NATIONAL PROOF-OF-CONCEPT DESCRIPTION – GERMAN CELL

FINAL VERSION

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TABLE OF CONTENT

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LIST OF FIGURES

Figure 1: Aerial view of the Shamrockpark with the former headquarter building of the Ruhrkohle AG (Source: own representation) ... 10
Figure 2: Map of the development plan of the Shamrockpark area (Source: own representation) ... 11
Figure 3: 3D model of the Shamrockpark development plan (Source: own representation) ... 11
Figure 4: Sketch of the heating network structure of the Shamrockpark (Source: own representation) ... 13
Figure 5: Schematic representation of the energy system modelling tool KomMod (Source: own representation) ... 16
Figure 6: Energy flow direction factors for scenario a) ... 18
Figure 7: Energy flow direction factors for scenario b) ... 18
Figure 8: Energy flow direction factors for scenario c) ... 18

ABBREVIATIONS

aFRR	Automatic Frequency Restoration Reserve
FCR	Frequency Containment Reserve
API	Application Programming Interface
CHP	Combined Heat and Power Plant
CO_2	Carbon dioxid
COP	Coefficient of Performance
FCR	Frequency Containment Reserve
HW	Thermal heat (ger. Heizwärme)
ICT	Information- and Communications technology
CC	Compression Chiller
LEC	Local Energy Community
LowEx Wärmenetz	"Low Exergy" heating network characterized by low operating temperatures
mFFR	Manual Frequency Restoration Reserve
NRW	Northrhine-Westfalia
PV	Photovoltaics
RAG	Ruhrkohle AG
SRE	Shamrock Energie GmbH
Th	Thermal
TNK	Temperature level coupling (ger.Temperaturniveau-Kopplung)
DHW	Domestic hot water
ÜNB	Transmission system operator (ger. Übertragungsnetzbetreiber)
VLT	Supply temperature (ger. Vorlauftemperatur)
VNB	Distribution system operator (ger. Verteilnetzbetreiber)
HP (WP)	Heatpump (ger. Wärmepumpe)
WUeT	Heat exchanger (ger. Wärmeübertrager)

1 EXECUTIVE SUMMARY

This report describes the procedure as well as the results from the German Cell of the CLUE project, where solutions for Local Energy Communities (LECs) at the demo site Shamrockpark have been investigated. In the German cell, FAKT AG was commissioned with the building planning and implementation, E.ON AG with the planning of the ectogrid and the research institute Fraunhofer ISE with the optimisation of the overall energy system and the investigation of flexibility calculations.

In the CLUE-Shamrockpark project, the planning, implementation and operation of a LowEx low-temperature grid, a so-called ectogrid, on the former Shamrockpark coal mine site in Herne is being demonstrated. The energy system is characterised by a low-temperature local heating network that integrates the use of low-temperature waste heat sources. In addition to the ectogrid with a warm conductor (22°C) and a cold conductor (12°C), the energy system also includes a high-temperature heat network with a flow/return temperature of 90°C/50°C. The ectogrid forms the core of the energy system and serves simultaneously as an energy source to cover the heating demand and as an energy sink to cover the cooling demand of the connected buildings and server rooms. Heating and cooling requirements are very well balanced in the Shamrockpark at transitional times. While cooling demands predominate in summer and the heating demands are larger in winter. Due to the possibility of balancing the demands, the ectogrid offers great potential for energy savings. Due to the low temperature of the ectogrid, additional waste heat from nearby industrial plants can be used.

In order to conduct more detailed theoretical investigations of the energy system, Shamrockpark was modelled with the KomMod energy system optimisation model. For this purpose, the modelling tool was extended to be able to map bidirectional energy flow between heat grids at different temperature levels. In the model it could be shown that, by using the synergies of the ectogrid and the possibility to feed in waste heat at a low temperature level, 56% of the heating demand can be covered by the local waste heat sources and the electricity demand for cooling can be reduced by around 46% in comparison to conventional cooling with compression chillers. However, these numbers are only result of an optimization modelling and have to be proven in real operation.

The planning process of the Shamrockpark area has been greatly influenced by regular changes regarding the purpose of buildings and their energy requirements. These difficulties in the planning process have been analysed and recommendations for the planning of LowEx energy systems are elaborated. In general, when designing a LowEx energy system, it is important to identify the potential energy sources on site and in parallel to analyse the possible energy demand in detail. All available energy sources should be included, such as low-temperature sources like waste heat, waste water, geothermal energy and the possibility of using photovoltaic systems. When determining the demand profiles, existing building structures and user behaviour are closely considered.

Considering the advanced operation of a LowEx network, possible business models for providing external flexibilities through the Shamrockpark energy system have been evaluated. On the one hand, the possibility of providing balancing power and, on the other hand, peak load reduction was examined. While the results show there is little potential for peak load reduction in the Shamrockpark under given assumptions, the use of the flexibilities of the ectogrid for the provision of balancing power is promising and should be investigated in more detail. A guideline for developing business models for LECs in sector coupled energy systems has been developed aiming at facilitating the implementation of similar projects throughout Europe.

Finally, social acceptance is another crucial factor for successful implementation of a new energy system. From stakeholder analysis and a survey on the Shamrockpark tenants' perception on new energy systems such as ectogrid one can conclude that the implementation on site was societally accepted during the time of research.

2 DEMONSTRATION SITE SHAMROCKPARK

2.1 Development of the Neighbourhood

Herne is a large city with about 160,000 inhabitants and is located in the Ruhr area in North Rhine-Westphalia (NRW) in the west of Germany. In the past, Herne was strongly influenced by hard coal mining. Among other things, the Shamrock coal mine was well known.

Figure 1: Aerial view of the Shamrockpark with the former headquarter building of the Ruhrkohle AG (Source: own representation)

Shamrockpark is centrally located in Herne. It was the site of the former administrative headquarters of Ruhrkohle AG (RAG) (see Figure 1). In 1970, RAG comprised around 80% of the German hard coal industry and employed around

170,000 people. In 2018, hard coal mining in Germany ended and RAG left the site. The location gives the district a significant charisma for the industrial location of the Ruhr Area, which is characterized by coal.

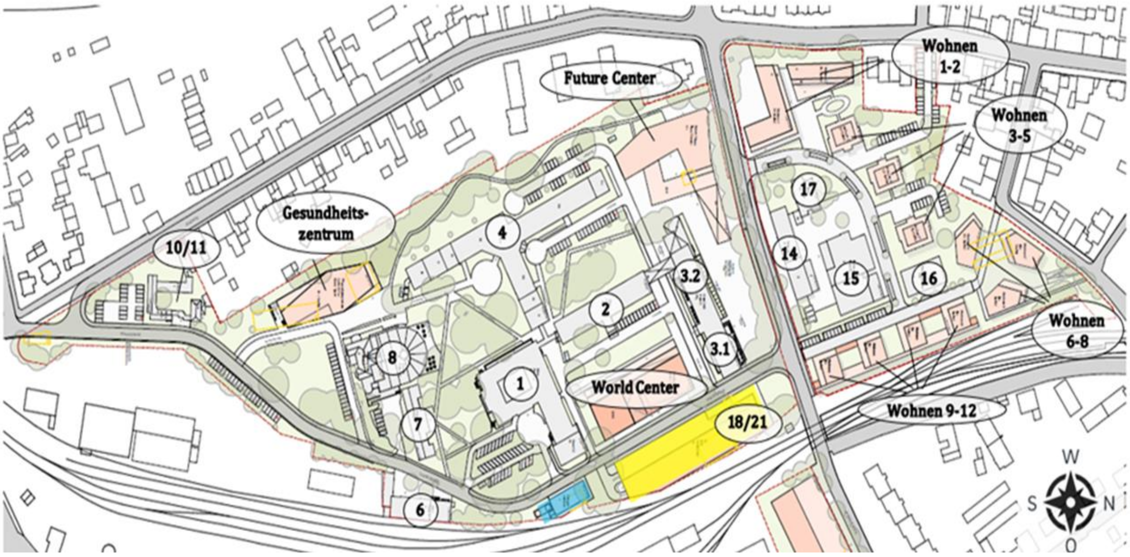

Figure 2: Map of the development plan of the Shamrockpark area (Source: own representation)

Now the neighbourhood is to be revitalised. The district development comprises a gross floor area of about 100,000 m² with about 50% existing buildings being refurbished and 50% new buildings. Office buildings, hotels, a data centre, a retirement home and residential buildings will be built as shown in Figure 2 and Figure 3. The numbers and notations in the graphic are later used for further descriptions. Due to a compact construction style, green spaces and the old tree population are to be preserved as far as possible.

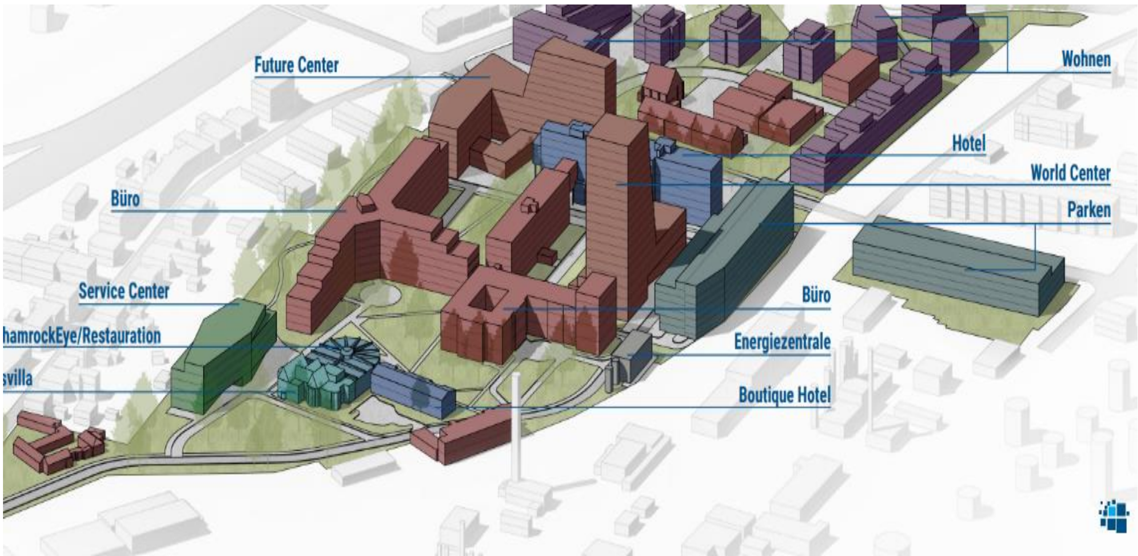

Figure 3: 3D model of the Shamrockpark development plan (Source: own representation)

2.2 Energy system of the Shamrockpark

To supply the neighbourhood with heating and cooling, the energy supplier E.ON and Stadtwerke Herne have founded a joint subsidiary. This joint venture company is pushing ahead with the construction of a so-called LowEx district heating network based on ectogrid technology.

The ectogrid concept was developed by E.ON and consists of a 5th generation cold district heating network. The basic idea is to distribute quantities of heat at a low temperature of e.g. 22°C to consumers, who use it to generate the necessary temperatures decentrally in the buildings with heat pumps. This has the advantage that low-temperature heat sources can be used. In the Shamrockpark, for example, waste heat from a neighbouring chemical park at around 25°C is used. And waste heat can also be fed into the cold district heating network on a decentralised basis, e.g. from refrigeration machines for air-conditioning buildings or also from data centres or other functional buildings. Another advantage is that the pipelines do not need to be insulated due to the low temperature and can also partially absorb heat from the ground.

The Shamrockpark has an annual heat demand of about 9 GWh. In terms of heat supply, a distinction must be made between the existing buildings, which require a flow temperature of approx. 55°C for heating with radiators, and the new buildings, which require a flow temperature of only 35°C with surface heating. The heat supply is provided decentrally by around 30 heat pumps in the individual buildings, which draw heat from the ectogrid for this purpose. Heat storage tanks in the heating centre and in the buildings enable the thermal system to provide heat via the heat pumps. The scheme of the district heating system is shown in Figure 4.

Charging stations for electric vehicles are planned on a large scale in the Shamrockpark, which can also be operated in a controlled or bidirectional manner. Thus, these can also provide flexibilities.

Due to the delays in implementation, the energy system was only planned and initial work on implementation was carried out during the CLUE project period. For example, the pipeline to transport the waste heat from the neighbouring energy park to the planned energy centre was laid. Due to the insolvency of the project developer, FAKT AG, the work was temporarily suspended in autumn 2022.

The aim of the ectogrid is to supply the connected consumers with highly efficient and emission-free heat. To this end, all surplus heat sources are to be used. Energy is only supplied to the system when the energy available in the system has been consumed. [1]

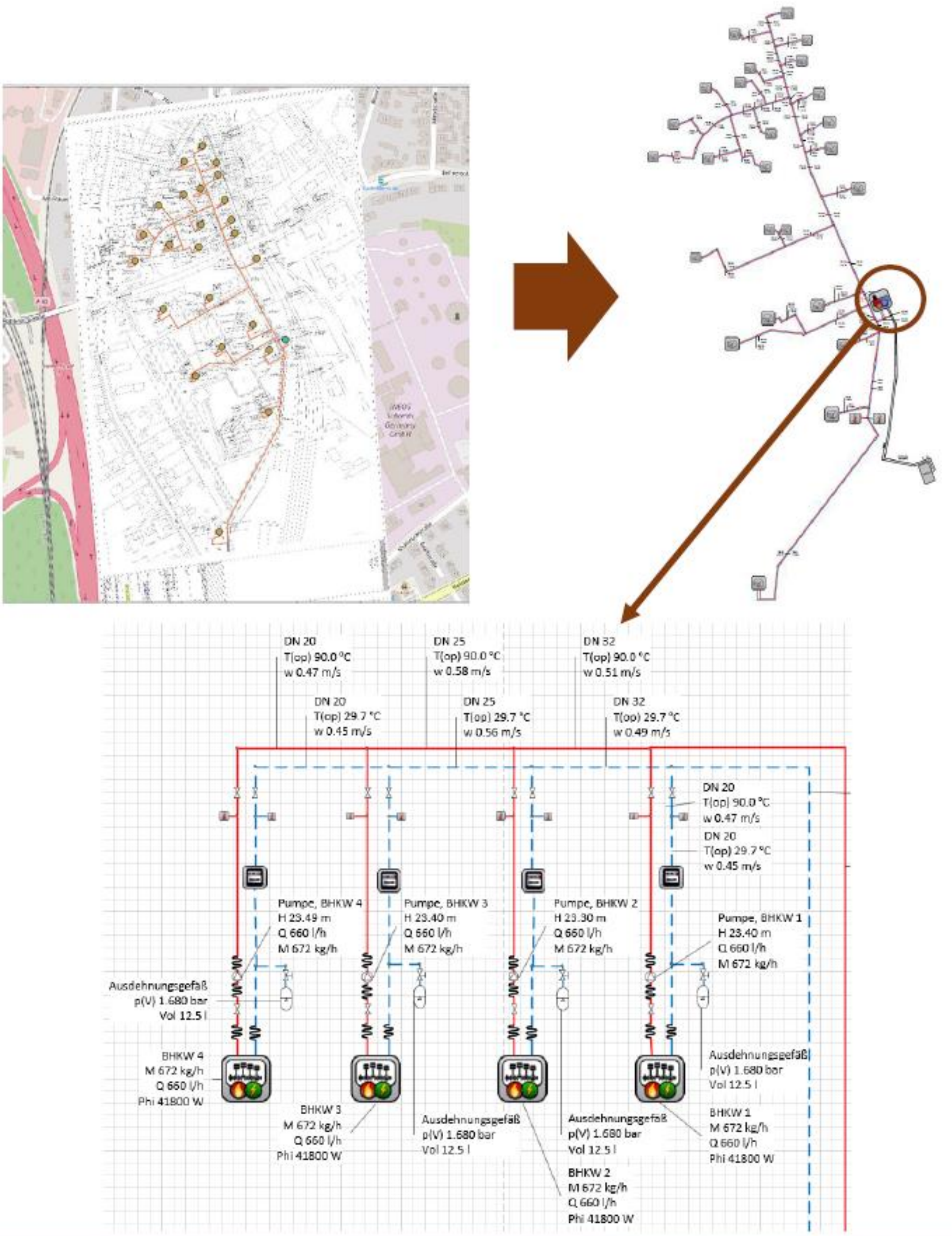

Figure 4: Sketch of the heating network structure of the Shamrockpark (Source: own representation)

3 OBJECTIVES OF THE GERMAN CLUE CELL

3.1 Optimization of the cold district heating system

Shamrockpark is one of the first projects to demonstrate the ectogrid concept in Germany. Cold district heating networks of the 5th generation have been investigated in various ways, but their use has been limited so far [2]. Therefore, the CLUE project investigated how the cold district heating grid can be optimally configured. In particular, the question arises at which point in the district heating network thermal storage units with which capacities can be integrated most sensibly. Furthermore, the question arises as to whether the heat flow between the prosumers poses challenges for the operation when this possibly changes direction.

In order to calculate the optimal configuration of the ectogrid for the Shamrockpark, the modelling tools were further developed within the framework of CLUE and extensive simulation and optimisation calculations were carried out. The aim was to calculate the optimal thermal storage capacities and other capacities of the system components.

3.2 Identification of external flexibilities provided by the district

To achieve climate neutrality globally and nationally, cities and their neighbourhoods are striving for a climate-neutral energy supply. This is based on a high efficiency of the neighbourhoods and the highest possible share of locally generated renewable energy. Since urban neighbourhoods are usually not able to supply themselves with renewable energy due to the usually high energy demand density, they are dependent on additional energy imports from the surrounding neighbourhoods and especially from the rural areas around the city, where e.g. wind energy or biomass are available as complementary renewable energy sources.

An important indicator for the energy system of a neighbourhood is thus the load profile for the imported residual energy quantities of the neighbourhood. If this is very pronounced (e.g. if there are high surpluses from solar energy in summer and a high energy demand for heating and the electricity supply in winter), then the neighbourhood may place a burden on the upstream energy system.

However, neighbourhoods can not only be a load, but can also help support the upstream power system if they are designed and operated appropriately. This is the case if they can provide flexibilities, for example in the form of balancing energy.

In pure electricity systems, this can be done by providing electricity storage or demand side management. In sector-coupled electricity-heat systems, flexibilities can also be provided in the form of thermal storage. The flexibility is provided by heat pumps drawing electricity to heat storage units and thus increasing the grid load. Or the load of the heatpumps is reduced and the heat demand is covered from heat storage units, reducing grid load.

The extent to which a neighbourhood with an ectogrid can provide external flexibilities for surrounding neighbourhoods or the upstream electricity system was investigated through optimisation calculations using the example of Shamrockpark.

3.3 Renewable energy communities in sector coupled energy systems

The activities of renewable energy communities are usually limited to the electricity sector, as trading and exchange of electrical energy between community members is in principle easy, as all prosumers are interconnected via the general supply electricity grid and in principle it is possible to feed in electricity quantities at all points in the electricity grid. In the heating sector, on the other hand, district heating networks connecting prosumers often do not exist. If a district heating network exists, the transport of heat in the pipes is tied to the physical transport of the heat transfer medium (e.g. hot water), which is why the heat can usually only be transported in one direction. The decentralised feeding of heat into district heating networks is also made more difficult by the different temperature levels of the heat quantities; for example, waste heat e.g. from washing processes or cooling machines usually has a lower temperature than is found in the heat distribution network and can therefore not be absorbed by it.

The ectogrid is a new approach and has the potential for interesting business models for renewable energy communities, because on the one hand the low temperature level of the district heating network makes it possible to feed in heat quantities at all points in the heating network, and on the other hand the decentralised heat pumps enable a business model for the renewable energy communities that captures the coupled heat and power exchange between the community members, making it potentially economically attractive.

The German CLUE project therefore investigated the extent to which the business model of renewable energy communities can be applied to coupled power-heat systems.

4 MODELLING TOOL DEVELOPMENT

4.1 Goal of the tool development

The energy system optimization modelling tool KomMod was used for the calculations on the energy system of the Shamrockpark. It was further developed and adapted for the project. In the following, the modelling tool will be shortly described and the required extension will be explained**.**

KomMod is a linear energy system optimization modelling tool. It identifies the minimum-cost combination of supply technologies for an energy system given specific goals and defined constraints. It maps the dynamics of the system by optimizing the entire energy system (electricity, heat and electricity for e-mobility) in hourly temporal resolution over the course of the year. This enables the detailed representation of fluctuating energy sources and the analysis and consideration of the feasibility of the individual technologies. As input data, KomMod requires demand profiles for electricity, heating and cooling in hourly resolution for one year. In addition, economic and technological parameters are required for all technologies considered, as well as detailed information on the potential of the available energy sources. This information is supplemented by data on the climate.

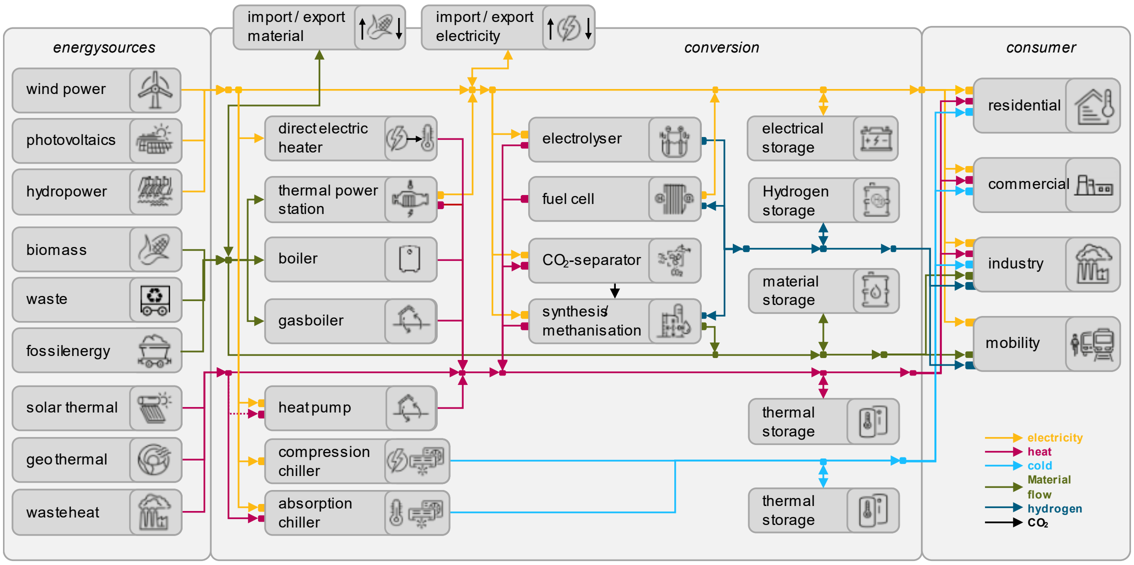

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Figure 5: Schematic representation of the energy system modelling tool KomMod (Source: own representation)

For the modelling of the Shamrockpark, it is necessary to map the bidirectional energy flows of the ectogrid. So far, in KomMod it was only possible to map unidirectional energy flows in heating networks, therefore the tool was further developed within the CLUE project.

4.2 Development of the Modelling Tool KomMod

For a correct model of the Shamrockpark district according to specified hydraulic plans, KomMod has to be extended by some new components and work steps.

The basic principle of the Shamrockpark is the coupling of the ectogrid with the heating and cooling networks of the individual buildings, which are defined as separate temperature levels in KomMod. This coupling has to be bidirectional. For the heat extraction from the ectogrid and the feed into a building network on a higher temperature level, the network heat pump (NetzWP) component is created. For an energy flow from a higher temperature level into the ectogrid, the heat exchanger (WUeT) is implemented.

In KomMod, energy balances are calculated for the ectogrid as well as for all other temperature levels. In the modeling of the Shamrockpark, the ectogrid is considered simultaneously as a heat source and also as a heat sink, whose temperature and thus energy level is to be kept constant. When covering heat demands, energy is extracted from the ectogrid as a source and there is a negative energy input into the balance. When cooling requirements are met, energy is added to the ectogrid as a sink, resulting in a positive energy input into the balance. This coupling is achieved with the newly developed components.

4.2.1 Extended heat pump model (NetzWP)

The new heat pump component is based on the conventional heat pump component that was already existent in KomMod. The previous heat pumps were used only for extracting thermal energy from the environment (e.g., air), for which no source-side balancing was required. In the Shamrockpark modeling, the ectogrid is used as a heat source whose temperature/ and consequently energy level is to be kept constant. The energy extracted from the ectogrid is therefore included in an additional function for each time step and balanced in the individual temperature levels.

The heatpump couples the ectogrid to a higher temperature level. The coupling, or raising to the temperature level, is done using electrical drive power for compression in the heatpump. were used only for extracting thermal energy from the environment (e.g., air), for which no source-side balancing was necessary.

4.2.2 Heat exchanger model (WUet/TNK)

The heat exchanger (WUeT) or temperature level coupling (TNK) is used when it is not necessary to raise the temperature level by adding electrical energy. Three scenarios can be identified for this at Shamrockpark:

a) Transfer of energy from a higher temperature level to the ectogrid.

b) Coupling of a cold generator at a lower temperature level with the ectogrid.

c) Covering a cooling demand from the ectogrid.

The energy flows of a temperature level are designed in KomMod according to the passive sign convention. Incoming energy is positive, outgoing energy is negative. Furthermore, in KomMod so far heat demands and cooling demands are both represented as positive energy flows. Thus, also the negative heat flow providing for a cooling demand is a positive energy flow in KomMod. So far, this hasn’t been an issue, since heating and cooling demands were not coupled. In Shamrockpark, however, cooling and heating networks are coupled via the ectogrid. For the balancing of the ectogrid and the other temperature levels, a consistent sign convention of the energy flows is essential. The new WUeT module is therefore defined with two factors that correctly represent the sign of the incoming and outgoing energy flow in the balance. In the following figures, the source (cold or heat) is defined on the left of the TNK and the ectogrid is defined as the heat sink on the right.

In case a), the energy flow is from a network of higher temperature into the ectogrid, as shown in Figure 6. The factors are positive on both sides, since the balancing is already correctly implemented via the definition of the passive sign convention. In the energy balances, energy is extracted from the source and transferred to the ectogrid. This case of coupling can represent, for example, the transfer of energy from the district heating network to the ectogrid.

Figure 6: Energy flow direction factors for scenario a)

In case b) shown in Figure 7, the energy is provided at a lower temperature level from a compression chiller (CC). In KomMod, this is considered as a positive energy flow from the source point of view. The direction of the arrow refers to the direction of the cold flow and thus away from the CC. Due to the temperature level coupling, the ectogrid is cooled by the negative heat input. Accordingly, energy is extracted from the ectogrid during the transfer of heat and the factor must be included in the balancing of the ectogrid with a negative sign.

Figure 7: Energy flow direction factors for scenario b)

Case c) describes the coverage of a cooling demand from the ectogrid by passive cooling (Figure 8). In this case, the circuit medium is returned to the heat exchanger at an increased temperature. Cooling demand thus causes a heat flow to TNK. For a correct balancing of the source side, the factor for the flow direction must therefore be negative, so that the cooling demand is covered. From the point of view of the ectogrid, passive cooling causes a heat input and is balanced positively.

Figure 8: Energy flow direction factors for scenario c)

In addition to defining the flow direction, the factors can also be interpreted to describe losses at the heat exchangers. In the heat exchanger, the factors can always be between 0.5 and 1.0, or between -1.0 and -0.5. Consequently, the total minimum transfer efficiency of 25%, that can be implemented so far, results when the factors for source-side and perpendicular-side flow direction are set to 0.5. With a suitable choice of factors, an efficiency range of 25-100% can be defined.

5 RESULT 1: OPTIMIZATION OF THE COLD DISTRICT HEATING SYSTEM

At the beginning of the CLUE project, different design variants for the ectogrid heat supply system of the Shamrockpark were examined in detail by E.ON as part of a precursor project. The concept developed in the course of this project was the basis for the planning and implementation of the energy system, insofar as it has been carried out up to the present time.

As part of the CLUE project, the first step was to model the planned Shamrockpark energy system using the advanced modelling tool KomMod as the basic variant. In a second step, variant calculations were then carried out with KomMod to calculate the external flexibilities (e.g. balancing energy) that the Shamrockpark neighbourhood can provide for the surrounding neighbourhoods. The boundary conditions such as the maximum load of the neighbourhood were varied and, for example, the necessary thermal storage capacities required for this were calculated.

The modelling results are shown below.

5.1 Determining the data basis for modelling made difficult by dynamic planning processes

Since the development plan for Shamrockpark was adopted late and the plans for the buildings were repeatedly adjusted, the expected energy requirements have also changed regularly. The bases for the calculations were always adapted to the current planning. The calculations presented here are based on the most current planning status in the second half of 2022.

For example, the production of solar electricity was not taken into account, as the installation of a photovoltaic system is no longer included in the current plan. The sustainable mobility concept with an area-wide charging infrastructure for electromobility was restricted, as an originally planned multi-storey car park is no longer realised in the current planning.

The simulation models for determining the dynamic time series for the heating and cooling requirements of the buildings were adapted to the respective planning status. The addition of the data centre results in an additional large cooling demand, which significantly changes the demand structure of the neighbourhood. Findings on the cooling capacity of the surface heating systems used in the residential buildings of Shamrockpark were provided. According to empirical values from practice, the maximum cooling capacity of an underfloor heating system is approx. 50% of the maximum heating capacity.

To take into account the extraction of waste heat from the neighbouring Ineos chemical plant, historical data on the temperature of the waste heat was used for the simulation. The simulation results were evaluated in particular with regard to the heat losses and the temperatures occurring in the energy centre. It was shown that the combination of an insulated outer duct and an uninsulated earth duct leads to low heat losses and temperature drops, so that the function of waste heat integration is still given.

The design of the buildings supplied via the low-temperature network was constantly adjusted. For example, the southernmost building, House 10, will not be connected to the low-temperature network after all. In return, two other buildings, House 6 and the health centre, will be supplied via the low-temperature network in the future. The planning of the cooling supply for the Shamrockpark was adjusted to provide for redundancy of the cooling supply for the data centres. For this purpose, 1.1 MW of the compression cooling capacity originally planned in the energy centre will be relocated decentrally to the common transfer station of the two data centres, Building 15 and Building 16, together with a free cooler.

The adjustments described above have led to various iteration steps and scenario calculations for the Shamrockpark to date, which could not yet be completed at the time of reporting due to the stagnating planning activities of the project developer. The illustrations clearly show the complex planning process. Final results cannot yet be presented at the conclusion of the CLUE project. The energy system is still only available as a draft, which has been adapted to the current planning status of the district.

5.2 Energy system model of the Shamrockpark

5.2.1 Derivation of the energy system model

The modelling of the energy system in Shamrockpark is a complex challenge due to the large number of individual buildings, the resulting different temperature levels, the large number of components and the use of the ectogrid heating network. The simplifications and aggregations made for this purpose are presented below:

(a) Aggregation of the ectogrid's cold and hot conductors.

The ectogrid assumes the role of the central neighbourhood network, with the difference that both hot and cold conductors are to be used to cover heating and cooling demand. To simplify the modelling, the hot and cold conductors are represented as one node. This is a valid simplication, given that KomMod calculates based on energy balances. The ectogrid is thus assumed to be a grey box, which has a common energy level. When heat is needed to cover the heating or DHW demand, energy is extracted from the ectogrid. When cooling the server rooms, i.e. meeting cooling demand, energy is added to the ectogrid. The temperature levels within the grey box do not play a role in the energy flow-based modelling using KomMod. For the calculation of the coefficients of performance (COP) of the heat pumps, the temperatures of 22°C for the hot conductor and 12°C for the cold conductor are assumed to be constant over the year and are fixed as the source temperature for the individual heat pumps.

The two thermal storage tanks in the energy centre are also combined since the storage tanks are coupled together and can therefore be modelled as one large, central stratified storage tank.

The decision not to consider thermodynamic or hydraulic processes leads to a strong reduction in terms of programming and calculation effort. For the detailed hydraulic planning, the project partner RWTH Aachen University has already carried out corresponding simulations in advance.

b) Aggregation of the building schemes into equal temperature levels

There are several different temperature levels, most of which are coupled with each other. The buildings' heat demands are aggregated for each different temperature level. In this way, the original 27 buildings of the neighbourhood could be reduced to 8 temperature levels relevant for the ectogrid. The heating and cooling requirements of each building are thus summarised in the respective temperature level.

c) Adapt, revise and create new KomMod components.

Due to the large number of different temperature levels within the neighbourhood and their coupling with each other, the new components described in chapter 3.3 must be incorporated into KomMod for correct modelling. The grid heat pump explicitly draws energy only from the ectogrid and has no direct connection to external heat sources from the environment. They are therefore fed with a fixed temperature level of 22°C. The heat exchangers serve as a coupling unit between different temperature levels. They are necessary to enable the energy flows between the temperature levels. All components are described by means of linear systems of equations so that they can be implemented in the linear optimisation using KomMod.

The listed simplifications are summarised in Figure 9. The KomMod model Shamrockpark was built on the basis of this representation.

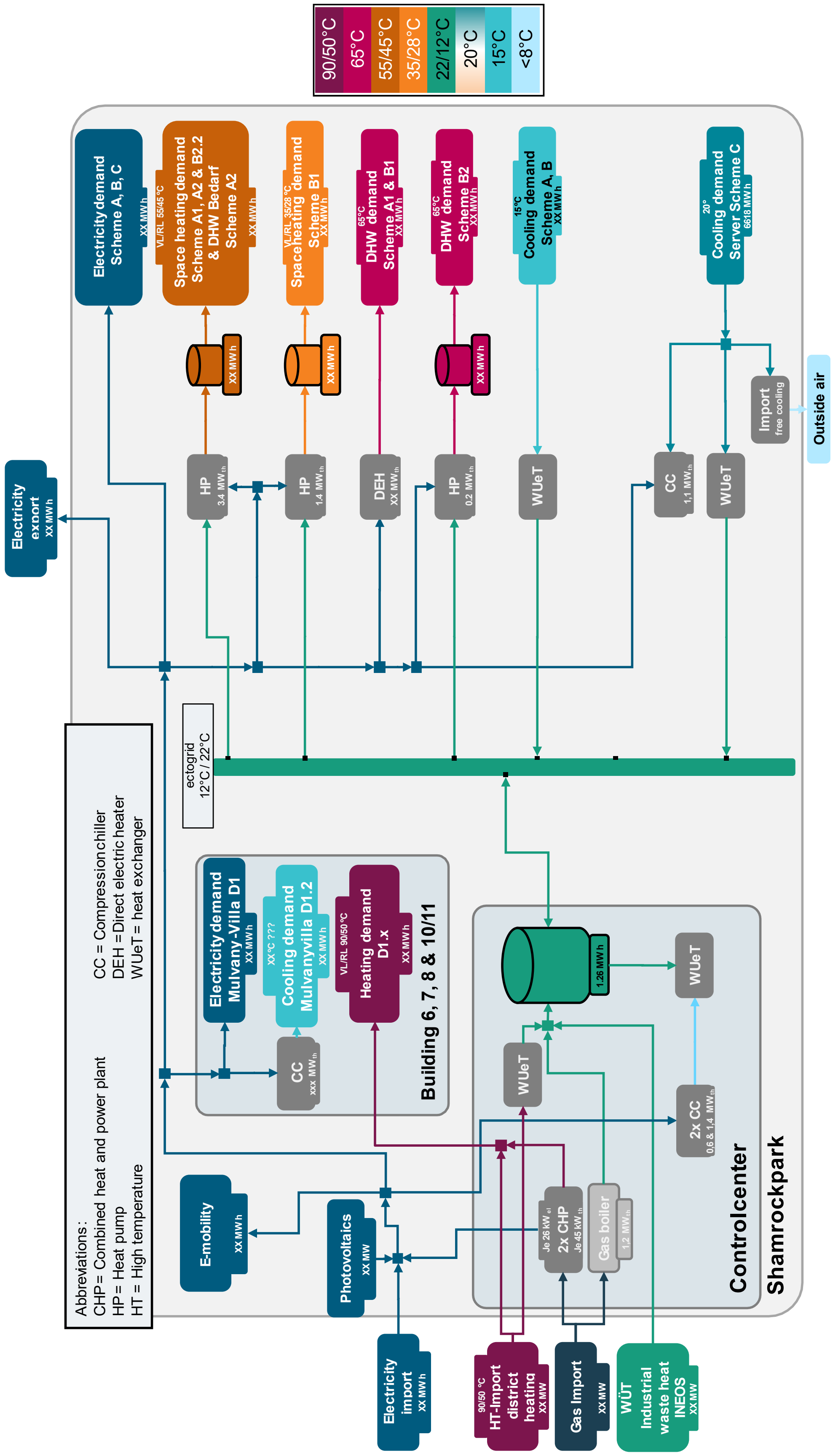

Figure 9: Representation of the Shamrockpark energy system after simplification and aggregation (Source: own representation)

Source: own representation

The most important quantities in the energy system of the Shamrockpark are the demand for heating and cooling. The annual course for heating and cooling in Figure 10 clearly shows the seasonal influences. Only the demands of the buildings connected to the ectogrid are considered here. The outdoor temperature curve used in the modeling is derived from climate data for the period 1995-2012 for Shamrockpark and have been received from RWTH Aachen. Based on the outdoor temperature, the heating and cooling energy demand for the buildings was calculated.

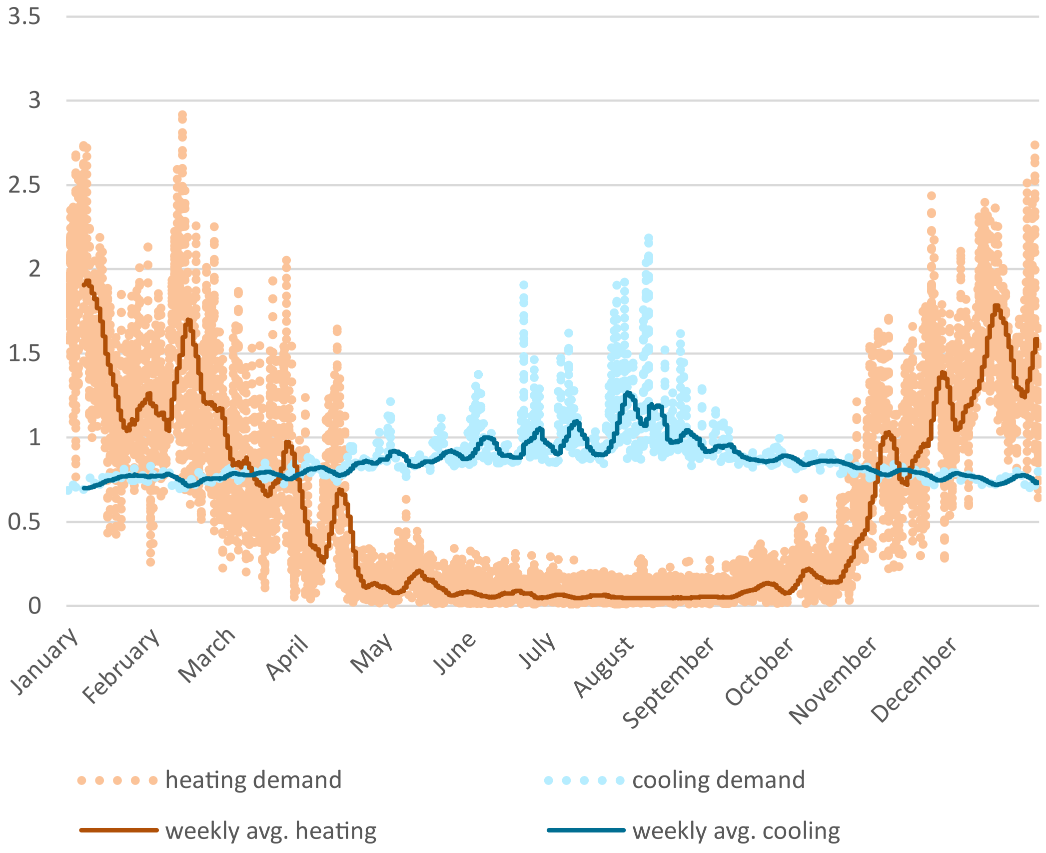

Figure 10: Heating and cooling requirements supplied by the ectogrid over the course of the year (Source: own representation)

The operation of the servers also requires a high base load for cooling, which must also be covered in winter. Even in cold months, at least 0.682 MW of cooling capacity must be provided. In the summer months from May to September, there are additional load increases for building and server cooling depending on the outside temperature. The maximum value is reached here in August at 2.223 MW.

At the beginning of the year, the heat demand, consisting of domestic hot water and space heating demand, is very high depending on the low outside temperatures. Here, the energy system must be able to cover load peaks of up to 2.913 MW. The high proportion of heating energy required then decreases steadily over the course of the year until May. In the summer months from June to September, only domestic hot water is required for the most part. From September onwards, the proportion of space heating energy increases again.

Table 1 below shows the annual energy quantities that are to be covered based on the specified demand series. Due to the constant base load for cooling the server rooms throughout the year, almost 85% of the cooling demand falls on this.

Table 1: Annual demands for electricity and the different temperature levels in the Shamrockpark

Annual energy demands		**in MWh**
electrical	**Total electrical building demand**	15,056
thermal	90/50°C	1,491
	65°C (supplied by heatpump)	202
	65°C (supplied by direct electric heater)	0
	55/45°C	4,786
	35/28°C	1,299
	20°C Server	6,618
	15°C	887
	Cool Mulvany	224
	Total heating demand	7,778
	Total cooling demand	7,729

A number of simplifications and assumptions have been applied to facilitate the modelling process:

- The costs for grids, heat exchangers and PV are neglected.
- Waste heat and free cooling are assumed as free imports with limited availability. It is assumed that at an outdoor temperature lower than 8°C, free cooling can always cover the cooling demand of the system. Furthermore, at an outdoor temperature of 25°C, the waste heat provided by the industry is assumed to be sufficiently large to cover the heating demand of the neighbourhood.
- The electrical energy needed to operate pumps, fan coils and recoolers is neglected.
- There is no heat exchange between ectogrid and the surrounding earth. This assumption is made because both hot and cold conductors are insulated.
- No maximum restriction is set for the optimisation of the decentralised storage. Possible space restrictions in the buildings are not considered.

5.2.2 Optimisation results

The most important variables of the calculation results are presented below. In the basic scenario, additional decentral warm water storages are only installed at the 65°C temperature level. The reason for this is that the demand profile shows very high peak loads that cannot be met by the installed heat pumps alone. Since a fixed electricity price is assumed, there is no incentive to preferentially operate HP at certain times. For the cost-optimised buffering of heating and cooling demands, the central storage is sufficient.

Table 2: Annual amount of energy of import and generation

Source		Form of energy	Form of energy	Amount of energy in MWh/a	% of energy demand
Electrical grid	import	electrical		17,443*	97%
PV	generation	electrical		206	1%
CHP	generation	electrical		416	2%
		thermal		525	7%
District heating	import	thermal		970	12%
Industrial waste heat	import	thermal	heat	2,200	28%
Free cooling of Servers	import	thermal	cool	1,296	17%
Gas boiler	generation	thermal	heat	629	8%
CC	generation	thermal	cool	4,225	41%
Heat pumps	generation	el. demand = waste heat	heat	1,308	17%
Total	import	thermal	heat	3,170	41%
			cool	1,296	17%
	generation	thermal	heat	2,462	32%
			cool	4,225	54%
	ectogrid	**thermal**	**heat**	**2,146**	**27%**
			cool	**2,208**	**29%**

* 15,056 el. building demand

Table 2 lists the annual energy quantities for import and generation. It can be seen that the heat imports are very low compared to the electricity imports. This is due on the one hand to the generally high electricity demand, but also to the very low proportion of self-generated solar power. On the other hand, it is due to the synergy effects of the ectogrid, which enables the use of waste heat from the server rooms amounting to 6,618 MWh. In addition, a large part of the thermal energy from the industrial waste heat can be integrated into the ectogrid. This clearly shows that these waste heat sources can be efficiently coupled into the low-temperature grid.

The annual energy demand of the consumers connected to the ectogrid from Table 2 for cooling (7,729 MWh) and heating (7,778 MWh) is supplied with significantly lower energy imports due to the synergy effects in the ectogrid compared to a conventional heating network. By using the low-temperature waste heat (2,200 MWh) from the neighbouring industrial park and the server rooms on site, the demand of 7,778 MWh is offset by 970 MWh of district heating, 1,154 MWh from gas combustion and 1,308 MWh of electrical energy for operating the heat pump. That is a total of 4,324 MWh (55% of the demand) of thermal supply/generation and 1,308 MWh of electrical supply. 2,146 MWh (28% of the demand) are thus covered by the waste heat on site. 4,346 MWh of thermal energy (56% of the demand) are thus tapped through the use of low-temperature waste heat. These are the savings compared to a conventional high-temperature heat network. On the cooling side, 2,208 MWh (29% of the demand) is provided by extracting heat through the operation of the heat pumps to meet the heat demand, 1,296 MWh (17% of the demand) is provided through the use of free cooling and 4,225 MWh (54% of the demand) is provided through the operation of the compression chillers. A saving of 46% is achieved here compared to conventional cooling using only compression chillers.

6 RESULT 3: EXTERNAL FLEXIBILITIES PROVIDED BY THE DISTRICT

Within the CLUE project, business models for the provision of external flexibilities through low-ex heat grids were discussed and evaluated through variant modelling. Calculations for the provision of different flexibilities were carried out and the results are presented.

6.1 Evaluated business models

For the evaluation of the extent to which flexibilities in the energy system of the Shamrockpark can be used to provide grid services for the external distribution grid, two main cases are being investigated. One is the provision of balancing power and the other is the reduction of the required power rating through peak shaving or load shifting. Other types of flexibilisation include the use of discounted heat pump electricity tariffs, where the heat pumps can be switched off by the grid operator on an hourly basis, as well as cost optimisation in the case of dynamic electricity purchase costs, either by purchasing electricity on the exchange or purchasing via dynamised tariffs.

In the following, however, only the provision of balancing power and the reduction of maximum load through load shifting will be considered.

6.1.1 Provision of balancing power

To maintain the frequency in the electricity grid at a constant 50 Hz, balancing power needs to be supplied to the grid. If the frequency drops 0.01 Hz below, positive balancing power needs to be supplied. If it is 0.01 Hz too high negative balancing power needs to be supplied, i.e. the load is increased. For this purpose the transmission system operators (TSO) tender out different kinds of balancing power: Frequency Containment Reserve (FCR), automatic Frequency Restoration Reserve (aFRR) and manual Frequency Restoration Reserve (mFRR). These are different in terms of time-constraints, how fast they can be delivered and their minimum duration, as well as the minimum power that needs to be supplied. FCR needs to be supplied within 30s, whereas aFRR needs to be supplied withing 5 mins. A minimum capacity of 1 MW for FCR and 5 FCR for aFRR and mFRR must be provided [3]. Commercial aggregators [4, 5] enable the bundling of power plants so that control power can also be provided from smaller plants.

In the Shamrockpark, it is possible to provide balancing power by adjusting the operation of the heat pumps, compression chillers and gas boilers and by charging and discharging storage tanks. In principle, all types of control power could be provided in such a system if the control system can fulfill the corresponding time criteria. In practice, Frequency Containment Reserve (FCR) is already provided from pools of heat pumps [6]. In this study, however, only the possibility of automatic Frequency Restoration Reserve (aFRR) provision is considered, as FCR would not be represented accurately enough by an hourly resolved model like KomMod. Therefore, different scenarios are considered with regard to the amount and availability of control reserve.

6.1.2 Peak power reduction

The reduction of the peak load at the connection point of the Shamrockpark can also represent a grid-serving service for the grid operator and save costs. This can be achieved on the one hand through reduced grid charges due to the lower connected load required and on the other hand by shifting the loads to times when the electricity price is cheaper.

A distinction is made between peak shaving and load shifting. While peak shaving involves a pure reduction in load at certain times, load shifting means that energy is temporarily stored or plants are ramped up again at other times. The total amount of energy drawn remains the same.

In the context of this study, the possibility of load shifting in the Shamrockpark is investigated. This is done without changes on the demand side, the maximum power drawn at the grid connection point is kept below a certain maximum in order to relieve the upstream grid.

6.2 Modelling results

The provision of flexibilities with regard to the flexibilisation of the load profile (balancing power) and the possible reduction of the connected load (load shifting) in the Shamrockpark was evaluated conducting calculations in the KomMod model. The methodology for the evaluation is explained below and the results of the calculation of different scenarios are discussed. Since the size of the decentralised warm water storage units has not yet been determined in the building design, their size was included as a variable in the optimisation. This means that the results describe how large additional decentralised heat storage units would have to be in order to be able to provide the desired flexibilities. Decentralised cold storage is not provided for in the system, so cold demand can only be buffered via the central storage in the ectogrid.

6.2.1 Provision of balancing power

The possibility of providing secondary control reserve (aFRR) is evaluated on the basis of different variants. For this purpose, a profile for the called aFRR in the area of the TSO Amprion from the year 2022 is used, which is standardised to a maximum value of 100 kW or 200 kW respectively. This is significantly below the minimum capacity for aFRR of 5 MW, so an aggregator would be necessary for the provision of balancing power. With 1 MW installed electrical capacity of the heat pumps, this corresponds to 10 or 20% and 6.5 or 13% of the installed electrical capacity of the compression chillers of 1.55 MW in the ectogrid. This is offset against the electricity procurement profile from the reference operation of the base scenario for the Shamrockpark. This means that the Shamrockpark's electricity procurement is fixed to the reference operation without control reserve ± the aFRR profile. This is a simplified representation, but it is assumed that it is suitable for depicting a possible operation with the provision of balancing power.

The different variants of the calculations are:

1. **Negative aFRR**

Only negative aFRR is provided, i.e. heat pumps and compression chillers are operated at a higher level than in reference operation at the times required. The thermal storage tanks are loaded with surplus thermal energy. The aFRR profile is normalised to a maximum value of 200 kW. For this, all heat pumps and CHP units must not be operated at full load at any time during the reference operation. In the results of the baseline scenario, however, by no means all plants are operated at full load at any point in time.

2. **Positive + Negative aFRR at all times**

aFRR is provided in both directions at all times. In addition to limiting the maximum load, it is necessary to maintain a minimum output in reference operation at all times. For this purpose, a separate reference operation was calculated, which is also compared with the base scenario. The aFRR profile is normalised to a maximum value of 100 kW. Previous calculations showed that the provision of 200 kW aFRR is not possible without additional decentralised cold storage, which is not provided for in the system. Therefore, the maximum value was reduced.

3. Positive + negative aFRR only for timesteps with minimum load in base scenario

In this scenario, aFRR is only marketed if, in reference operation, the plants run at a minimum capacity that is greater than the control capacity offered. The aFRR profile is normalised in two subvariants to a maximum value of 100 kW and 200 kW.

An overview of the calculation variants is provided in Table 3.

Table 3: Overview of the calculation variants for aFRR provision

Scenario overview	
SRL1_neg_200kW	Provision of negative aFRR with maximum load of 200 kW at all time steps
MinLast_100kW	Provision of 100 kW minimum load for the provision of bilateral aFRR at all time steps
SRL2_pos/neg_all_100kW	Provision of 100 kW maximum bilateral aFRR at all time steps
SRL3_pos/neg_100kW	Provision of bilateral aFRR with maximum 100 kW, if load in reference scenario > 100 kW. Availability at 8254 of 8760 time steps.
SRL3_pos/neg_200kW	Provision of double-sided aFRR with a maximum of 200 kW, if load in the reference scenario > 200 kW. Availability at 7303 of 8760 time steps.

The calculation results of the different variants were evaluated in relation to operating variables and the expansion of decentralised thermal storage capacities with the base scenario. For a rough monetary estimate, a capacity price of 200 €/day/MW and an energy price of 100 €/MWh are assumed for the provision of aFRR [7]. Since an aggregator is mandatory for the remuneration of the control reserve provision in the Shamrockpark, it is assumed that only 50% of the market profits go to the SRE. The result evaluations are briefly summarised below for the scenarios.

1. Negative aFRR: SRL1_neg_200k

No additional storage is required for the provision of negative control reserve. The electrical import increases by approximately the amount of balancing power. The total costs therefore do not increase significantly (2,700 €). This is offset by approved revenues of 9,200 €, resulting in a profit of 6,500 €.

Flexibility is provided through a change in the amount of waste heat purchased (+32% in the annual amount) and the flexible operation of free cooling (+52% in the annual amount of energy). This is done because the waste heat and free cooling are free energy imports. The annual energy quantities of district heating and CHP generation do not change significantly. The generation of the gas boiler increases by 10%.

2. **Positive + negative aFRR at all points in time: SRL2_pos/neg_all_100kW with reference operation MinLast_100kW**

    a. MinLoad_100kW: No additional storage is required for reference operation with minimum output of 100 kW. There are also hardly any deviations in the energy quantities purchased. Only the generation of the gas boiler increases by 10%. The total costs correspond to the base scenario. In this scenario no balancing power is marketed, it represents the reference operation required for SRL2_pos/neg_alle_100kW.

    b. SRL2_pos/neg_alle_100kW: For the provision of bilateral control power at all times, there is a large increase in storage (almost tripling of storage capacities). This results in a slightly reduced electrical import quantity. The generation of the gas boiler increases by 14%. The total costs increase by 15,000 € compared to the baseline scenario. Compared to approximate revenues from the balancing power of about 9,000 €, losses of 6,000 € are incurred. Increased use of waste heat (+27%) and free cooling (+54%) also results here.

4. **Positive + negative aFRR only for timesteps with minimum load in base scenario: SRL3_pos/neg_100kW and SRL3_pos/neg_200kW**

    a. SRL3_pos/neg_100kW: For the provision of 100 kW aFRR on 343 days a year, there is also a need for increased storage capacity (about 2.5 times). Here, the total costs increase by 13,000 €. Compared to approximate revenues from the control reserve of approx. 8,500 €, losses of 4,500 € are incurred. Increased waste heat utilisation (+29%) and free cooling (+55%) can also be observed here. The generation of the gas boiler increases by 14%.

b. SRL3_pos/neg_200kW: To provide 200 kW aFRR for 304 days a year, there is a need for an extreme increase in storage capacity (approximately quadrupling). This increases the total costs by 19,000 €. Compared to approximate revenues from the balancing power of about 15,000 €, losses of 4,000 € are incurred. Increased waste heat utilisation (+30%) and free cooling (+52%) can also be observed here. The generation of the gas boiler increases by 8%.

By changing the operation of the plants in the Shamrockpark, limited control power can be provided. The modelling of the one-sided provision of negative balancing power amounting to approx. 20% of the installed capacity of the HP/CHP can be managed at all times without additional storage. A two-sided provision of control reserve, on the other hand, leads to a greatly increased expansion of storage, which greatly restricts, if not prevents, the economic efficiency of the provision of control reserve. The flexibilities are raised from the adapted operation of the thermal storage, the use of waste heat and the free cooling of the server rooms. The magnitude of the storage expansion in the scenarios of bilateral control reserve provision is not considered realistic. This would mean 290,000 to 420,000 l of decentralised storage in addition to the planned 2x 60,000 l of central storage. Spatial limits were not included in the modelling due to incomplete data, but it is assumed that only very limited space is available in the buildings for decentralised heat storage.

The possibility of adding storage in the modelling was limited to decentralised storage for heat supply. Buffering of the cooling demand is only possible via the central storage. This means that less flexibility is available in summer.

However, the significance of the calculation results is limited, as the modelling only depicts one possible operation with balancing power. This fixes the electrical supply of the Shamrockpark relative to the optimal operation in the base scenario. In reality, it would be possible to adapt the reference operation without control reserve to current operating conditions such as storage levels. This would allow more flexibilities to be increased. Extended modelling that depicts more flexible operation can provide a more accurate estimate. The monetary estimate of the possible profit from the provision of balancing power was only made very roughly. Due to the low maximum possible control power in Shamrockpark, it is necessary to provide it via an aggregator, so the revenue depends on the individual offer of the providers.

Thermal inertia of the buildings was not included in the modelling. Due to the typically very high inertia of the systems, demand could be made more flexible, but this could impact on occupant comfort. The potential for this type of flexibilisation is estimated to be high, but difficult to model.

Possibilities for increasing the flexibility potential for the control power are either a larger design of the thermal storage or the expansion of the energy system with a larger photovoltaic system and a battery storage. This would make it possible to significantly raise the capacity limit for the balancing power and call up flexibilities from the adapted operation of generation plants, heat procurement, thermal storage and battery storage.

From the examination of the calculation results, it can be summarised that the pure provision of negative balancing power could presumably be easily managed profitably in the Shamrockpark, since even with permanent readiness for the provision of balancing power, there are hardly any additional costs for the operation of the energy system. Only an increase in the generation of the gas boiler could be observed, which would lead to a higher amount of CO2 emissions. In order to obtain a conclusive evaluation of the possibility of providing both positive and negative balancing, however, further studies would have to be carried out that better depict the operation of the energy system when targeting the marketing of balancing power. The expansion of decentralised storage facilities dedicated to the provision of balancing power throughout the year is probably uneconomical under the given assumptions. An adaptation of balancing power marketing to given operating conditions would be more expedient. However, this still needs to be investigated in more detail.

6.2.2 Peak power reduction

The possibility of reducing peak power is modeled by limiting the maximum available power for electric import. This was calculated in two different scenarios for two limits. The impact on operation and decentralized storage capacities is investigated. Two different scenarios were calculated to investigate the possibility of reducing the peak electrical demand of Shamrockpark as shown in Table 4.

Table 4: Description of the scenarios for peak load reduction

Scenario Overview	
MaxLast_3.5MW	Restricting the maximum electrical import to 3.5 MW.
MaxLast_3.3MW	Restriction of the maximum electrical import to 3.3 MW

With a maximum value of 3.268 MW for the building electrical demand and a total maximum load of 4.175 MW in the base scenario, the maximum potential to reduce the connected load by load shifting of the heat pumps and compression chillers is rather low with 0.907 MW (22% of the maximum load). The calculation results show that a limitation to 3.5 MW or 3.3 MW maximum load is only possible in combination with large additional thermal storage capacities. For the limitation to 3.5 MW, about 2.5 times the total storage of the base scenario is needed. For 3.3 MW even the 7-fold. Shamrockpark has an electrical demand profile that is strongly dominated by building demands. This again exhibits a high base load due to the existing server rooms. As a result, the potential for load shifting in Shamrockpark is rather low. The additional storage capacities needed for the peak power reduction represent much higher cost at a low potential. Thus, for this system applying peak power reduction is not economically viable.

However, if the load profile were more strongly characterized by the demands of heat pumps and compression chillers, the potential would be significantly greater. One other more economic possibility to reduce the connected load could be the installation of a battery storage or a PV system. This could cushion the peak loads of the building demand profile. With an average import power of 1.991 MW in the baseline scenario, the maximum potential for peak load reduction here would be 2.184 MW (52%).

7 RESULT 2: RECOMMENDATIONS FOR PLANNING LOWEX ENERGY SYSTEMS

LowEx energy systems are an important component of a sustainable energy supply, as these systems are characterized by their high energy efficiency and low CO_2 emissions. The following planning recommendations could be derived from the experience gained during the planning and development of the ectogrid system for Shamrock Park:

1. **Sound analysis of renewable energy sources**: The use of renewable energy sources such as geothermal, groundwater or aerothermal is an important factor for sustainable energy supply and functionality of LowEx energy systems. The system should be planned in such a way that the proportion of energetically integrated high-quality renewable energy sources is as high as possible. Heat recovery represents another important factor for the use of energy sources. Heat recovery from processes or waste water enables efficient integration of unused heat. Care must be taken to ensure that temperature levels are as high as possible in order to make the operation of decentralized heat pumps as efficient as possible. In addition, the integration of renewable electricity, for example via PV systems, should be examined.

2. It should be noted that the geographical location has an impact on the different climatic conditions and that this can result in different system concepts and components. Therefore, the geographical location should be taken into account to ensure optimal energy supply and utilization of energy sources.

3. The energy distribution system including the building structure plays a major role on the demand side and sets the underlying parameters. When planning a LowEx system, it is important to keep the entire system in mind. The system should be considered as a whole with the buildings to ensure that all components work together functionally and have high energy efficiency. Care should

be taken, especially in new construction projects, to ensure that the distribution system is designed for low temperature. In addition, building insulation must be considered to make assumptions about consumption and performance. The types of use of the buildings are also reflected in the demand structures, as they result in different consumption profiles and user behavior.

4. From the parameters mentioned under point 3, a district-specific consumption load curve should be generated, which makes it possible to determine hourly demand and performance. In order to determine the demand of the building in all times of the year and under consideration of peak loads. In this way, it can be ensured that the LowEx system can meet the demand. Different temperature scenarios should be determined and their impact on the energy system should be considered.

5. In the next step, the generators should be designed according to the requirements of the demand profiles. The dimensioning should always be based on the standard outside temperature in order to guarantee heat supply even on particularly cold days. The special feature of the LowEx network is that both the network as a source for the heat pump and the heat pumps in the buildings must be correctly dimensioned.

6. In order to provide energy transport via the LowEx system, the pipe network must be correctly dimensioned. The spread and network dimensions must be determined and based on the demand structure. It should be taken into account that there may be extensions to the network or changes in demand as the system progresses. In addition, it must be assessed whether a high number of rejuvenations of components in the network is economically attractive or whether standard sizes are used, which can offer price advantages. This should then be followed by an iteration stage by re-simulating the impact of the standard sizes on the power system.

7. In a further iteration stage, optimization through storage capacity should be considered. Energy storage can help to increase the energy efficiency and self-sufficiency from the grid.

8. Planning an automated control unit is another important component of the system. Intelligent energy optimization systems can help minimize energy consumption by automatically adjusting power plant operation to meet needs. In addition, forecast-based control systems can have a positive impact on the upstream power grid. These flexibilities were investigated by Fraunhofer ISE as part of the project.

9. Implement a continuous energy monitoring: Continuous monitoring can help identify and correct potential problems early, before they become major issues. Plan continuous monitoring in your LowEx system to ensure it is operating efficiently and reliably.

Overall, planning recommendations for LowEx energy systems are varied and require careful analysis and consideration of several factors.

8 RESULT 4: BUSINESS MODELS FOR RENEWABLE ENERGY COMMUNITIES IN SECTOR COUPLED ENERGY SYSTEMS

LECs are usually only active in the electricity sector. This is partly due to the fact that electricity is easily transportable and tradable, as all producers and consumers are connected via an electricity grid.

There are also energy cooperatives in the heating sector that jointly operate district heating networks, for example. However, their business model options are very limited, as only a limited number of consumers are connected to the district heating network and network expansion is relatively costly. On the other hand, the distribution of heat quantities requires the physical transport of a heat transfer fluid (usually water). This makes distribution relatively inflexible and reversing the direction of energy flow costly.

However, the sector-coupled organisation of power-heat energy communities, where the district heating network distributes heat at a low temperature, could have great potential. The heat at the desired temperature is then provided decentrally in the buildings with heat pumps using electricity. Such cold district heating networks have the advantage that the decentralised supply of heat quantities is considerably simplified, since corresponding heat sources, e.g. in the form of waste heat from refrigeration machines, are only available at low temperature. Secondly, the connected prosumers can actively withdraw quantities of heat from the cold district heating network in a controlled manner due to the use of heat pumps. In such an electricity-heat energy community, the electricity can be shared within the energy community and used decentrally for heat generation.

Such a concept was investigated for Shamrockpark.

The current organisation of the heat supply was compared with a heat supply with an electricity-heat energy community with energy sharing.

The energy supply in the neighbourhood is organised in this way today:

- The district heating network with the decentralised heat pumps is operated by the local energy supplier (LES).

- The buildings receive heat at the desired temperature level, the increase of the temperature from the cold district heating network to the desired temperature level is carried out by the LES.
- For the operation of the heat pumps, the LES buys electricity on the general electricity market at usual conditions.
- The PV system on the central parking garage is operated by the LES; the electricity is fed into the public grid and remunerated at the usual conditions.

This concept had to be chosen because local electricity exchange (energysharing) within energy communities is not yet possible in Germany due to current regulation.

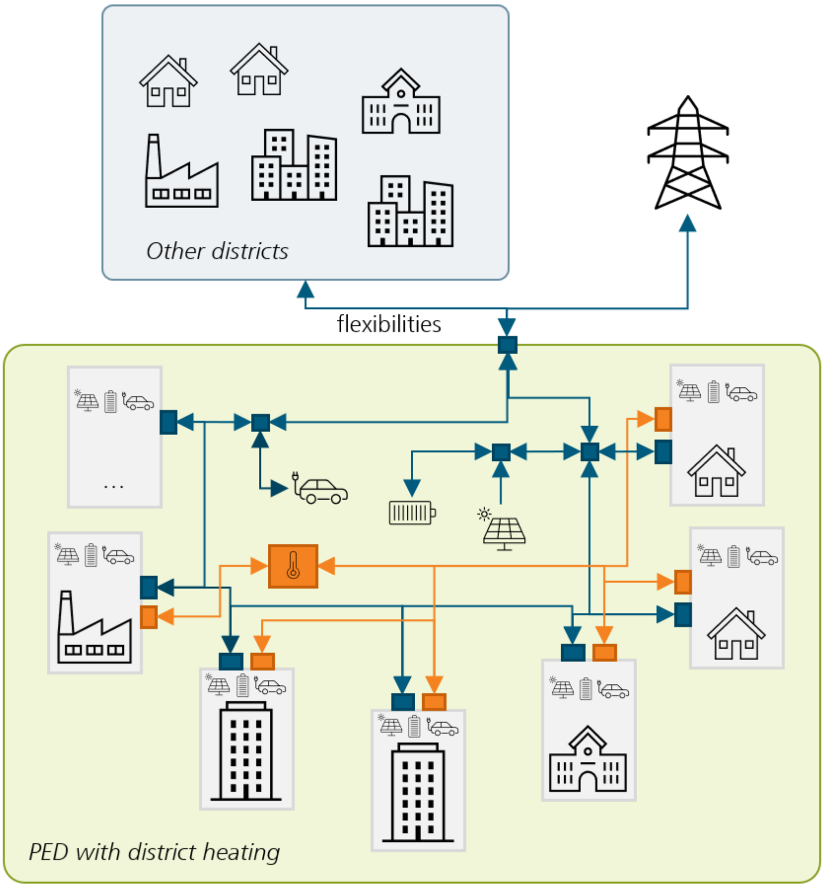

Figure 11: Structure of a Power-heat-community (Source: own representation)

The **desirable organisational form with power-heat-LECs** is as follows:

- The LES forms a LEC with the energy consumers and brings in the district heating network, the heat pumps and the PV system as assets.

- The LEC operates the energy system and shares both the solar power and the heat quantities between the members.
- The solar electricity generated in the neighbourhood is used to operate the heat pumps, and the heat pumps are controlled (and existing storage tanks are charged and discharged) in such a way that a maximum share of the solar electricity is used directly in the neighbourhood

Through this constellation (see also Figure 11), consumers in the power-heat energy community can benefit from increased self-supply with renewable energies and reduced heating prices due to the use of locally generated solar electricity.

A calculation of the economic benefits of this concept was not possible, as too many influencing factors and boundary conditions are unknown. Therefore, this business model will be investigated in further projects.

9 EVALUATION OF USER BEHAVIOUR

FAKT AG and Fraunhofer ISE worked together to investigate reservations about technical solutions and develop measures to create acceptance together with local stakeholders. Two main activities were a stakeholder workshop, which formed the basis of the stakeholder analysis, and the survey of the users of the Schamrockpark regarding their attitude towards new technologies, such as the ectogrid. This made it possible to derive an assessment of the extent of stakeholder acceptance for the ectogrid. With the insolvency proceedings of FAKT AG, further activities, such as the development and dissemination of additional information materials, could not be carried out.

9.1 Stakeholder analysis

As part of the research on user integration, a stakeholder analysis workshop was held in Herne on October 2, 2020. The objective was to identify the risk assessment towards the technology LowEx energy system ectogrid as well as towards the flexibility use. Ms. Wrobel (FAKT AG) as well as two other persons from FAKT AG, Mr. Bruskolini (E.ON) and Mr. Gölz (Fraunhofer ISE) participated in the workshop.

A stakeholder analysis was developed as a result. Regarding reservations and acceptance, the group of tenants in the Shamrockpark was identified as the most important stakeholder group for the success of the project, as they are directly affected by noise etc. during the conversion but are also the end users of the heating and cooling and thus also financiers, as the costs are apportioned via the ancillary costs and will bring FAKT AG the "cash-in". Also, the need for information regarding the technology and heating or cooling supply is already pronounced, here it would be important to continue the work package activities.

The stakeholder analysis can be visualized in the following diagrams, which were developed in the context of the D3.2 LOCAL ENERGY COMMUNITY ARCHITECTURE DESCRIPTION of ERA-Net Smart Energy Systems [8].

The report shows that two legal frameworks and 10 stakeholders identified Herne-Shamrockpark (Germany). Those which hold different roles and positions in the CLUE-project. Figure 12 displays the positioning of the stakeholders according to their spatial scale (state-district-local) and their importance in the project. Those stakeholders most relevant in their role and in the local context are found int the core of the bubble (see Figure 12) [8].

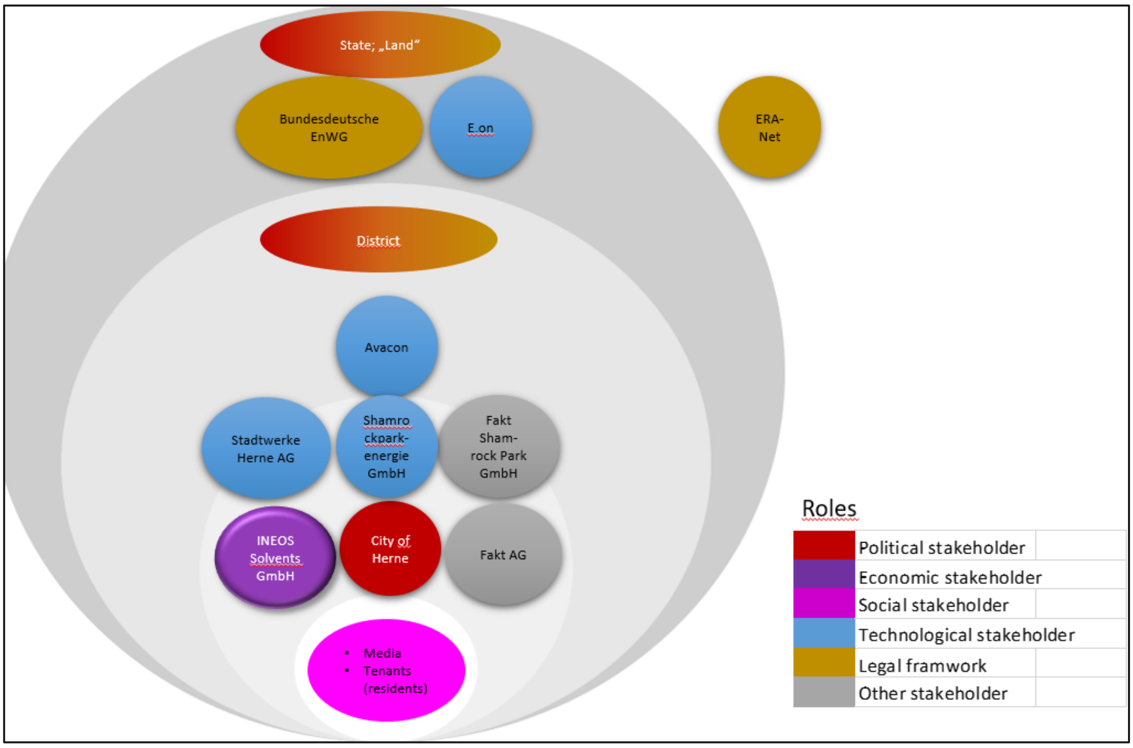

Figure 12: Position and roles of the stakeholders in Herne-Shamrockpark as described in [8]

Figure 12 shows, that the media and tenants – from the group of social stakeholders have a key role in the CLUE- project in Shamrockpark. Furthermore, the stakeholders of Germany have different roles, which are mostly technological, social and other stakeholders. Moreover, the legal frameworks of the German EnWG and ERA-Net were used in the CLUE- project of Shamrockpark (see Figure 13) [8]. The stakeholder group of tenants was a key group in further activities in the work package.

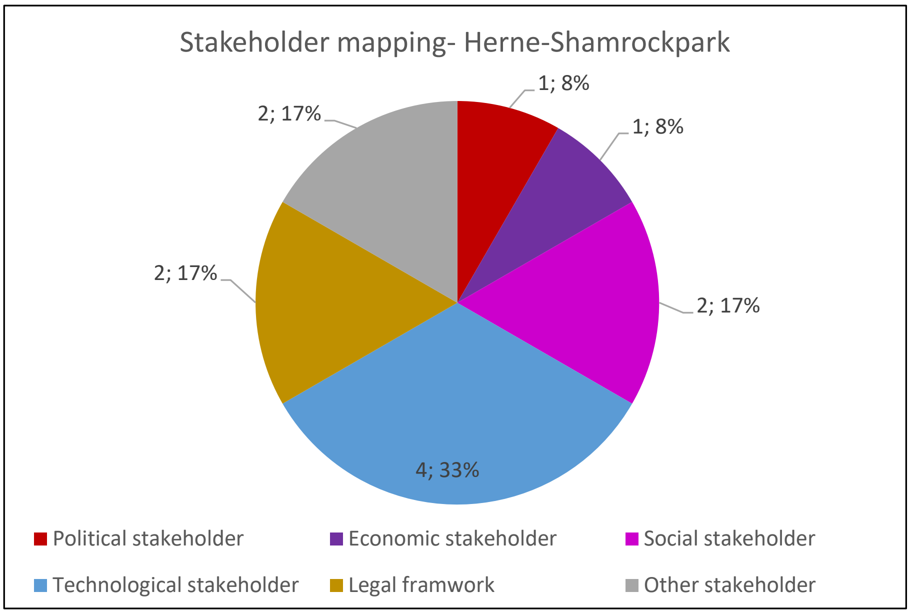

Figure 13: Roles of the stakeholders in Herne-Shamrockpark as described in [8]

The result of the stakeholder mapping is that all the stakeholders in Shamrockpark are already aware and active [8].

9.2 User survey

As a result, FAKT AG agreed with ISE to conduct a user survey among the tenants in the existing buildings. Since they were not informed about the technical plans at that time, the survey was combined with an information campaign to explain the planned technical systems. FAKT AG was responsible for approaching local users and acquiring respondents. The aim of the survey was to capture the attitudes of Shamrockpark users towards the technical solutions.

The information campaign was played as a video format between the question blocks of the survey. This contained information on the technical development of the heat networks and the role of the ectogrid, as well as the planned structural changes in Shamrockpark.

The survey covered assessments of the system currently in use, attitudes towards ectogrid, and acceptance of ectogrid according to the Technology Acceptance Model (TAM). The Technology Acceptance Model according to Davis (1985) [9] is a psychological model that measures the implementation probability of a new system, taking into account perceptions of usefulness, manageability, and interest.

The survey was conducted in two passes. In the first run, the survey was sent via email as an online questionnaire in December 2021. Since the responses were significantly below expectations, FAKT AG launched a second call. In the second call, posters were hung in entrances to Shamrockpark buildings as an acquisition measure for additional survey participants. The posters contained information about the goals and format of the survey, as well as a QR code that interested parties could scan to access the online survey home page. In addition, the survey design was adjusted for the second run and the number of questions and video interruptions were reduced to counteract survey dropouts due to the length of the questionnaire.

In the first run, only 5 questionnaires were completed. The second run of the survey ran through June 2022, with a total of 16 questionnaires completed that met the quality criteria and were analyzed. The remaining questionnaires were either filled out too quickly or only incompletely and were thus removed from the evaluation.

The amount of 16 participants is to be evaluated as low, so that the representativeness of the results is estimated as insufficient. Furthermore, it can be assumed that interested persons filled out the questionnaire and thus the interest of the entirety of the users in Shamrockpark is lower than highlighted in this evaluation.

Most participants were between 30 and 60 years old (70%) and three quarters classified themselves as male. Just under 90% of participants work at Shamrockpark while the remainder use Shamrockpark to attend on-site appointments.

9.2.1 Attitude towards technology

The first section of the questionnaire assessed technology affinity. Questions explored attitudes toward (new) technology, interest, knowledge, and motivation to implement.

Respondents showed a rather high affinity for technology, so it can be inferred that there is interest in technologies and innovation. For example, there is a high affinity for efficiency: about one in three of the respondents likes it when technology works efficiently. However, there is proportionally low understanding of heating systems, with only 31% indicating low knowledge of building systems (Figure 14).

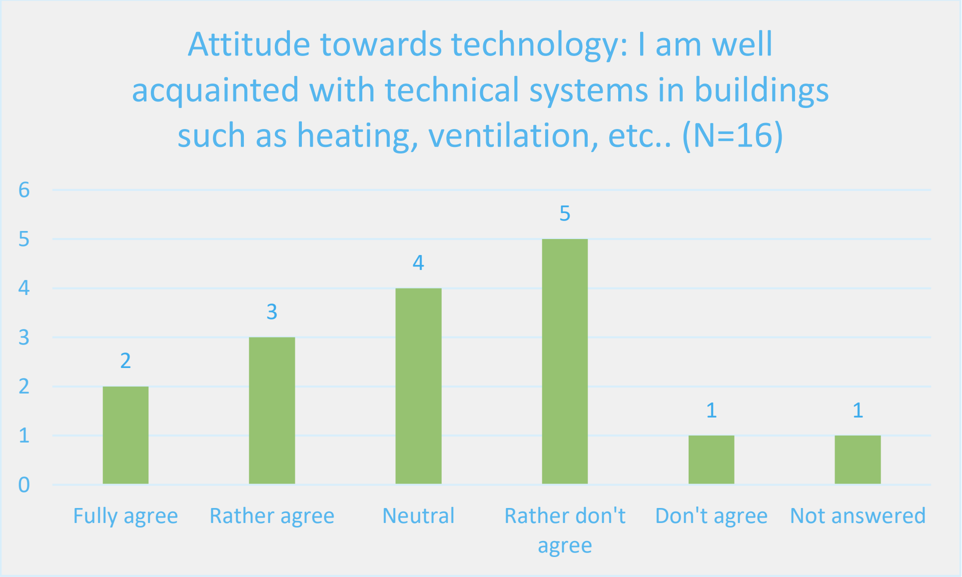

Figure 14: Results of exemplary item for attitude towards technology

9.2.2 Satisfaction of indoor climate

The second section of the questionnaire asked about satisfaction with the indoor climate in the Shamrockpark buildings. In general, there was a high to medium level of satisfaction, as three-quarters of respondents indicated that they were generally satisfied with the indoor climate.

There are differences between seasons: In fall and winter months, satisfaction is particularly high at 94% (Figure 15), while in spring and summer months, satisfaction is slightly lower.

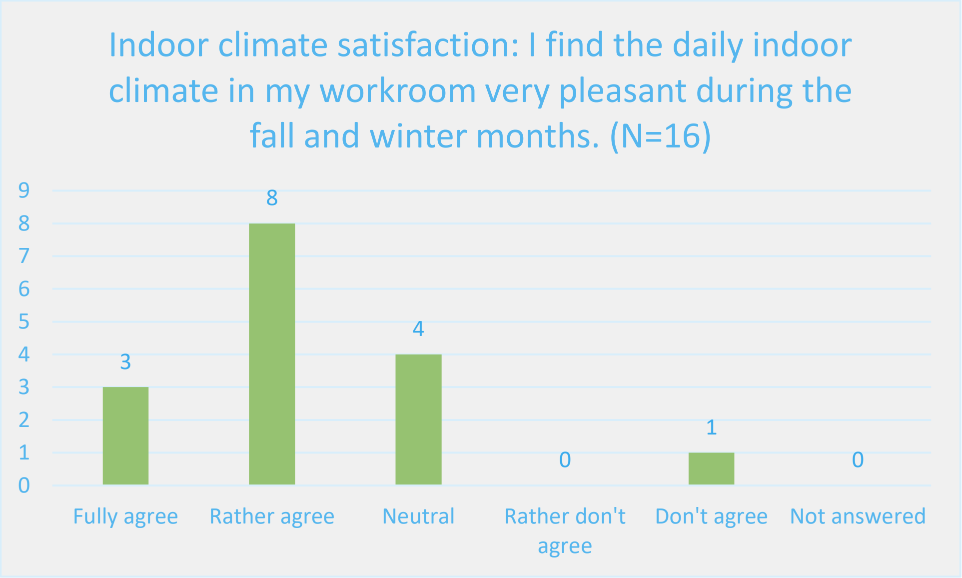

Figure 15: Results of exemplary item for indoor climate satisfaction

9.2.3 Assessment of CO_2 emissions

In the third section, the assessment on CO_2 emissions from Shamrockpark was surveyed. Surprisingly, an indifference was found regarding CO_2 emissions: Just over half (56%) estimate the CO_2 emissions of the current heat supply as "normal" (Figure 16). Only one third (31%) of the respondents consider the CO_2 emissions of the current heat supply to be high or very high (Figure 16).

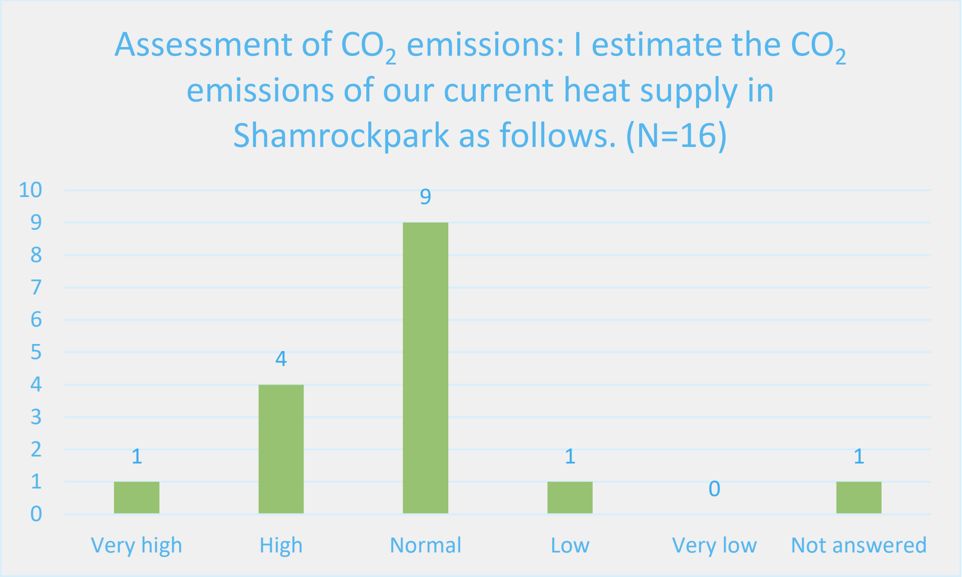

Figure 16: Results of exemplary item for assessment of CO_2 emissions

9.2.4 Attitude towards climate protection

In the fourth section of the questionnaire, the attitude towards climate protection was recorded. Half of the respondents find climate protection very important or important and also environmental protection in everyday life important. Whether climate protection is seen as an individual or collective task cannot be clearly separated: 44% think that one's own behavior plays a role (Figure 17). At the same time, half of the respondents think that climate protection can only be achieved if everyone participates.

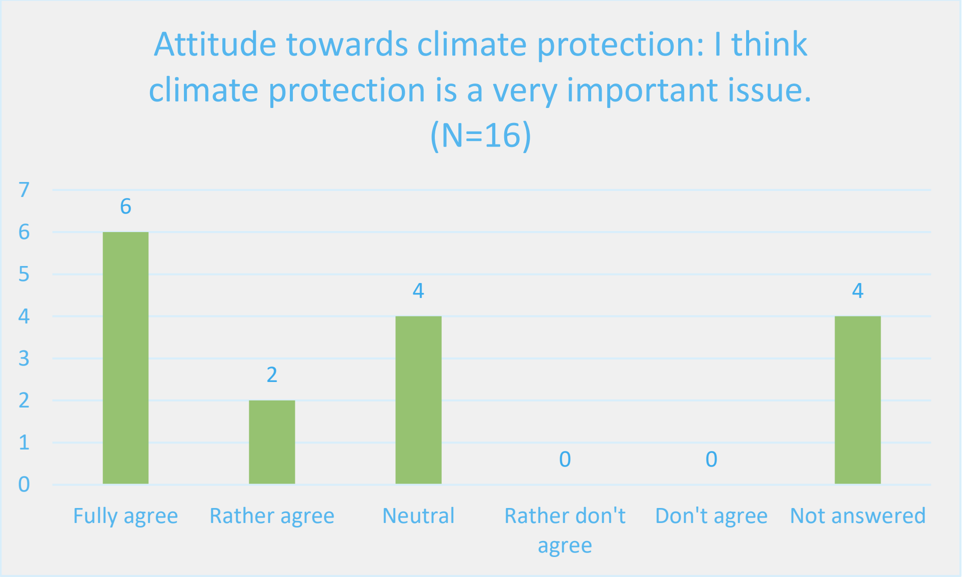

Figure 17: Results of exemplary item attitude towards climate protection

9.2.5 Attitude towards ectogrid

In the penultimate section, the attitude towards ectogrid is recorded. 38% of respondents recognized a potential of ectogrid for increased independence from oil and gas prices (Figure 18). Respondents also valued ectogrid as a low-risk technology: less than 10% perceived risk from heating systems like ectogrid (Figure 19). Additionally, more than half believed in achieving long-term sustainable heat and power supply.

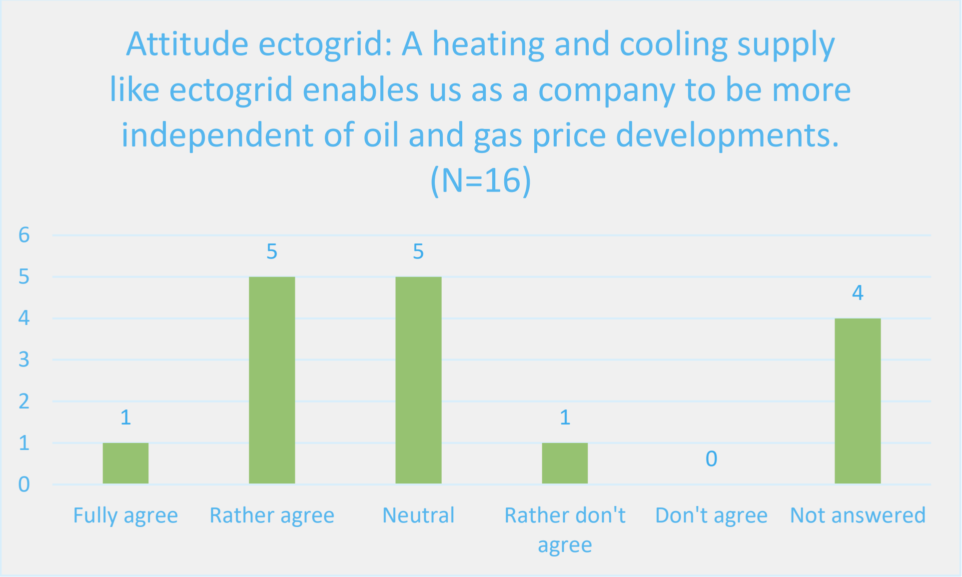

Figure 18: Results of exemplary item 1 for attitude towards ectogrid

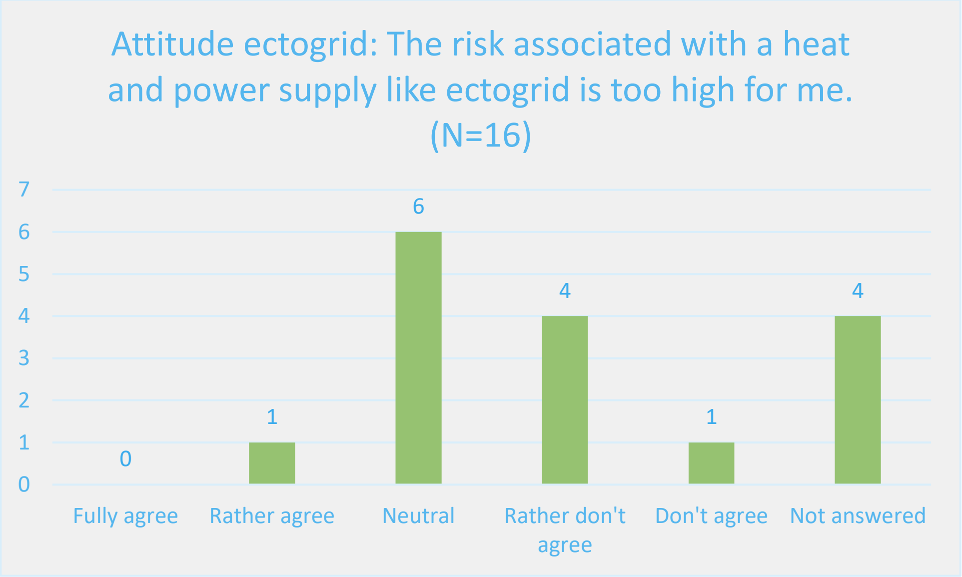

Figure 19: Results of exemplary item 2 for attitude towards ectogrid

9.2.6 Technology Acceptance Model

The last section of the questionnaire queried the TAM, the Technology Acceptance Model according to Davis (1985) [9]. The technology acceptance model measures how likely a new system is to be implemented and used, considering perceptions about usefulness, manageability, and interest.

The response rate for this section was lower than the previous section and the evaluation is based on nine fully completed questionnaires, so the validity of the results is limited (Figure 20). The evaluation showed that the new system is perceived as rather useful and rather user-friendly. Furthermore, respondents have a slightly positive to neutral attitude towards the use of the new system. The behavioral intention to use the system tends to be positive. Thus, the variables queried indicate that use is more likely than not. However, the valence is not strongly pronounced, which may indicate an indifference to heating systems.

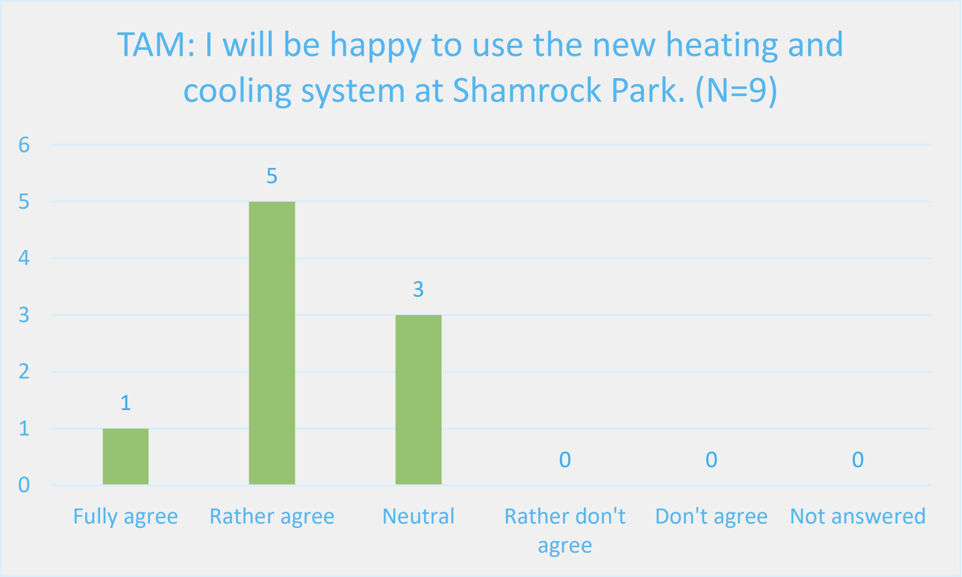

Figure 20: Results of exemplary item for TAM

9.2.7 Conclusions

In summary, it can be stated that participants of the survey show a rather high affinity to technology and are already quite satisfied with the current indoor climate. Interest in and understanding of the impact of the thermal system on climate emissions is not particularly strong. While participants in the survey indicated a rather high interest in climate protection, they show a medium understanding of climate protection through the new system. Nevertheless, a rather positive attitude towards ectogrid was recorded. The measurement by TAM showed that the use of the new system is rather likely, as neutral to positive values were measured.

For the classification of the results, a reflection of the composition of the respondents is helpful: The low response rate limits the significance and representativeness of the results. Furthermore, it can be assumed that mainly interested and curious users of Shamrockpark took part in the online survey. Among them, there was a low level of interest and knowledge of the heating systems. Accordingly, it can be concluded that other users of Shamrockpark are also not opposed to the implementation of new technologies. Although no pronounced motivation and particularly positive acceptance for the ectogrid was measured, it cannot be assumed from these results that there will be serious gaps in acceptance.

For the further course of the project and the implementation of the ectogrid, it may nevertheless make sense to take measures to increase acceptance. For example, the respondents are not aware of the positive climate impact of the new technology. This aspect could be further explored in information campaigns. In the design of information materials, careful consideration should be given to the extent to which restrictions on individual measures of heating and cooling management at the room level are caused by the ectogrid. Although these apparent limiting aspects are not perceived as particularly negative according to the evaluation, excessive emphasis could reduce acceptance towards the technology.

With the insolvency proceedings of FAKT AG, the work planned by FAKT AG in the work package for user integration and acceptance (for example, by creating and disseminating further information materials) could no longer be carried out.

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