Development of an Energy Transition Cycle in the City of Eisenstadt

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1 ABSTRACT

In course of the project “Creative Circle” a so called “energy transition cycle” in Eisenstadt is developed. This energy transition cycle aims to support the efficient use of the local renewable energy production. In addition, climate change adoption measures are implemented.

The local district heating network, the sewage treatment plant and photovoltaic systems form the basis of the project. A large part of the population is currently supplied with heat from the district heating network that is mainly heated with biomass. Currently, a part of the heat goes unused with the wastewater to the sewage treatment plant. This is set to change in the future. The thermal energy in the wastewater will be integrated into the district heating network by using a heat pump. With regards to the electricity supply, a renewable energy community was established. The electricity demand of the heat pump as well as the electrical demand of the inhabitants of Eisenstadt can be partly covered with renewable energy from the energy community, at favorable tariffs. The energy from the energy transition cycle is also used for the environmentally friendly operation of a multifunctional Cooling Center, which provides a cool place to shelter from extreme heat free of charge and also functions as a social meeting point. As first part of the energy transition cycle, the Cooling Center located in the town house of Eisenstadt was completed in summer 2023. The foyer in the town hall was redesigned to make the stay as pleasant as possible and an innovative cooling system was implemented. The planning of the wastewater heat utilization at the sewage treatment plant was carried out in parallel. The integration of a heat pump in the sewage treatment plant shows considerable potential for reducing biomass and gas consumption and increasing the efficiency of the district heating network. However, the implementation of the project is not without its challenges. The technical design of the heat pump integration requires careful planning and coordination with the existing systems. Choosing the right size of heat pump, taking the biomass system into account, and increasing efficiency are complex tasks that need to be tackled carefully. Detailed planning and economic evaluations are currently being carried out.

Keywords: waste water heat pump, cooling centre, enery transition cycle, energy community, participation

2 INTRODUCTION

To prevent a further progress of the climate change and to achieve the European as well as the national climate targets, comprehensive measures are needed, which include an increasing share of renewable energy sources in the energy supply. In addition to that, cities in particular are already strongly effected by summer overheating. The number of hot days (days over 30°C) has doubled to tripled in Austria in recent decades [GeoSphere Austria, 2022]. Thus, climate change adaptation measures are also needed, which should take place in addition or complementary to climate protection, as the inertia of the climate system means that climate change will continue to progress even if we reduce emissions. The aim of climate change adaptation is therefore to react proactively to future climate change and to take measures to avoid future damage and take advantage of opportunities that may arise.

On behalf of the Austrian government and the federal provinces, climate scenarios for Austria have been created on the basis of global climate models in order to have a reliable, high-quality and application-oriented basis for dealing efficiently with the challenges of climate change at the level of the federal provinces. These scenarios allow the following key statements to be made for Burgenland, the federal state in which Eisenstadt is located [Novakovits, 2020]:

- Mean annual temperatures rise from 10.0°C to at least 11.3°C by 2050. By 2100, average temperatures will rise to 12.2°C (climate protection scenario) and 13.8°C (business-as-usual scenario).

- A slight increase in annual precipitation and especially winter precipitation is to be expected in the near and distant future.
- Today Burgenland has recorded an average of 10.1 hot days per year. In the near future there will be almost twice as many, in the distant future even around 25 or 42 days depending on our future way of life and economy.

The aim of the project "Creative Circle"[1] is therefore to develop and implement an so called "energy transition cycle" in Eisenstadt. The energy system of the city will be set up as a circular economy. That means, that the locally available resources and energy flows should be used locally. The local district heating network, the sewage treatment plant and photovoltaic systems form the basis of the project. A large part of the population is currently supplied with heat from the district heating network that is mainly heated with biomass. Currently, a part of the heat goes unused with the wastewater to the sewage treatment plant. This is set to change in the future. The thermal energy in the wastewater will be integrated into the district heating network by using a heat pump, thus closing the "heat cycle" in the city. In this way, the amount of biomass used should be reduced and an upcoming expansion of the district heating network will be supported. Figure 1 provides an overview of this overall concept.

With regards to the electricity supply, a renewable energy community was established that contributes to the local use of locally generated electricity. Energy communities enable the exchange of electrical energy across properties without involving an energy supplier by using the public electricity grid. The electricity demand of the heat pump as well as the electrical demand of the inhabitants of Eisenstadt can be partly covered with renewable energy from the energy community, at favorable tariffs. Another focus area of the project is the increasing overheating in summer and the associated need to adapt to climate change. The energy from the energy transition cycle is also used for the environmentally friendly operation of a multifunctional cooling center, which provides a cool place to shelter from extreme heat free of charge and also functions as a social meeting point. The Cooling Center will be open to all residents of Eisenstadt, be easily accessible and be characterized by multifunctional usability in order to make the space more attractive.

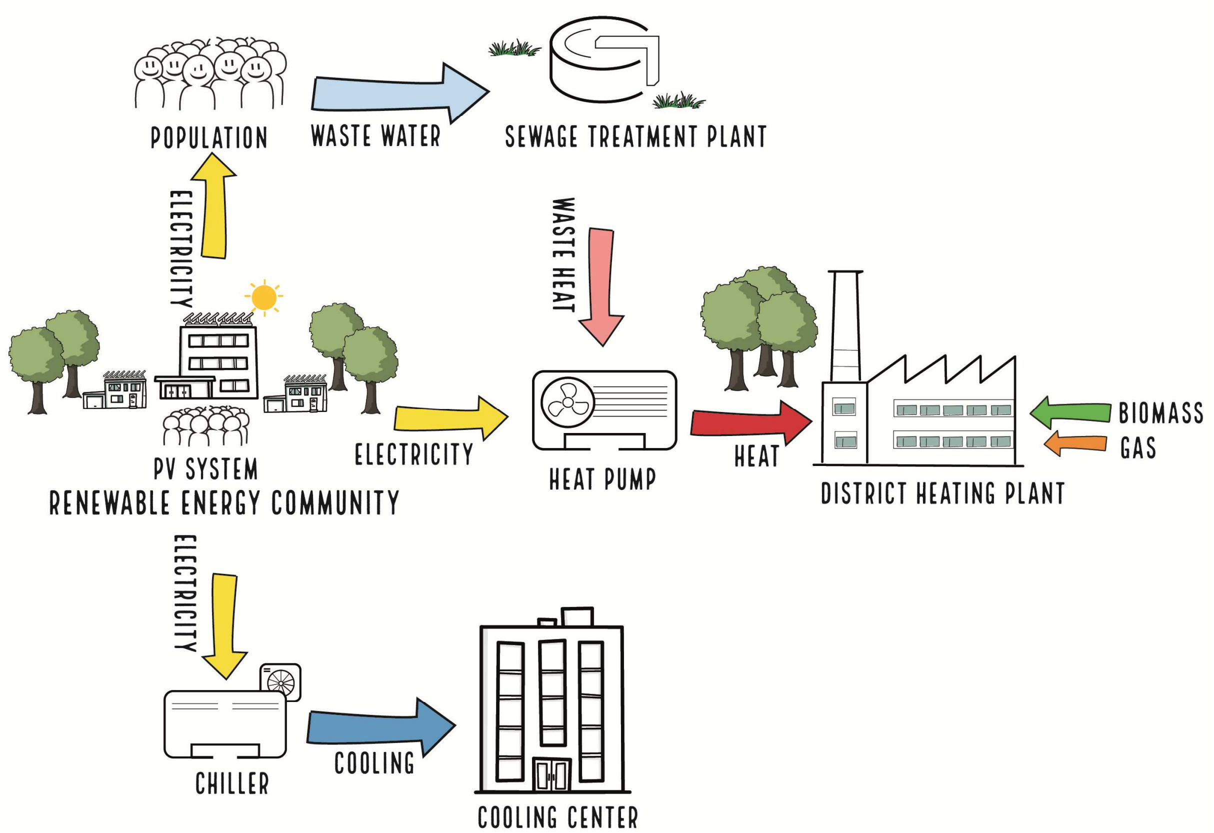

Figure 1: Schematic illustration of the energy transition cycle in Eisenstadt

[1] https://creativecircle.myportfolio.com/

Spending a few hours in a cool environment reduces the risk of vulnerable populations being exposed to heat. Those who adjust their behavior to spend time in a cool place during a heat wave are less likely to suffer from heat wave mortality. A study of the 2003 European heat wave surveyed family members of those who died to determine behavioral factors that influenced mortality. The study concluded that staying in a cooler environment during a heat event was associated with a lower risk of death. [Vandentorren et al., 2008] A meta-analysis of the risks and protective factors associated with heat-related mortality found that going to an air-conditioned room reduced the risk of death by about 66 % compared to those who did not go to air-conditioned rooms. [Bouchama, A., et al, 2007]

Although cooling centers are a widely used climate change adaptation measure in the United States, Europe, and Canada, there are only a few studies that have examined the direct health effects of their use. Most research on cooling centers focuses on an evaluation of implementation and use. While there is a lack of research that directly assesses cooling center use on health outcomes, there is strong evidence that extreme heat is detrimental to health and that staying in a cool environment can help maintain a safe core body temperature and reduce mortality. The research suggests that implementing more comprehensive heat plans that include cooling centers as a strategy has saved lives. Thus, the use of cooling centers should not be a stand-alone measure, but a part of a city's comprehensive heat plan (heat stress response planning). [Widerynski et al.,2017]

There is some evidence in the literature summarized in Widerynski et al. about what supported the implementation and use of cooling centers, such as accompanying communication strategies, public relations, and the involvement of a large group of different stakeholders and multifunctional facilities. The literature shows many different ways in which cities have informed the public about the location of cooling centers and specific heat events. These included issuing heat alerts with relevant information, including providing real-time information, locations on an easily accessible website, and reaching vulnerable populations with brochures and other informational materials. A cooling center that serves several different functions, such as a library or community center, can help attract a wider variety of visitors. [Widerynski et al.,2017]

Barriers or obstacles to accessing or using Cooling Centers include limited access to transportation, fear of leaving home or inability to leave home, not wanting to leave pets behind, populations that do not self-identify as vulnerable, and the general stigma that Cooling Centers are only relevant for "old people." Some individuals were unsure of what to do in a Cooling Center and expressed concern about sitting in a room all day with nothing to do. Many of these barriers can be overcome through awareness and proper planning. Educating the public about what cooling centers are and who is at risk can help increase occupancy and save lives. [Widerynski et al.,2017]

Therefore, awareness-raising measures are another important aspect of the project Creative Circle. The aim is to reach local people, including those groups that have so far been underrepresented in the energy transition and climate policy and to take them along on the path to sustainable energy use and a lifestyle adapted to climate change. In coordination with the municipality, goals and measures for climate change adaptation are also to be anchored in the urban development plan, which is currently being revised.

3 METHOD

The comprehensive research question of the project requires a methodological diversity that includes both, technological and participatory elements. With regard to the technological dimension, the focus is on the integration of renewable energies and the coupling of different energy sectors. This includes the local district heating network, the sewage treatment plant, the local renewable energy community as well as the Cooling Center. In the first step, concepts were drawn up for the individual measures, which will be combined in a further step to form the energy transition cycle.

3.1 Cooling Center

The first step was to carry out a requirements analysis of the Cooling Center and identify possible locations. The requirements were divided into exclusion criteria and so-called location criteria. All locations that fulfill the exclusion criteria were rated according to the location criteria in order to identify the optimal location. The criteria were defined as follows:

- Exclusion criteria:
  - Consumption free area not given.
  - Exclusion of population groups.
  - Barrier-free access not given.

Location Criteria	Description	Weighting
Accessibility	mobility hub, local public transport, within walking distance, intermodal, intervals	30 %
Location	central, presence in the urban space, user frequency, possible added value in the route chain	20 %
Ownership/economy	city-owned real estate, rental or purchase of real estate	20 %
Opening hours	seasonal, ensuring accessibility during predicted periods of heat, including on Saturdays, Sundays and public holidays	10 %
Fulfillment of requirements for awareness raising, knowledge transfer and participation	multifunctional, temporary, permanent - spatially and functionally separated possible or overlapping of functions/uses	5 %
Technical infrastructure	district heatingPV-System, drinking water, etc.	5 %
Structural and legal requirements	accessibility and safety of use, fire protection, statics/strength, thermal insulation, hygiene/health, building regulations, ...	5 %
Feasibility/time horizon	until when can the construction work be completed and the Cooling Center go into operation	5 %

Table 1: Location Criteria incl. weighting of the criteria

Based on this evaluation, two locations were identified, both of which are very suitable for the Cooling Center. One is the foyer of the town hall, and the other is a mobile solution that could be set up in a central but shady location (Domplatz or main square). Cooling concepts were developed for both solutions and presented to the municipality as the decision-maker. The location in the foyer of the town hall was ultimately preferred, although it is still a possibility that additional mobile solutions will be installed in the future if the Cooling Center in the foyer of the town hall is evaluated positively.

3.2 Wastewater heat utilization

A circular energy economy approach is realized by utilizing a heat pump, which will be installed at the wastewater treatment plant site. This heat pump uses the energy from the wastewater to supply heat to the district heating network. To close the energy circle, the heat pump is powered with energy from the local renewable energy community, in addition to the power procured from the grid.

At the moment a biomass heating plant with a total thermal output of 7 MW, supported by a gas boiler, covers the city's heating requirements. A photovoltaic system at the site of the sewage treatment plant and the local renewable energy community contribute to electricity generation. The technical design of the heat pump integration was evaluated according to different sizes of heat pumps (i.e., thermal powers of 0.6 MW, 1.4 MW, and about 2 MW) and variable temperatures (i.e.,) of the heat source (wastewater treatment plant) and heat sink (heat network). Data from the wastewater treatment plant, the heating plant and the district heating network from the last three years as well as forecasts for the future utilization of the heating network have served as the basis for the dimensioning.

Techno-economic analyses show that the biggest heat pump can cover a thermal load of up to 2 MW, which is sufficient to cover the entire summer load of district heating. As a next step, the research includes a detailed analysis of the investment costs for the different heat pump sizes and an evaluation of the associated business models. This will be crucial to determine the optimal size of heat pump to be installed and to calculate the heat production costs. An additional life cycle assessment will provide further evaluation criteria for the comparison between the use of a heat pump and the previous operating strategy.

3.3 Renewable Energy Community

To increase the share of renewable energy sources and to provide incentives to produce and use the energy locally, the EU renewable energy directive has further developed the process of emancipating the end consumers towards active participants in the energy system. Parts of that directive have been transposed to national law in the “Erneuerbaren-Ausbau-Gesetzespaket” in July 2021, which enables the establishment of so-called renewable energy communities in Austria. A renewable energy community is a community of producers, consumers and ‘prosumers’ amongst which renewable energy can be exchanged. In case of renewable electricity, the public distribution grid can be used. To create additional incentives the energy exchanged in the community is subject to reduced grid fees, taxes and levies.

As shown in Figure 1, the energy community can be seen as the central element of the energy transition cycle, as it supplies all three sub-areas (electricity cycle, heating cycle, Cooling Center):

- Local renewable electricity production is brought together by the energy community and distributed back to local consumers.
- The heat pump for wastewater heat utilization will be supplied with energy from the energy community.
- The chiller in the Cooling Center is supplied by the energy community (in addition to the municipality's own PV-consumption).

At the start of the project “Creative Circle”, plans were already in place in Eisenstadt for the establishment of a renewable energy community ("Energiegenossenschaft Eisenstadt"). After consultation with those responsible, the Raiffeisen Nachhaltigkeitsinitiative Burgenland and the municipality of Eisenstadt, it was decided to cooperate and to integrate the aspects of the energy transition cycle described above into this energy community. This cooperation also ensures that this form of organization will continue to exist beyond the duration of the project, thus guaranteeing, that a central element of the energy transition cycle has been structurally integrated and secured for the long term.

3.4 Participation

The involvement of the local population, especially those groups that have so far been underrepresented in the energy transition, is an important aspect in establishing the energy transition cycle. The opportunities for participation and the measures taken and planned in this regard are shown in Table 2.

Electricity cycle	Heat cycle	Cooling Center
Participation as a member of the renewable energy community Participation as a consumer, producer and prosumer Participation through voting rights at the general meeting	Participation as a district heating consumer Automatic participation through the use of waste heat from wastewater	Active participation through the use of the Cooling Center Participation and opportunities for co-design through co-creative (further) development Survey and evaluation of design requirements for the Cooling Center Opportunity for feedback directly in the Cooling Center

Table 2: Participation and opportunities for involvement in the energy transition cycle

4 INTERIM RESULTS

The research project is still ongoing but some interesting interim results have already been achieved with regard to the planning and simulation analysis of the individual aspects of the energy transition cycle.

4.1 Urban development

At the level of urban development and spatial energy planning, the approaches to action are multi-layered and complex. In addition to concrete spatial and technical measures, awareness-raising and integration into strategic planning instruments such as the urban development plan play a crucial role.

The aim of the project is therefore also to reach local people – including those demographic groups that have been underrepresented in energy transition and climate policy so far – and to involve them in the transition towards sustainable energy use.

At the urban development level, the municipality of Eisenstadt is developing an urban development plan in collaboration with external teams of experts. In doing so, the provincial capital is fulfilling an obligation under the Burgenland Spatial Planning Act 2019, which requires all Burgenland municipalities to draw up such a concept by 2026.

The collaboration and integration of the findings and results from the research project therefore represent an unique opportunity to anchor these in a formal, strategic instrument at municipal level and to incorporate topics such as spatial energy planning, climate-friendly mobility and the application of energy transition cycles.

An exchange with representatives of the municipality of Eisenstadt and the utilization of synergies in the further development process have already taken place and are planned to continue. Synergies between the research project and the requirements of the municipality to fulfill the obligations according to the Burgenland Spatial Planning Act 2019 can be utilized.

As one of the previous evaluation of the existing urban development plan of Eisenstadt, it was noted that further planning and concepts are necessary in the area of spatial energy planning as well as in the area of climate-friendly mobility and infrastructural measures. Important goals and approaches for action include (cf. Municipality of Eisenstadt, 2022):

- Further implementation of PV systems on public buildings
- Organising events on the topics of energy-efficient construction/renovation and renewable energy
- Establishment of a community for renewable energy
- Phasing out fossil fuels, especially gas heating, and promotion of alternatives: District heating, geothermal energy, heat pumps, PV systems etc.
- Building renovation strategy to reduce energy requirements
- Expansion and improvement of public transport services / reduction of inner-city private transport
- Expansion of cycling infrastructure
- Sustainable construction
- Unsealing and soil protection
- Greening with climate-adapted trees and shrubs
- Creation of a sustainability and climate protection plan for the city
- Information campaign (events, informational materials, actions) including the creation of a digital information platform
- etc.

4.2 Cooling Center

As first part of the energy transition cycle, this Cooling Center located in the town house of Eisenstadt was completed in summer 2023. The foyer in the town hall was redesigned for the Cooling Center to make the stay as pleasant as possible and to create a social meeting place.

The original concept of the energy transition cycle envisaged cooling the Cooling Center with an absorption chiller using the local district heating network as a source. However, as the town house is not (yet) connected to the district heating network, it was necessary to redesign the operation of the Cooling Center and install a classic compression chiller. But even in this concept, environmentally friendly operation was ensured, and local energy resources were used - the town house, as a municipal building, has its own PV system and is also part of the energy community, i.e. if it is not possible to cover its own needs with its own PV system, the demand is covered by the energy community. The fact that the Cooling Center is operated in the summer months (when most of the solar radiation occurs) means that it is possible to achieve a high degree of solar coverage.

The technical concept was developed by the project, the implementation was commissioned by the municipality of Eisenstadt. In order to keep the cool air on the floor in the open space, an innovative type of air distribution was used. The air is guided across the room by means of textile ducts, which are very finely perforated, allowing the air to flow out evenly at a slow velocity. These enable pleasant cooling, while simultaneously reducing operating costs. Moreover, the Cooling Center should also become a social meeting place, where the energy transition in Eisenstadt is being driven forward together with the inhabitants.

Figure 2: Left: Opening Ceremony of the Cooling Center, right: Distribution of the cool air via textile ducts (© Sandra Koeune)

4.3 Wastewater heat utilization

The planning of the wastewater heat utilization at the sewage treatment plant was carried out in parallel. It was decided that the heat pump should be able to take over the operation of the district heating network during the summer months. Therefore, a thermal capacity of about 2 MW is needed. Moreover, the heat pump had to be designed for the flow temperature of the heating plant (currently approximately 85 °C). The current layout with such a heat pump, yields a yearly average coefficient of performance of 3.30. Subsequently, the biomass boiler could be deactivated in the summer months (i.e., June to September) and the district heating network could be fully supplied by the heat pump, as shown in figure 3. Additionally, the heat pump is able to substitute the use of the gas boiler, which is a further step towards a fully decarbonized and renewable coupled energy system. A parallel operation of the heat pump and the biomass boiler was not possible in this particular case as the biomass boiler is already operating in the lowest range of partial load operation during the summer months.

The detailed planning and the economic evaluation of the wastewater heat utilization are still ongoing. Initial estimates have shown that the current tariff situation (electricity vs. biomass and heat) makes the economic evaluation of the investment project a challenge. In addition, it is still difficult to estimate how tariffs will develop over the next few years. On the other hand, there are good funding opportunities for the required investment costs and the integration of the heat pump into the energy transition cycle also has a positive effect on economic efficiency.

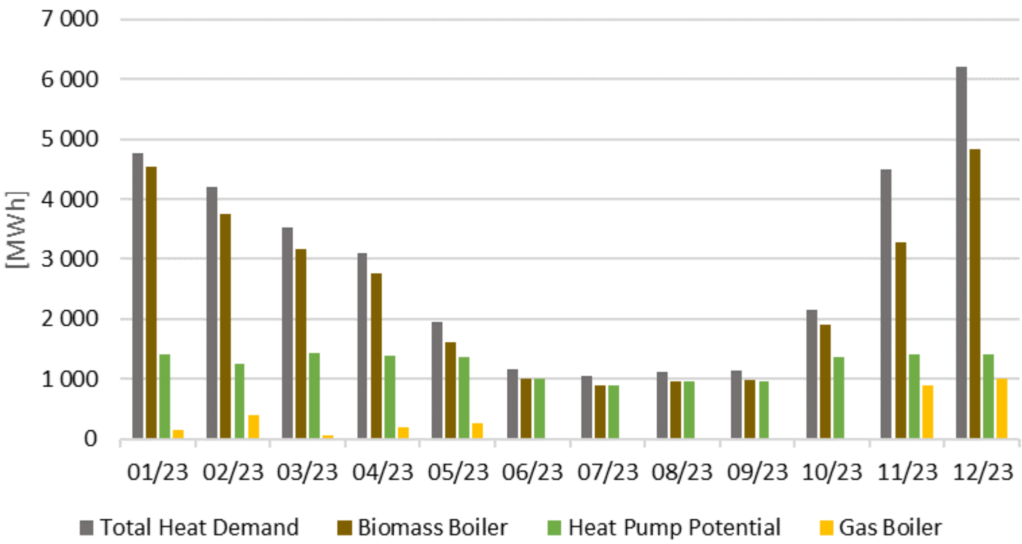

Figure 3: Comparison of the heat demand with heat production and the potential of a heat pump with a thermal capacity of 2 MW based on data from the year 2023.

4.4 Renewable Energy Community

The renewable energy community in Eisenstadt was put into operation in 2022. It is a regional energy community that enables all residents and SMEs in the city area to participate, regardless of whether they have a generation plant (mostly photovoltaic systems) or not. The energy community was started with a small number of participants but is expected to grow strongly over the upcoming months and years. The electricity available within the energy community is distributed fairly among the participants according to a fixed distribution formula. Lower tariffs are charged for electricity purchased via the energy community than for electricity purchased from the public electricity grid. The same applies to producers or prosumers, who can feed their (surplus) electricity into the energy community at favorable conditions. The specific tariffs are adjusted on an ongoing basis, depending on the general development of the electricity market.

Once the heat pump has been installed and put in operation, it is planned that the heat pump will participate in the energy community as an additional consumer so that the power supply can be partly covered by local renewable electricity from the energy community. The proportion of this depends mainly on how the energy community develops in the meantime. As the heat pump is a significant consumer, the additional integration of large generation plants into the energy community would favorable.

5 CONCLUSION AND OUTLOOK

The results of the “Creative Circle2 project so far are very promising. The integration of a heat pump in the sewage treatment plant shows considerable potential for reducing biomass and gas consumption and increasing the efficiency of the district heating network. The local energy community enables increased use of locally generated electricity and helps to reduce dependence on external energy sources.

The Cooling Center in Eisenstadt's town hall, which was already opened in summer 2023, is another milestone in the project. It not only offers a cool retreat on hot days, but also promotes social interaction and exchange between residents. The successful implementation of the Cooling Center shows that the population is actively involved in the energy transition process and is responding positively to the changes.

However, the implementation of the project is not without its challenges. The technical design of the heat pump integration requires careful planning and coordination with the existing systems. Choosing the right size of heat pump, taking the biomass system into account and increasing efficiency are complex tasks that need to be tackled carefully.

In addition, it was shown that social acceptance and participation are of crucial importance. Comprehensive awareness-raising is necessary in order to involve all sections of the population, especially those who have been underrepresented in the energy transition and climate policy to date. The Cooling Center is an important tool here, not only to provide protection from the heat, but also to act as a social meeting place.

The “Creative Circle” project in Eisenstadt therefore shows a promising way how urban energy systems can be sustainably transformed. The integration of renewable energies, the coupling of different energy sectors and the active participation of the population are key components for a successful energy transition. The preliminary results are promising, but there is still work to be done.

The research will continue in order to refine the technical implementation, strengthen social acceptance and ensure the economic viability of the project. The progress made is not only important for Eisenstadt, but can also serve as a model for other urban areas facing similar challenges in the context of the energy transition.

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