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INVESTMENT SPECIFICATION FOR THE INTEGRATION OF AN ENERGY STORAGE IN HUC OF WEIZ

D.T2.1.4

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Title	INVESTMENT SPECIFICATION FOR THE INTEGRATION OF AN ENERGY STORAGE IN HUC OF WEIZ
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Summary

1. INTRODUCTION

This investment specification document (pre-investment concept) includes all the aspects to be evaluated before starting with investments and procurement procedures, including also the aspects already included in preliminary project design steps incl. energy audit where available. Each pilot fills in this document to ensure that all relevant aspects will be considered in the procurement of the identified storage solution.

The investment specification is linked and should include the outcomes and contributions of other documents and project results (see also Figure 1 below):

- Deployment desk outcomes, including expectations of stakeholders supporting the pilots (A.T1.1);
- Feasibility study of the pilot (A.T1.2);
- Results of the application of the Energy Management System (EMS) tools in the storage planning and design (A.T3.1);
- Monitoring of Key Performance indicators (KPIs) specified for pre-investment stage (paragraph 2 of template for the HUC pilot action report, D.T2.2.1);
- Existing preliminary projects of reference for the pilot investment;
- Existing energy audit / analysis of consumption for pilots.

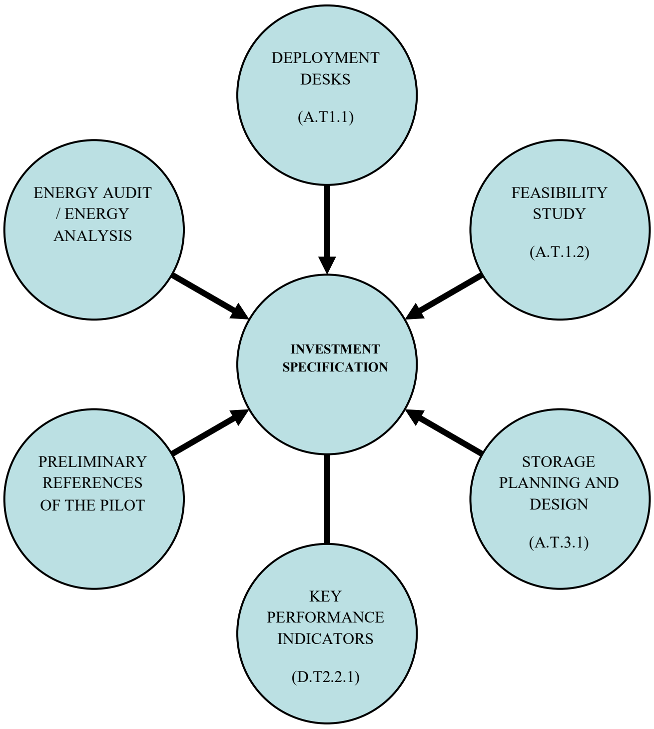

Figure 1. Interrelations between the elements for consideration in the pre-investment concept

The aim of the project is the integration of a central heat storage tank into the existing heating plant of the local heating network in the historic monument and landscape protection zone of Weizberg as well as the implementation of a new control system with a fully integrated, intelligent load management with mutual communication of all plant components.

The boiler section of the heating plant is currently operated mainly in the disadvantageous partial or low load range due to the lack of a central heat storage tank. This leads to increased fuel consumption and pollutant emissions (CO, NOx, dust and volatile unburned CnHm emissions). In addition, due to the lack of a central storage tank, the heating network is used as a thermal buffer to absorb the heat supplied by the boilers, particularly in the burnout phase, in order to be able to supply the decentralised hot water storage tanks at the customers' premises. In this way, the heating network is constantly maintained at correspondingly high flow temperatures and unnecessary heat losses of the network (distribution losses) occur.

The innovation of this project takes place on the storage tank as well as on the system level. On the one hand it takes place on the system level, by the implementation of a new control with a coherent load management of all system components (boiler plant, central storage, network and decentralised storage at the consumers) by mutual communication of these and by access to the control of the decentralised storage at the consumers. On the other hand, it takes place on the storage level with the integration of a central heat storage in the historic monument and landscape protection zone.

Only the implementation of the fully integrated, intelligent load management of all system components in interaction with the central heat storage tank and the decentralised heat storage tanks at the customers' premises makes it possible to minimise the disadvantageous operating mode of the boiler plant and prevents the local heating network from being used as a thermal buffer. These planned measures thus increase the flexibility and energy efficiency of the entire biomass heating plant. Essentially, the following positive effects will be achieved:

- Use of the heating network as a thermal buffer is avoided → lower heat losses (distribution losses), optimised fuel utilisation;
- Operation of the heating network during the summer months only at certain times when hot water is required and after communication with the decentralised storage → Lower heat losses (distribution losses) and savings on pump energy;
- Saving of primary energy (fuel savings) by increasing efficiency → CO2 savings through lower energy expenditure for the provision of the wood chips (production, transport, etc.);
- Lower emissions of pollutants (carbon monoxide (CO), dust, NOx and volatile organic carbon compounds (CnHm));
- Increase of the service life of the plant components → Significant saving of ecological resources, which would result from an early complete renewal of the boiler plant.

One of the main reasons for the lack of a storage tank and other measures to increase efficiency is the location of the heating plant in the historic monument and landscape protection zone of Weizberg, where the church and the parish buildings are protected as a historical monument and a protected site. At present, the integration of large heat storage units and other measures for local heating networks in historical districts represents a great challenge due to the strict conditions imposed by the protection of the townscape and historical monuments. However, especially in these districts, which are protected as historic sites and monuments, there is a backlog demand with regard to energy efficiency and the use of renewable energy sources.

This project will demonstrate a possible solution to this problem by the innovative implementation of a central water buffer storage and a new load management system in the listed town centre of Weizberg. The constructional requirements for compliance with the protection of the townscape and monuments are to be fulfilled by the new solution concepts. This project can and should therefore serve as an innovative best-practice facility and as a model for simplified technical and above all economic implementation at other protected sites. It can thus enable a significant increase in the proportion of renewable energy sources in historic city centres.

This project thus demonstrates the use of an already widely tested technology (water buffer storage) for the hardly tested area of application in districts and buildings under monument or site protection. Furthermore, the new load management including mutual communication of all plant components on system level represents an innovative approach. For these reasons, the use of this storage solution goes beyond the state of the art and emphasizes the innovative character of this project.

2. INITIAL SITUATION AND CONTEXT

2.1. Localization of the storage

The storage will be installed next to the building “basilica Weizberg” located in the city of Weiz, in the historical and monumental protected area of Weizberg. It will be connected to the regional local biomass heating network Weizberg as shown in Figure 2 and Figure 3. See D.T1.2.3. “Feasibility study for implementing energy storages in Weiz (AT)” for more details[1].

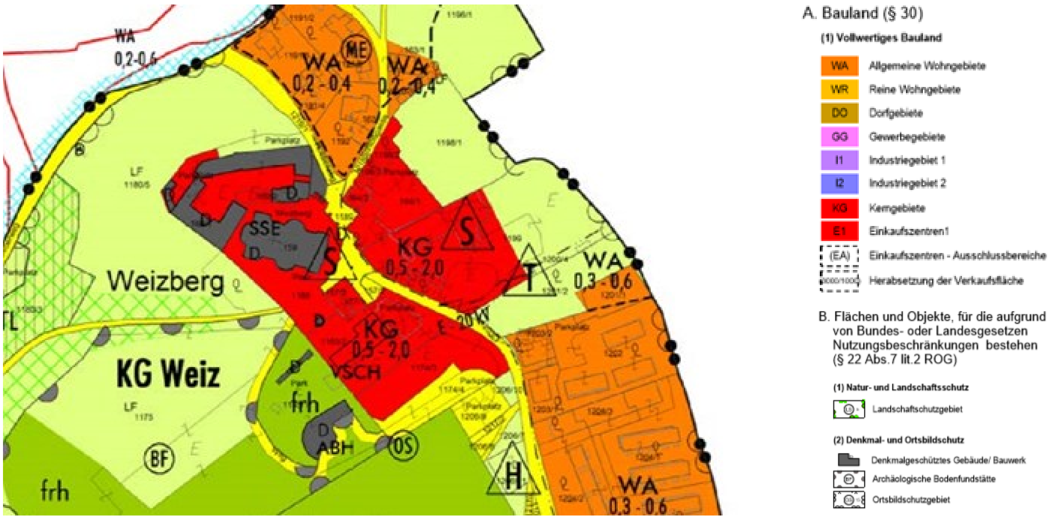

Figure 2. Excerpt from the zoning plan for the focus area Weizberg, in German (Source: zoning plan No. 1.0 - Stadtgemeinde Weiz, as at: 26.09.2019, Original: http://www.weiz.at/files/stadt-weiz/dokumente/Verordnungen/fwp_weiz_kl_1.pdf)

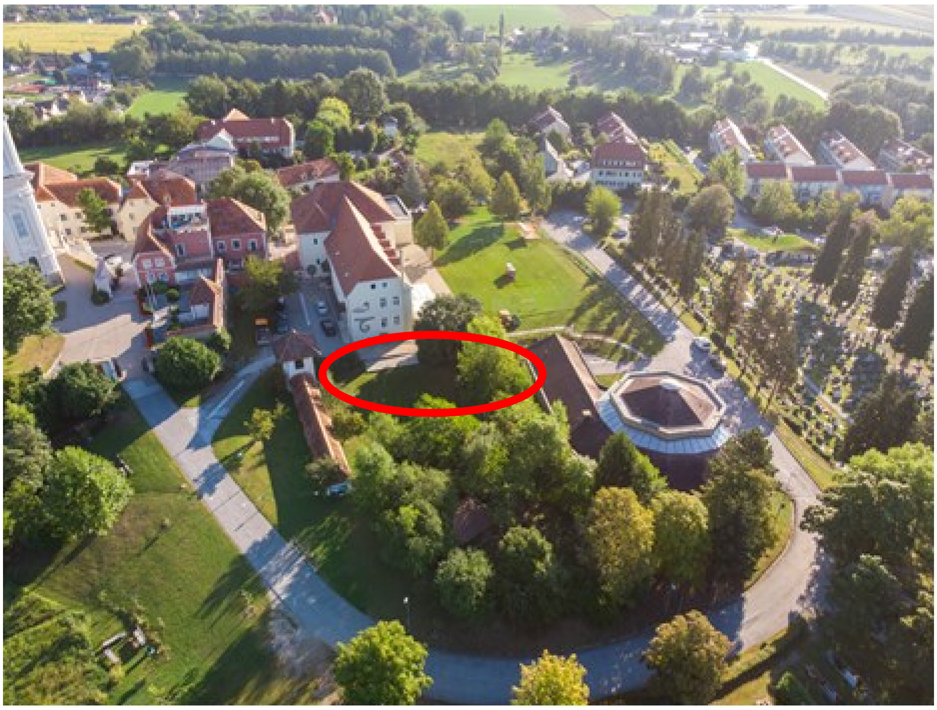

Figure 3. Future storage location

[1] Store4HUC (2019): “Feasibility study for implementing energy storages in Weiz (AT)”, https://www.interreg-central.eu/Content.Node/WP/WPT1.html, last access 10.03.2020

2.2. Actual energy users that the storage will serve

Plant Description

The local heating network and heating plant of the cooperative "Biomasse Heizwerk Weizberg reg. Genossenschaft mbH" was built in 1999. The heat supply of the local heating network with 12 consumers is ensured by two biomass boilers fired with regional wood chips (see Table 1 for details and connected power in kW). The largest consumers are a hotel business and the parish of Weizberg. The plant is currently operated without storage and without additional oil or gas boilers as a fail-safe measure. Characteristic values for the heating network and the boiler plant can be found in Table 2 and Table 3. Table 2 also contains a list of available decentralised hot water storage tanks (charging storage tank) at the consumers of the heating network.

Table 1. Consumers of the heating grid

Consumer	Object address	connected power in kW
1	Parish building; Weizberg 13; 8160 Weiz	125
2	Hotel; Weizberg 2; 8160 Weiz	330
3	Municipality; VS Weizberg; 8160 Weiz	170
4	Church Weizberg; 8160 Weiz	20
5	Weizberg 13; 8160 Weiz	50
6	Weizberg 7; 8160 Weiz	38
7	Messner house; Weizberg 17; 8160 Weiz	20
8	Schlossgasse 8/10; 8160 Weiz	22
9	Weizbergstrasse 36; 8160 Weiz	25
10	Weizberg 13; 8160 Weiz	30
11	Weizberg 11; 8160 Weiz	28
13	Schlossgasse 7; 8160 Weiz	15
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Table 2. Key characteristics of the existing heating grid

Heating grid				
Energy users	12	[-]		
Grid length	773	[trm*]		
Connected power	917	[kW]		
Sold heat (2017/18)	1457	[MWh]		
Temperatures	Winter (Oct-Apr)		Summer** (Mai-Sep)	
Flow temperature (average)	81	[°C]	79	[°C]
Return temperature (average)	57	[°C]	58	[°C]
Avarage temperature difference	24	[°C]	21	[°C]
Decentralised hot water storage				
Consumer 2	750	[Litre]		
Consumer 5	500	[Litre]		
Consumer 6	500	[Litre]		
Consumer 8	500	[Litre]		
Consumer 13	300	[Litre]		

Legend:

*) Grid length in metres

**) In case of receiving the requested co-financing in Austria DHW will be decentralised

Table 3. Key characteristics of the existing boiler plant (2 poilers)

Boiler plant		
Power	840	[kW]
Boiler 1	300	[kW]
Boiler 2	540	[kW]
Used biomass (2017/18)	1896,3	[srm*]
	417,68	[atro. to]
	22,8	[% humidity]

Legend:

*) Cubic metres

The high return flow temperatures of the local heating network have optimisation potential. Therefore, optimisation measures (renewal of the heat exchangers, hydraulic balancing, renewal of the control system, etc.) have already been carried out at the second largest consumer (Weizberg parish) to reduce the return temperatures. Further optimisation measures (additional heat storage tank and heat exchanger, optimisation of the control system, etc.) have already been implemented or are planned for the largest consumer (hotel operation).

2.3. Actual energy use and energy balance

As shown in Figure 4, over the course of the year, with the daily mean values of the output (kW; yellow boiler 2; red boiler 1) and operating hours of the boilers (h; line), the operating year of the heating plant can be divided into three different periods, which are explained in more detail below.

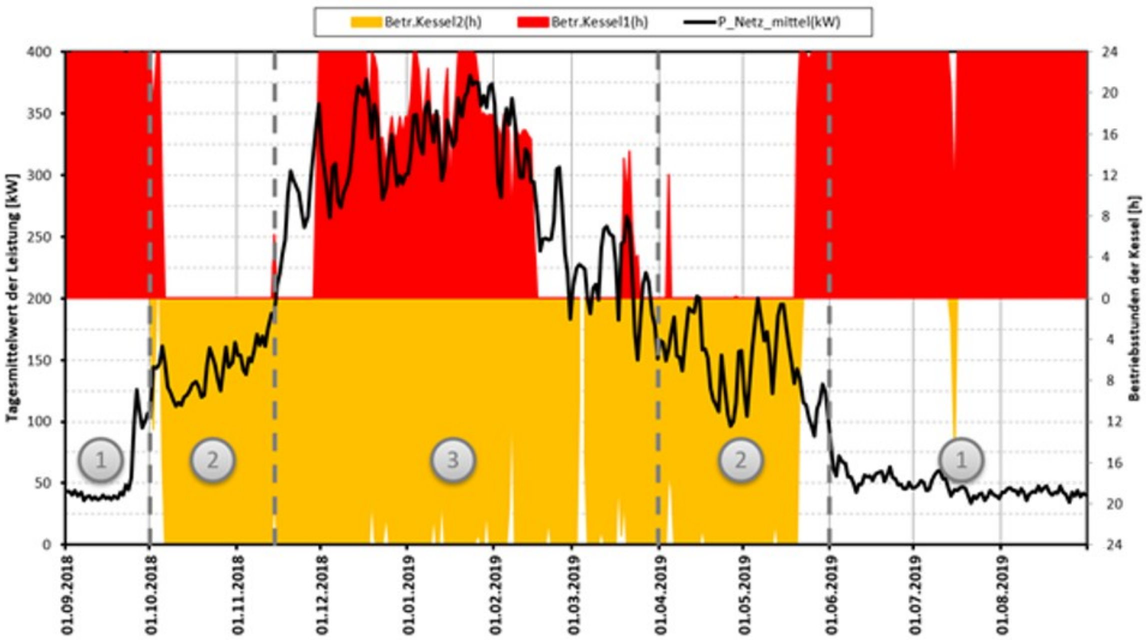

Figure 4. Daily mean values of the power of the local heating network and operating hours of the two boilers. Red: operating hours, boiler 1. Orange: operating hours boiler 2.

Period 1 (from the beginning of June to the end of September):

The low heat requirement in summer (see Figure 4) requires the operation of the smaller boiler (Boiler 1 - 300 kW; Boiler 2 is not used during this time) from June to September at very low partial load (8% to 15%). Thus, a continuous operation of the boiler is not possible and it comes to the cyclic operation of the boiler shown in Figure 5. The non-continuous mode of operation is recognizable from the oscillating operating parameters (boiler temperature, exhaust gas temperature, actual value residual O2, actual value secondary air stage). As shown in Figure 6, the repetitive cycles consist of the firing phases of insertion, ignition and run-up (start-up phase), as well as the standard combustion and the subsequent burn-out. These cycles are repeated in the summer months (period 1) about 13 to 15 times a day. As a result, around 2/3 of the operating states are in the start-up and burn-out phase.

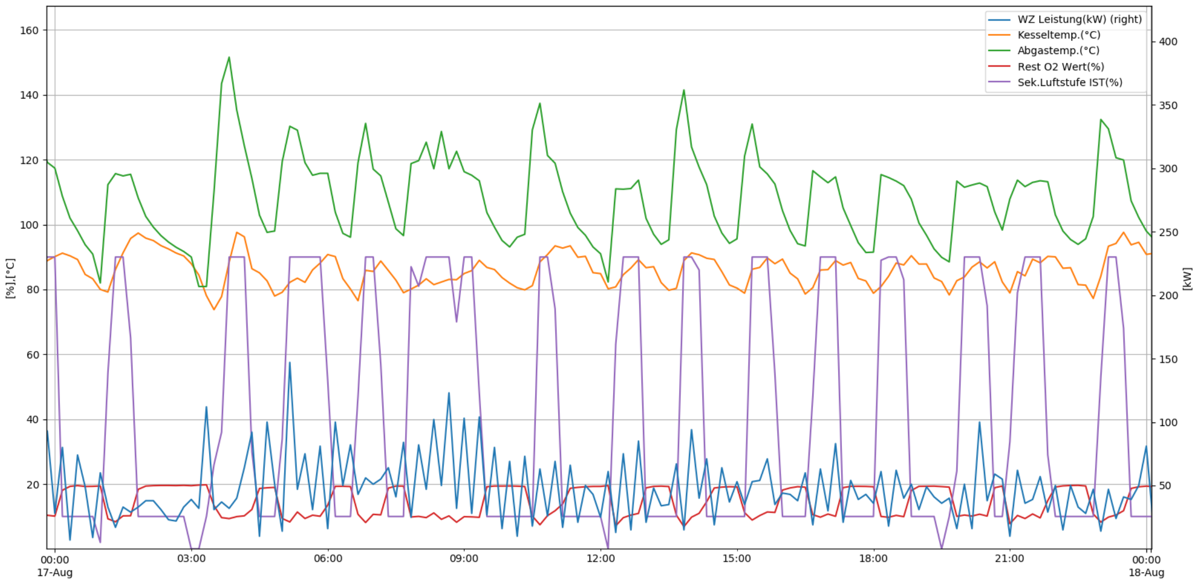

Figure 5. Various operating parameters of boiler 1 on a typical day in period 1

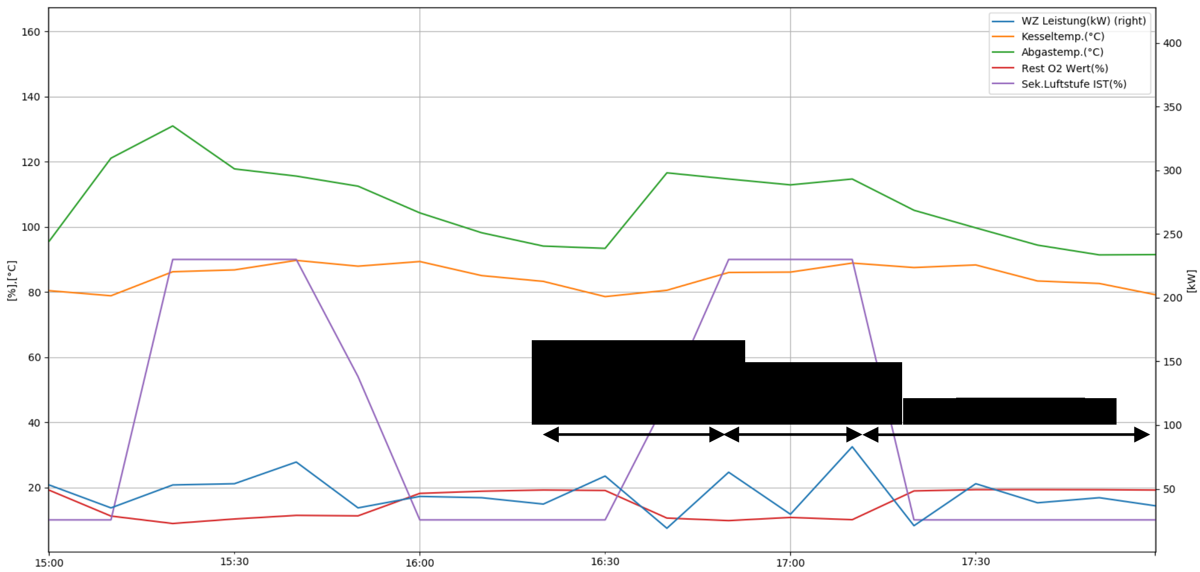

Figure 6. Various operating parameters of boiler 1 for one cycle on one day in period 1 (08/17/2019, 3:00 p.m. to 6:00 p.m.).

This cyclical operation leads to the following disadvantageous operating conditions of the boiler system:

- Reduced efficiency in start-up and burn-out phase;
- Increased CO, NOx, dust and volatile unburned CnHm emissions in the start-up and burn-out phase;

Furthermore, especially in the summer months, due to the missing central heat storage and the low heat demand, the heating network is used as a thermal buffer to absorb the thermal energy of the boilers especially in the burnout phase. Thus, the heating network is operated at elevated temperatures, combined with increased heat losses.

Period 2 (from the beginning of October to the middle of November, and from the beginning of April to the end of May):

As can be seen from Figure 4, the large boiler (Boiler 2 of 540 kW) is already in operation at the beginning of October, although the average power of the local heating network is below the 300 kW nominal heat output of Boiler 1. Just single load peaks above 300 kW (see Figure 7[2] and Figure 8) occur and most of the measured power values are below 300 kW. With a storage, these peak loads could be covered (peak shaving) and the heat supply could be ensured until Mid-November with the smaller boiler. However, since there is no storage, boiler 2 must go into operation due to the power peaks and is therefore operated in a disadvantageous partial-load range due to the low power requirement of the network, analogous to boiler 1 in period 1 (see above).

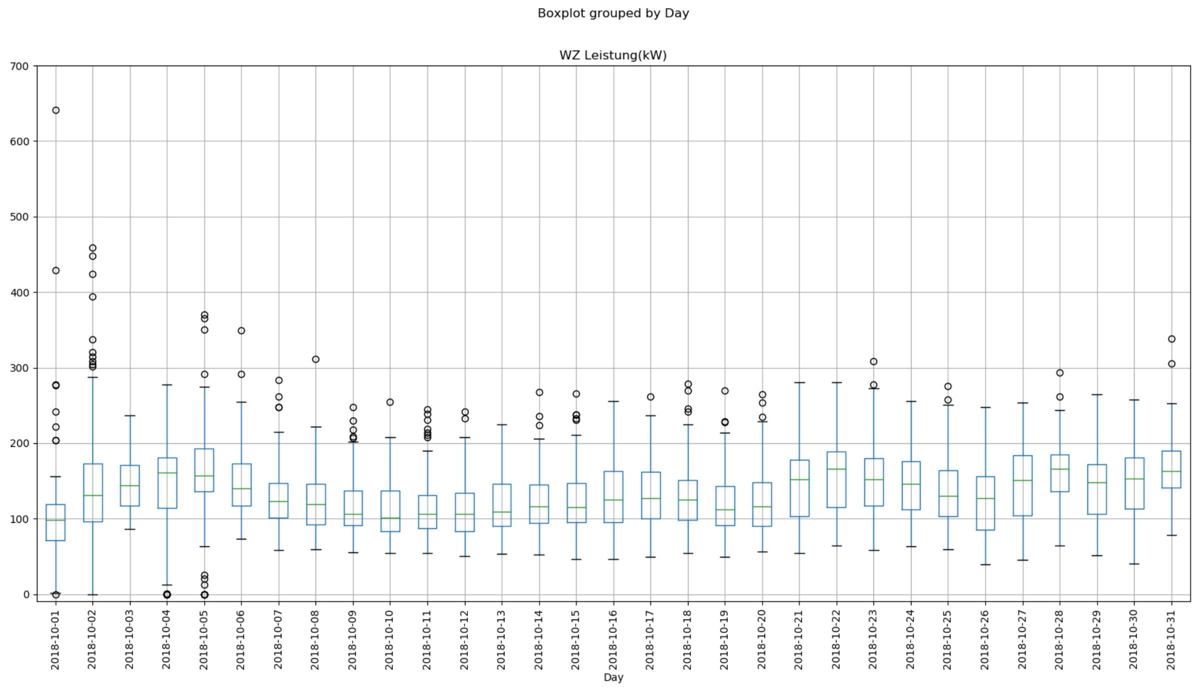

Figure 7. Snapshot of the load of the local heating network in October 2018. Circles: outliers, top whisker: 1.5 * interquartile range (IQR) from box, box top: upper quartile, box middle: median, box bottom: lower quartile, bottom whisker: 1.5 * IQR from box

Period 3 (from the middle of November to the end of March):

As can be seen from Figure 4, in addition to the large boiler, during the winter, the small boiler also operates to cover individual peak loads in the range of 500 kW (See Figure 9). Therefore, boiler 1 is again operated in the disadvantageous partial-load range.

In Figure 10 the comparison of the produced heat, the sold heat and the use of biomass of the periodes 2017/2018 and 2018/2019 can be found. Additonally, Figure 11 shows the heat production (dark blue) and the heat losts (light blue) since 2006/2007.

[2] This box corresponds to the area in which the middle 50% of the data is located. It is therefore limited by the upper and lower quartiles, and the length of the box corresponds to the interquartile range (IQR). This is a measure of the dispersion of the data, which is determined by the difference between the upper and lower quartiles. Furthermore, the median is drawn as a continuous line in the box. This line divides the entire chart into two areas, each containing 50% of the data. Its position within the box thus gives an impression of the skewness of the distribution underlying the data. If the median is in the left part of the box, the distribution is skewed to the right, and vice versa.

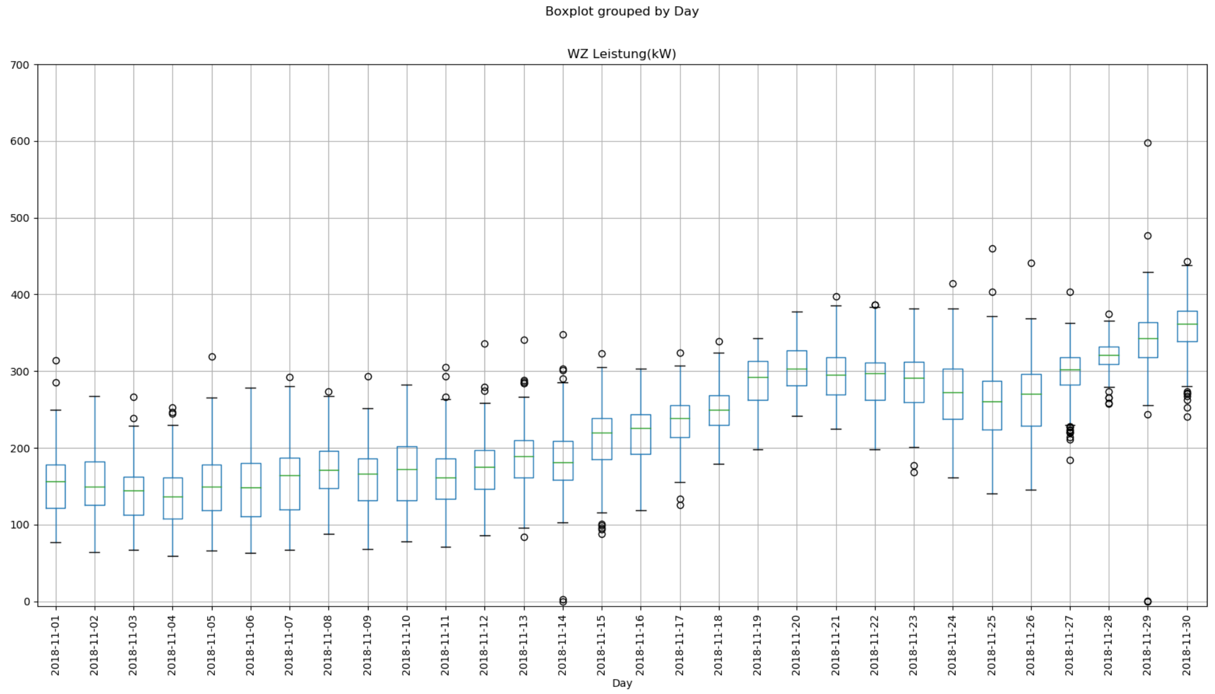

Figure 8. Snapshot of the the load of the local heating network in November 2018. Circles: outlier, upper whisker: 1.5 * IQR of box, box top: upper quartile, box middle: median, box bottom: lower quartile, lower whisker: 1.5 * IQR of box

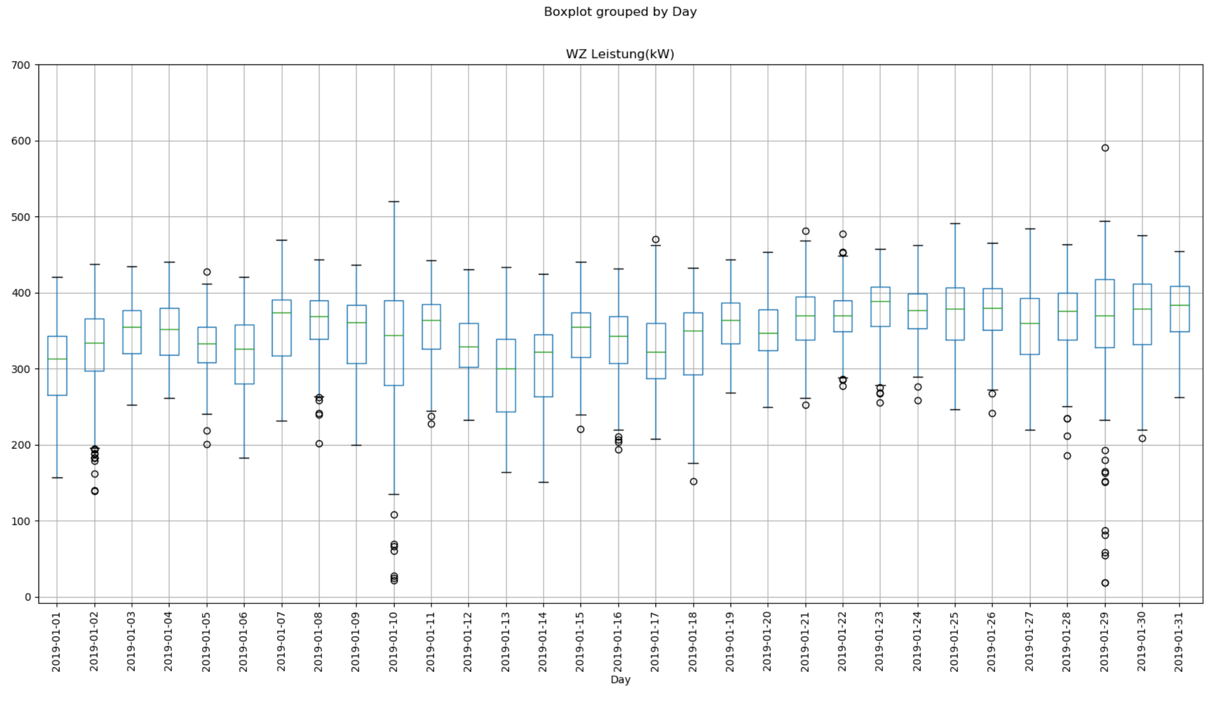

Figure 9. Snapshot of the load of the local heating network in January 2019. Circles: outlier, upper whisker: 1.5 * IQR of box, box top: upper quartile, box middle: median, box bottom: lower quartile, lower whisker: 1.5 * IQR of box#

heatproduction

	Balance 2018/2019	Balance 2017/2018
Weizberg produced heat	1458,00 MWh	1481,00 MWh
Sold Heat	1429 MWh	1457 MWh
Use of biomass	1930,0 srm – 406,67 atr.to – 26,8% humidity	1896,3 srm – 417,68 atr.to – 22,8% humiditiy

Figure 10. Heat production, sold heat and use of biomass

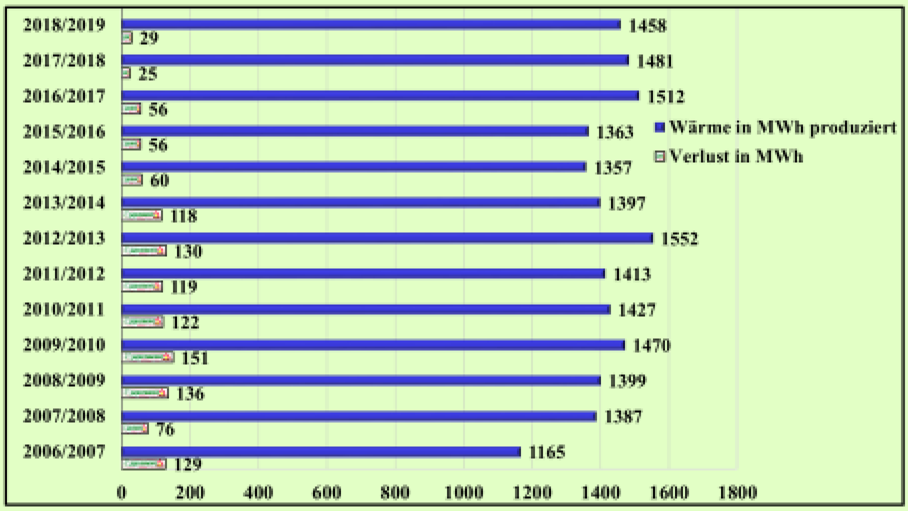

Figure 11. Heat production in MWh

3. CONSTRAINTS AND REFERENCE STANDARDS

3.1. Technical standards

At the national level in Austria there are no specific standards for thermal storages.

Only for the method for calculation the power and the storage volume required for the dimensioning of systems for DHW heating is the ÖNORM EN 12831-3: 2018 01 15

Summary:

This European Standard describes a method for calculating the power and the storage volume required for the dimensioning of systems for DHW heating. The applicability ranges from direct drinking water heaters (no storage volume and a comparatively large effective heat output) to larger storage systems with a comparatively low heat output and large storage volumes). This European Standard applies to the following storage systems for drinking water: (1) Storage systems that are characterized by a minimal mixing range (such as stratified drawer drinking water storage or drinking water storage with external heat exchangers). These systems are referred to in this standard as "storage loading systems"; (2) DHW cylinders and hot water cylinders with a pronounced mixing area (such as domestic hot water cylinders with internal heat exchangers) are referred to in this standard as "mixed cylinder systems"; and for other purposes. The scope of application also includes standardization procedures for determining the energy requirements for DHW heating. This standard deals with the need for heated drinking water in buildings. The calculation of the energy requirement for systems for drinking water heating applies to residential and non-residential buildings, another building or for an area of a building. The relative position of this standard within the EPB standard package in the context of the modular structure is set out in EN ISO 52000-1.

3.2. Building, monument and heritage protection regulation

The area of the heating plant (Gst. Nr. 1185/1, KG 68266 Weiz, EZ 2153) in the historical city centre of Weizberg is located in a protected area according to the zoning plan (see Figure 2). In Austria, the protection of historic sites and monuments in historic urban centres or other districts is subject to the Building[3] and Regional Planning Act[4] of the Länder and the Austrian Monument Protection Act[5]. In this context, the preservation of the local image and of historical monuments in the respective local image protection zones[6] is monitored by a local image expert, in the context of building permits. Structural changes in protected areas therefore require a building permit including a positive assessment of the protected area.

The planned extension for the accommodation of a heat storage tank, a machine room, a switch room, a retaining wall as well as the associated changes in the terrain on the southwest side of the boiler house, behind the laying-out hall, thus directly influence the existing townscape. Therefore, the following requirements have to be fulfilled by special structural measures due to the approval situation (see Figure 12):

- The aim should be to implement the building, mostly underground, below ground level;
- Utilization of existing buildings to cover the extension and associated restrictions regarding the dimensions of the extension;

[3] https://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=LrStmk&Gesetzesnummer=20000070

[4] https://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=LrStmk&Gesetzesnummer=20000069

[5] https://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=Bundesnormen&Gesetzesnummer=10009184

[6] http://www.umwelt.steiermark.at/cms/beitrag/10025584/686638/

- Specially adapted design of the visible facades with regard to colour and geometry while complying with the requirements for weather resistance;
- Minimally invasive integration, in order not to influence existing natural conditions such as trees and bushes.

The innovative structural integration of the storage facility in the historic urban centre, which is protected as a landscape protection zone, is intended to meet all these requirements and to ensure that the extension blends in unobtrusively with the overall view and does not have any negative effects on the landscape.

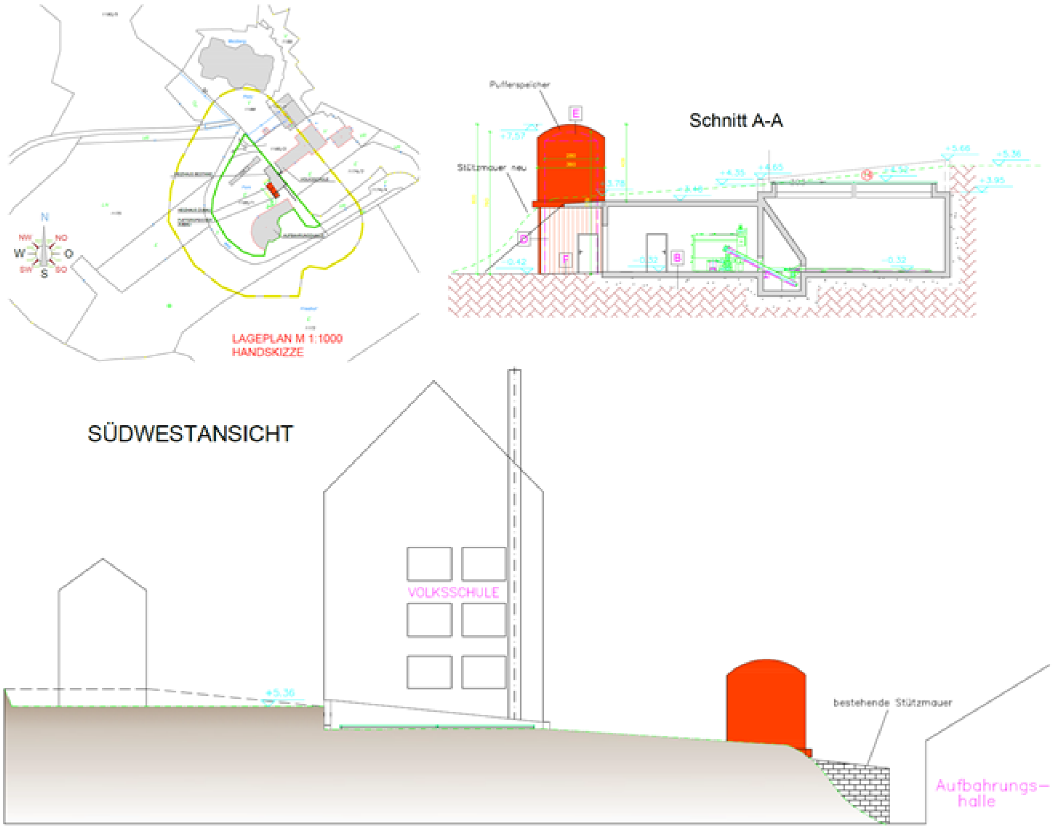

Figure 12. Draft plans of the implementation of the storage

In order to enable the implementation of the new control system with a coherent load management through mutual communication of all system components (boiler system, storage tank, network and decentralised storage tanks at the consumers), access to the control system of the decentralised hot water storage tanks at the consumers premises (see Table 2) is necessary. This agreement has already been reached with the corresponding consumers by extending the heat supply contract and the maintenance agreement.

4. STORAGE DESCRIPTION AND REQUIREMENTS

4.1. Product technical specifications

4.1.1. Storage technical requirements

Figure 13 shows a pre-selection and the feasibility of possible storage solutions for the biomass heating plant Weizberg[7,8]. The considered storage solutions were subdivided into sensible, latent and thermochemical thermal energy storages (TES). Technologies that are not feasible, including the reasoning, can be found in red in the figure. The analysis of possible storage variants showed that additionally to the conventional water tank storages, two more storage variants are conceivable for the project in question. On the one hand a hybrid storage consisting of macro-encapsulated PCM (phase change material) and water as storage medium combined in a conventional steel tank and on the other hand a vacuum-super isolated water tank.

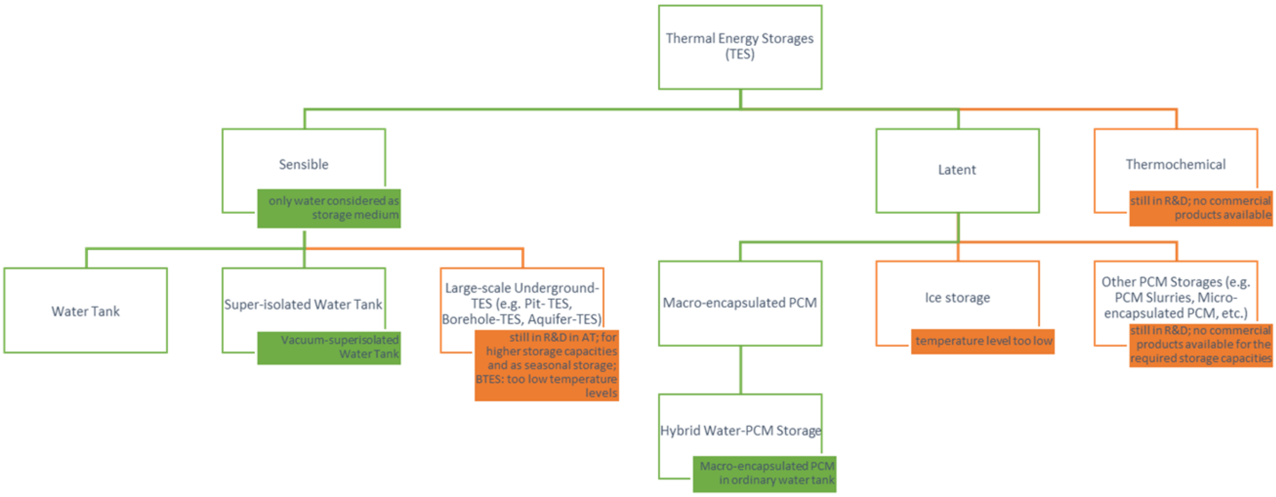

Figure 13. Storage possibilities for the biomass heating plant Weizberg. Red: Not-feasible. Green: Feasible

Vacuum super-isolated water tanks can store energy more efficiently (lower heat losses – heat conduction 4 to 10 times lower) compared to conventionally insulated water tanks[9,10]. Thus, they can be used as long-term storages (weekly or monthly). However, the heating plant in Weizberg is operated with biomass boilers as the only heat source. There is no other available volatile RES (e.g. solar thermal), which would require long-term storage. Therefore, there is no need for long-term storage. Furthermore, a vacuum super-isolated water tank with a storage volume of 38 m³ would cause additional investment costs of +25 % compared to a conventional water tank[11].

The hybrid storage with macro-encapsulated PCM has the advantage that the needed volume for the storage, because of the higher energy density, could be decreased. A reduced space requirement of the storage would be advantageous for the integration in a HUC. However, the additional costs of +92.5 % for a volume saving of 5 m³ compared to a conventional 40 m³ water tank are not economically feasible.

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[7] EASE, EERA, EUROPEAN ENERGY STORAGE TECHNOLOGY DEVELOPMENT ROADMAP, 2017. https://eera-es.eu/wp-content/uploads/2016/03/EASE-EERA-Storage-Technology-Development-Roadmap-2017-HR.pdf (accessed April 1, 2019).

[8] M. Sterner, I. Stadler, eds., Energiespeicher - Bedarf, Technologien, Integration, 2., korrigierte und ergänzte Auflage, Springer Vieweg, Wiesbaden, 2017.

T. Beikircher, Superisolierter Heißwasser-Langzeitwärmespeicher - Abschlussbericht, Technische Informationsbibliothek u. Universitätsbibliothek, 2013. doi:10.2314/gbv:749701188.

[9] T. Beikircher, Vakuumsuperisolation (VSI): Stand der Forschung und Entwicklung zu höchsteffizienter Dämmung und Wärmespeicherung im Gebäudebereich sowie in der energieeffizienten Industrie, (2017). https://www.hs-karlsruhe.de/fileadmin/hska/EIT/Aktuelles/seminar_erneurbare_energien/Sommer_2017/Folien/29032017VSIBeikircher.pdf (accessed July 22, 2019).

[10] M. Rottmann, Isolierung von Hochtemperatur-Wärmespeichern, (2019).

[11] T. Beikircher, Superisolierter Heißwasser-Langzeitwärmespeicher - Abschlussbericht, Technische Informationsbibliothek u. Universitätsbibliothek, 2013. doi:10.2314/gbv:749701188.

From the technical and economic considerations mentioned above it emerges that under these conditions the implementation of a conventional water tank can be considered as the most promising solution.

Water tank storages are a mature and cost-efficient technology. Therefore, they are widely used in the residential and district heating sector. Water tank storages could be seen as state-of-the-art for storing thermal energy.

4.1.2. Configuration and relation of the storage with the grid and RES production plant

Within the framework of this project, an extension to the existing boiler house (see Figure 14) to accommodate a heat storage tank, an engine room, a control room, a retaining wall and the associated changes to the terrain are to be carried out first. Furthermore, a water buffer storage tank with a storage volume of approx. 38 m^3 is to be installed (see Figure 15). All of these measures are to be carried out in compliance with the legal situation (see Section 3.2) in accordance with the conditions under monument and site protection law. As initial planning approaches show, these requirements could be met by a dome-shaped construction of the upper part, which only partially protrudes above the ground level, and by an "inconspicuous" façade adapted to the surroundings (see Figure 12). In addition to the storage tank, the additionally required peripheral components such as piping, expansion system, network pump and heat meter are newly installed.

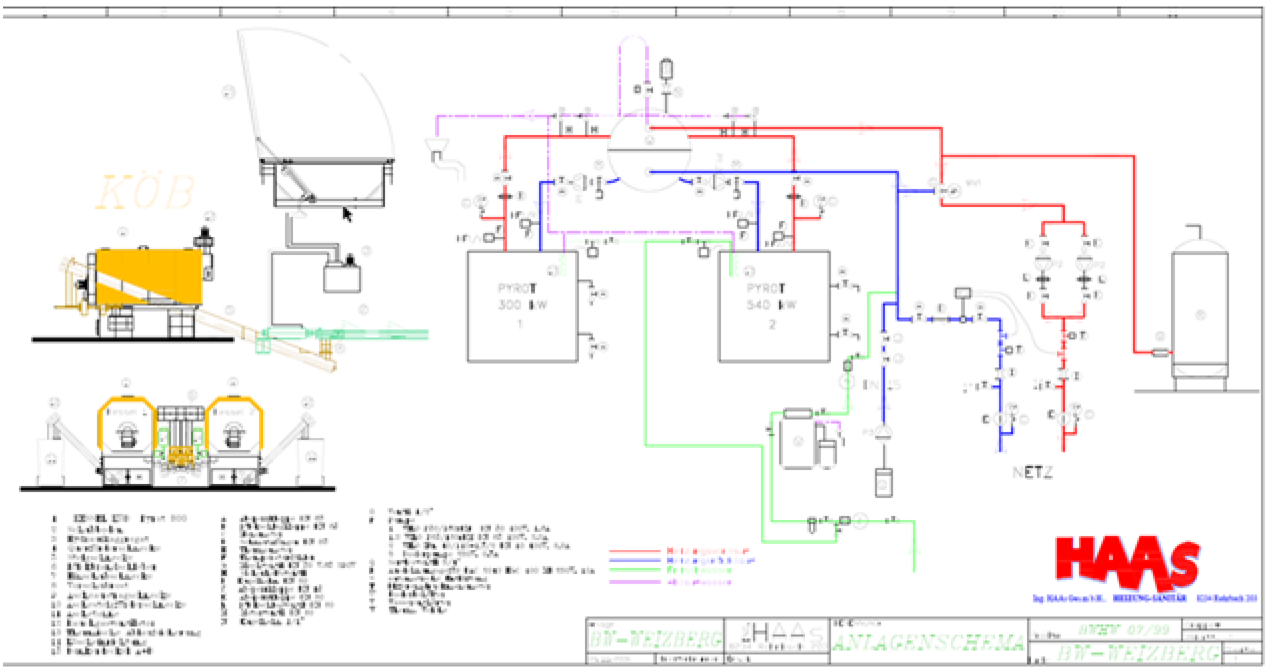

Figure 14. Actual hydraulic plan

Furthermore, a new control system with a coherent load management of all system components (boiler system, central storage tank, network and decentralised storage tanks at the consumers) by means of mutual communication, including access to the control of the decentralised storage tanks at the consumers (see Table 2), will be implemented.

In addition, a new visualisation of the control system and data recording according to "quality management heating plant" will be installed. The required peripheral components such as piping, expansion system, grid pump, heat meter and control/EMS system with visualisation and data recording will be newly installed or renewed, respectively. The newly implemented storage in accordance with the newly implemented control and EMS system will raise the flexibility of the local heating grid. This enables two new essential operating modes:

- Load balance: The boiler plant can be operated at an advantageous higher base load range instead of continuously at a low fluctuating partial load.

- Peak-load covering: Individual load peaks, especially in autumn and spring, can be covered by the storage. Therefore, the start-up of an additional boiler, operating at low loads, can be avoided.

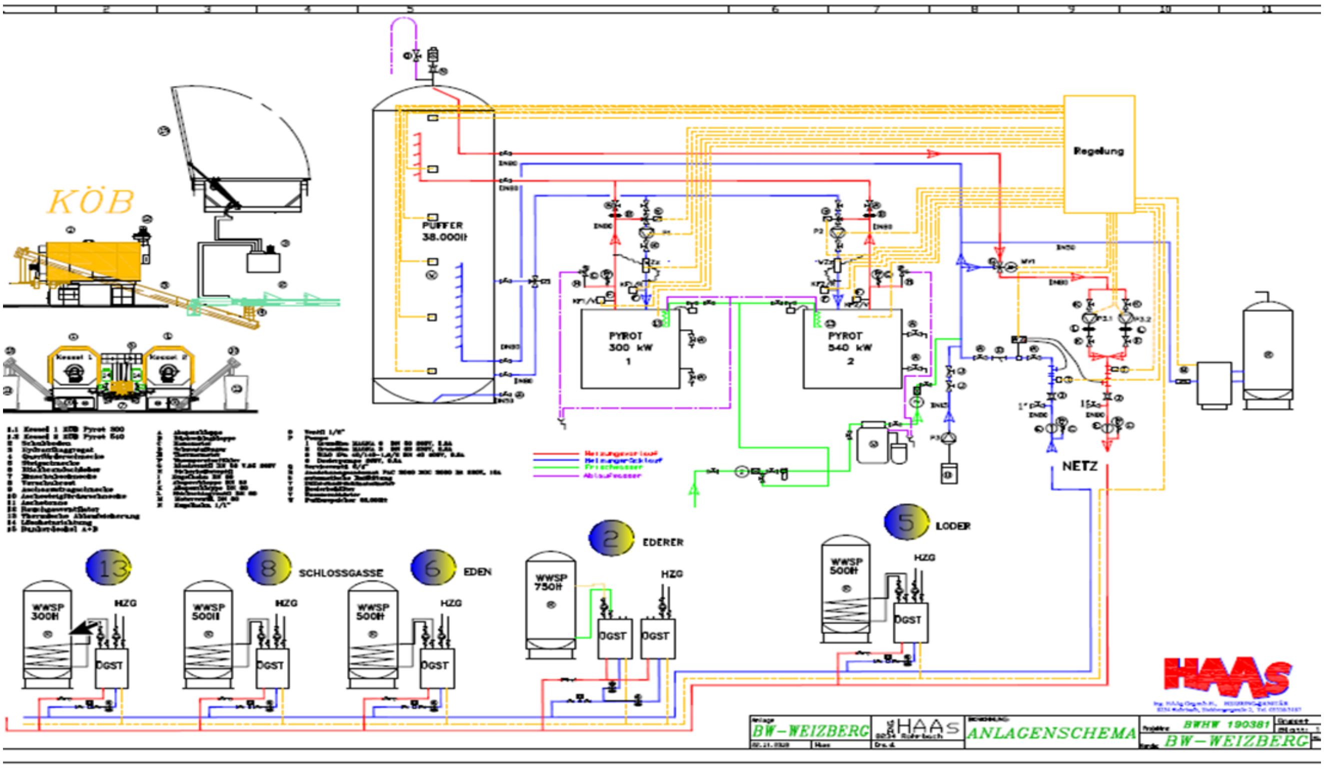

Figure 15. New hydraulic plan for storage implementation

The regulation of the district heating network and the storage will be (predicted, not finally decided) most probably the MR 12 by the company Schneid (see Figure 16). The control unit MR-12 will be used as a district heating, district cooling and heating controller. The modular structure enables simple and quick adaptation to the conditions of the system to be controlled. An expansion to seven regulated heating circuits in the PLC version is possible at any time. Optionally, a hot water tank, buffer, solar system, circulation pump, boiler with return flow increase or boiler release can also be implemented. Depending on the configuration, there are numerous possible applications. This versatility distinguishes the MR-12 control unit[12].

Figure 16. Regulation device from the company Schneid

[12] Schneid Gesellschaft m.b.H. (2020): MR12 Basismodulregler mit AKP; https://schneid.at/product/mr12-basismodulregler-mit-akp/; last access 10.03.2020

4.2. Performance requirements

The aim is the integration of a central heat storage unit in the heating plant of the local heating network in the district of Weizberg, which is protected as a historical monument and a protected site, as well as the implementation of a new control system with a coherent load management of all plant components (boiler units, central storage unit, network and decentralised storage units at the consumers) by means of their mutual communication. This fully integrated, intelligent load management of all plant components in interaction with the central and decentralised heat storage facilities enables the disadvantageous cyclical operation of the boiler plant to be minimised and prevents the local heating network from being used as a thermal buffer. These measures increase the flexibility and energy efficiency of the entire biomass heating plant.

In detail, the following improved operating modes for the different periods of the operating year compared to the actual situation are only made possible by the new load management in interaction with the heat storage facilities (centralised and decentralised):

Period 1 (from the beginning of June to the end of September):

Boiler 1 charges the storage tank once a day in the advantageous higher full load range instead of always in low partial/low load and is then taken out of service. The rest of the daily demand is covered by the storage tank. For the target storage size of 38 m^3, the maximum storage capacity[13] is around 1327 kWh. The coverage of the energy consumption of the grid in period 1 as shown in Figure 17 can be ensured with this operating mode.

The integration of the new load management in interaction with the heat storage tanks (centralised and decentralised) ensures that boiler 1 can be operated continuously in the advantageous higher load range and still prevent the use of the grid as a thermal buffer. Excess heat from the boiler system (especially in the burnout phase) is temporarily stored in the central heat storage tank so that it can then be distributed to the consumers as required by communicating with the decentralized storage tanks (see Table 2) without increased distribution losses. In detail, the new load management and full access to the control of the decentralised DHW cylinders of the consumers enables the following operating mode in the summer months.

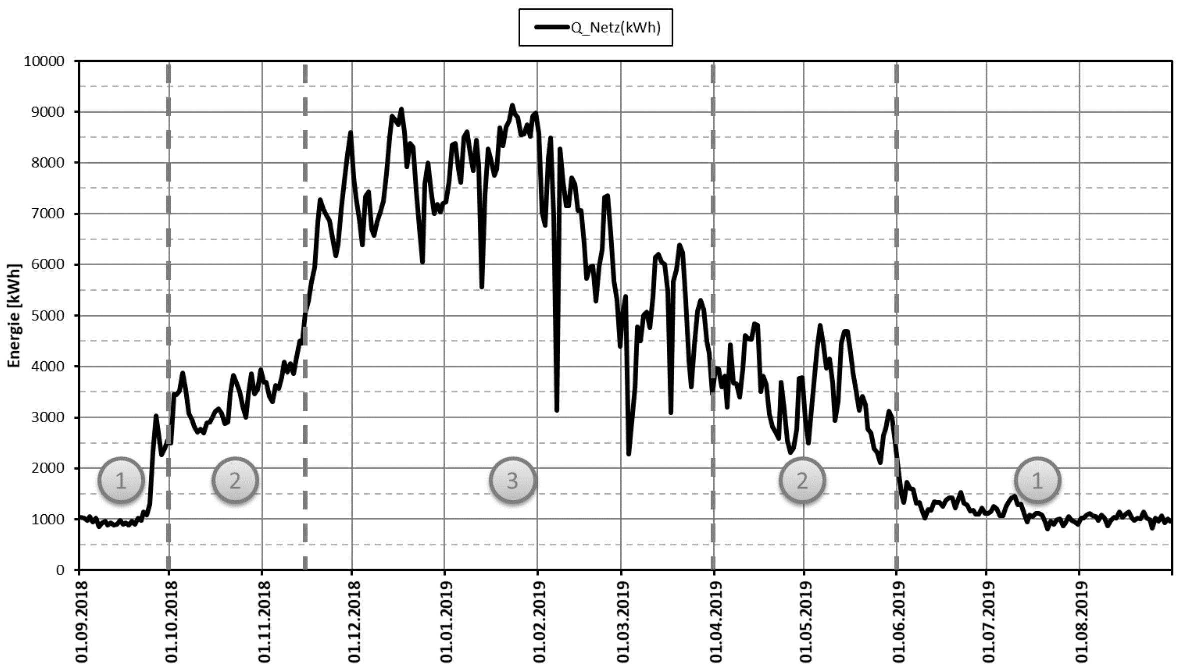

Figure 17. Daily values of the energy supplied to the grid.

[13] 1,164 [kWh/(m^3K)] x 38 [m^3] x 30 [K] = 1327 [kWh]

During the summer months, the heating grid should only be operated when the consumers require hot water and after communication with the decentralized hot water storage tanks. During the rest of the time, the heating network should be operated with reduced temperatures and flow rates. This should reduce distribution losses on the one hand and save pump energy on the other. With an assumed maximum loading capacity of the decentralised hot water storage tanks of 550 kW (10.5 m^3/h) [14] and an average daily demand of 1100 kWh (see Figure 17), the heating network would therefore only have to be operated at full load for two hours per day[15]. The remaining time the heating network is operated with flow temperatures of 45°C, at a reduced volume flow of 0.8 m^3/h[16].

Period 2 (from the beginning of October to the middle of November, and from the beginnng of April to the end of May):

Boiler 1, instead of boiler 2 in the disadvantageous partial/low load range, is operated continuously in the advantageous higher load range and the occurring individual load peaks (see Figure 8) in this period are covered by the storage tank. In this way, peak loads of 400 kW, for example, can be covered by the storage tank for a period of about 3.3 h and the heat supply can be ensured[17].

The integration of the new load management in interaction with the heat storage tanks (central and decentralised) ensures that boiler 1 can be operated continuously in the advantageous higher load range and still prevent the use of the grid as a thermal buffer. Excess heat from the boiler system (especially in the burnout phase) is temporarily stored in the central heat storage tank so that it can then be distributed to the consumers as required by communicating with the decentralised storage tanks without increased distribution losses.

Period 3 (from the middle of November to the end of March):

Boiler 2 is operated continuously in the advantageous higher load range and the occurring individual load peaks (see Figure 10) in this period are covered by the storage tank and a connection of boiler 1 in the disadvantageous partial/low load range is no longer necessary. The storage tank can, for example, cover power peaks of 600 kW for a period of about 2.2 h and ensure the heat supply[18].

The integration of the new load management in interaction with the heat storage tanks (central and decentralised) ensures that boiler 2 can be operated continuously in the advantageous higher load range and still prevents the use of the grid as a thermal buffer. Excess heat from the boiler system (especially in the burnout phase) is temporarily stored in the central heat storage tank so that it can then be distributed to the consumers as required by communicating with the decentralised storage tanks without increased distribution losses.

The integration of the new load management system and the central heat storage tank has the following positive effects:

- Use of the heating network as a thermal buffer is avoided → lower heat losses (distribution losses), surplus heat from the boiler plant is used optimally;
- Operation of the heating network during the summer months only at certain times when hot water is required and after communication with the decentralised storage facilities at the consumers → Lower heat losses (distribution losses) and savings of pump energy;
- Generally, more dynamic operation of the local heating network possible → Consumers can be served more quickly with the required temperatures without the inertia of the boiler plant;

[14] 1,164 [kWh/(m^3K)] x 38 [m^3] x 30 [K] = 1327 [kWh]

[15] 1100 [kWh] / 550 [kW] = 2 [h]

[16] To avoid damage to the district heating pipeline due to thermal expansion, the network cannot be completely shut down. Therefore, the network must be operated with a minimum volume flow.

[17] 1,164 [kWh/(m^3K)] x 38 [m^3] x 30 [K] / 400 [kW] = 3,3 [h]

[18] 1,164 [kWh/(m^3K)] x 38 [m^3] x 30 [K] / 600 [kW] = 2,2 [h]

Furthermore, the planned measures by load balancing and peak load coverage will prevent or reduce the disadvantageous partial/low-load operation of the boiler plant and thus achieve the following positive effects:

- Increase of the efficiency of the fuel boilers → Saving of primary energy (fuel savings) → CO2 savings through lower energy expenditure for the provision of the wood chips (production, transport, etc.);
- Lower emissions of pollutants (carbon monoxide (CO), dust, NOx and volatile organic carbon compounds (CnHm));
- Increase of the service life of the plant components → Significant saving of ecological resources, which would result from an early complete renewal of the boiler plant;
- Increase of sweeping intervals (more time windows are available due to the on/off operation of the boiler plant) → Increase of efficiency, reduction of pollutant emissions;
- Extension of maintenance intervals → lower maintenance costs.

4.3. Minimum project targets

By referring to the accomplished deliverable DT1.2.3 Feasibility study for implementing energy storages in Weiz (AT) with the following citation: “The biomass heating plant Weizberg already offers a heat supply with the CO2 neutral and 100% renewable energy source wood, but the plant is currently inefficient due to a lack of a thermal energy storage. Thus, at present more wood is burned than necessary and the locally limited surface consumption is substantially higher than necessary…”. In addition, a related new Energy Management System allows a higher control of the overall DH. The following investigation results are commenting the other key performance indicators (KPIs) defined in the already completed deliverable D.T2.1.1 Urban Key Performance Indicators:

The Key Performance Indicators have been developed to evaluate and monitor the effectiveness of pilot actions, assessing technical, economic and environmental aspects. A set of them has been identified giving to STORE4HUC PPs a consolidated tool for monitoring the successfulness of the pilots and to evaluate the potential impacts and benefits of their replicability in historical urban centres.

For each KPI a description sheet has been defined. These sheets contain a short introduction to the KPI, the field of applicability and the definition of the calculation method. Each monitored indicator (KPI) must be evaluated at different stages of the HUC pilot actions, according to the contents and timeline included in D.T2.2.1 (template for HUC action report).

4.3.1. KEY PERFORMANCE INDICATORS (KPIs)

This paragraph reports on the KPIs identified to evaluate the impacts of the pilot actions on different aspects and benefits foreseen by the implementation of energy storages in HUCs.
KPIs are classified in 2 different categories:

- **Pilot specific KPIs**, specifically aimed to measure the performance and evaluate the results of the storage investment and the direct benefits of its application, coupled with a suitable control algorithm for their energy management. Each PP must identify its pilot specific KPIs, depending on the features of its pilot investment
- **Urban KPIs**, identified to measure or evaluate the benefits of the pilot action at urban level or other intermediate levels (for example: municipal properties). All PPs are required to monitor these common urban KPIs.

In order to understand the meaning of the implemented indicators, a short introduction to the definition of the parameters referred to energy consumption is necessary.

In the following indicators these parameters have been defined:

- $E_{c,i}$: i-th thermal/electrical energy consumption of the pilot system, supplied by external source for one year [kWh]
- $E_{c,tot} = \sum E_{c,i}$: total thermal/electrical energy consumption of the pilot system, supplied by external sources for one year [kWh]
- $E_{self\text{-}RES,i}$: i-th consumed energy from self-production of local RES system in a year [kWh]
- $E_{self\text{-}RES} = \sum E_{self\text{-}RES,i}$: total consumed energy from self-production of local RES systems in a year [kWh]
- $E_{TOT} = E_{c,tot} + E_{self\text{-}RES}$: total thermal/electrical energy consumption of the pilot system for one year [kWh]

Moreover, to evaluate these indicators and compare the calculated values during the reporting period, a fixed set of conditions is defined in order to adjust the calculated values from their actual conditions to the common fixed set of conditions.

The adjustment terms are defined from identifiable physical facts about the energy governing characteristics of equipment/system. Two types of adjustments are possible:

- Routine Adjustments – for any energy-governing factors, expected to change routinely during the period of calculation of the indicator, such as weather conditions, annual lift runs, hours of utilisation of the system.
- Non-Routine Adjustment - for those energy-governing factors which are not usually expected to change, such as the facility size, the heated volume or the use of the system.

Table 4. Complete list of KPIs

Indicator	Category	Description	Measurement Unit
KPI_1: External energy needs of the pilot system	Pilot specific KPI	Energy consumption supplied by external sources	[kWh]
KPI_2: External energy cost of the pilot system	Pilot specific KPI	Cost of the energy supplied by external sources	[€]
KPI_3: Average yearly CO_2 abatement	Pilot specific / Urban KPI	CO_2 emissions	[t CO_2]
KPI_4: Autarky rate	Pilot specific / Urban KPI	Energy self-sufficiency	[%]
KPI_5: Use of energy from RES	Pilot specific / Urban KPI	RES self-consumed energy, associated to storage	[kWh]
KPI_6: Security of energy supply	Pilot specific KPI	Hours without service interruptions/discomforts	[-]
KPI_7: Power peak	Pilot specific KPI	Average power peak	[kW]
KPI_8: Profitability	Pilot specific KPI	Net Present Value / Investment	[-]
KPI_9: Stimulation of the local economy	Urban KPI	New jobs created calculated through estimation of investment and replicability potential	[-]

KPI1: External energy needs of the pilot system

Applicability for objects of assessment

Pilot specific KPI	Yes
Urban KPI	No
Thermal energy storage	Yes
Electric energy storage	Yes
RES system	Yes

Description	Energy consumption supplied by external sources
Input parameters & Calculation	Calculation method: 1. Total thermal/electrical energy consumption of the pilot system, supplied by external sources for one year $\mathbf{E_{c,tot}}$ [kWh] 2. Calculation of Key Performance Indicator: $\mathbf{KPI_1 = E_{c,tot}}$
Measurement Unit	[kWh]
References	Efficiency Valuation Organization, *International Performance Measurement and Verification Protocol*, 2017

Status quo:

$\mathbf{KPI_1 = E_{c,tot}}$ = 1,833,500 [kWh]

Background and assumptions:

- Consumed wood chips by heating plant in business year 18/19 (01.07.-30.06.): 1930 [$m^3_{(loose)}$]
- Lower heating value (LHV): 950 [$kWh/m^3_{(loose)}$]
  - Calculated according to [[19]]
- Electrical energy consumption not considered, as electrical energy is only used as auxiliary energy for circulating pumps, for instance, and amounts to only a very small proportion of the total energy consumption.

Target (prediction):

$\mathbf{KPI_1 = E_{c,tot}}$ = 1,726,607 [kWh]

Background and assumptions:

- Predicted savings with planned measures: 5.83 [%]

[19] Working group QM Holzheizwerke, Quality Management Holzheizwerke - Planning Handbook, (2008).

KPI2: External energy cost of the pilot system

Applicability for objects of assessment

Pilot specific KPI	Yes
Urban KPI	No
Thermal energy storage	Yes
Electric energy storage	Yes
RES system	Yes

Description	Cost of the energy supplied by external sources
Input parameters & Calculation	Calculation method: 1. External thermal/electrical energy cost[1] **C_E** [€], as function of yearly energy profile of each external energy source 2. Thermal/electrical energy consumption profile of the pilot system, supplied by external sources for one year **$E_{c,tot}$** [kWh] 3. External thermal/electrical cost of peak power taken from external sources **C_P** [€], which also includes the contracted power delivery with the external source 4. Sequence of peak powers absorbed from the external sources on yearly basis **P_{peak}** [kW] 5. Calculation of Key Performance Indicator: **$KPI_2 = \Sigma [C_E(E_{c,i}) + C_P(P_{peak})]$**
Measurement Unit	[€]
References	-

[1] This cost must include all expenses related to energy purchasing, energy distribution and transportation, energy meter management, system charges and taxes.

Status quo:

$KPI_2 = \Sigma [C_E(E_{c,i}) + C_P(P_{peak})]$ = 51,338 [€]

Background and assumptions:

- The wood chips boilers are the only energy source for the local heating network. Therefore, there is no peak load boiler or similar → **C_P** and **P_{peak}** are zero.
- Consumed wood chips by heating plant in business year 18/19 (01.07.-30.06.): 411 [$t_{(dry\ matter)}$]
  - Conversion factor: 4.7 [$m^3_{(loose)}/t_{(dry\ matter)}$] (with 25% water content)
- Wood chips price in business year 18/19 (01.07.-30.06.): 125 [$€/t_{(dry\ matter)}$] or 26.60 [$€/m^3_{(loose)}$] or 0.028 [€/kWh]
  - constant over the whole year

Target (prediction):

$KPI_2 = \Sigma [C_E(E_{c,i}) + C_P(P_{peak})]$ = 48,345 [€]

Background and assumptions:

- Also, in future there is no peak load boiler or similar planned → $\mathbf{C_P}$ and $\mathbf{P_{peak}}$ are zero.
- Predicted wood chips price: 125 [€/$t_{(dry\ matter)}$] or 0.028 [€/kWh]
    - Represents the wood chips price for the business year 19/20 and according to the heating plant operator the price will stay constant for the next few years.

KPI_3: Yearly CO2 emissions

Applicability for objects of assessment

Pilot specific KPI	Yes
Urban KPI	Yes
Thermal energy storage	Yes
Electric energy storage	Yes
RES system	Yes

Description	CO_2 emissions
Input parameters & Calculation	Calculation method: 1. Total thermal/electrical energy consumption of the pilot system, supplied by external sources for one year $\mathbf{E_{c,tot}}$ [kWh] 2. CO_2 emission factor to be applied to the energy source **EF** [t CO_2/kWh], e.g IPCC emission factors 3. Calculation of Key Performance Indicator: $$\mathbf{KPI_3 = E_{c,tot} \times EF}$$
Measurement Unit	[t CO_2]
References	Covenant of Mayor: http://www.eumayors.eu/IMG/pdf/technical_annex_en.pdf

Status quo:

$\mathbf{KPI_3 = E_{c,tot} \times EF}$ = 29.34 [t CO_2]

Background and assumptions:

- **EF** = $16x10^{-6}$ [t CO_2/kWh]
    - Mean value of the emission factors of [19], [20] und [21], as the emission factors from the literature fluctuate considerably.

Target (prediction):

$\mathbf{KPI_3 = E_{c,tot} \times EF}$ = 27.63 [t CO_2]

[20] Austrian Institute for Building Technology, OIB Guideline 6 - Energy Saving and Thermal Insulation OIB-330.6-009/15, (2015). https://www.oib.or.at/sites/default/files/richtlinie_6_26.03.15.pdf (accessed May 28, 2018).

[21] ÖNORM EN ISO 52000-1, Energy performance of buildings - Specifications for the assessment of energy performance of buildings - Part 1: General framework and methodology, Vienna, 2018.

KPI4: Autarky rate

Applicability for objects of assessment

Pilot specific KPI	Yes
Urban KPI	Yes
Thermal energy storage	Yes
Electric energy storage	Yes
RES system	Yes

Description	Energy self-sufficiency
Input parameters & Calculation	Calculation method: 1. Consumed energy from self-production of local RES system in a year $\mathbf{E_{self\text{-}RES}}$ [kWh] 2. Total thermal/electrical energy consumption of the pilot system for one year $\mathbf{E_{TOT}}$ [kWh] 3. Calculation of Key Performance Indicator: $\mathbf{KPI_4 = [E_{self\text{-}RES}/ E_{TOT}] \times 100\ \%}$
Measurement Unit	[%]
References	Deliverable D.T3.2.4 "Validation report and establishment of the autarky rate tool & the checklist"

Status quo:

$\mathbf{KPI_4 = [E_{self\text{-}RES}/E_{TOT}] \times 100\ \% = 0\ [\%]}$

Background and assumptions:

- **There is no self-production of a local RES system for the heating plant → $E_{self\text{-}RES}$ is zero. The only (external) energy source are wood chips, provided 100% by local farmers → $E_{TOT} = E_{c,tot}$.**

Target (prediction):

$\mathbf{KPI_4 = [E_{self\text{-}RES}/E_{TOT}] \times 100\ \% = 0\ [\%]}$

Background and assumptions:

- Also, in future there is no self-production of a local RES system planned.

KPI5: Use of energy from RES

Applicability for objects of assessment

Pilot specific KPI	Yes
Urban KPI	Yes
Thermal energy storage	Yes
Electric energy storage	Yes
RES system	Yes

Description	Consumed energy from self-production of local RES systems in a year
Input parameters & Calculation	Calculation method: 1. Consumed energy produced by local RES systems in a year $E_{self\text{-}RES}$ [kWh] 2. Calculation of Key Performance Indicator: $KPI_5 = E_{self\text{-}RES}$
Measurement Unit	[kWh]
References	-

Status quo:

$KPI_5 = E_{self\text{-}RES} = 0$ **[kWh]**

Background and assumptions:

- **See KPI_4.**

Target (prediction):

$KPI_5 = E_{self\text{-}RES} = 0$ **[kWh]**

Background and assumptions:

- **See KPI_4.**

KPI6: Security of energy supply

Applicability for objects of assessment

Pilot specific KPI	Yes
Urban KPI	No
Thermal energy storage	Yes
Electric energy storage	Yes
RES system	Yes

Description	Percentage of time without interruptions/discomforts in terms of operation of local energy consumption system without service interruptions/discomforts
Input parameters & Calculation	Calculation method: 1. Number of hours without interruptions/discomforts on yearly basis $\mathbf{N_{no\_interrupt}}$ [h] 2. Total number of hours of local energy consumption systems operation on yearly basis $\mathbf{N_{tot}}$ [h] 3. Calculation of Key Performance Indicator: $\mathbf{KPI_6 = N_{no\_interrupt} / N_{tot} \times 100\ \%}$
Measurement Unit	[%]
References	-

Status quo:

$\mathbf{KPI_6 = N_{no\_interrupt} / N_{tot} \times 100\ \% = 99.23\ [\%]}$

Background and assumptions:

- N_{tot} = 8760 [h]
  - The heating plant is operated the whole year.
- $\mathbf{N_{no\_interrupt}}$ = 8692.17 [h]
  - The $N_{no\_interrupt}$ was derived from the evaluation of monitoring data for one year (reference year: 01.09.2018 – 31.08.2019). It was assumed that a interruption/discomfort or under-temperature occurs when the flow temperature of the network drops below 65 [°C] for at least 100 [min].
  - There were 67.83 [h] with interruptions, of which 12.5 [h] occurred during regular maintenance (sweeping), which were not removed from the calculation because at the same time there were under-temperatures in the network.

Target (prediction):

$\mathbf{KPI_6 = N_{no\_interrupt} / N_{tot} \times 100\ \% = 100\ [\%]}$

Background and assumptions:

- Based on the planned measures and the implementation of the storage, it is assumed that no interruptions/discomforts or under-temperatures of the network will occur in the future.

KPI7: Peak power

Applicability for objects of assessment

Pilot specific KPI	Yes
Urban KPI	No
Thermal energy storage	Yes
Electric energy storage	Yes
RES system	Yes

Description	Average yearly peak power delivered from external energy sources
Input parameters & Calculation	Calculation method: 1. Array of monthly peak powers delivered from external energy sources $\mathbf{P_{peak,month}}$ [kW], where *month* goes from January to December [$P_{peak,January}$, $P_{peak,February}$, … , $P_{peak,December}$] 2. Calculation of Key Performance Indicator: $$KPI_7 = \frac{1}{12} * \sum_{month=January}^{December} P_{peak,month}$$
Measurement Unit	[kW]
References	-

Status quo:

KPI_7 = 476 [kW]

Background and assumptions:

$P_{peak,January}$	591	[kW]
$P_{peak,February}$	551	[kW]
$P_{peak,March}$	646	[kW]
$P_{peak,April}$	481	[kW]
$P_{peak,May}$	639	[kW]
$P_{peak,June}$	336	[kW]
$P_{peak,July}$	218	[kW]
$P_{peak,Augus}$	211	[kW]
$P_{peak,September}$	275	[kW]
$P_{peak,October}$	641	[kW]
$P_{peak,November}$	598	[kW]
$P_{peak,December}$	525	[kW]

- $P_{peak,month}$ for each month are derived from the evaluation of monitoring data for one year (reference year: 01.09.2018 – 31.08.2019).

- Max values of the power provided from the boilers to the network (measured at the heat meter of the network) were taken.

Target (prediction):

KPI_7 = 400 [kW]

Background and assumptions:

- In future, the operating year can be devided into 3 periods and the boilers and heating plant should be operated as follows:
  - Period 1 (June to September): Only boiler 1 (300 kW) is in operation and ensures the heat supply in interaction with the storage.
  - Period 2 (October to mid-November & April & May): Only boiler 1 is in operation and ensures the heat supply in interaction with the storage.
  - Period 3 (mid-November to March): Only boiler 2 (540 kW) is in operation and ensures the heat supply in interaction with the storage.
- Assuming the max power of the boiler in operation leads to following $P_{peak,month}$:

$P_{peak,January}$	540	[kW]
$P_{peak,February}$	540	[kW]
$P_{peak,March}$	540	[kW]
$P_{peak,April}$	300	[kW]
$P_{peak,May}$	300	[kW]
$P_{peak,June}$	300	[kW]
$P_{peak,July}$	300	[kW]
$P_{peak,Augus}$	300	[kW]
$P_{peak,September}$	300	[kW]
$P_{peak,October}$	300	[kW]
$P_{peak,November}$	540	[kW]
$P_{peak,December}$	540	[kW]

KPI8: Profitability

Applicability for objects of assessment

Pilot specific KPI	Yes
Urban KPI	No
Thermal energy storage	Yes
Electric energy storage	Yes
RES system	Yes

Description	Net Present Value / Investment
Input parameters & Calculation	Calculation method: 1. Calculation of Net Present Value: $NPV = -I_0 + \sum_{t=0}^{t} [\frac{R_t}{(1+i)^t}]$ NPV = Net Present Value [€] I_0 = investment [€] R_t = Net cash inflow-outflows during a single period t [€] t = numbers of time periods i = discount rate or return that could be earned in an alternative investment 2. Calculation of Key Performance: **KPI_8 = NPV / I_0**
Measurement Unit	[-]
References	-

Status quo:

Not applicable.

Target (prediction):

KPI_8 = NPV / I_0 = 2.66 [-]

Background and assumptions:

- I_0 = 292,402.53 [€]
  - Estimated costs of planned measures on the basis of the offers obtained from vendors.
- R_t = 77,220.72 [€]
  - Difference between net cash inflow (revenue from sold heat) and net cash outflow (expenditures for fuel, operation and maintenance)
  - assumed to be constant over the entire period
- t = 15 [a]

    - the number of time periods is assumed to be 15 years according to the technical life of the thermal pilot (defined in KPI_9)
- i = 3 [%]
    - Assumption
- NPV = 778,266.88 [€]
    - Net Present Value after t time periods

KPI9: Stimulation of the local economy

Applicability for objects of assessment

Pilot specific KPI	-
Urban KPI	X
Thermal energy storage	X
Electric energy storage	X
Only energy storage integrated by RES system	X

Description	New jobs created calculated through valuation of investment and its maintenance and operational costs
Input parameters & Calculation	Calculation method: 1. Total cumulated expense of the storage installed, calculated as the Investment (*CAPEX* [€]) + associated Operation&Maintainance costs ($OPEX$ [€], evaluated on the system technical life: 20 years for electric pilot and 15 years for thermal pilot) 2. Constant K [€], equal to 200.000 €, that represents an empirical factor calculated as the ratio between a generic Company turnover and the number of company employees 3. *r*, equal to the number of the same storage solutions potentially installed in the district/region, considering a mid-term perspective of 5 years after the end of the pilot project. At the pre-investment stage consider this parameter equal to 1 4. Calculation of Key Perfomance Indicator: $KPI_9 = (CAPEX+OPEX) * r / K$
Measurement Unit	-
References	-

Status quo:

Not applicable.

Target (prediction):

$KPI_9 = (CAPEX+OPEX) * r / K = 1.50$ **[-]**

Background and assumptions:

- *CAPEX* = 292,402.53 [€]
  - Estimated costs of planned measures on the basis of the offers obtained from vendors
- *OPEX* = 6,906 [€]

- Operational expenses only related to the storage were taken into account for a technical lifetime of 15 years of the thermal pilot.
- Estimated total operational expenses (all costs for the operation of the entire heating plant, not only for the storage, excl. fuel costs) per year: 15,346 [€/a]
- Estimated proportion of operational expenses for storage only (estimate of an expert in this field): 3 [%]

4.3.2. Energy and material balances to show the environmental effect by comparing the situation BEFORE and AFTER project implementation

Efficiency characteristic curve of the boilers

In order to be able to calculate the fuel consumption of the current operating year (01.09.2018 to 01.09.2019) and the future fuel consumption after integration of the storage tank, an efficiency curve was first generated as a function of the load of the boilers. Values from the literature[22,23] were used as a basis. Figure 18 shows the generated efficiency curve as a function of the boiler load. The generated efficiency curve was graphically approximated to the literature values using a power approach of the form:

$$f(x) = a \cdot x^n$$

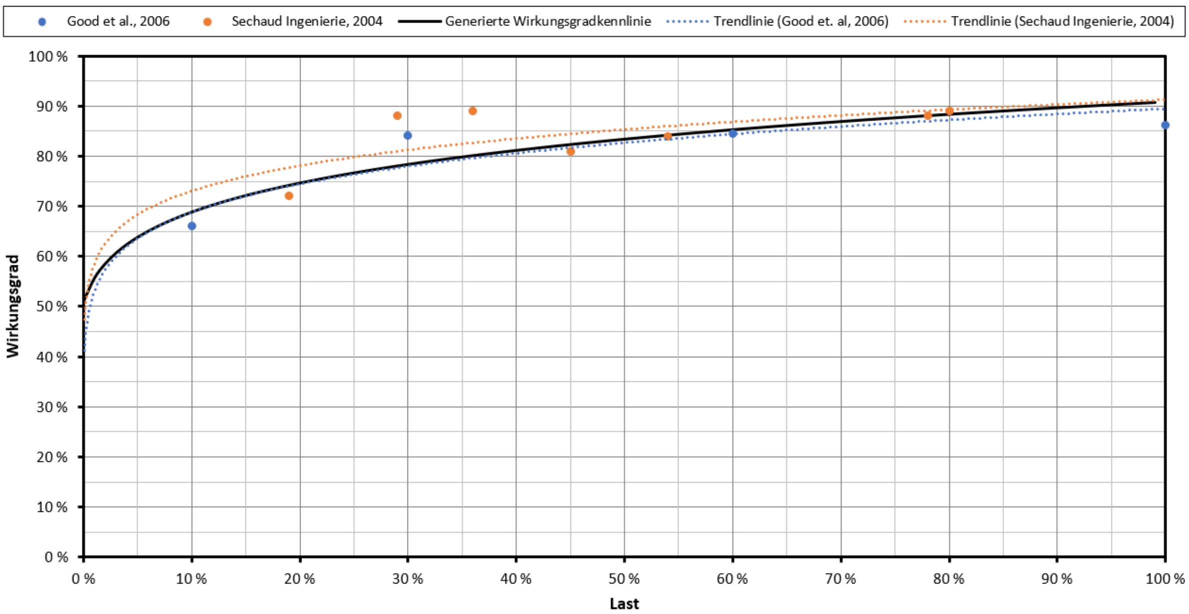

Figure 18 Generated efficiency curve of the boiler from literature values.[22,23]

4.3.2.1. Calculation of the current fuel consumption

The fuel consumption of the current operating year was calculated from the measured performance values of the grid (in 10-minute intervals) on the basis of the generated efficiency curve in relation to the respective current boiler load.

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[22] J. Good, T. Nussbaumer, J. Delcarte, Y. Schenkel, Determination of the Efficiencies of Automatic Biomass Combustion Plants - Evaluation of Different Methods for Efficiency Determination and Comparison of Efficiency and Emissions for Different Operation Modes, 2006.

[23] F. Mermoud, A. Haroutunian, J. Faessler, B. Lachal, Impact of load variations on wood boiler efficiency and emissions:, The current heat losses of the heat network (distribution losses) in the summer months (June to September) were calculated from the measured supply and return temperatures of the network (in 10-minute intervals) and from literature values [3] for the specific heat losses per route metre. The pipe type and the different pipe dimensions (DN) with the respective pipe lengths of the heating network were taken into account. A constant temperature of 10 °C was assumed for the ground temperature. Archives Des SCIENCES. (2015) 12.

4.3.2.2. Calculation of the current distribution losses in the summer months

The current heat losses of the heat network (distribution losses) in the summer months (June to September) were calculated from the measured supply and return temperatures of the network (in 10-minute intervals) and from literature values[19] for the specific heat losses per route metre. The pipe type[24] and the different pipe dimensions (DN) with the respective pipe lengths of the heating network were taken into account. A constant temperature of 10 °C was assumed for the ground temperature.

4.3.2.3. Calculation of the currently required pump energy in the summer months

The currently required pump energy of the heating network in the summer months (June to September) was calculated from the measured volume flows (in 10-minute intervals) and the performance curve of the pump[25] according to the manufacturer's data sheet.

4.3.2.4. Calculation of future fuel consumption and future distribution losses and pump energy in the summer months

The future value was calculated according to the planned mode of operation for the different periods of the operating year using the following calculation approaches

Period 1 (June to September):

Fuel consumption

For this purpose, the fuel consumption was calculated for several typical days in this period, assuming that the boiler charges the storage tank under full load and then switches it off. Afterwards the fuel savings were calculated compared to the actual measured fuel consumption for these days.

The future fuel consumption for the whole period was then calculated from the fuel savings obtained for the typical days and the actually measured output values in 10-minute intervals.

Distribution Losses

The distribution losses were calculated according to the operating mode described in section 4.2. It was assumed that 2 hours per day the heating network is operated at elevated temperatures and the decentralised hot water storage tanks are charged, and the rest of the day (22 hours) the heating network is operated at reduced temperatures and reduced flow rate. The heat losses were then calculated from the assumed temperatures and from the literature values[25] for the specific heat losses per metre of route.

Pump energy

The pump energy was calculated analogous to the distribution losses with the assumed volume flows (see section 4.2) and the performance curve of the pump.

Period 2 (October to mid November, April and May):

Fuel consumption

For the calculations in this period, it was assumed that the small boiler (boiler 1) alone takes over the power requirements of the network. The fuel consumption was therefore calculated at 10-minute intervals from the actual measured power values and the generated efficiency curve as a function of the boiler load.

Period 3 (mid November to March):

Fuel consumption

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[24] Type of pipe installed: Plastic casing pipe in double-pipe design

[25] Installed mains pump: Wilo IPn 40/140-1.5/2

The calculations for period 3 were carried out in the same way as for period 2. However, boiler 2 was used instead of boiler 1.

4.3.2.5. Calculated future energy and pollutant savings

Table 5 shows the results of the calculations described above.

Table 5. Theoretical savings

		Before	Afterwards
Distribution losses (Jun.-Sept.)	[MWh]	19,37	11,54
Savings	[MWh]	7,82	
	[%]	40,40	
Pump energy (Jun.-Sept.)	[kWh]	3 024,58	2950,43
Savings	[kWh]	74,15	
	[%]	2,45	
Amount of biomass used	[MWh]	1 805,67	1 700,31
Savings	[MWh]	105,36	
	[%]	5,83	
Amount of biomass used[26]	[srm*]	1 894,19	1 783,67
savings	[srm*]	110,52	
	[%]	5,83	
Savings of CO_2 equivalent emissions[27,20,21]	[t/a]	1,69	
Saving other pollution (fuel)[28]			
- **CO**	[kg/a]	332,06	
- **NO_x**	[kg/a]	48,74	
- **Staub**	[kg/a]	30,72	
- **C_nH_m**	[kg/a]	67,13	
Reduction of CO2-equivalent emissions (pumpEngy)[29]	[kg/a]	25,80	
Reduction of CO2-equivalent emissions (total)	[t/a]	1,71	
Theoretical CO_2-saving[30]	[t/a]	32,77	

Legend:

*) Cubic metres

[26] Base of calculation : Hu=953,27 kWh/srm (25% atro)

[27] Saved emissions for the provision of the biomass (production, transport, e.g) calculation base: CO_2-equivalent emission factor=16 g/kWh$_{EE(Bst.)}$;

[28] Saved emissions based on the biomass fuel savings; calculation base: CO=3,15 g/kWh$_{EE(Bst.)}$, NO_x=0,46 g/kWh$_{EE(Bst.)}$, dust=0,29 g/kWh$_{EE(Bst.)}$, C_nH_m=0,64 g/kWh$_{EE(Bst.)}$;

[29] Saved emissions due to saved pump energy assessed with general electricity mix of Austria; calculation basis: CO2 equivalent emission factor=348 g/kWhEE;

[30] Is that CO2 saving that would result from the lower fuel consumption if the saved fuel were assessed with the CO2 equivalent emission factor of heating oil, with the assumption that the peak load coverage of the heating plant could not be achieved by a storage facility but by an oil boiler or the biomass saved by this heating plant could replace the fuel of another fossil-fired heating plant. Calculation basis: CO2 equivalent emission factor = 311 g / kWhEE (letter)

4.4. Life cycle costs

It is enabled the collection, aggregation and filtering of the energy data and other information that are provided by a wide range of equipment (such as installed meters) and sources mainly responsible for energy production and consumption. The information gathered is afterwards exported to a service layer for enabling peak load reduction, demand shifting, optimum storage exploitation, and consumption forecasting as well as grid flexibility and reliability. Special concern will be attributed to take advantage of the fact that the scale of related building blocks may allow significant optimizations of the local network with lower CAPEX per end-user as well as for better flexibility. The CAPEX is given in Table 6 below. The maintenance costs OPEX can't be calculated yet as it is depending on robust monitoring data.

Table 6. Investment costs

Costs categories	Costs [€]
Storage	55.633,75
Heating pipes	44.687,49
Regulation	18.961,07
Electrical installation	19.251,60
Emergency heating station and water treatment	15.466,15
Construction costs for boiler room construction according to service specification	116.174,56
Planning and tendering	22.227,90
Total excluding VAT	292.402,53

Additional investments are largely due to the implementation of the storage facility in a historic city centre with protected status and listed buildings and the associated difficult and cost-intensive construction requirements. However, these are to be contrasted with the positive environmental effect achieved for protected historical town centres, which is only made possible by this additional investment.

In terms of energy, the water buffer storage is a proven technology and can be considered the most cost-efficient solution compared to other storage technologies due to the high number of charging cycles (almost daily complete charging and discharging of the storage, see section 4.2). Additional investment enables positive environmental effects for protected historical town centres and storage technology is the most energy-efficient solution, yet.

4.5. Process related specifications

4.5.1. Timeframe

In Table 7 the work plan is shown. It includes management aspects, the realisation of construction work and the implementation of the storage. In addition, dissemination activites are foreseen after the completion of the work.

Table 7. Timetable pilot Weizberg

Workpackages / MMM.JJ	Mar 20	Apr 20	May 20	June 20	July 20	Aug 20	Sep 20	Oct 20	Nov 20	Dec 20	Jan 21	Feb 21
Projectmanagement												
Project start	■											
Project documentation	■	■	■	■	■	■	■	■	■	■	■	■
Projectcontrolling	■	■	■	■	■	■	■	■	■	■	■	■
End of projekt												■
Implementation of the building measurments												
Tenders	■	■	■									
Implementation of building measurs			■	■	■	■	■	■				
Implementation storage												
Preperation and planning		■	■	■								
Implementation storage				■	■	■						
Dissemination												
Articles and newspapers										■		
Workshop with members of biomasse team									■	■	■	
Monitoring												
Ongoing measurements									■	■	■	■

4.5.2. Environmental management

The energy supply of the local heating network Weizberg is currently monovalent, using wood chip biomass boilers. Since biomass is considered CO_2-neutral, the energy supply can be regarded as completely renewable even before the planned measures. If a thermal energy storage unit is integrated into the existing heating plant, this storage unit will therefore also be fed 100% from renewable energy sources in the future. Nevertheless, in the future there will be lower CO_2 emissions due to the lower energy expenditure for the provision of the wood chips, fuel savings due to lower heat losses of the grid (distribution losses) and savings of pump energy. In addition, there are fewer pollutant emissions (especially CO and dust) from the combustion.

The integration of the new load management system and the central heat storage system will have the following positive effects:

- Use of the heat network as a thermal buffer is avoided → lower heat losses (distribution losses), surplus heat from the boiler plant is used optimally
- Operation of the heating network during the summer months only at certain times when hot water is required and after communication with the decentralised storage facilities at the consumers → Lower heat losses (distribution losses) and savings of pump energy
- Generally, more dynamic operation of the local heating network possible → Consumers can be served more quickly with the required temperatures without the inertia of the boiler plant

Furthermore, the planned measures by load balancing and peak load coverage will prevent or reduce the disadvantageous partial/low-load operation of the boiler plant (see section 2.3) and thus achieve the following positive effects

- Increase of the efficiency of the fuel boilers → Saving of primary energy (fuel savings) → CO_2 savings through lower energy expenditure for the provision of the wood chips (production, transport, etc.);
- Lower emissions of pollutants (carbon monoxide (CO), dust, NO_x and volatile organic carbon compounds (C_nH_m));

- Increase of the service life of the plant components → Significant saving of ecological resources, which would result from an early complete renewal of the boiler plant;
- Increase of sweeping intervals (more time windows are available due to the on/off operation of the boiler plant) → Increase of efficiency, reduction of pollutant emissions;
- Extension of maintenance intervals → lower maintenance costs.

In quantitative terms (see section 4.3.2.5), the fuel savings in the summer months due to the lower distribution losses would amount to about 8 MWh and would mean a reduction in distribution losses of about 40%. This would mean that the saved pump energy (pump current) for the summer months would amount to about 74 kWh.

Overall, due to the more efficient operation of the boiler plant and the lower distribution losses, the annual savings of fuel energy would amount to about 105 MWh or 110 srm of wood chips. Together with the saved pump energy, this results in a saving of about 1.7 t CO2-equivalent emissions per year, which would otherwise be incurred for the provision of the wood chips or due to the pump current. In addition, the following other pollutant savings result from the combustion: CO approx. 332 kg/a, NOx approx. 49 kg/a, dust approx. 31 kg/a and CnHm approx. 67 kg/a. The dust emissions are particularly relevant here, since Weiz is considered a region with a fine dust load.

Furthermore, a flue gas measurement carried out on one of the boilers showed that CO emissions during the heat-up and burnout phase are 9 times higher than those of the standard firing (see section 2.3). Cyclical operation (constant alternation between standard firing and the heat-up and burnout phase), which occurs mainly in summer, with these increased CO emissions would be avoided by integrating the storage tank and the new load management system.

Finally, a theoretical CO2 saving can also be assumed, which would result if the saved fuel were evaluated with the CO2 equivalent emission factor of fuel oil, with the assumption that the saved biomass of this heating plant could substitute the fuel of another fossil-fired heating plant or that the peak load coverage of the heating plant could be provided by an oil boiler instead of a storage tank. These theoretical CO2 savings result in a reduction of CO2 emissions of about 33 t/a (see section 4.3.2.5).

5. RISK ASSESSMENT

5.1. Risk assessment for the work execution phase

In the work execution phase, the contractor is asked for the assessment of the probability of defects and malfunctions due to the installation of the storage system, and their criticality, is required to the contractor.

Require an energy type selectivity analysis during the execution of the works, taking into account the coordination between the installed equipment with reference to the operating curves and technical data sheets provided by the manufacturers.

5.2. Risk assessment for the operational phase

In the operation phase, the contractor has asked for the assessment of the probability of failures or under-performance occurring **during the operational phase of the storage system**, leading to consequences in terms of increased energy costs and reduced service life

It is also advisable for the installer to carry out a risk analysis on the basis of the specific installation characteristics of the storage tank, based on the possibility of the event occurring and the probability that it will cause damage.

Within an European project with the acronym KIS-PIMS, a project born under the CIP[31] program of the European Commission, a risk assessment tool[32] has been developed intended to induce peripheral services that cover the whole life of renewable energy technologies. This tool detects the risks by addressing their priorities in regards to the likelihood and corresponding impact (via Likert scales) based on a list of inquiries conducted in interviews with the deployment desk of Weiz. It considers the expert opinion on i) Technical, ii) Intellectual Property, iii) Commercial, iv) Management and v) Financial risks. It provides the investor(s) respectively decision makers with a visual potential risk appraisal (see Figure 19) via a number of inquiries and allows at least an assessment of priorities of the risk attributes given above.

Analysis results of the interviews in the frame of the Deployment desks visualised in Figure 19 show that in regards to Intellectual Property, Commercial, and Management risks the stakeholders declare it as low respectively in the green area. The Technical and Financial risks are determined as medium likely, however related impact is estimated as not relevant. Both attributes are influenced by challenges related to an efficient integration into the existing district heating and to consider requirements in regards to the monumental protection of connected buildings.

[31] ec.europa.eu/cip/

[32] The tool itsel is an Excel instrument with macros. The interviewees have been answered during the presentation of it on the desk deployment meeting on 11-12-19 and it was typed directly into the notebook. For confidential reasons of the company that has developed and designed it up to becoming commercial, profound background information are kept confidential.

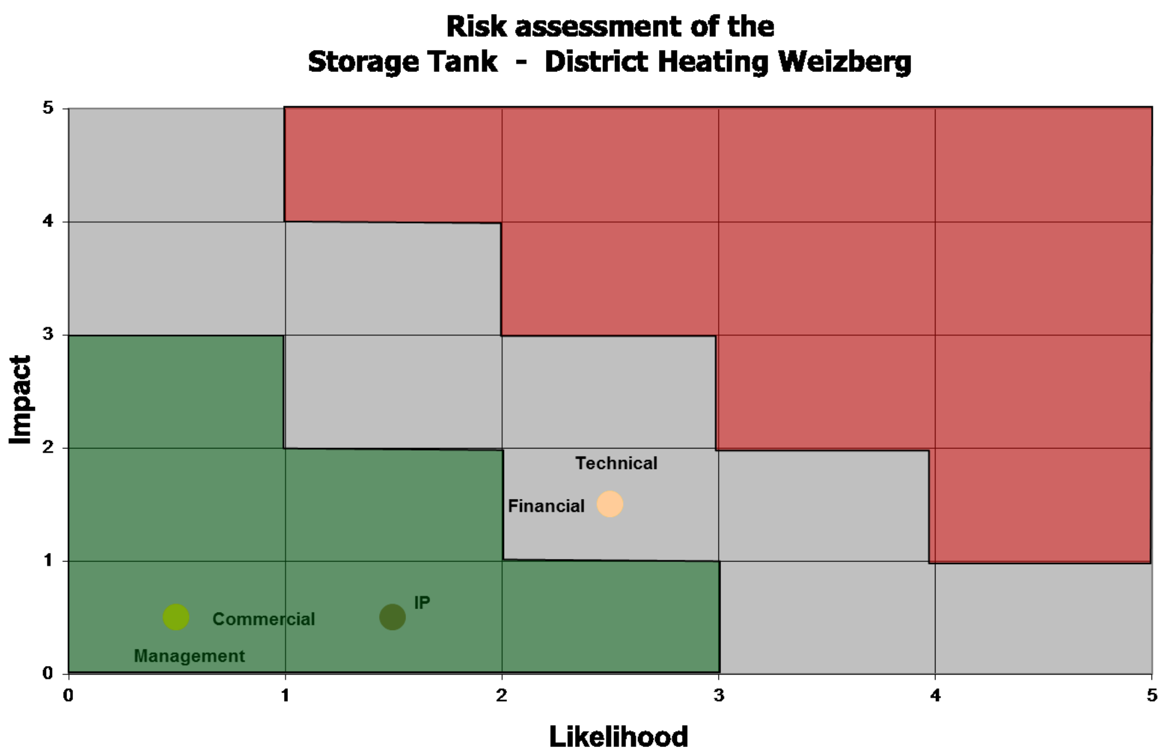

Figure 19 Risk assessment of the Store4HUC pilot in Weiz, Source: EU-Project KIS-PIMS

6. PROCUREMENT PROCEDURE

6.1. Type of tendering procedure

In Weiz, relevant procurement procedures are depending on who is investing according to the national procurement law. The Dorda Brugger Jordis Rechsanwälte webpage provides an overview about relevant laws: For the State (Bund) and public bodies on the central government level, the Federal Public Procurement Law 2006 (Bundesvergabegesetz 2006 – "BVergG 2006") implements Directives 2004/17/EC and 2004/18/EC (aspects on content) as well as Directives 89/665/EEC and 92/13/EEC (review proceedings). First, the BVergG 2006 provides the legal framework for awarding public works, supply and service contracts as well as works and service concessions and contests (the "classic regime"). Second, it contains regulations coordinating the public procurement procedures of entities operating in the water, energy, transport and postal services sector (the "sector regime"). Under both regimes, it covers public tenders above and below the thresholds of Regulation (EC) 2083/2005. Third, the BVergG 2006 comprises procedural provisions relating to the review of the award of public contracts. The BVergG 2006 is also applicable for all aspects on content of public tenders awarded by the nine Austrian Provinces (Bundesländer) and the communities and public bodies governed by them. However, the review proceedings on the regional and local level are exempted from the BvergG 2006 and are subject to nine different provincial laws. These provincial laws do not materially differ from the review proceedings provided for by the BVergG 2006."[33] It is required by law to have open calls across Europe for construction services above the threshold value of €186,000. Below €100,000, service activities such as detailed planning can be assigned directly.

6.2. Eligibility criteria for the procurer

Usually eligibility criteria are related to the particular services, system components and competences requested. Expected skills are chosen via the analysis of provided references. In addition, a so-called competence matrix is used for the documentation of the agreed responsibilities of all involved project stakeholders and their roles for each work package and responsibility for reaching the expected project results. This is also reflected in the invitation of corresponding experts to the deployment desk in Weiz apart from the regular construction team meetings on-site.

6.3. Minimum technical specifications

Related data can be found in the accomplished deliverable D.T1.2.3 Feasibility study for implementing energy storages in Weiz (AT).

[33] www.dorda.at/publications/austria-public-procurement