responsibilities, which indirectly, is has regulatory power over the DH sector.

Administrative faults requiring immediate attention extend over the relationship of local authorities with publicly owned DH grid operators, which are eligible to be sanctioned by the former in case of poor performance. In this sense, the shareholding structure over a local DH network and means that local authorities would have to sanction themselves when targets or commitments are not met, which is less likely to happen. Political influences are, again, an intermediate in this process as sanctions are sometimes still not applied if the DH operator presents certain interest towards the local authorities. In this regards, ANRSC should direct their attention towards adapting the framework around the problem and lessen the subsequent negative effects on the DH sector.

9. Conclusion

History of the Romanian heating sector in the 1960's begins with the development of a district heating system. Present in more than half of the large cities, it reflects a legacy of the former political regime designed to cope with a rapidly evolving industry sector between 1960 and 1970. Following changes in the political environment of the late 1990's affects economy and industry as well as the district heating sector which can no longer comply with the needs of the consumers. Massive disconnections from the district heating become a wide spread phenomena and along with it, a new affordable alternative given the modest financial possibilities of the average Romanian consumer-gas water boilers. However, boilers have recently fallen under the regulation of the EU ErP Directive which demands higher standards of efficiency and low emissions at the cost of higher investment prices for the consumer. And given the ongoing liberalization of the Romanian energy market for household consumers, attention is now drawn upon the competitive potential of district heating. The study is therefore led by the following research question:

Can DH provide an affordable alternative for consumers in Onești given the competitive case of the current individual solutions?

In order to address this topic, the methodology develops on the design of three scenarios for the case study of Onești-a vivid example illustrating the heating system's changes of the past two decades similar to most of the other Romanian municipalities. Similar to the current situation, Scenario 1 was designed (as reference) to analyze the effect of the ErP Directive and ongoing liberalization of the energy market on the heat price paid by the consumers which connected to an individual heating system. The other two scenarios focus attention towards a district heating alternative and explore the implementation of the CHP technology in connection with an industrial size boiler and thermal storage. Scenario 1 highlights the utilization of gas while Scenario 3 analyzes a biomass fired CHP plant.
All scenarios consider the implication of a bank loan to cover for the specific investment costs. The annuity payment method is then used to calculate regular payments which are incorporated into the final value of the heat price in order to compare Scenario 1 to the alternatives provided by Scenario 2 and 3. In this regards, high expenses of biomass conversion technology assumes expensive heating costs which lessens its competitive potential compared and focus it pun on Scenario 2 as a competitive alternative. Furthermore, the sensitivity analysis investigated the circumstances which may hinder the competitive development of such alternative (like higher IR) or favor its application (which could be further achieved by lower fuel prices).
Although it has been proven that a feasible business case for district heating on natural gas can be created within the external conditions provided by Onești, it has to be said that this feasibility is highly sensible to slight changes and could therefore easily be rendered unfeasible. From a business economic perspective, it is difficult to produce a feasible business case given the competitive advantage of individual heating solutions. Concluded from these facts is that district heating, it does not represent a feasible alternative from a consumer point of view.

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Annex 1: Transcriptions of the interviews

1. Interview with Magda Chiper- general manager of the local Ferroli branch in Onești

The interview with Mrs. Chiper was intended as a direct contact with one of the major local distributors of thermal equipments. With over 60 years of experience in the heating industry and present in 14 European countries and Asia, Ferroli is one of the main producers and distributors of thermal equipments on the Romanian market. Mrs. Chiper is also an engineer with a vast experience in custom sizing and selling gas boilers for the consumer segment in Onești. The conversation concluded with useful technical information that would later on contribute to scenario development within the methodology chapter as well as economical aspects concerning condensing gas boiler technology in order to estimate the level of costs for consumers. As a direct competitor which exploited the shortcomings of DH, suppliers of individual gas-fired heating appliances have a decisive role and influence over the consumers' choice and perspective regarding heating alternatives for their homes. Subsequently, their strategic activity and presence on the market influences potential planning of the Government and local authorities in regards to the competitiveness of DH over individual solutions now, as well as in the future.

2. Interview with Nicolae Balaș- secretary of the owner's association Nr.10 in Onești

Mr. Nicolae Balaș is secretary of owner's association Nr. 10, one of the 25 associations that exist in the city of Onești and has been actively involved in many of the Municipality's council meetings with the purpose of representing the interests of his voters. The contribution of his interview enabled the author to get a better understanding of the opinion apartment owners have towards DH and IH as well as the level of awareness in regards to the obligations imposed by the European ErP Directive. Owners' associations play a key role in the management of DH in Romania (Regulating DH in RO, 2010). Their competences extend over framework service agreements with the utility companies. Particularly, they are an important intermediate in the process of billing of the consumers thus ensuring their payment in due time as well as for providing data about the "identity of defaulting households" hampering the overall effectiveness of the DH system. With the possibility of filing legal action against such households, owners' associations pose as a key member of the regulatory actors in the DH context of Onești. Moreover, their role could prove to be a strategic aid in improving overall local and national framework of DH to be analyzed should collective heating solutions regain leverage over individual solutions in the future. As for the project, owners' associations were important to be contacted as to understand the result of their influence over the local DH system of Onești.

The interview gave additional insights on how the interests of the apartment owners are represented within the council meetings of the Municipality and their direct influence on some aspects of the decision making process, in which they are allowed to express their opinion. With regards to this matter, Mr. Balaș expresses his own as well as his voters' general disappointment towards the performance and evolution of the DH system that they have experienced since the establishment of Termon. More precisely, they feel that political interests have stirred the attention of the Municipality officials and that their participation in matters they can also decide upon is merely a false impression they are led to believe in order to gain their votes and trust for the upcoming election campaigns. On the other hand, consumers seem to have grown fond of as gas boilers and tend to disregard DH, mainly because their higher efficiency and smaller cost of the gas bill. As for the recent obligations imposed by the European ErP Directive, Mr.Balaș strongly believes that consumers will maintain their attitude towards heating their homes with gas boilers regardless of the slight increase in costs caused by the EU's decision.

3. Video conference interview with Liviu Tarola- administrator of the local utility company Termon

The interview was meant as a direct contact with the local utility company – Termon with whom an email correspondence and video conference was held instead, given that unforeseen events lead to the face to face meeting not being eventually possible. Termon has been running under the management of the Municipality of Onești for the past 10 years since its establishment as a utility company in February, 2006. From the interview with Mr. Tarola, the author intended to obtain a deeper understanding of the current technical and financial state of the utility company, as well as a precise overview of the responsible parts involved in the decision making process and management of Termon along the years of its existence. As found out later, besides the active position as administrator of Termon, Mr. Tarola is also part of an administrative utility department of the Municipality of Onești, in charge with managing and allocating funding from the local budget for investments and maintenance of the DH utility company. This opportunity has been seized as a mean of communication with a representative of the local authorities which, in essence, act as "statutory bodies in charge of setting up, organising, monitoring and controlling DH services". (Regulatig DH in RO, 2010) This attribution, along with the assurance of financial resources, has been transferred to local authorities in 2006 with the passing of the Decentralization Law. (Official Gazette of Romania, 2006) In this case, the Municipality of Onești has partial control over the management DH operations and has the responsibility of assuring the implementation of measures approved by the Government, as well as ensuring the allocation of state budget directed towards the utility company-Termon.

Nevertheless, a direct interview with the head of the management behind the Municipality's administrative utility department was not possible, which stresses the importance of interviewing Mr. Tarola in understanding the strategy and intentions of a regulatory actor with significant influence over the local DH system and its future.

Among others, the interview was initially thought develop on the matter of future planning and existence of the company given the number of disconnections from the DH system that have occurred since 2006 and small number of remaining consumers. Instead, the outcome of the conducted video conference revealed that in March, 2016 the Municipality decided to shut down Termon and considered declaring bankruptcy in the near future because of the considerable amount of debt accumulated over the past 4 years as well as lack of essential investment in the infrastructure of the system that eventually led to poor technical performances.