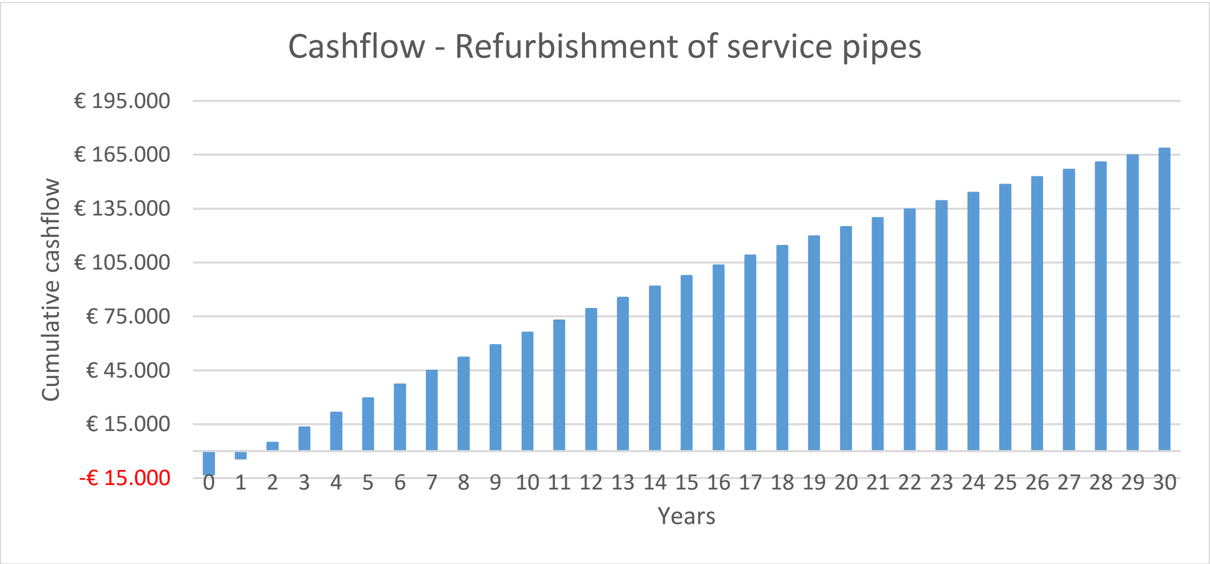
Upgrading the performance of district heating networks in Europe

Project No: 785014

Summary on business models and initiating investments for upgrading district heating



WP 5 – D 5.5

October 2020

Authors: Borna Doračić[7], Mislav Čehil[7], Nastia Degiuli[7], Anes Kazagić[5], Ajla Merzić[5], Dino Trešnjo[5], Emanuele Zilio[8], Reto Michael Hummelshøj[8], Robert Andrzej Sederberg-Olsen[8], Sebastian Grimm[6], Daniel Heiler[6], Laura Del Saz[2], Thomas Pauschinger[2], Stefano Morgione[9], Matteo Pozzi[9], Simone Rossi[10], Paola Mari[10], Evaldas Čepulis[3], Elena Pumputienė[4], Jan Herpel (SWMR)
(numbers in superscript refer to the project partners on page 3)

Reviewers: Tomislav Pukšec, UNIZAG FSB
Neven Duić, UNIZAG FSB
Dominik Rutz, WIP

Contact: Tomislav Pukšec
UNIZAG FSB
Email: Tomislav.puksec@fsb.hr ,Tel: +38516168494
Adress: Ivana Lučića 5, 10 002, Zagreb, Croatia
www.fsb.hr

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 785014. The sole responsibility for the content of this report lies with the authors. It does not necessarily reflect the opinion of the European Union nor of the Executive Agency for Small and Medium-sized Enterprises (EASME). Neither the EASME nor the European Commission are responsible for any use that may be made of the information contained therein.

Upgrade DH website: www.upgradedh.eu

Project Consortium and National Contact Points:

WIP Renewable Energies, project coordinator, Germany[1]
Dominik Rutz [Dominik.Rutz@wip-munich.de]
www.wip-munich.de

Steinbeis Research Institute for Solar and Sustainable Thermal Energy Systems, Germany[2]
Carlo Winterscheid [Winterscheid@solites.de]
www.solites.de

Lithuanian District Heating Association
(Lietuvos Silumos Tiekeju Asociacija), Lithuania[3]
Audrone Nakrosiene [audronenakrosiene@gmail.com]
www.lsta.lt

Salcininku Silumos Tinklai, Lithuania[4]
Elena Pumputienė [elena.pumputiene@sstinklai.lt]
www.sstinklai.lt

JP Elektroprivreda BiH d.d.-Sarajevo, Bosnia-Herzegovina[5]
Anes Kazagic [a.kazagic@epbih.ba]
www.epbih.ba

AGFW Projektgesellschaft für Rationalisierung, Information und Standardisierung mbH, Germany[6]
Sebastian Grimm [s.grimm@agfw.de]
www.agfw.de

University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia[7]
Tomislav Pukšec [tomislav.puksec@fsb.hr]
www.fsb.unizg.hr

COWI A/S, Denmark[8]
Reto Michael Hummelshøj [rmh@cowi.com]
www.cowi.com

OPTIT Srl, Italy[9]
Matteo Pozzi [matteo.pozzi@optit.net]
www.optit.net

Gruppo Hera, Italy[10]
Simone Rossi [simone.rossi@gruppohera.it]
www.gruppohera.it

Euroheat & Power – EHP, Belgium[11]
Alessandro Provaggi [ap@euroheat.org]
www.euroheat.org

Contents

1. Introduction

The overall objective of the Upgrade DH project is to improve the performance of district heating (DH) networks in Europe by supporting selected demonstration cases for upgrading, which can be replicated in Europe.

The Upgrade DH project supports the upgrading and retrofitting process of DH systems in different climate regions of Europe, covering various countries: Bosnia-Herzegovina, Croatia, Denmark, Germany, Italy, Lithuania, Poland, and The Netherlands. In each of the target countries, the upgrading process will be initiated at concrete DH systems of the so-called Upgrade DH demonstration cases (demo cases). The gained knowledge and experiences will be further replicated to other European countries and DH systems (replication cases) in order to leverage the impact.

Core activities of the Upgrade DH project include the collection of the best upgrading measures and tools, the support of the upgrading process for selected DH networks, the organisation of capacity building measures about DH upgrading, financing and business models, as well as the development of national and regional action plans. In addition, an image raising campaign for modern DH networks will be carried out in the Upgrade DH project. The outcome will be the initiation of DH upgrading process in the above-mentioned target countries and beyond.

The present report summarizes business models for the upgrading measures of each of the 8 demo cases of the project. The business models have been developed after the upgrading measures have been selected and analysed from the technical perspective. Each of the business cases has been elaborated by taking into account the main parts of the business model presented in the report “Guideline on business models and financing schemes for retrofitting DH networks”.

Each summary includes a brief description of the current state and the planned project, the national and local framework for district heating in the target country, technical and investment data of the measure, elaboration of the planned costs and revenues which will occur during the lifetime of the project, as well as the feasibility analysis through calculating the economic indicators such as internal rate of return (IRR) and the net present value (NPV) of the project. All of these have been elaborated in detail as a part of confidential reports, available only to the Commission and the project partners. In order to publicly share the most relevant results of the business model elaboration, this document presents a summary of the developed business models for each case.

2. Summary of Tuzla, Bosnia and Herzegovina

In general, the business model of district heating is rather simple: the objective is to produce cheap heat which is then efficiently distributed to the customers (end consumers). Based on the homogeneity of the product, few parameters beyond accessibility and price are considered as competitive attributes. On a deregulated energy market, district heating has become just one among many heating options, which compete in price and reliability, and also through more subjective and abstract values such as service quality, environmental impacts and social acceptance. These factors are not easily translated into simple comparison of price. The pricing itself can have an influence on the attractiveness of an alternative due to what type of price model is being deployed.

It is thus important for the district heating system of Tuzla that the processes which will be utilized in order to produce values do not produce externalities that in the end will hurt itself. Firm survivability is thus dependent on what value is created, as well as how it is created. A number of factors define a simple business model: framework and other border conditions, technology used, and ownership models. Furthermore, dynamic changes in the energy and technology markets, as well as the adaptation of national framework represent a challenge which innovative business models can tackle, in order to produce better economy and consumer experience.

The greatest benefit of the district heating system of Tuzla is based on the economies of scale, compared to the cost of individual heating systems. However, as the DH system today is outdated due to obsolete equipment and lack of capital investment, this has led to poor performance in heat distribution and inefficiencies which are complemented by the use of coal which will be subject to CO_2 taxes in the near future. Simple efficiency upgrading measures can considerably increase the system's performance and the financial profitability, while reducing operating costs and environmental emissions.

Taking into account the objectives of the City of Tuzla and its sustainable energy strategy vision, the overall upgrading project idea was developed, identifying the following key upgrading measures:

1. *Optimization of the operation of two cogeneration units in the thermal power plant (TPP) Tuzla with an integration of a heat storage system.*
2. *Integration of renewable energy sources in the heat production portfolio of the DH system Tuzla - solar thermal collectors:*
   a) *Solar thermal collectors in area of Tuzla CHP*
   b) *Solar thermal collectors at Tuzla University Campus and Hospital*
3. *Upgrading of the Tuzla DH network to resolve hydraulic issues and increase energy savings:*
   a) *Replacement of the main pipeline. Separated thermal stations for Tuzla DH, Lukavac DH and future Zivinice DH. Upgrading of heat exchangers for reducing the temperature regime.*
   b) *Replacement of the existing main network pump with a new frequency regulated main network pump.*
   c) *Installing temperature limiters on the main return pipe on the primary side of the house substations.*
4. *Installing thermostatic valves for heating room temperature regulations.*

District heating projects are financially intensive projects. The operation has high fixed costs such as insurance, interest expense, property taxes, utilities expenses and depreciation of assets. In district heating systems with high fuel costs there is also a considerable risk of rising fuel costs throughout the project lifetime. It is important to carefully manage the cost side of the DHC projects which also presents some opportunities or flexibility.

To assess the commercial viability of the identified upgrading measures of the district heating networks, the total capital costs of the presented system, the costs related to the operation and maintenance, and the revenues from the sales of heat and electricity and avoided carbon taxes, have been estimated.

An overview of the **key performance indicators** mentioned above is given below:

Measure	IRR	NPV	PBP
Operation optimization TPP TZ (3&4)	79.20%	19,996,867	1
Integration of RES - TPP Tuzla	-4.68%	-1,804,697	20
Integration of RES - Hospital/Campus	-5.66%	-379,631	20
Resolving hydraulic issues - Replacement of main pipeline	57.34%	7,914,066	1
Resolving hydraulic issues - New frequent regulated pump station	132.46%	4,866,093	1
Resolving hydraulic issues - Installation of temperature limiters	17.55%	93,219	2
Installation of thermostatic valves	11.60%	23,503	9

A sensitivity analysis was also conducted using different parameters of the business model, by investigating the impact of investment costs, discount rate and interest base rate on the economic performance of the project. By analysing all the conducted results, it was concluded that the upgrading measures behave quite rigidly on the change of investment costs, so that even a possible change of CAPEX in the range -30% to 30% have not changed the status of the project from profitable to unprofitable, and vice versa.

Within all the proposed measures, only the integration of solar collectors into the district heating system does not prove cost-effective. Therefore, a sensitivity analysis was performed by changing the financing schemes, i.e. increasing the share of grant funds and reducing credit indebtedness, and own funds were retained at a share of 10%. The conducted analysis showed that for both measures of solar collector installation, projects become profitable when the share of the grant amount is 50% or more.

Affordability, low carbon footprint and security are seen as the three critical characteristics of Tuzla's future energy system. In this respect, district heating offers towns and cities many attractive characteristics. In particular, under the right governance models, it can offer also social benefits by lowering energy costs and alleviating fuel poverty.

Using the characteristics and composition of the primary fuel (coal), more precisely its emission factor, which is used in CHP Tuzla, it was easy to calculate (estimate) environmental savings by implementing upgrading measures. Social benefits were also assumed so they are listed together in the table below.

Upgrading measure	**Benefits**	
	Environmental	Social
Operation optimization TPP TZ (3&4)	– CO2 reduction: 68,500,0 tonnes/year – NOx reduction: 137.0 tonnes/year SOx reduction: 1,488 tonnes/year PM10: 11.5 tonnes/year	– Reduced fuel poverty – Air quality improvement and associated public health impacts – More reliable energy supply – Demonstrate the local commercial viability of modern district energy systems

	– PM2.5 reduction: 11.5 tonnes/year	
Integration of RES - TPP Tuzla	– CO_2 reduction: 5,000 tonnes/year NOx reduction: 10.0 tonnes/year – SOx reduction: 108.6 tonnes/year – PM10: 0.8 tonnes/year – PM2.5 reduction: 0.8 tonnes/year	– Reduced fuel poverty – Diversifying energy supply – Creating economic development and jobs in manufacturing, installation and maintenance. – City image-raising campaign – Air quality improvement and associated public health impacts – Local wealth retention and economic development through the use of locally available energy resources
Integration of RES - Hospital/Campus	– CO_2 reduction: 1,149 tonnes/year – NOx reduction: 2.3 tonnes/year – SOx reduction: 25.0 tonnes/year – PM10: 0.2 tonnes/year – PM2.5 reduction: 0.2 tonnes/year	– Reduced fuel poverty – Diversifying energy supply – Creating economic development and jobs in manufacturing, installation and maintenance. – City image-raising campaign – Air quality improvement and associated public health impacts – Local wealth retention and economic development through the use of locally available energy resources
Resolving hydraulic issues - Replacement of main pipeline	– This measure will enable further expansion of the network of district heating systems, especially in the sloping parts of the city where so far only individual fireboxes have been used. It is estimated that the implementation of this measure would enable the delivery of an additional 120,000 MWh per year, which is approximately 1,350 households.	– Increased security of supply – Reduced maintenance – Improved comfort – Air quality improvement and associated public health impacts – Additional income opportunities for the local government – Improved coordination of local stakeholders
Resolving hydraulic issues - New frequent regulated pump station	– CO_2 reduction: 11,813 tonnes/year – NOx reduction: 23.6 tonnes/year – SOx reduction: 256.7 tonnes/year – PM10: 2.0 tonnes/year – PM2.5 reduction: 2.0 tonnes/year	– Increased security of supply – Reduced maintenance – Air quality improvement and associated public health impacts
Resolving hydraulic issues - Installation	– CO_2 reduction: 1,000 tonnes/year – NOx reduction: 0.9 tonnes/year	– Local job creation

of temperature limiters	– SOx reduction: 0.1 tonnes/year – PM10: 10.4 tonnes/year – PM2.5 reduction: 10.4 tonnes/year	– Increased efficiency and economies of scale in the energy system
Installation of thermostatic valves	– CO_2 reduction: 572.0 tonnes/year – NOx reduction: 863.4 tonnes/year – SOx reduction: 14,164 tonnes/year – PM10: 1,800 tonnes/year – PM2.5 reduction: 228.9 tonnes/year	– Reducing heat energy costs – Improved comfort – Local job creation – Improved coordination of local stakeholders – Community engagement – Air quality improvement and associated public health impacts

After the conducted economic analysis, sensitivity analysis and social-environmental analysis, the basis was created to start more decisively in conversations and presentations with the company management, local government representatives, building managers, tenants, etc. After the first iteration of talks and discussions with company managers and city government representatives, huge support was received towards the implementation of the upgrading measures.

The obtained results clearly show the upgrading measures which can be easily and quickly implemented. A great advantage is that certain measures can be implemented in parallel, where the initiators can be different parties and participants in the district heating system, so that decisions can be best made on the basis of a long-term strategy including the view of JP Elektroprivreda BiH as a producer of heat energy, of the heat distributor utility, of the City of Tuzla as the owner of the DH system, and of course of the citizens as the main actors due to which the district heating system exists. Such long-term strategy could also contribute to the development of a 10 to 20-year District Heating Energy Action Plan, with necessary actions, policies, and investments to deliver Tuzla’s full potential for modern and energy efficient district heating system.

3. Summary of Middelfart, Denmark

The upgrading measures considered in the city of Middelfart are the result of a long collaboration between the local district heating company Middelfart Fjernvarme Amba, and the consultancy company COWI. Since the beginning of the Upgrade DH project, the focus of the upgrading was to increase the share of renewables in the heat production as well as to improve the use of the available resources, and to optimize the management of the network.

Increasing the share of renewables

Before 2018, approximatly 2/3 of the heat supplied to the DH transmission system TVIS was from a natural gas fired CHP plant. With increased focus on climate changes and the higher standards required by the Danish governments, the Municipalities (including Middelfart Municipality) supplied by the TVIS system, agreed to convert the CHP plant to biomass. It increases the share of CO_2 neutral production units from 27% to 94% in 2020 and thereby decreases CO_2 emission by approximatly 83%. It was estimated that the reduction of CO_2 is equal to approximatly 10,000 tCO_2 (equiv) per year.

The woodchip-based CHP plant is now built and commissioned in the town of Skærbæk, between the two main cities Fredericia and Kolding. The plant supplies heat for the district heating transmission system TVIS, which is the main heat supplier for the DH network in Middelfart Municipality. The yearly amount of energy received by Middelfart DH is about 8% of the total energy delivered by the system. The CHP plant has a power capacity of 90 MW_{el} and a heat capacity of 230 MW_{th}.

Based on the technical details defined before, the investment analysis was conducted as well as a feasibility study. The initial investment is around 200 M€, which leads to an evaluation of the financing resources, which requires access to a bank loan. Afterwards, considering the operation and maintenance cost, the revenue of the heat sales and the savings obtained by using biomass, the expected payback period was calculated to be around 25 years. The sensitivity analysis showed that the variation of natural gas and biomass prices have a high impact of the feasibility of the project.

In terms of ownership model, different actors were involved in the conversion of the CHP plant. The utility Ørsted is the owner of the plant, which is the main actor involved. However, the conversion costs were covered with the contribution of the TVIS transmission system, which is a partnership of the four municipalities that are supplied by the system, where Middelfart Municipality has around 8% of the shares. The ownership of the production system and transmission system are going to be the same after the conversion.

Due to the high focus on the sustainability and CO_2 reduction targets established by the Danish government, the project was further evaluated for the environmental costs/benefits and it was considered as feasible. The conversion process started during the Upgrade DH project and the plant is soon going to be fully operative.

Network optimization and resources available

Regarding the network optimization and resources available, the second upgrading measure considered was the refurbishment of old service pipes. The replacement of old service pipes at Middelfart DH company was based on employees' knowledge of the network as well as based on not verified assumptions, which do not always lead to the best use of economic resources available. However, a new system that combines Termis analysis of the service pipes and measurements from the energy meters in the district heating system can identify the areas where the service pipes are in poor conditions. Based on that, it will be possible to plan the replacement of the existing pipes in a more efficient way, giving the priority to the service pipes that affect the network's performances the most.

The results obtained in the city of Næstved, which is a follower doemo case in the Upgrade DH project, gave good insights about this new calculation tool, which is now in the process to be applied in Middelfart.

Middelfart DH company allocates every year around 1,350,000 € (10,000,000 DKK) of the earnings coming from the heat sales for the renovation of the DH network, and more specifically for the service pipes. It guarantees a continued check and upgrade of the distribution network in the municipality.

The evaluation of the investment considered an upgrade of the Termis system, which is installed in Middelfart of around 13,000 €. The system will mainly improve the allocation of the economic resources for the renovation of service pipes, which will be focused on the pipes that show the worse performances. In that way, it is possible to replace the pipes in bad conditions at first, which would avoid extra costs in case an extra reparation would be needed if they were not replaced. Therefore, the annual savings were evaluated as avoided extra costs for unexpected failures of old service pipes.

The calculation of the payback period showed that this investment is going to be repaid within 2 years from the installation of the calculation tool, as it is shown in Figure 1. In terms of financing sources, it is expected that the project is financed by the district heating company.

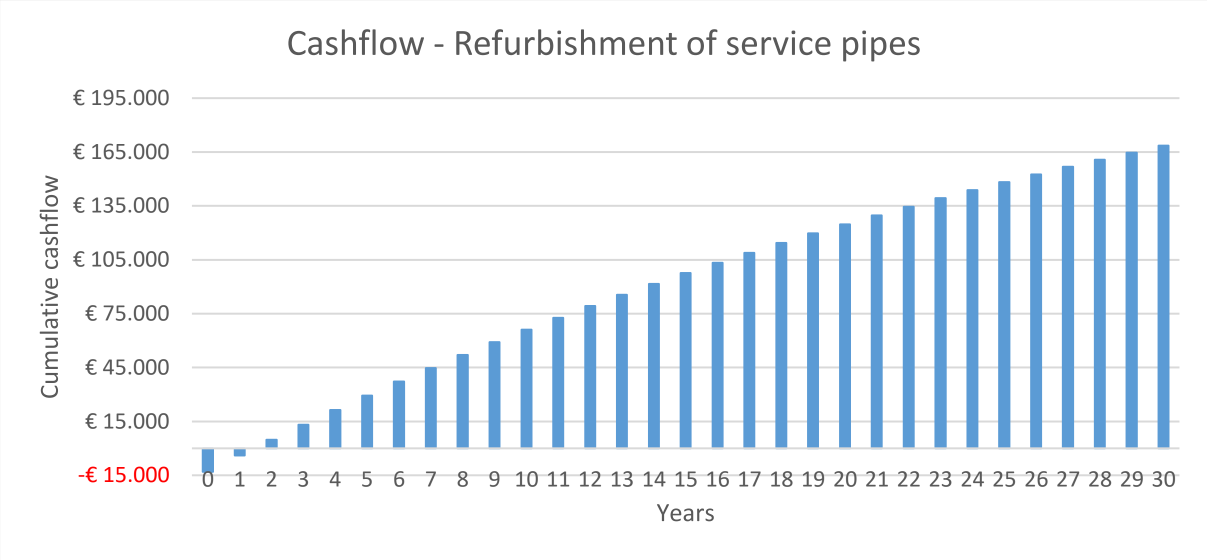


Figure 1 Cumulative cashflow for the refurbishment of service pipes tool in Middelfart

Figure 2 shows the sensitivity analysis conducted for the implementation of the tool. The analysis shows a good result of the upgrading measure, also seen in the short payback period. As it is noticed, the largest variation of the IRR is given by the variation of the yearly savings, that can be achieved by implementing the tool which affect the amount of money that can be used to repay the investment. Also, the initial investment resulted as a relevant parameter in the sensitivity analysis. However, the solution shows general high feasibility.

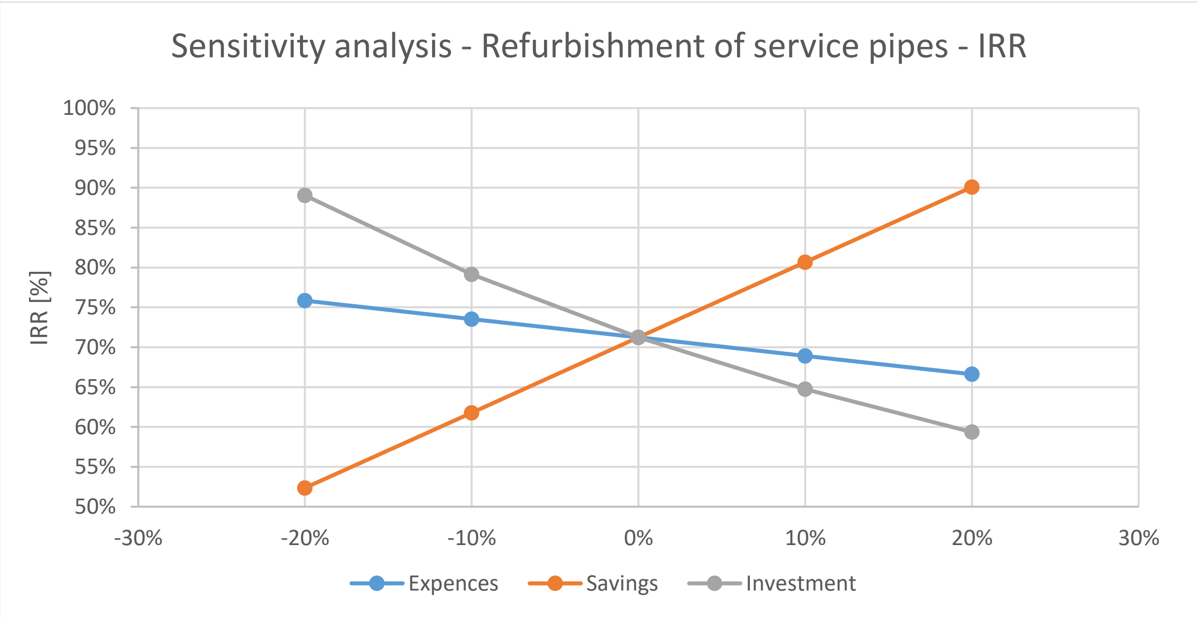


Figure 2 Sensitivity analysis for the refurbishment of service pipes tool in Middelfart

In terms of ownership model, the introduction of the new method for the refurbishment of old service pipes is not expected to affect the existing ownership model.

As it was already mentioned, the implementation of the tool is in progress. There is a close collaboration between the district heating company and the consultancy company to use the results in the most efficient way and to further develop the tool.

Organizational optimization of the network

The last upgrading measure considered the organizational optimization, where Middelfart DH will be merged with the smaller neighbouring district heating company in the city of Ejby. The purpose of supplying a more efficient operation and maintenance of the district heating systems with a more efficient allocation of the resources available, both from the human and economic side. The resources can be rearranged and distributed more efficiently, lowering the expenses and reducing the number of employees.

It is expected that the reorganization does not require any specific investment, since it is only an optimization of the organization chart, with the reduction of employees' number. The new organization is considering the construction of a new office building, which is not counted as part of the required investments for the merger of the two companies.

The same ownership model of Middelfart Fjernvarme (private consumer-owned cooperative), which is the biggest company, is going to be applied also in Ejby. However, there is not a radical change in Ejby's DH company, since it is also a private company owned by the users.

The merger do not require initial investment, but it will lead to a certain amount of savings per year. Therefore, the organizational optimization is going to bring a positive influence on the economy of the new company. However, it must be mentioned that the aim of the merger is to better organize and operate the two companies, which will lead to a future expansion of the network and to the need of new employees in the coming years. The merger process is already in progress and is going to be finalized during the coming months.

4. Summary of Sisak, Croatia

Since the representatives of the district heating production and distribution companies have been involved in project activities from the start of the project, it has been determined early in the project that the most interesting upgrading measure for the district heating system in Sisak is the implementation of the thermal storage unit in the form of the buffer tank. The reasoning behind this has been extensively elaborated in D4.4 of the Upgrade DH project. Due to such high interest of the relevant stakeholders, mainly the directors of the heat production and heat distribution companies in Sisak (HEP Proizvodnja and HEP Toplinarstvo), the business model for this measure has been developed in a close cooperation with them, which enabled achieving a high level of detail and accuracy of the analysis.

After calculating the technical details of the thermal storage unit in the Upgrade DH project, investment data needed to be analysed and collected. In order to be as accurate as possible, a company which produces buffer tanks was contacted to share the investment figures for the chosen configuration of the storage tank. Overall, for the steel tank with 66.6 MWh of installed capacity, including the 12 MW heat exchanger, the foundations (civil works), measurement equipment and the connection pipes, the investment costs amount to 1,610,000 €, which are depreciated linearly through different time periods (i.e. equipment 10 years, civil works 15 years).

Among the relevant parts of the business model are the ownership model and the financing sources (i.e. ways of funding the project). Since the thermal storage unit is currently considered as a means to increase the efficiency of the existing biomass cogeneration unit, which is owned by HEP Proizvodnja, the only possible ownership model for thermal storage unit is the continuation of the existing ownership (i.e. project owned by HEP Proizvodnja). This would be the case with most upgrading measures in Croatia, due to a high share of the Croatian district heating market being covered by the HEP Group (which HEP Proizvodnja is a part of). Furthermore, since this project would fall into the category of small projects in the HEP Group portfolio based on its investment costs, it is most likely that the funds would be provided by the HEP Group itself, i.e. no loan would be needed. However, both the scenario with 50% bank loan and the scenario without the loan have been analysed to cover both cases.

The most relevant part of the business model in any case is the economic evaluation of the planned project. It is always crucial that the input data in the calculations is double checked with the relevant actors in order to decrease the uncertainties of the results, nonetheless certain assumptions always need to be made and for that reason, it is crucial to present a sensitivity analysis to take into account the potential changes of different parameters. Along with the investment data and funding options, required input data include all the revenues on the annual level, as well as all the costs. For thermal storage integration in Sisak, revenues would consist of reduced peak load boiler use and the reduced use of steam line during the summer period. These are both reflected in the lower consumption of natural gas and amount to 312,440 €/a. On the other hand, the costs of the project are rather lower, since there is no need for additional personnel or additional software. Therefore, they consist of the operation and maintenance costs and the insurance costs and amount to 10,539 €/a. By taking into account all these parameters, the lifetime of the project (20 years) and the discount rate (5%, to discount future cashflows to the present value), the net present value of the project has been calculated at 1,512,272 €, giving the internal rate of return of 14.9% and the payback period of 6.1 years.

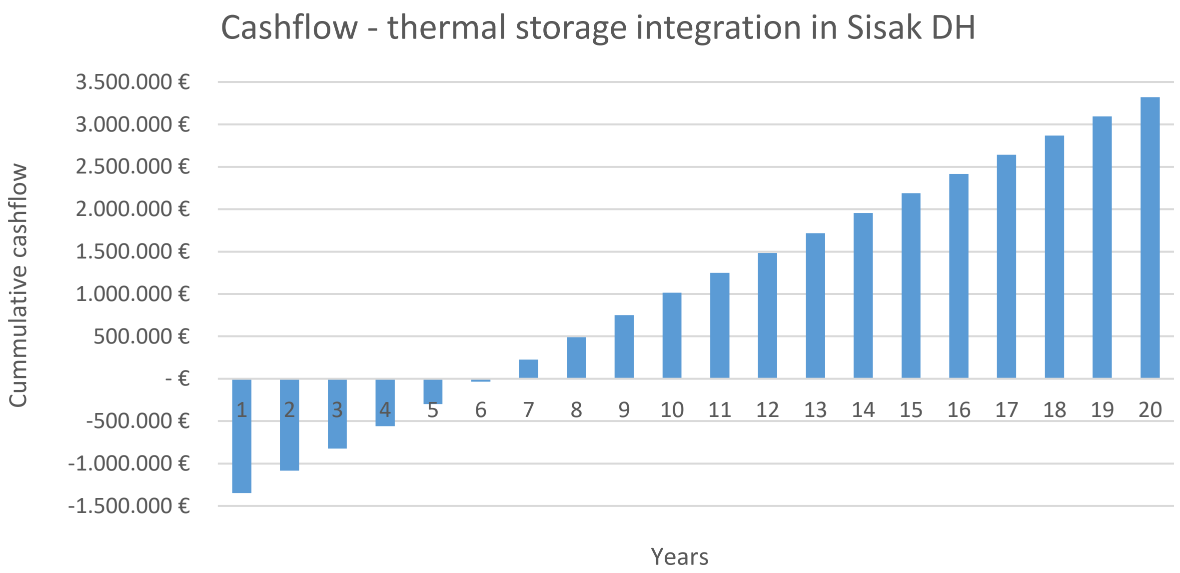


Figure 3 Cumulative cashflow of thermal storage integration in the DH system of Sisak

The results of the economic analysis have shown that the project is very feasible and that it would result in high returns for the company, as graphically shown in Figure 3. This would practically not change even if 50% of the money had to be loaned from the bank. Since the representatives of the district heating system in Sisak were rather uncertain regarding the investment costs, the sensitivity analysis was performed for the following parameters:

- Natural gas price
- Investment costs
- Running costs

The results of the sensitivity analysis showed that the project is sensitive to the changes in the natural gas price, which are however assumed rather low and are not expected to be lower than the current price, making it rather improbable that it would have a negative effect on the project. The operating costs affected the feasibility of the project by a small margin, while the investment costs had a higher effect, but the project was still feasible even when the investment costs were increased by 60%, as shown in Figure 4.

Such a project would have a relevant socio-environmental impact at the local level, from the perspective of decreasing the emissions of pollutants, namely CO_2 emissions by 2,145 t, NO_x emissions by 382 kg, SO_2 emissions by 12 kg and CH_4 emissions by 115 kg. By reducing the environmental effect, especially the emissions of the local pollutants, the health of the local population increases, which is one of the main social benefits of such a project, but also the fact that the public opinion towards DH would increase due to such project which promotes efficiency and increase of renewables in DH production.

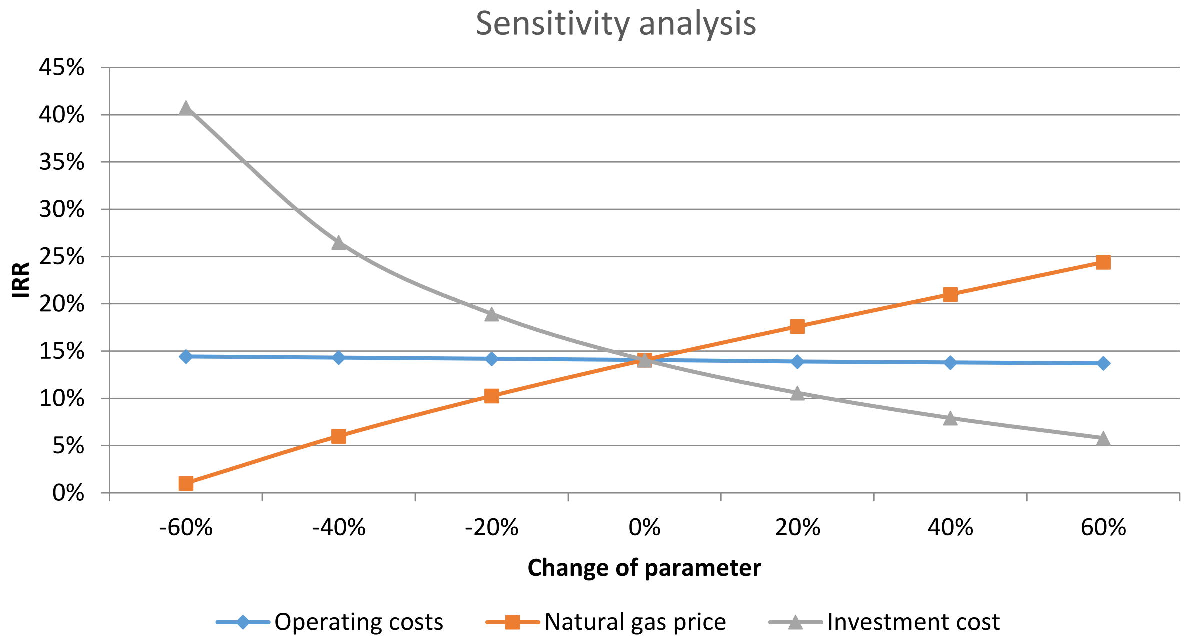


Figure 4 Sensitivity analysis of relevant parameters and its effect on the IRR of the thermal storage integration project

Finally, the business model has been discussed in detail with the representatives of the heat production and heat distribution companies in Sisak and they have been made aware of the high feasibility of this project. The interest of the relevant stakeholders to implement such a project is shown by the fact that on all the working group meetings, at least one director was present and on most of the meetings both the directors of the heat production company and heat distribution company in Sisak were present. Therefore, it can be concluded that with the results of the Upgrade DH project, the investments into the upgrading of Sisak DH have been initiated and the realization potential of the project has been increased, with high potential to start the project implementation in the next couple of years.

5. Summary of Marburg, Germany

The municipal utility - Stadtwerke Marburg (SWMR) – is responsible for the whole district heating process chain, from generation to distribution and sales. As the representatives of SWMR were involved right from the beginning of the project, all areas of the entire district heating system could be considered in the analysis. Starting from the assessment of the current situation the details were elaborated during the second phase of the Upgrade DH project.

Together with the support of Upgrade DH project partner Optit, detailed hydraulic calculations of the DH grid with different scenarios and multiple upgrade opportunities were detected. The following text will focus on the UM “optimisation of the pump operation” as this turned out, to be the most relevant topic in Marburg, but also for other DH systems that are involved in the project. In addition, the cost-effectiveness of replacing the network pumps often does not appear economic at first glance, as the investment costs only appear to be offset by small savings.

General Information/ Framework conditions

The ownership model and the DH business itself will not be affected by replacing the pumps and even there are not really funding opportunities in Germany for that, but the UM is quite interesting. The reason for that is not unique in Marburg, and on an experience base, the situation is similar in many DH systems all over the world. In most cases, pumps prove to be robust components that, if operated and maintained properly, will still work properly after several decades. For the example in Marburg the Pumps were built in the 60s and are still running with no major problems. If only the simple replacement of old pumps by new pumps of the same size is considered a business case, the investment cost are easy to identify by asking a pump manufacturer and the expected savings will be comparatively low, even though the efficiency of pumps has improved in recent decades.

To benefit from an exchange of the network pumps some detailed analysis of the DH system is necessary. A typical DH system once was designed for a specific maximum heat demand (maybe with some backup for further expansions) at a certain temperature level, that was significantly influenced by the temperature at which heat could be extracted from a (mostly fossil) power plant or which temperature level was necessary for the application (individual industrial requirements).

In the last decades a lot has changed here, new generation plants reach efficient operating conditions at much lower temperatures, which are still sufficient for room heating and the energy demand of individual consumers is decreasing (e.g. due to better insulation materials or warmer outside temperatures during winter). In that case the initial planned pumping power is oversized, and the pumps are operating in inefficient part load situations all over the year.

Revenue Management

For the reliable supply of the customers of a district heating system it is important, that the appropriate amount of heat can be transported through the DH grid. On the one hand, this is influenced by the available flow temperature (taking into account the spread to the return temperature) but also by the volume flow. The network pumps must be able to provide the maximum necessary volume flow, this also requires thinking about future operating strategies such as planned temperature reductions. Since the efficiency of a pump is reduced in the partial load range, the most frequently occurring partial load operating conditions must be taken into account in addition to the maximum output, which is usually only required for a few hours per year.

The technical analysis on Marburg shows that the DH system could be operated reliably when the installed pumping capacity is reduced from ≈250 kW to ≈120 kW. After comprehensive analysis, it can be assumed that current pumps in Marburg, dimensioned according to the current real operating conditions, enable an increase in efficiency (at 2 of 3 pumps) of almost 25%. The total energy demand is calculated as nearly 30% of the current energy demand of around 480 MWh/ year. With a power price of 0.22 €/kWh the potential savings will be up to:

$$0.7 * 480{,}000 \frac{kWh}{year} * 0.22 \frac{€}{kWh} = 73{,}920\ €/year$$

Investment

Keeping one 30 kW pump the investment for two new pumps around 45 kW is estimated (based on manufacturer price information and including software modifications and installations) with 95,000 €. As service and maintenance costs will also apply for the old pumps, the running costs are not considered further here.

Economic calculations and feasibility

The following values are calculated based on the formula of the Upgrade DH report “Guideline on business models and financing schemes for retrofitting DH networks” assuming that the reduced energy costs could be handled as cash inflows. Comparing the cash inflows with the total invests the payback period is less than 1.5 years and the economic benefit of the UM quite easy to see. For the calculation of the NPV and IRR is assumed an investment without bank loan and an internal discount rate of 7%, within a period of 5 years even knowing that the pumps should operate way longer.

As the calculations are based on some assumptions, it is necessary to see, how variations in the values could affect the KPIs. The investment could increase, for example due to unforeseen problems that increase the effort. On the other hand, the savings will be depending on the real operation mode and the fluctuating power costs. However, the sensitivity analysis shows that also an increase on investment of +50% or a reduction of the savings (-50 %) leads to quite positive KPIs:

	Basic	Invest + 50%	Saving -50 %
Total Investment	95,000 €	142,000 €	95,000 €
Savings of el. Power costs per year	74,000 €	74,000 €	37,000 €
Internal discount rate i=	7 %	7 %	7 %
NPV	190,000 €	150,000 €	50,000 €
Payback period	1.5 years	2.25 years	3 years
IRR	60 %	33 %	18 %

The following figures provide an overview on the sensitivity from a reduction of the savings or an increase of the investment to the IRR and the NPV. Figure 5 shows the impact of increasing investment costs, starting from 95,000 € on the left up to 142,000 € on the right end of the graph. Figure 6 illustrates the impact on the calculations in case the assumed savings of around 74,000 € on the right end will reduce to around 37,000 € at the left end.

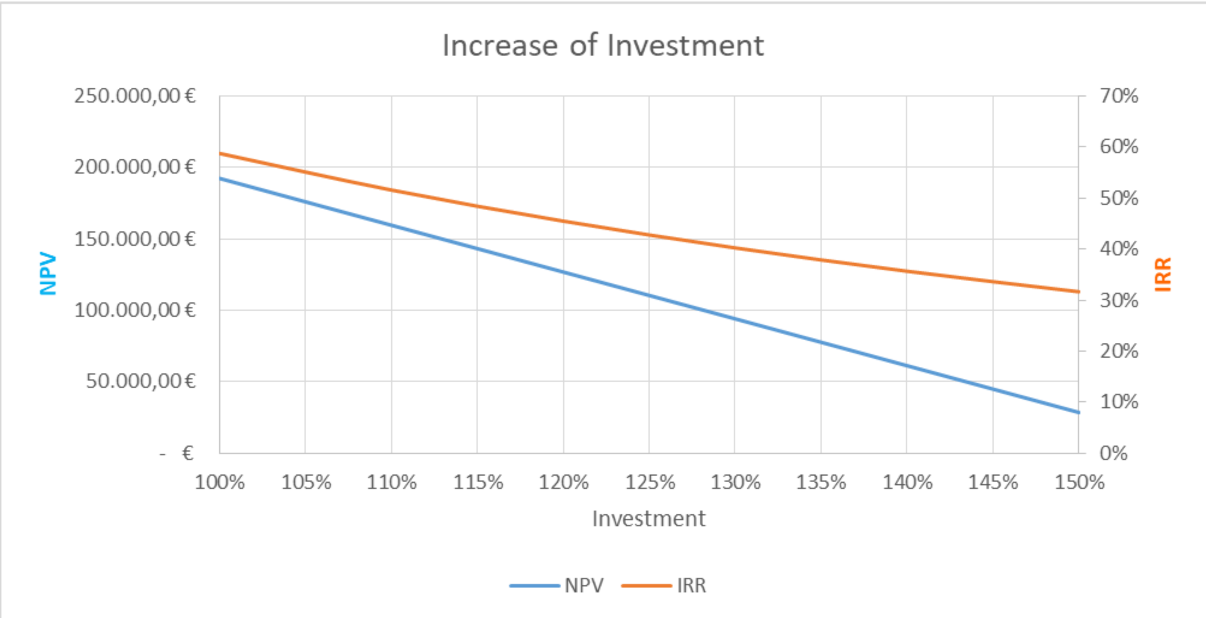


Figure 5: Effects on increasing investment costs up to 150%

Final results

The different UM were discussed with the DH representatives during the whole project phase, also the economic opportunities and business models. Especially the investment into new pumps let to fruitful discussions. The SWMR double-checked all the assumptions and technical calculations to evaluate the measure. Based on the results of the project, an investment request was forwarded to the company management. The subsequent internal audit of the economic efficiency also came to the conclusion that the measure is worthy of support. The internal detailed planning and the request for concrete offers was then started.

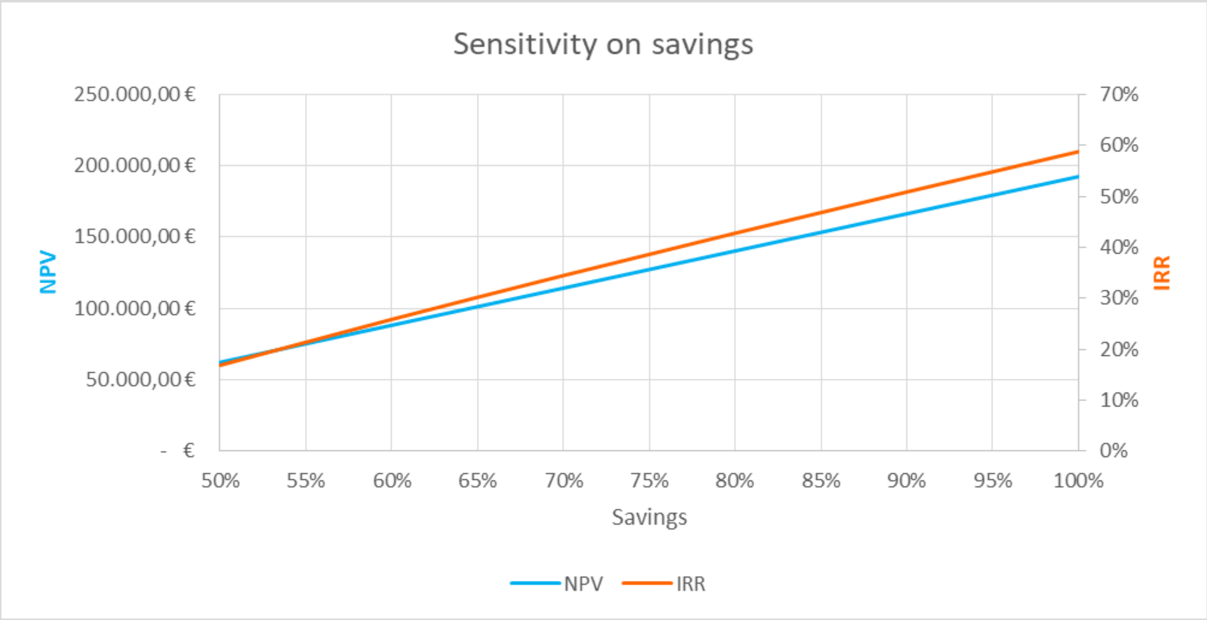


Figure 6: Effects on reductions of the savings down to 50%

6. Summary of Ferrara/Bologna, Italy

Refurbishment of the geothermal heat exchanger in Ferrara

The intervention is aimed at refurbishing the heat exchange section of the geothermal system, which currently yields an average annual heat production of 73.7 GWht, increasing its efficiency, thus its capacity, without compromising its long-term sustainability.

The measure is carried out together with Enel Green Power, a major player in the Italian energy framework, and it is integrated in a project with a greater scope, linked to the geothermal source concession. In this arrangement, all costs and revenues deriving are basically split in half between the two companies. The procurement stage has reached an advanced point, though encompassed in a broader upgrading scheme aimed at fully maximize the geothermal source capacity and output.

The geothermal source refurbishment will allow for a primary energy demand reduction up to around 4.8 GWh, constituting the main revenue component of the investment. The main operational costs are linked to periodic maintenance costs. The investment feasibility analysis outlined very promising results, estimating a payback time within the first year.

The resiliency of these indicators was assessed with respect to variation in the boundary conditions and financial assumptions specifically of gas prices and investment costs. It showed that the investment indicators remain quite positive.

The upgrading measure is in the final design phase, where the last details are only to be finalized. Since the early analysis seems to indicate very promising financial investment indicators, there is a clear intention from the company to proceed with the implementation. The exact timeline of the actual implementation is not set, yet the process seems to be proceeding towards completion.

Heat pumps integration in Bologna

Berti-Pichat is a complex system, which features heat/chill/electricity provision. The 3 CHP engines do manage to provide for the base load, yet gas boilers are vastly used during the peaks of heating season.

The measure involves the installation of heat pumps in the Berti-Pichat system, allowing for a greater utilization of the CHP units, while recovering a share of heat not currently utilized (because of its low temperature) and decreasing the usage of gas-fired boilers.

The implementation phase involves significant investment costs linked to mechanical/hydraulic interventions, as well as IT activities for SCADA connection.

Cogeneration in Italy is subject to subsidies to the extent its “high efficiency” can be proven with respect to given regulatory standards, in the form of gas cost discount and economic incentives, thus constituting a potential revenue stream directly proportional to the amount of energy produced and the generation efficiency, thus encouraging for upgrading measures targeting cogeneration facilities.

The other main revenue driver is constituted by the avoided costs of gas boilers consumption, whose usage should decrease significantly as the heat pumps are operated in the heating season. For a more conservative approach, the analysis does not take into account the reduced electricity consumption linked to the boiler burners and the utilities of the cooling circuits of the CHP units. The operating costs connected to the upgrading measure are constituted by the electricity consumption of the heat pumps (in terms of missed electricity sale) and the maintenance costs for the asset.

The feasibility analysis confirmed the sustainability of the investment, so that a significant capital investment is expected to reach breakeven within 3 years, leveraging also on regulatory incentives (related to high-efficiency cogeneration). Sensitivity analyses were carried out, in order to assess the investment parameters in case of a fluctuation of the main drivers (gas prices, cogeneration incentive structure, electricity market prices), outlining that the returns were still very interesting even in the most negative scenario.

The upgrading measure went from design to actual implementation already within the project’s timeframe, expecting its full completion in the coming heating season.

Smart Substations Analytics

The concept of smart substations involves a significant infrastructural effort, requiring to enable the metering on both the primary and secondary side with fine granularity. The measure aims at achieving a better customer knowledge and profiling through advanced analytics, while decreasing pumping costs.

Contacts with the manufacturers have been established and preliminary discussion defined a first cost estimate for the heat exchange stations. Nevertheless, it has to be taken into account that the investment per se may vary quite a lot, since preliminary figures considered a very conservative scenario, where the approach required an overhaul of the substation, while, in some instances, it may not be completely necessary.

Apart from these aspects, there is an intrinsic value in the infrastructural investment, since it would increase the monitoring capability at the users, thus allowing more easily fault detection and network thermal-hydraulic management. Although these factors are hard to quantify, they are indeed important “positive externalities” of the approach application.

The main revenue component of the upgrading measure is currently being calculated based on its effects to decrease pumping costs, i.e. more efficient electricity consumption. Additional revenue driver linked to increased efficacy in leaks and heat losses detection, that may produce significant extra savings, were not yet not object of the analysis, given the short time span and limited scope of the pilot (only 10 substations).

Additionally, Smart Substations would enable various additional optimization strategies, ranging from Demand Side Management (with effects on peak shaving) to (potentially) modulation of primary side temperature (with positive impacts on heat losses and lower generation costs),as well as identification of alternative network topological configuration (which may be considered in a subsequent phase, once the pilot reaches a significant enough coverage of the network).

So far, Hera decided to proceed with a limited pilot, which has shown interesting potential in terms of technical and economic benefits. Although there is strong commitment towards larger implementation, some factors are still missing to achieve definitive elements regarding economic feasibility of the analytics-driven strategy. The current focus is the set-up of a field pilot trial, whose preliminary results may be benchmarked against the real-time measured data for a more significant assessment.

If the field test confirms the expected positive outlook, a larger scale implementation might come to fruition, leading to the installation of metering devices at over 1,200 substations.

7. Summary of Salcininkai, Lithuania

“Salcininku silumos tinklai” is the municipality’s district heating company that operates 14 boiler houses in Šalčininkai county in which it produces and distributes heat to residents and institutions in 10 different locations.

The total installed heating capacity is 48 MW. Heat is supplied via 18.7 km long pipelines which are connected to 2,168 consumers, 96.8% of whom are residents.

The main (largest) DH network is located in Šalčininkai city. The heating systems at user size are usually designed for 80/60°C temperatures. The design temperature for hot water is 52°C. The supply temperature varies from 70 to 95°C throughout the year.

One of the most significant areas of impacts that the company seeks to improve is heat distribution. Investments in infrastructure of pipelines in the district heating network of Salcininkai started more than 30 years ago. Throughout the existence of this DH system, millions were invested. The seriousness of the issue and necessity of network optimization was identified by comparing DH system parameters to other DH systems of the country.

Technological heat losses in 2018 were 10.2 GWh, which stands for 26.1% of the total heat produced. As mentioned before, a significant part of district heating network has been operated for more than 30 years which means that they are not optimized for present-day demand. Network insulation is outdated in many places and does not ensure the thermal conductivity requirements which leads to considerable heat losses. Reinforced concrete pipeline channels are often filled with groundwater. As a result, the external corrosion of pipelines speeds up, leading to cracks of the network.

Network optimization is a long-term step by step strategic approach which will lead to more efficient DH network.

Furthermore, the company is struggling to deal with low summer season demand (1 MW or less), the boiler that is used to meet this demand is 6.5 MW of rated heat capacity. Because of the limited biomass boiler operational capacity variation (usually 40-100%) unsustainable techniques are used to produce heat at low demand (bypassing economizers, etc.). This type of usage decreases the lifetime of the boiler and highly reduces the efficiency.

The installation of a solar collector field with a possible heat storage implementation to the current boiler house would eliminate the struggle of dealing with low summer season demand. The implementation of solar district heating would increase the annual average efficiency of the current biomass boiler by eliminating the need of boiler for summer. The heat production would be more flexible, efficient, and diverse. The lifetime of the current main heating source would be prolonged and primary energy demand would decrease.

For both of the upgrading measures (network optimization and solar thermal implementation) business models have been developed in a close cooperation with the company which led to precise and detailed results. Both upgrading measures were technically analysed in detail.

Using statistics from various district heating company refurbishment projects, approximate network refurbishment prices were identified and the total project value to this date would be nearly 3,000,000 €. However, considering that pipe refurbishment would overall cost in between 4,000,000 € to 5,000,000 € taking 3.5% yearly inflation due to very long-term (20 - 30 year) implementation period and project preparation costs into account.

The integration of solar thermal energy into existing DH system is a complex combination of finding the right balance between size of investment and the right selection of working modes. In such system, to ensure optimum system performance and maximum usage of solar energy, it is necessary to install the heat storage and use the existing heat source (biomass boiler) only if the energy produced and stored by the sun was not enough. The total investment for solar thermal implementation (combination of 11,600 m^2 solar collector field, 2,600 m^3 volume heat storage and other auxiliary equipment) in the main district heating system of Salcininkai would cost nearly 4,000,000 €.

The only potential funding sources for the pipe refurbishment will be funds of the DH company and loans depending on the scale of the project and the company's financial situation during the implementation moment. The bank loan for similar projects are around 5% of the annual interest rate.

Taking into consideration subsidy schemes for solar thermal energy available today, the project could be financed from the European Structural Funds by up to 50% of the eligible costs. Due to the scale of the project and the considerably fast installation it is obvious that the company would be forced to cover the necessary part of investment using bank loan which yearly interest rate would be around 5%. Due to the fact that the loan will be quite significant for the company and its capital might not be sufficient enough therefore municipality might give guarantee to the bank in order to help DH company to implement the project. Private capital of DH company is usually used as security deposit (mortgage) for the bank.

According to Optit's network optimization analysis, comparing current technical configuration of the network to the fully optimized and refurbished network and assuming that the working hours, load and similar characteristics remain similar, yearly primary energy demand reduction would be approximately 2.57 GWh. However, it is necessary to take into account that the network optimization will most likely be a 30-year refurbishment plan which means revenue will increase on a year by year basis. Assuming that the primary energy reduction will decrease each year by 1/30 of 2.57 GWh value and taking into account 3% yearly inflation for current fuel price (10 Euro per MWh) we can identify that the increase in revenue on the 30th year will be around 60,000 Euro.

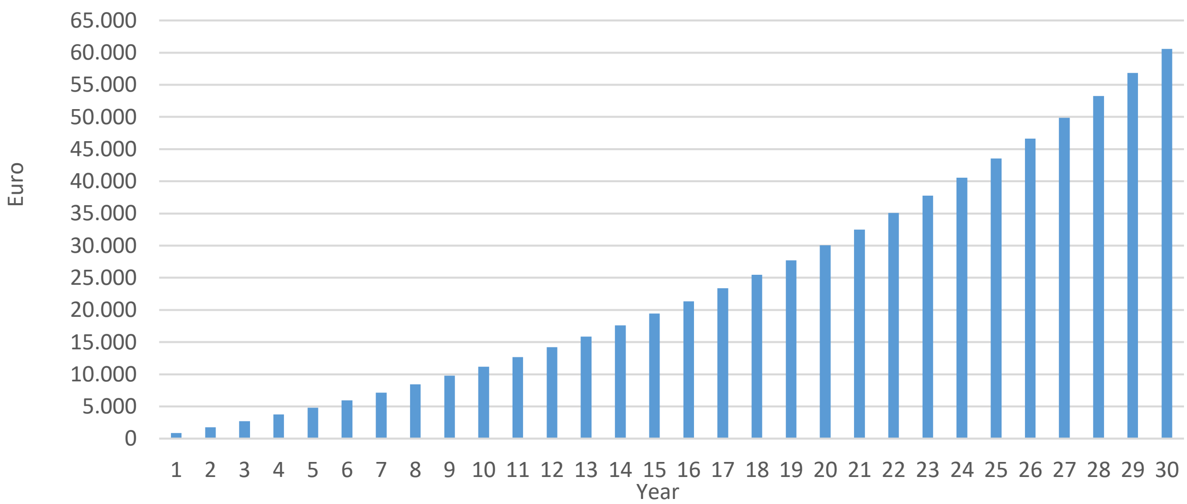


Figure 7 Approximate yearly revenue increases due to constant increase in energy savings

Solar thermal integration would only be available to accomplish if current heat production alternatives are more expensive. Taking into consideration alternative heat production solutions (biomass boilers) and its total costs, at current stage solar thermal implementation only would be available if solar thermal would receive higher intensity subsidies. However, considering the current framework and economic situations, higher incentives or other support schemes are necessary in order to achieve these conditions.

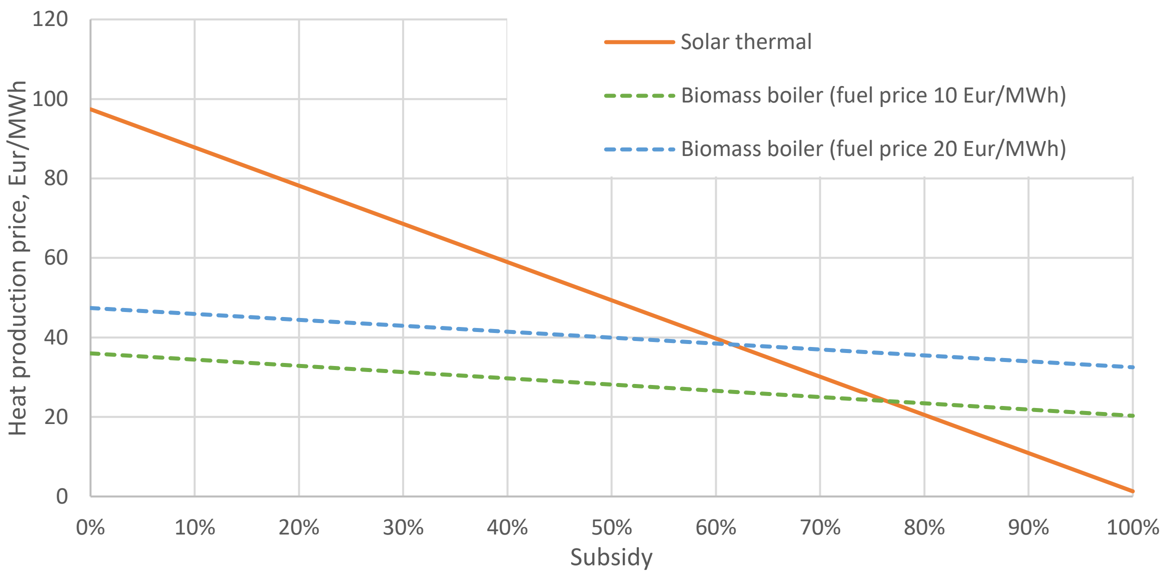


Figure 8 Heat production price comparison for competing technologies

Taking into account socio-environmental impacts of network refurbishment, the significant positive effect would result from primary energy demand reduction which is based on Optit's analysis and which indicates that biomass consumption would be reduced by 2.57 GWh.

Since a solar thermal system would be installed together with a thermal storage, it would lead the elimination of the gas boiler usage during the short-term peak demand periods and which would mean a reduction of the CO_2 emissions.

Total greenhouse gas emissions would be reduced by 236 $t_{CO2(equiv.)}$ on a yearly basis.

The realization potential for full network refurbishment throughout 20-30-year period is confidently probable. Each year, old pipes depreciate which means they will be replaced using the refurbishment plan. However, in some cases and some segments of the system it may not be possible to implement new diameters since parts of the network might have old higher diameter pipelines and the calculated solution might not be sufficient for the current user consumption. Therefore, minor changes might happen in the refurbishment plan throughout the period.

Since the National Energy Regulatory Council of Lithuania works with the perspective of lowest cost principle and their approval is a must prior to any investment project implementation the realization potential of solar thermal is dependent on the economic situation changes - existing subsidies or biomass prices influence which could make the solar thermal system a cheaper alternative than the currently installed biomass boiler.

8. Summary of Grudziadz, Poland

Poland's plan for fossil fuel neutrality is to achieve it before 2060. Poland deals with massive social and economic challenges due to the extensive use of coal as primary energy fuel source in all sectors.

City of Grudziadz's district heating system is mainly powered by coal, though 20% can be managed already by biofuels. The operator, OPEC Grudziadz, is already actively seeking means to lower the use of coal by, among others, manual reduction of supply temperature now using Termis Offline software as an analytic and hydraulic tool. However, further upgrading measures are discussed to optimize the network as well as means to lower low emission sources in the city. The collaboration between COWI and OPEC Grudziadz is ongoing. OPEC Grudziadz has limited resources so each of the identified optimizations and upgrading projects are investigated and therefore implemented one at a time.

The action plan, which is emerging due to the Upgrade DH project, will be firstly to upgrade the existing Termis system so it would be a fully automatic district heating flow temperature optimization (FTO) system. It is based on weather prognosis and hydraulic capacity of the network, and as output it calculates the energy demand on hourly basis as well as the exact supply temperature that must be delivered to the customers. The temperature is then regulated by the SCADA system (control system). In this way, the heat supplier can lower the temperature but still fulfil the heat requirements of the customers. The optimization requires a limited intervention on the existing network, since it is only necessary to improve the control system based on the Termis prognosis.

Several scenarios were conducted in Termis, in order to map all the bottlenecks in the system which in order to lower the supply temperature and cope with higher flows need to be addressed before. Two new booster pump stations need to be created in the network. Economic analysis showed that both investment in Termis system upgrade and installation of two new booster pumps will pay itself in a matter of one to two years! This investment will be done by OPEC Grudziadz alone, such as savings created by this project will be available for reinvestment right after.

Further plans have arisen:

A further action for the network optimization is to connect a defined low emission residential area in the old part of the city centre. 29 residential buildings with apartments and a heat demand of 3 MW, are today powered by coal fired boilers/stoves. The plan is to connect those buildings with a low temperature district heating network. The goal will be achieved by constructing a temperature shunt from the adjacent main network running together with a total energy refurbishment of the flats (third party financed). This project is politically interesting for the town hall. Energy refurbishment of the flats will not be a part of OPEC Grudziadzs investment. OPEC Grudziadz will invest in new connections as well as distribution network. Simple return of investment calculation for this project is around 6.5 years without any loan. As of today, it is not yet known which economical model will be considered by OPEC Grudziadz. As this is a flag project in terms of lowering the low emission sources both for OPEC Grudziadz as well as the Town Hall, it is assumed as highly probable. By converting low emission sources to the cogenerated district heating, it is assumed that an emission reduction of 2,500 tons of CO_2 per year will be achieved.

OPEC Grudziadz would like to invest in the existing southern part of the network and supply that area with power from the heat pumps. The area will be isolated from the main network with a shunt, in order to be able to supply extra energy, 3 MW, in peak and winter load times. In total 6 MW of southern existing as well as future development customers are now discussed to be supplied by a 3 MW air to water heat pump powered by grid tied solar panel farm. It is assumed that achieved emission reduction of CO_2 will be of 381 tons per year.

The district heating company has also considered the implementation of a waste incinerator as well as heat pumps at the existing wastewater treatment plant at the northern part of the city to increase diversification of fuel as well as increase in the non-fossil share in the production. However, the planning, design and implementation process is not started yet, but it will be considered in the coming years, when the priority of the available resources will be moved to that purpose. In the meantime, other possible alternatives are considered to phase out the coal from the heat production.

An important aspect of all the upgrading measures is the ownership model. OPEC Grudziadz is a private company owned by the Grudziadz Municipality, which is the main and only shareholder (100% shareholder). It is expected that the ownership model will remain the same for all the presented upgrading measure, since it does not involve relevant changes in the company. Potential support schemes may accelerate the implementation of the identified measures.

9. Summary of Purmerend, the Netherlands

The plan of The Netherlands is to phase out the use of natural gas for the heating of buildings and introduce sustainable heat sources. In general, the energy sector is expected to achieve 80-95% reduction of CO_2 emission within the 2050.

Stadsverwarming Purmerend B.V. (SVP), the district heating company based in Purmerend has already started the conversion of its heating sources to biomass; however, further upgrading measures are discussed to optimize the network. The collaboration between Stadsverwarming Purmerend, and the consultant company COWI has been ongoing, and throughout the years this collaboration has contributed to the improvement of the optimization of the network. The interest in upgrading the district heating network is part of the strategy of the company, even though the different solution proposed must be considered one at a time, according to the available resources that can be used.

Optimization of the main line

The first action considered in the business model is the optimization of the main line. It must be optimized to handle the increase of heat demand as consequence of the larger number of customers that will be connected to the district heating network in the future. Furthermore, to face the new demand, the heat production capacity must be increased. The updated demand/production capacity requires the hydraulic upgrade of the network.

The optimization analysis was done with the software Termis, considering two different scenarios with a minimum and maximum development of the area and of the heat demand.

Based on the scenarios created, the length of the network that must be optimize varies from 1,701 m to 3,131 m. Afterwards, based on the data resulted from the optimization process, the economic analysis was done, to evaluate the feasibility of the project. The investment was calculated to be between 1.13 M€ and 3.1 M€ depending on the scenarios applied. Due to the limited resources, it is expected to require a bank loan for about 80% of the investment, while the remaining 20% will be covered by the company. It was then calculated the amount earning for extra heat sales to the new costumer as well as the required operation and maintenance of the network, which lead to a payback period of around 3.5 years. As result of the sensitivity analysis, it was seen that the variation of the investment and the amount of heat sales can highly affect the feasibility of the project.

The network optimization is now ongoing at different stages and it involves the hydraulic optimization of the main line as well as the distribution pipes. The optimization of the main line is expected to be planned that in the coming years, since new sustainable sources and new customers will be connected to the existing network. Right now, part of the available resources is used for the optimization of the distribution network, and in the next future the focus will be moved to the main line.

Implementation of the flow temperature optimization system

A further action for the optimization of the network is the implementation of the flow temperature optimization (FTO) system implemented with the software Termis. It is based on weather prognosis and hydraulic capacity of the network, and as output it calculates the energy demand on hourly basis as well as the exact supply temperature that must be delivered to the customers. The temperature is then regulated by the SCADA system (control system). In this way, the heat supplier can lower the temperature but still fulfil the heat requirements of the customers. The optimization requires a limited intervention on the existing network, since it is only necessary to improve the control system based on the Termis prognosis.

The feasibility analysis of this upgrading measure considered the investment that must be afforded to install the system, as well as the operation and maintenance costs and the savings obtained. It was calculated that the initial investment results equal to 200,000 €, which includes the implementation of the flow temperature optimization system with Termis and adjustment of the SCADA system. The low investment leads to a short payback period, which was calculated to be around 1.5 years. It is expected that due to the limited investment required, it can be financed by the resources available at the district heating company. The sensitivity analysis showed that the savings obtained with the introduction of the system can mostly affect the investment, which are highly dependent to the fuel price.

The upgrading measure was considered as a possible measure to optimize the network and it is in the process to be further evaluated. However, the solution is paused since other measures are prioritized.

Implementation of the biomass plant

Due to the expected increase of users connected to the district network, Stadsverwarming Purmerend B.V. intends to build a second biomass plant of 16 MW capacity + 8 MW buffer capacity in Baanstee Nord, which was suggested to be implemented in 2021-2023. The biomass boiler will contribute to achieve a larger share of renewable sources in the heat production as well as contribute to fulfil the increased heating demand that is forecasted for the coming years. The implementation of a buffer will help to flatten the heat demand and provide part of the heat demand during the peak periods.

The feasibility analysis for the introduction of the new biomass model evaluated the required investment that should be considered by the district heating company. It was calculated that the cost for the new 16 MW biomass boiler will be around 8.3 M€, while the implementation of the 8 MW buffer tank will cost around 1.15 M€. It is expected that the investment will be covered 80% by a bank loan, while the remaining 20% it is expected to be covered by the district heating company. Considering the operation and maintenance cost, and the savings achieved by using biomass instead of natural gas, the calculation of the payback period showed that it will be slightly longer than 25 years, as shown in the cumulative cashflow in Figure 1. However, the calculation only considered the economic point of view, without accounting the environmental benefits for the society. The new plant will contribute to reduce the emission of 8,800 tons of CO_2 per year.

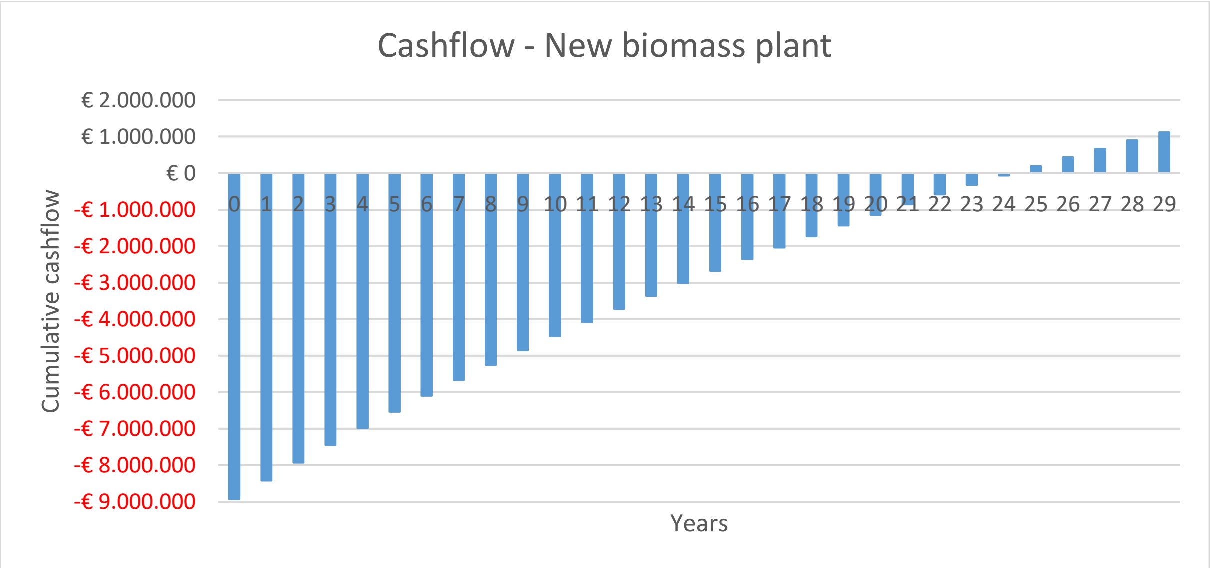


Figure 9 Cumulative cashflow for the new biomass plant in Purmerend

The sensitivity analysis showed that the highest impact on the project is given by the fuel price, since it leads to a difference in the yearly savings that can be achieved by using the biomass to replace the natural gas. A reduced difference between the two fuel prices affects the feasibility of the project, which is not expected in the coming years. Lastly, the initial investment can remarkably affect the feasibility of the project, limiting the interest in implementing the biomass plant.

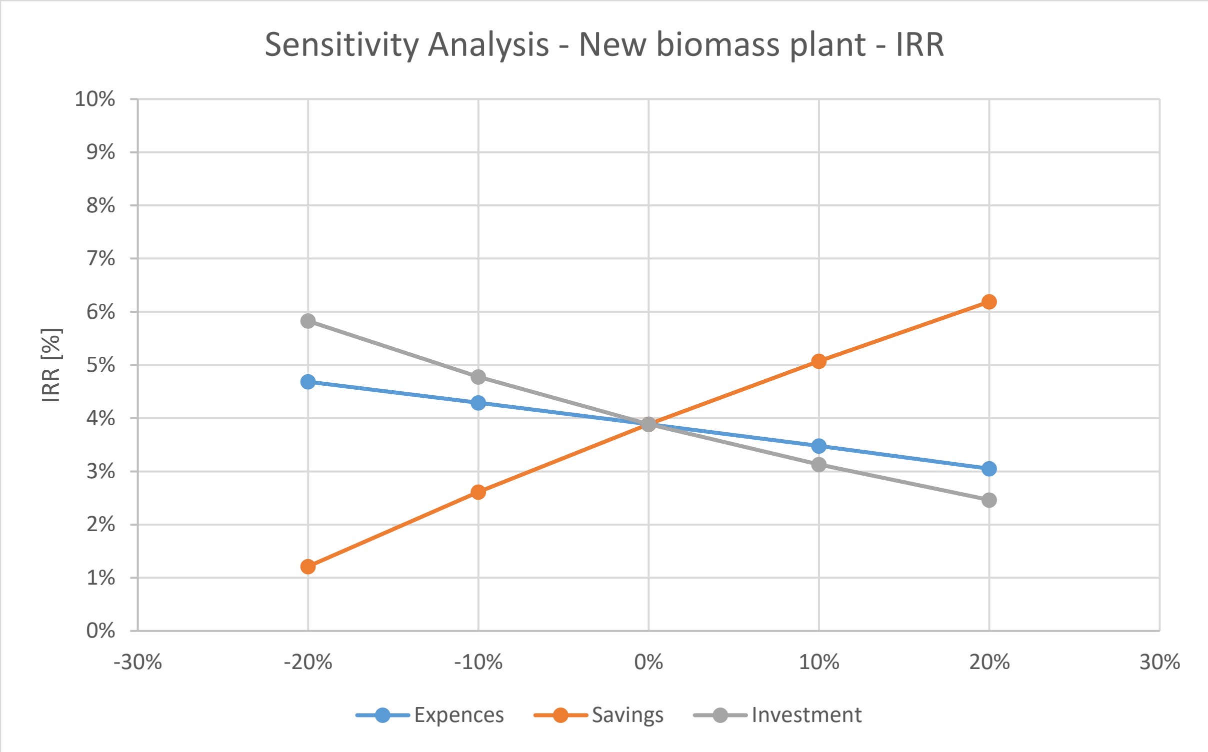


Figure 10 Sensitivity analysis for the new biomass plant in Purmerend

The district heating company has considered the implementation of the biomass plant as solution for increasing the renewable share in the heat production. However, the implementation process is not started yet, but it will be considered in the coming years, when the priority of the available resources will be moved to that purpose. In the meantime, other possible alternatives are considered to phase out the individual natural gas from the heat production i.e. introducing centralized heat pumps.

An important aspect of all the upgrading measures is the ownership model. Stadsverwarming Purmerend B.V. a public company owned by the Purmerend Municipality, which is the main and only shareholder (100% shareholder). It is expected that the ownership model will remain the same for all the presented upgrading measure, since it does not involve relevant changes in the company.