A1 – Masterplan district heating 2050

Subject:	*Masterplan District Heating 2050 / Development of District Heating Scenarios - Simulations for Future Feed-in Options*
Short description:	*This document describes the measure of future scenarios of the DH supply*
Date of last update:	06.09.202 (update by AEE INTEC)
Authors:	M. Salzmann, AEE INTEC with participation of Energie Graz and City of Graz – Environmental department
Region, country:	Graz, Austria
Partners involved:	AEE INTEC, Energie Graz, City of Graz – Environmental department
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Figure 1: 3D model district of Reininghaus, Source: Wärmeversorgung Graz 2020/2030, Statusbericht 2019

Initial situation

Based on the local conditions in the City of Graz and the surrounding we will evaluate different scenarios for district heating sources for Graz based on renewable energy sources. Population growth, energy efficiency scenarios and the effect of climate change will be considered. As a main result the necessary heat storage capacity to shift surplus renewable energy sources from the summer time to autumn and winter time will be calculated.

The further development of the masterplan Graz, also within the framework of this project, is an important focus for the coming years. It is of great importance to further increase efforts in order to support and carry out an energy turnaround.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 952873.

Fact box

Parameter	**Unit**	**2018**	**2022**
Network pipe length	km	412	449
Connected load for billing	MW	712	776
Buildings supplied		11.000	12.800
Appartments supplied		71.000	85.500
Maximum power	MWth	450	388
Heat generation	GWh/a	1.100	1.218
Heat generation plants power		Basis Survey	
Combined heat and power	MWth	630	550
Fossil fuels	MWth	595	595
Solar thermal	MWth	11,8	11,8
Heat pumps	MWth	12,2	12,2
Biomass	MWth	5	5
Waste heat direct	MWth	45,25	88,25
		-	10
Road to 100% strategy – yes/no?		Yes	Yes

Objectives

One main objective is to have different supply scenarios evaluated as a base for the future ”Masterplan” for Graz DHC. The Masterplan aims towards the highest possible share of alternative energy sources (renewable & waste heat incl. combined heat and power & environmental heat), additional increases in energy efficiency in buildings, customer plants and in the overall district heating system as well as maintaining the security of supply (CHP, waste heat, solar, etc.) and for the provision of the required power even on cold winter days.

Description of the measure

The measure focused on finding different ways (scenarios) for supply and expansion of the Graz DH network. Together with subcontractors experienced in network simulation the Graz project partners worked on those Scenarion proactively.

Potential barriers were how to connect the locations that aren’t yet connected and to find a proper supply source for them. Other barriers were to find solutions to implement as many RES as possible while matching with the high net temperatures. We tried to overcome those barriers by working closely togehter and establish an update and know-how exchange culture to use all fields of expertise as good as possible.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 952873.

Results

In the Masterplan District Heating 2050 for Graz, four scenarios up to the complete decarbonisation of the heat supply were outlined, based on the decarbonisation strategy of the district heating system for the greater Graz area up to a share of 80% of renewable energy sources and waste heat by 2035.

As pictured in Figure 2 this roughly results in the following range of energy supply shares from the individual supply types between the different scenarios: Heat from combined heat and power (CHP) Mellach in the range of 0 % to 16 %, waste heat at high temperature level between 12 % and 27 %, waste heat at low temperature level in combination with heat pump between 5 % and 14 %, biomass heat with 14 %, energetic use of residual materials with 14 %, solar thermal heat with 1 %, additional heat from renewable energies or waste heat with 3 % to 12 % and green gas for peak load and reheating with about 10 %. In all four scenarios, there is a need for long-term heat storage to store surplus heat in summer and transfer it to autumn/winter. Depending on the scenario and the assumed calculated storage management, the water storage volume lies between 1.5 million m³ up to 6 million m³. With these assumptions and measures, a decarbonisation of the district heating supply in the Graz area by 2040 can be presented with the best possible consideration of the regional framework conditions.

		2040			
	2030	Szen 1	Szen 2	Szen 3	Szen 4
KWK	ca: **16%**	+/- 0%	- 8%	- 16%	- 16%
Abwärme	ca. **48%**	+ 7%	+ 7%	+/- 0%	- 17%
Wärme aus ern. Quellen	ca. **15%**	+ 3%	+ 12%	+ 29%	+ 45%
Erdgas	max. **20%**	- 20 %			
Grünes Gas	**0%** (?)	+ 10%			

Figure 2: District heating supply for the Graz area - key data of the 4 scenarios for the period until 2040 (note: the percentages refer to the total district heating supply; scenarios 1 to 4 show the change compared to the period until 2030)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 952873.

Lessons learned

The prerequisite for the implementation of the calculated scenarios is that high-temperature heat pumps are ready for the market by 2035 and/or a reduction in grid temperatures becomes possible.

The district heating generation mix is very much dependent on local conditions (e.g. heat sources for heat pumps, hydrogeological conditions for the use of geothermal energy and the use of the deep underground as heat storage (aquifer storage), ...)!

The storage volume is very dependent on storage management: seasonal storage with discharge in autumn versus additional use as load balancing storage.

In the past years, due to the existing contractual framework conditions, about 75% of the district heating for the greater Graz area was provided by Energie Steiermark Wärme GmbH (shareholder 100% Energie Steiermark AG, which in turn is 100% owned by the province of Styria) or its subcontractors in its network (e.g. Verbund Thermal Power GmbH). The share of district heating supplied by Energie Graz GmbH (shareholder 51% Holding Graz, 49% Energie Steiermark AG) or its subcontractors in its grid is thus around 25%. The complexity of the stakeholder composition poses an additional challenge for the further decarbonisation of district heating supply in Graz.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 952873.

Subject:	**Thermal storage - hydrogeological investigation of**
Short description:	*This document describes the measure of thermal storages for the Graz DH net.*
Date of last update:	06.09.2023 (update by AEE INTEC)
Authors:	M. Salzmann, AEE INTEC with participation of Energie Graz and City of Graz – Environmental department
Region, country:	Graz, Austria
Partners involved:	AEE INTEC, Energie Graz, City of Graz – Environmental department
Document download:	www.res-dhc.eu/

Figure 1: Storage project HELIOS in Graz, Source: Energie Graz

Initial situation

The Graz DH network stakeholders are aware that Graz has to face that a high share of RES in the future needs a thermal storage solution as a core technology. Currently storage solutions are implemented and further investigated.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 952873.

Fact box

Parameter	Unit	2018	2022
Network pipe length	km	412	449
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Heat pumps	MWth	12,2	12,2
Biomass	MWth	5	5
Waste heat direct	MWth	45,25	88,25
		-	10
Road to 100% strategy – yes/no?		Yes	Yes

Objectives

In the field of thermal energy storage (TES), necessary and appropriate heat capacity sizes in order to optimize the operation of district heating in the area of Graz are to be identified and the legal framework for their use is to be promoted (creation of priority areas and reserves). Furthermore, evaluations of the technical feasibility of different storage concepts (e.g. high operation temperature vs. low operation temperature) and concept developments for storage integration in the environment of heat generation plants will be carried out with the help of different simulation methods and tools (e.g. Modelica/Dymola). Based on the concepts developed and their economic evaluation, the realisation and implementation of a corresponding storage concept is being considered.

Description of the measure

Economic & energetical investigations for storage systems are to be carried out within this measure. Seasonal storages (PTES) (for scenarios) as well as the operational thematic (TTES day/week buffer) will be investigated. One barrier might be if there is enough space „within“ the City of Graz limits (area). We could overcome this barrier by develop a possibility to use the top surface ot the storage for an urban purpose. Possible sources nearby the potential storage areas also need to be investigated to minimize heat transport losses. Also geological investigations for underground storage systems regarding the actions of decarbonisation of DH network are planned.

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All potential and design studies for the integration of large heat storages contribute to show a big picture of feasibility grid flexibility in Graz.

The timeplan will be updated during the 1st quarter of 2022.

Results

This study describes the basic feasibility of cavern storage in the urban area of Graz. Hydraulic engineering and rock mechanics criteria were defined, which are useful for the construction of caverns, and these criteria were compared with the geological conditions. While the southern and eastern parts are ruled out due to their unsuitable geology (sediments & sedimentary rocks), solid rock lithologies can be identified in the west, northwest and north, in which cavern construction is possible in principle. However, the existing district heating network in the northwest is too far away from the bedrock lithologies and the area is therefore ruled out. Possible sites could therefore be identified in the west and northwest of the city of Graz. These are located in bedrock and offer the necessary topographical and logistical conditions for the construction of cavern storage facilities. The potential sites are the *Admonter Kogel* hill (see Figure 2) in the northwest of Graz and the former *Karolinen* quarry in the west. According to the current state of knowledge, the site at the *Karolinen* quarry is favoured due to the potentially stronger karst phenomena at the *Admonter Kogel*.

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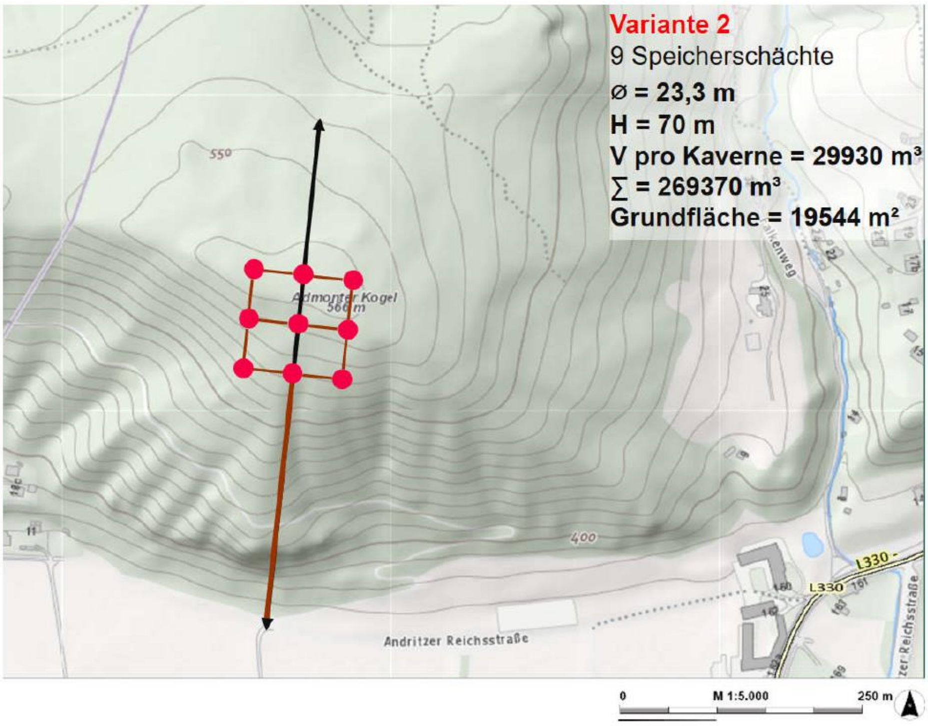

Figure 2: Plan view of a theoretically possible storage facility at Admonter Kogel (variant 2) according to the study, consisting of 9 storage shafts with a total volume of 269,370 m³. The tunnels to be excavated are shown in brown and the storage shafts in red. This illustration is for illustrative purposes only and is therefore only to scale to a limited extent.

For both sites, a possible concept with different storage volumes has been worked out, which is based on the principle of individual storage shafts. This makes it possible to select the volumes according to demand and to expand them as demand increases. The results show that in principle it can be assumed possible to construct cavern storage facilities in the urban area of Graz. However, it should be noted that both the geological/rock mechanical assessment is based on literature and the actual local conditions may be different than expected. The variants of storage caverns presented must also be regarded as conceptual. In addition, the favourable areas are located in areas of possible karstification, which is why special attention must be paid here. Furthermore, the study points out possible water law issues relevant for approval in the case of the implementation of such a project. Also the charging cycles are important for the design of storage caverns, which is why these should be determined in advance. It is therefore essential to carry out further investigations in order to explore the possibilities, refine the concepts and finally be able to plan in greater detail.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 952873.

Lessons learned

The results of the cavern study are purely literature-based, which makes further studies necessary. If test boreholes are drilled in the future, this may lead to a change in the geological/rock mechanical conditions for assessing the suitability of the sites. For detailed planning, it is also important to define the storage cycles in advance, as these determine the design of the storage caverns. Especially the design of the storage caverns can influence the approvability in the area of sealing.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 952873.

Subject:	*DC – economic system solutions based on Austrians DC status*
Short description:	*This document describes the measure implementing an economic DC system in the area of Graz and the steps towards it.*
Date of last update:	06.09.2023 (update by AEE INTEC)
Authors:	M. Salzmann, AEE INTEC with participation of Energie Graz and City of Graz – Environmental department
Region, country:	Graz, Austria
Partners involved:	AEE INTEC, Energie Graz, City of Graz – Environmental department
Document download:	www.res-dhc.eu/

Figure 1: Heat pump implemented in the Graz' district of Reininghaus, Source: Energie Graz

Initial situation

Currently there is no DC network established in the area of Graz. At the moment there are a few "island-solutions" cooling rather small areas and single buildings. Therefore this measure is planned to be implemented.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 952873.

Objectives

On the topic of district cooling, evaluations of the competitiveness of district cooling and the development of innovative/ecological cooling concepts (local cooling networks, neighbourhood solutions, micro-networks, etc.) for urban areas are planned, including the possible use of absorption chillers in the district heating network in Graz.

The survey is intended to serve as a guideline or decision-making basis for the implementation of a future economic district cooling system in Graz.

Description of the measure (1/2 page to 1 page)

In the first place it is planned to have a study about the status of DC in Austria carried out until December 2022. It has to be investigated which demands exist and which sources could serve this purpose. Also it has to be kept in mind that there is a trend for increasing cooling demand in urban areas.

Project partners as well as experienced subcontractors will work closely together to investigate an economically feasible system solution for DC in Graz.

At the beginning, general observations on district cooling in Austria and Europe were carried out. Furthermore, interviews/conversations with refrigeration network operators and refrigeration machine manufacturers were conducted.

Afterwards, innovative/ecological cooling concepts for urban areas were considered with a focus on the general conditions in Graz.

Results

The basic prerequisites for setting up a district cooling network are initial customers ("large consumers") and high purchasing densities.

The following are conducive to the use of heat-driven chillers: Re-cooling at a low temperature level, cooling network at as high a temperature level as possible, favourable drive heat, as high a temperature level as possible for the drive heat.

When planning heat-driven cooling, the entire system must always be considered (chiller, re-cooling, pumps, storage, heat recovery option, full cost consideration, ...).

A "good mix" between heat-driven (mainly base load) and conventional chillers should be aimed for.

At drive temperatures of 75 °C, as prevailing in the Graz district heating network in the summer months, special machines or almost "standard machines" with re-cooling at low temperature levels (river or well water) would be preferred for supply. For heat-driven cooling, cheap drive heat is required.

If there is a lack of purchasing densities, decentralised solutions or microgrids are more preferable.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 952873.

Lessons learned

In order to realise a district cooling network, initial customers or a corresponding purchasing density are required. Initial customers would be potential large customers such as hospitals, shopping centres or large office complexes.

The study shows which framework conditions are necessary for an economically operated district cooling network on a large scale.

Small-scale alternatives are microgrids or decentralised solutions.

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Subject:	***Return by supply – Evaluate DH areas where customer needs and supply via return match best***
Short description:	*This document describes the action on the evaluation where to realize DH supply by return most efficient*
Date of last update:	08.09.2023 (update by AEE INTEC)
Authors:	M. Salzmann, AEE INTEC with participation of Energie Graz and City of Graz – Environmental department
Region, country:	Graz, Austria
Partners involved:	AEE INTEC, Energie Graz, City of Graz – Environmental department
Document download:	www.res-dhc.eu/

Figure 1: DH transfer station, Source: Energie Graz

Initial situation

In the Graz DH system there are already a few buildings and quarters supplied via return flow. Stakeholders see big potential in the further development of this measure.

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Fact box

Parameter	**Unit**	**412**	**449**
Network pipe length	km	712	776
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Maximum power	MWth	1.100	1.218
Heat generation	GWh/a		
		Basis Survey	
Heat generation plants power		630	550
Combined heat and power	MWth	595	595
Fossil fuels	MWth	11,8	3,5+5,7+2,6
Solar thermal	MWth	12,2	12,2
Heat pumps	MWth	5	5
Biomass	MWth	45,25	88,25
Waste heat direct	MWth	-	10
Road to 100% strategy – yes/no?		Ja	Ja

Objectives

Main objective is to carry out in which areas supply by return flow makes sense in the most economical way. This means showing in detail where supply and customer demand match best.

Description of the measure

As systemic measures in the field of district heating, investigations are being carried out for heat supply. One possibility is to supply buildings from the existing network return flow (no reversal of the flow direction, sufficient mass flow, all year round, etc.). Therefore project partners as well as experienced subcontractors will work closely together to investigate the high potential areas for an economic implementation. One main barrier will be to define a point where it is economic feasible to supply a building or quarter by an existing return flow and especially if this is possible all over the year.

It is planned to have the outcome of this measure as a decision base for demonstrators and if possible, realize their implementation during this project.

Results

The existing pipe network model for the district heating network in Graz has been examined to determine which sections of the district heating pipeline would be suitable for return heating. The criteria for a suitable district heating pipe section are that there is no reversal of the flow direction and that a sufficient mass flow is available all year round. To evaluate these criteria, simulations were carried out with the *Sir3S* pipe network calculation

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programme. In the *Sir3S* pipe network calculation programme, the district heating network of Energie Graz was modelled using a *GIS* (Geo Info Service) display. Based on the modelled district heating network, three reference states were set and calculated using measured values provided. A low-load, medium-load and high-load model has been set up and calibrated, in which static calculations can be carried out.

Lessons learned

In terms of simulation, the effects of converting a consumer to return heating were examined in more detail in a suitable area with two district heating shafts, 22 consumers and a connected load of 3.75 MW.

Conclusion: In the investigated area, the criteria for a return flow supply were fulfilled. The largest consumer drew a heat output of 431 kW in the high-load case, which can also be called up in the case of a switchover to return flow supply. In any case, switching consumers to return flow supply must always be considered individually, as there is an influence on the entire district heating network.

The results of this study have already led to a customer request for such a switch to return flow supply for an existing customer in the area studied.

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Subject:	*User integration and further measures*
Short description:	*This document describes the measure off user integration as well as further non-technical aspects.*
Date of last update:	08.09.2023 (update by AEE INTEC)
Authors:	M. Salzmann, AEE INTEC with participation of Energie Graz and City of Graz – Environmental department
Region, country:	Graz, Austria
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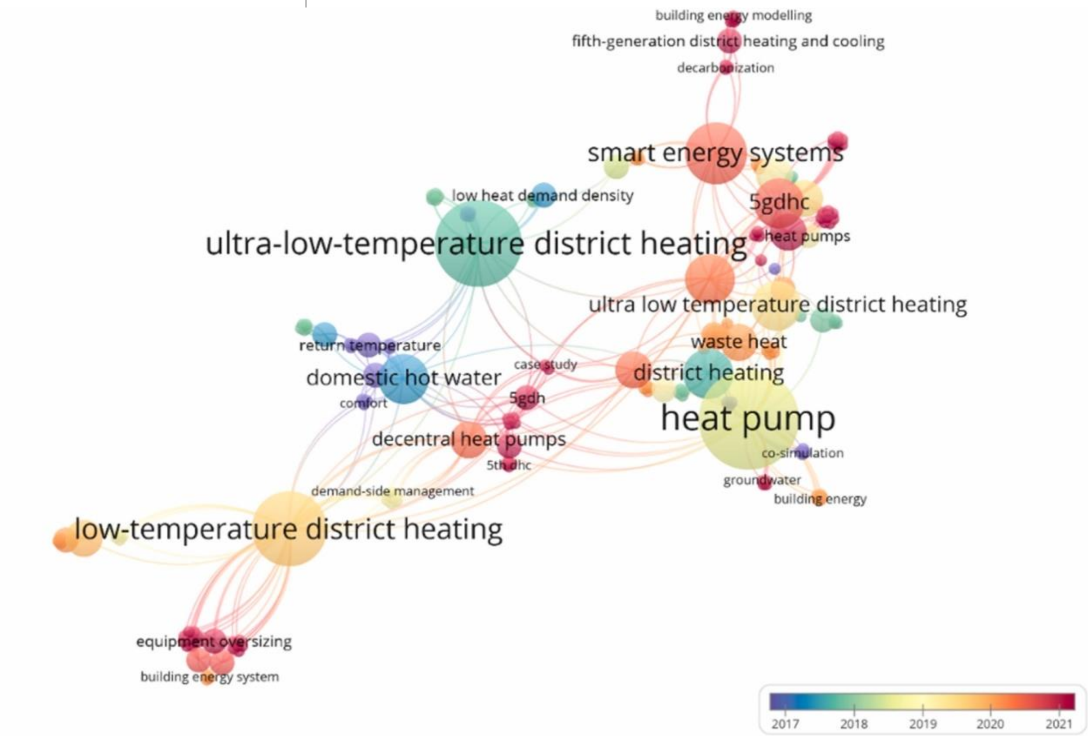

Figure 1: Technological developments for future heat grids for consideration in sustainable business models, Source: Gjoka, K., et.al. https://doi.org/10.1016/j.rser.2022.112997

Initial situation

District heating is a key area for sustainable energy infrastructure that has both environmental and social impacts. In this context, the relevant stakeholders and the anticipated business model are crucial. Especially in urban areas, heat supply faces major challenges due to changing environmental regulations, technological advances and changing consumer preferences, among others. In this context, the active involvement of users,

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whether as end users, prosumers or cooperating stakeholders, is gaining importance in order to develop a sustainable and future-proof business model.

The anticipated business model plays a central role in how the provision of thermal energy is organised, how value is created and how sustainability is ensured. Traditionally, this business model focuses on producing thermal energy and delivering it to customers in a predefined quality, trouble-free. In urban areas, housing cooperatives and property managers act as an interface to the end customers. The existing heat supply contracts often offer less flexibility for end customers and are based on a tariff structure with high fixed cost shares, which makes it difficult for customers to visualise incentives to save energy. The high network temperatures in many district heating networks make the transition to more modern technologies (Generation 4 and 5) more difficult. A necessary change in technical, environmental and economic terms is required to increase efficiency and ensure long-term, secure business relationships.

Objectives

The measure aimed to collect and evaluate methods and concepts for stakeholder engagement - in particular, with focus on the "users" of district heating. Thus, different communication modules were identified, which support a sustainable relationship management. Based on the stakeholder analysis, the identified needs and degrees of influence could be incorporated into the analysis and evaluation of future business models. In this context, an evaluation of a one-stop-shop as a contact point for flexible service packages has been carried out and potential innovative approaches were surveyed nationally and internationally. Topics such as "What is the benefit to the heating customer of lowering the room temperature?" "What are the advantages of low RL temperatures?", "Which measures have an added energy value for customers and operators?" served to sensitise users and provide the basis for the further development of future business models. The results were summarised in a guideline-oriented report.

Description of the measure

In addition to identifying and analysing the key stakeholders in district heating supply, the aim has been to identify challenges, needs and opportunities for effective user integration and to demonstrate the different methods and instruments in use. The identification of needs and requirements from data analyses, research and best-practice examples served as the basis for the development of the study. The data-based survey of the existing business model for heating networks and the derivation of future potentials were based on the empathy mapping and CANVAS model. In the derivation of the business models for the current and future situation, technical, economic and social boundary conditions have been surveyed and integrated into the development of the business models. In addition, innovative approaches of business and tariff models from other regions are included in order to represent the range and possibilities in the best possible way. Overall, the results were summarised in a guideline-oriented report and provide a basis for future developments.

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Results

The basis for active relationship management lies in knowing the relevant stakeholders and understanding their needs and the resulting impacts. Stakeholder engagement is a comprehensive approach and continuous process that pays attention to the demands of organisations and stakeholders, taking into account the entire value chain. In a four-step process of (1) identification of stakeholders, (2) determination of relevance, (3) comparison of expectations, ambitions and value propositions, and (4) initial considerations of goals, strategies and actions, it is possible to identify the relevant stakeholders and know their needs and influence, so that relevance can be derived considering the objectives. By way of example, Figure 2 gives a good overview of the results of a stakeholder analysis.

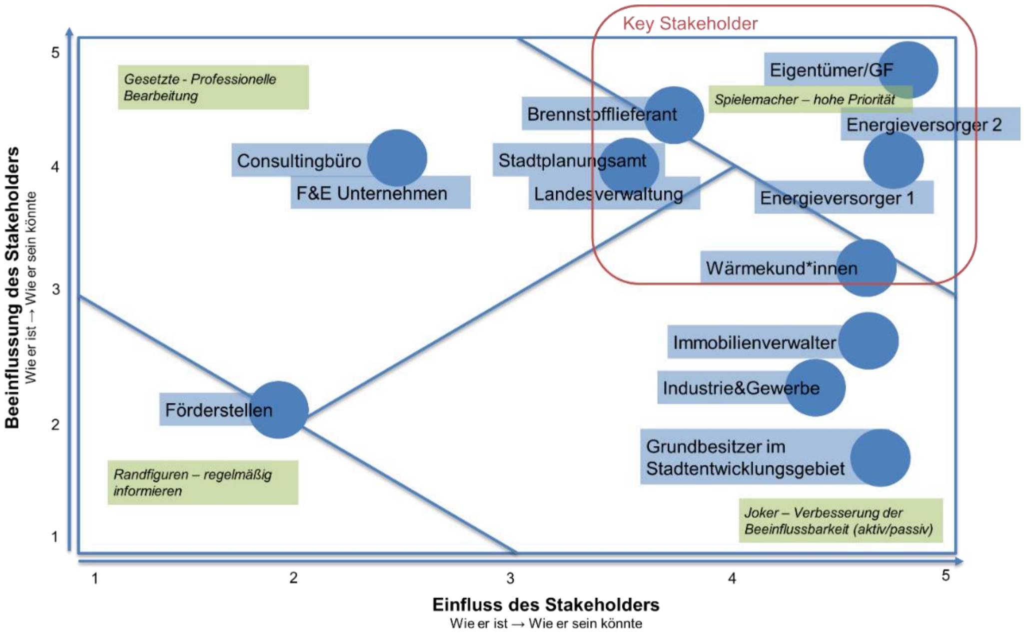

Figure 2: Stakeholder analysis based on the framework conditions in AT, data basis from the ThermaFlex project and RES-DHC applied according to the model for stakeholder analysis by G. Müller-Stewens[1].

The analysis of the needs of users and extended stakeholders served as a basis for the survey of approaches and possibilities for future business models. The results of the analysis indicate that heating utilities need to adapt their business models to remain competitive in a changing energy landscape. The uncertainty and volatility of the future outlook require the consideration of different scenarios to identify long-term success potentials. Openness to innovation, new technologies and change becomes a key factor. Increased digitalisation and transparency play a central role in supporting new technologies and service offerings. This enables stakeholders (key stakeholders, users and extended stakeholders) to participate more actively in

[1] G. Müller-Stewens und C. Lechner, Strategisches Management - Wie strategische Initiativen zum Wandel führen., Stuttgart: Schäffer-Poeschl Verlag, 2016.

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finding solutions. An important aspect is decentralisation, which allows alternative renewable technologies to be incorporated and combined with digital solutions. In this context, sound spatial and energy planning is just as essential as the creation of the necessary legal framework. It is emphasised that technological developments should be driven forward in parallel with the redesign of the business model. This means that innovations and technological advances should go hand in hand with changes in the business model to ensure optimal interaction.

Figure 3 gives a visualised overview of the approaches to changes in future business models and how the interaction can work through relationship management with the relevant actors. The results map the literature study with supplementary surveys.

Figure 3: Perspective business model for heating utilities 2050, created according to CANVAS model, Modified and extended according to Lygnerud, K., Popovic, T., Schultze, S. et.al. (2023) p. 5 ff. and Müller, A. (2021), p. 158 ff.

The future business model of heat supply and distribution relies on an extended value proposition that offers customers heating and cooling services as well as hot water supply in flexible tariff and service packages and also pays attention to comfort specifications. The focus is on low system temperatures for maximum energy efficiency. Digitalisation plays a crucial role in providing customised services in a cost-effective manner, supported by intelligent systems and learning algorithms. Customers have the option to actively participate in the development, with personal communication contributing to the long-term win-win situation between cooperation partners and prosumers.

Key partners expand to include decentralised heat providers, prosumers and joint ventures, while main customer groups, including urban district heating, developers and flat owners, benefit from flexible tariff structures. The traditional system structure of the heat price is giving way to a more transparent and flexible presentation.

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Exemplary implementations in Denmark (Copenhagen, Viborg, Rise) and Austria (Flachau, St. Johann i. Tirol) show how changes in the tariff structure can achieve positive energy efficiency results. The adaptation of the business logic and organisational structure ensures that innovation and change are sustainably integrated to successfully implement the innovative tariff and service offer.

Lessons learned & Impact

The final results are based on a literature study and survey, so that in the case of a concrete implementation of new business models or the development of an active user journey for sustainable relationship management, the detailed framework conditions at the Graz location must be analysed and further detailed studies are necessary.

The development of new business models and sustainable user integration is a challenging task, which, starting from a needs-oriented approach of the stakeholders, must take into account innovative technologies and the flexibility and adaptability to changing market conditions. In addition, besides the development of new business and service models, the implementation in a controlled environment has to be considered, so that feedback and initial information can flow into the optimisation. A sustainable business model aims not only to generate short-term profits but is oriented towards long-term value creation with clear visions for the future.

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