MONITORING OF RENEWABLE PROCESS HEAT PLANTS WITHIN THE GAS SECTOR

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Abstract

Natural gas is largely imported over long distances with high pressure, in order to optimize the utilisation rate of existing pipelines. Along the way, the gas needs to be decompressed in various stages until it can be fed into local gas grids situated close to final consumers. This central task of controlling the gas pressure level is done by gas pressure regulation and metering stations (GPRMS). There, the gas flow needs to be heated up prior to the process of decompression to avoid the gas from falling below the freezing point of water, which could cause operating failures. Besides pressure and temperature gradients as well as gas composition, the heating demand is directly proportional to the gas flow rate. The gas flow rate depends on the structure of the customers. GPRMS provide gas to a large variety of consumers. As a result, the heat demand is in most cases well balanced throughout the entire year and shows additionally a favourable temperature level for an efficient utilisation of renewable heating technologies. After summarizing the state of the art of GPRMS heating technologies and describing typical grid structures as well as other influencing variables on the shape of the heat demand, four concepts for renewable heating are presented. The concepts were successfully implemented at existing GPRMS-plants. One of those GPRMS was subject to a detailed monitoring, the results are evaluated and discussed in order to point out potentials for further improvements. The paper ends with a brief discussion of efficient approaches to assess the potential of utilizing renewable sources within the gas grid.

Keywords: natural gas grid, GPRMS, renewable Energies, SHIP - Solar Heat for Industrial Process, monitoring

1. Introduction to GPRMS

GPRMS are installed between long-distance and local gas grids to decompress the high-pressure gas flow, which is necessary to achieve an efficient transport capacity within the long-distance transportation network. The pressure reduction results in cooling due to the Joule-Thomson-Effect (JTE), which can freeze the equipment and endanger the gas supply to consumers. In order to prevent system failures and ensure the supply, the gas is preheated prior to expansion to such an extent that the temperature does not fall below the water freezing point as a result of the expansion. The resulting preheating demand has often not been the focus of plant operators, which led to predominantly energy inefficient GPRMS-plants. Since the major part of operating cost is caused by the gas and electricity consumption associated with preheating, a rethinking towards a more efficient GPRMS-technology is developing (Mischner et al., 2015). Within the framework of the "EffGas[1]" research project a total annual heating demand of 1 to 1.5 TWh/a was estimated for the preheating in all GPRMS-plants in Germany. About 30 percent of this preheating demand can be covered using renewable energies. The required temperature level of the gas flow between expansion, situated between 40 and 80 °C, is very favourable in terms of utilizing

[1] EffGas – Research project with the title: “Primary energy optimization of existing gas pressure control stations and development of measures for the existing stations in Germany”

doi:10.18086/swc.2019.12.14 Available at http://proceedings.ises.org

renewable heat generation technologies. The exact number of GPRMS in Germany is unknown so far, presumably around 5,000 GPRMS with relevant capacity are currently in operation in Germany. Besides decompressing the gas flow GPRMS are responsible for flow rate measuring, filtration, protection of increasing downstream gas grid pressure, and odorization (addition of odorous substances).

As mentioned before, GPRMS function as grid hubs within the gas supply grid. The grid structures can basically be divided into different levels as shown in Fig. 1. The gas transmission grid (Fig. 1, left) is the supra-regional grid which is responsible for transporting natural gas at high pressure levels from (often foreign) sources to local consumers. From these long-distance pipelines, the gas is transferred to the distribution grid of the local area supplier (Fig. 1, center), who finally delivers the gas to the end consumer (Fig. 1, right). As an example, the right part of Figure 1 illustrates a section of the distribution grid of the city of Kassel. Each point represents a GPRMS. In Chapter 3, four GPRMS are evaluated, located within the regional gas grid shown in Fig. 1 (center) and with heat supply based on renewable energies. This regional grid is divided into three sub-sections, the northern, southern and central ones. The central grid section supplies central Hesse between Kassel and Marburg. The GPRMS Ostheim from the north and the GPRMS Grossseelheim from the south feed into a common pipeline, which in turn supplies local grids via further downstream GPRMS at lower pressure. The other two investigated GPRMS are of central importance for the supply of wide areas in the southern and northern grid area as well as for major industrial consumers. A total of 75 GPRMS have been installed in this regional gas grid to supply end customers. In 10 of them renewable preheating systems could be implemented economically. The central location within Germany and Europe is a special feature of this grid area, as the grid section is supplied by many upstream pipelines. Therefore, the supply of the regional grid works at various pressure levels. While the northern section is supplied with a pressure level of around 20 bar, the central part of this regional grid is supplied with up to 90 bar.

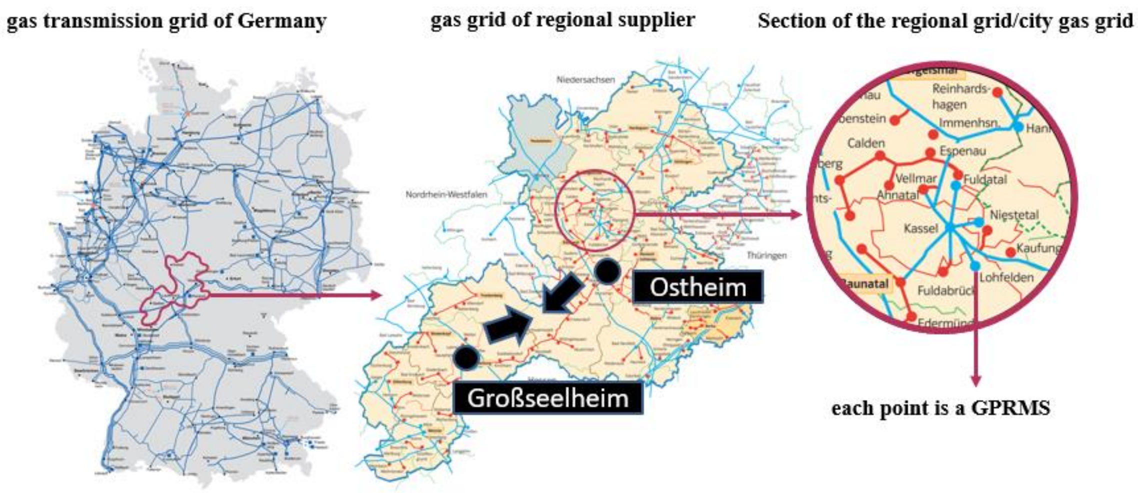
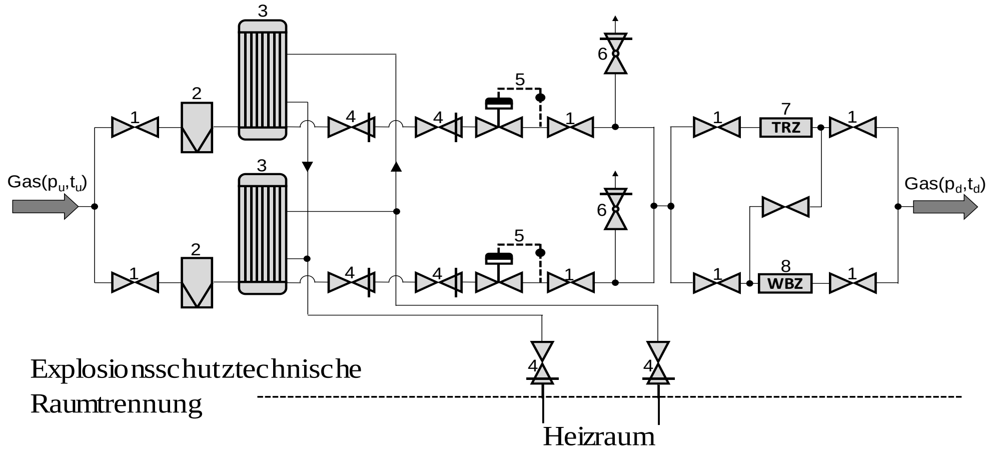


Fig. 1: Levels of gas grids in Germany with existing GPRMS

In the following, the typical hydraulic configuration of such a GPRMS, starting with the actual pressure control system, is discussed. Pressure control systems as shown in Fig. 2 usually have a redundant design in order to ensure gas supply even in the case of faults or maintenance work. Accordingly, all necessary components are doubled or bypasses are available. Starting with the gas entry from the left, the gas is filtered (2) in order to remove unwanted substances such as dust, water or hydrates. Behind, the gas passes through tube heat exchangers (3) required for preheating the gas flow. Horizontal designs are usually configured as counterflow-systems while vertical models as sketched in the hydraulic drawing are designed as concurrent flow systems. After the preheating, the gas is throttled (5) and cools down as a result of the decompression. The gas flow is then measured in this outlined hydraulic system (7 and 8) for a recalculation to standard conditions. In addition, safety devices are provided in (1), (4) and (6) which protect against impermissible pressure increases, release gas if necessary or mechanically disconnect the station from one of the grid sections. The schematic diagram also shows the spatial separation between the heating system (Heizraum) and other components to meet explosion protection requirements. Here, the safety shut-off valves (4) prevent natural gas from reaching the boilers at a pressure of up to 100 bar and igniting there.



1	Isolating valve	5	Gas pressure regulator
2	Filter with H_2O separator	6	Safety blow-off device
3	Heat Exchanger	7	Turbine flow meter (TRZ)
4	Safety shut-off device	8	Vortex flow meter (WBZ)

Fig. 2: Hydraulic plan of standard rails (Eurich 2017)

In general, the following three different hydraulic concepts can be found: throttled loop, deviation loop and bypass loop. Throttled loop is still widely used especially in old systems, while bypass loops are increasingly implemented in new plants. The deviation loop illustrated in Fig 3 is most frequently found. In this hydraulic concept the pump is located in the heat generator loop and delivers heat with an almost constant volume flow rate through the boiler. The temperature provided by the boiler is set to a constant value independently of the time of the year, whereas the actual adjustment of the delivered heat is controlled by mixing the flow into the return flow. For this purpose, a corresponding mixing valve is needed. This system is installed in 3 of the 4 GPRMS detailed in the following.

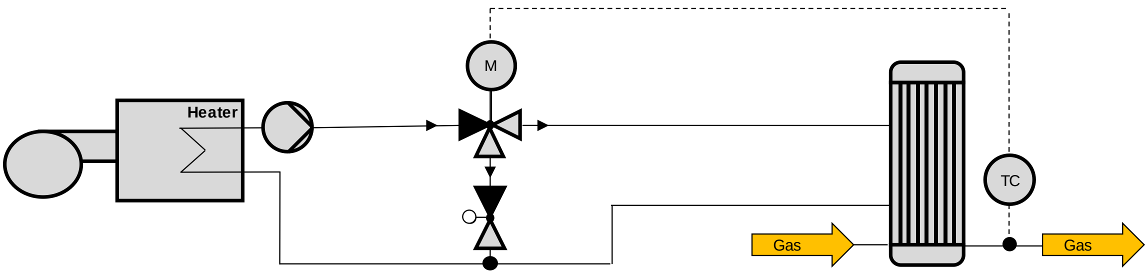


Fig. 3: hydraulic plan of a typical gas preheating system in deviation loop configuration (Eurich 2017)

As a consequence, this configuration leads to a constant volume flow rate in the heat generator loop and a variable flow rate in the heat exchanger loop. This operation mode enables a quick and efficient adjustment of the thermal output/performance during peak consumption periods. At times of low heat requirements below 20 %, the mixing valve operates close to its lowest closed position, which means that there is almost no defined control behaviour. In real operation, this leads to too much heat being introduced into the heat exchanger loop and the control parameter fluctuates around the setpoint. The gas outlet temperature (GOT) of the GPRMS is the control parameter in this case. Simple two-point or PI or PID controllers are often used as control algorithms, which compare the setpoint and actual value of the GOT to control the flow rate via the three-way valve in the heat exchanger loop. The gas outlet temperature is then subject to certain restrictions which are summarised in Chapter 2.

2. Heat demand of GPRMS

Contrary to an ideal gas, the throttling of a real gas leads to a temperature change. The trend and dimension of this change in temperature depends on the actual chemical composition of the gas as well as the pressure and temperature levels. The underlying physical effect is called Joule-Thomson effect (JTE). For natural gas, the temperature decreases and is nearly proportional to the pressure reduction for the conditions prevailing in the investigated pipelines, with a temperature reduction of about 0.5 K/bar (Mischner et al. 2015).

When a gas at pressure p_1 flows into a region of lower pressure p_2 without significant change in kinetic energy, the enthalpy remains constant and work is done on or by the fluid (Joule-Thomson expansion). This leads to a change in internal energy, depending on the initial and final states of expansion and on the fluid properties.

$$H = U + p \cdot V \tag{2-1}$$

where H is the enthalpy, U the internal energy, p the pressure and V the volume.

The Joule-Thomson coefficient μ_{JT} (JTK) is described as the partial derivative of the temperature with respect to the pressure, equation (2.2). If p·V increases in an isenthalpic expansion ($H_1 = H_2$), work is done by the fluid and U must increase, which leads to a decrease in temperature and results in a positive value of μ_{JT}. Vice versa, if p·V decreases, work is done on the fluid and if the increase in kinetic energy exceeds the increase in potential energy, the temperature increases and the value of μ_{JT} is negative. In the described case with natural gas as real gas, temperature change takes place due to pressure reduction for nearly adiabatic conditions.

$$\mu_{JT} = \left(\frac{\partial T}{\partial p}\right)_H \tag{2-2}$$

The main component of natural gas is methane. Methane has a positive value of μ_{JT} in the pressure range of 1..100 bar and a temperature of -30..100 °C. To make up for this physically related temperature drop, the natural gas in GPRMS is usually preheated starting from a pressure difference of about 16 bar to avoid system failures. For lower pressure differences, it is usually assumed that heat gains from the ambient (ground) compensate the temperature drop, prevent impairments and secure the gas supply. According to equation (2-2), the actual magnitude of this effect depends on the physical parameters of pressure and temperature of the real gas before and after expansion. Preheating in GPRMS is a central part in plant engineering and is described in DVGW G 499 (DVGW, 2015). According to this technical code, a simplified and rather practical approach is used to describe the heat supply needed for the natural gas expansion as shown in equation (2-3).

$$\dot{Q}_{VW} = \dot{V}_N \cdot \rho_N \cdot c_{p,m} \cdot \left[(p_1 - p_2) \cdot \mu_{JT,m} + (T_2 - T_1)\right] \tag{2-3}$$

For standard conditions of the natural gas flow rate ($\dot{V}_N$), an absolute heat demand is obtained as a function of the mean isobaric heat capacity ($c_{p,m}$), the standard density (ρ_N) and the mean JTK ($\mu_{JT,m}$) proportional to the pressure reduction and the difference between the inlet temperature (T_1) and the required target value of the gas outlet temperature (T_2, GOT). Furthermore, the physical values for the Russian H-gas and North Sea H-gas as well as mixture of H-gas and L-gas are documented in tabular form in DVGW G 499 2015 for the calculation according to this approach.

In addition to gas parameters, which depend on the composition of this natural product, the volume flow, the inlet and outlet pressures as well as the inlet and outlet temperatures of the gas define the heat demand as shown in equation (2-3). The gas parameters depend on the composition as well as on the absolute pressure and temperature gradients. In addition, the daily input and output pressures in the GPRMS can be presumed to be almost constant over the year. In contrast, the inlet temperature of the natural gas fluctuates between about 3 and 18 °C in the course of the year as shown in Fig. 4, similar to the soil temperature at a depth of 1 m in most GPRMS. The gas outlet temperature is the only variable that can be freely adjusted for direct efficiency measures. In addition to these two fluctuating quantities, the gas throughput is directly proportional to the absolute heat demand. As shown in Fig. 4 for real data of a GPRMS, this is subject to strong seasonal variations of 1:7 between summer and winter in this case. GPRMS which mainly supply industrial consumers show a more balanced load profile of 1:2 at best. If GPRMS predominantly supply weather-dependent space heating, the gas throughput can fluctuate more pronouncedly of up to 1:10. Accordingly, GPRMS with increasing industrial share are more suitable for renewable energies, as the seasonal heat demand profile is more balanced.

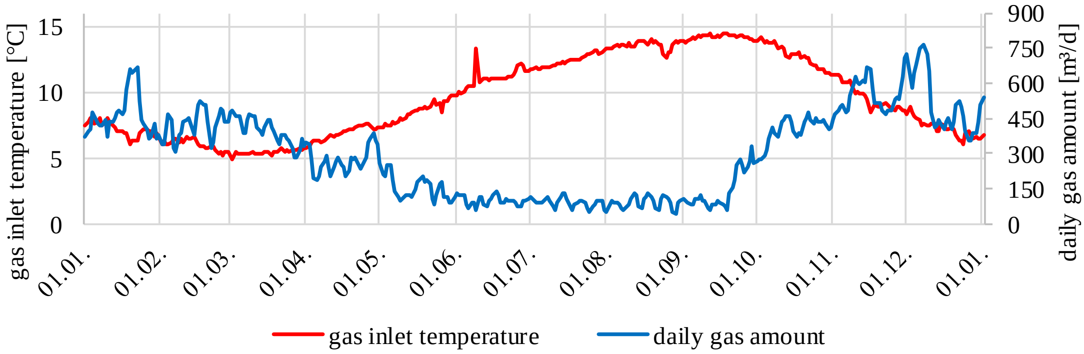


Fig. 4: fluctuation of gas parameters during the days of the year

The GOT from the GPRMS, which can be freely chosen by the operator, is subject to certain restrictions which have a wide variety of effects on operation and which must be observed in accordance with the security of supply. At temperatures below - 30 °C, higher hydrocarbons can precipitate and clog pipes. Residual water remaining in the natural gas can already condense below 0 °C and lead to the formation of gas hydrates, which in turn can narrow the cross-section of pipes and thus endanger the operation. If the gas outlet temperature and thus the surface temperature of the pipes is below the dew point of the ambient air, the humidity of the ambient air condenses on the gas pipes. This leads to a considerable amount of water accumulation and higher maintenance costs due to corrosion. During winter, low dew point temperatures of -5…5 °C are usual in Germany. In contrast, dew point temperatures in summer can be up to 25 °C. A constant setting of the GOT is therefore a compromise between the number of hours of condensation and the increased heat demand associated with a higher GOT. Renewable preheating concepts can therefore only be designed after this heat demand. However, at this point it is mentioned once again that the yearly heat load of a GPRMS occurs at a temperature level of 40 to 80 °C, which is favourable for renewable energies.

3. Introduction of existing plants

In this part alternative preheating concepts already implemented in the supply area of EnergieNetz Mitte GmbH are presented. Three of the four systems have been transferred to regular operation in recent years and were equipped with extensive monitoring equipment. The fourth plant (GPRMS Dillenburg) will be completed in summer 2019. Fig. 6 shows the solar thermal systems that have already been realised. The concepts are described chronologically according to their completion date.

Fig. 6: Grossseelheim, Germany (l): 355 m² –solar heating plant and biogas waste heat (2012)

Neu-Eichenberg, Germany (m): 135 m² solar heating plant and 3x41 kW_{th} gas heat pumps (2014/2015)

Ostheim, Germany (r): 440 m² solar heating plant and 3x41 kW_{th} gas heat pumps (2016)

GPRMS Grossseelheim

The first of the four concepts was developed as part of a research project investigating the potential of solar thermal preheating in GPRMS. In addition to essential analyses and evaluations, special components, particularly transportable buffer storages and solar heat transfer stations in shipping containers, were developed during the project to achieve the renewable preheating technology of GPRMS as cost-efficient as possible. The GPRMS mainly supplies a large chocolate producer with year-round process heat demand, and furthermore household customers with a more variable weather-dependent heating demand. Due to the high process heat demand throughout the year, this GPRMS offers the potential for an economic realisation of a system with up to 1,000 m² collector area. At the same time a biogas driven CHP plant was planned, which supplies a nearby local heating grid. The heat sources in decreasing order of priority are the solar thermal system, biogas and natural gas.

Because of the oversupply of waste heat from the CHP, the solar thermal plant was dimensioned smaller and the integration of waste heat from the CHP plant not required by the local heating grid was taken into account in the planning process. Both renewable heat generators deliver heat to a 24 m^3 pressureless storage, which was installed in a 20-feet shipping container. If heat is required, the temperature of the return flow to the gas preheater can be increased via an external heat exchanger. If the target flow temperature cannot be achieved by solar and waste heat, the downstream boiler cascade secures the desired temperature automatically. Both control loops for integration of solar or conventional heat are independent from each other and thus enable the required supply security. The realisation of this plant took place within the framework of a contracting model. The GPRMS operator pays only for the delivered renewable heat, at a price below the current gas price. The hydraulic concept of this system is shown schematically in Fig. 7.

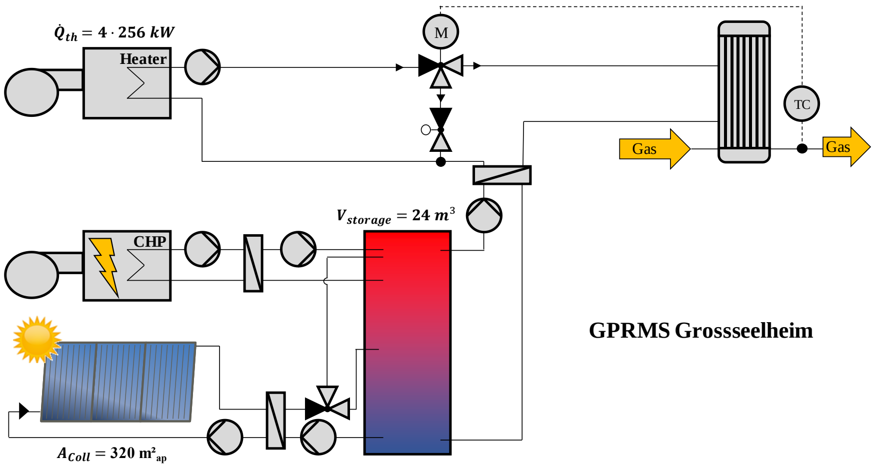


Fig. 7: Schematic hydraulic concept of the preheating system of GPRMS Grossseelheim (2012)

GPRMS Neu-Eichenberg

In this GPRMS, a space-saving rooftop solar thermal system in combination with three gas-absorption heat pumps was realised. Again, both heat generators are delivering heat to a buffer store and feed it into the return flow of the conventional heating cycle. The entire system periphery and the 10 m³ buffer storage are installed in a 20 feet shipping container according to its space-saving design. In addition, the aforementioned efficiency measure of dew point control was implemented for this GPRMS. The target value of the GOT is constantly adjusted to the dew point of the ambient air. The efficiency raises in winter months in accordance with the low dew point temperatures, while the efficiency is slightly reduced by the higher temperatures necessary in summer to avoid condensation. Thus, the summer heat demand increases, while the winter heat demand is reduced, which leads to increased possible solar coverage rates in summer. Under consideration of current energy market condition at the time of the implementation, this plant was financed as a self-investment project by the grid operator.

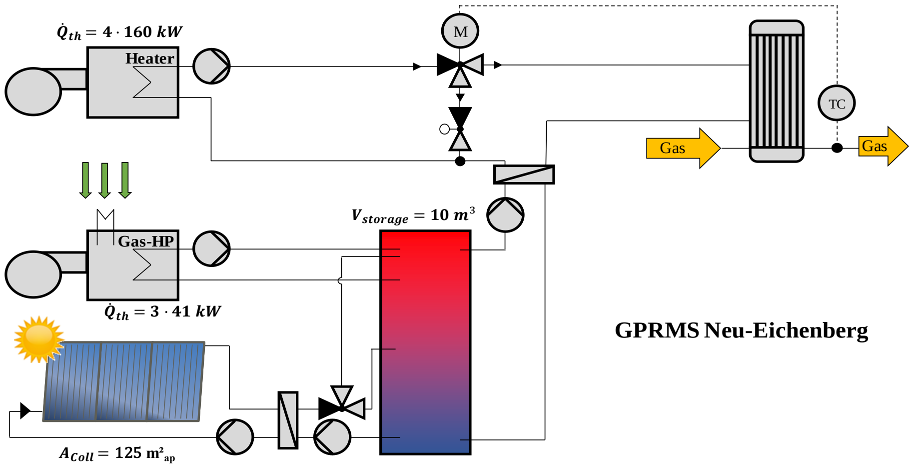


Fig. 8: Schematic hydraulic concept of the preheating system of GPRMS Neu-Eichenberg (2014/15)

GPRMS Ostheim

The third alternative preheating system was implemented as part of a new GPRMS construction project. Compared to existing GPRMS, only a few new plants of this size are built in Germany each year. Since the renewable preheating system was already considered in the planning process of GPRMS Ostheim, its building was optimized towards using solar thermal energy from the beginning. Therefore, part of the collector area could be installed on the station roof. The large flat-plate collectors heat up a 21 m³ modular buffer storage tank, which was installed in the heating room and is equipped with innovative vacuum insulation which allows space saving. As a special feature of this concept, a separate gas preheater is installed for an optimised integration of the renewable heat. The solar thermal system and the heat pumps work more efficiently at lower temperature levels. The preheated natural gas flows through a second gas preheater supplied by a 4 * 620 kW low-temperature boiler cascade connected in series, which provides additional heat if required, until the set-temperature is reached. This GPRMS is also equipped with dew point control.

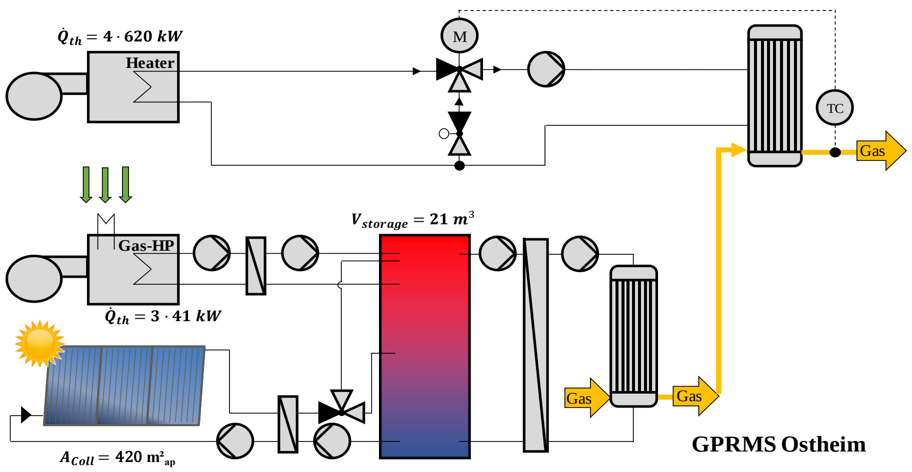


Fig. 8: Schematic hydraulic concept of the preheating system of GPRMS Ostheim (2016)

GPRMS Dillenburg

In addition to the three aforementioned GPRMS with renewable preheating concept, which belong to the category of GPRMS with a high maximum gas flow capacity, a fourth GPRMS Dillenburg (Fig. 9) from the middle output range with a throughput capacity of up to 10,000 Nm³/h is currently under modification in order to use renewable preheating. A 65 m² solar thermal system is used in combination with a small CHP unit, to load a buffer storage tank. Macro-encapsulated PCM modules are additionally installed in the upper third of the buffer store to increase the storage capacity in the range of the operating temperature of the CHP unit. As a special feature of this concept, a heating rod with a power consumption/heat output of 30 kW is additionally installed. It can be operated as an alternative to the CHP and is thus intended to stabilise the local low-voltage grid on a trial basis. In addition, this GPRMS is tested with a customized efficient control strategy, which is intended to enable cost-effective dew point control. This means the GOT is controlled in according to the actual dew point. For this control strategy the GOT is set at the lowest level preventing humidity of the ambient air to condense on the pipes. This control strategy reduces the yearly gas demand of the GPRMS of nearly 30 % compared to a control with a fixed GOTand maximizes the preheating demand in summer time when the dew point is at the highest level. According to the current utilisation of the GPRMS, the innovative heat concept ensures that the low-temperature boilers will only be required at peak times. Again, the renewable preheating is integrated in the return flow from the gas preheater.

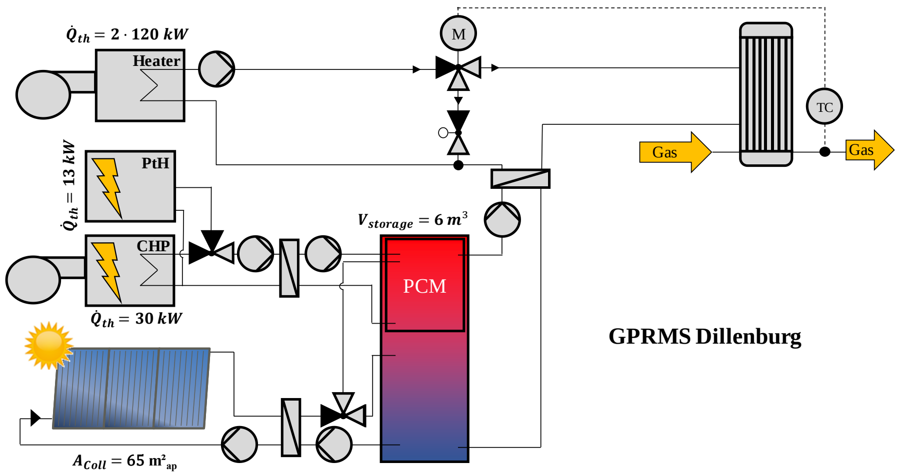


Fig. 9: Schematic hydraulic concept of the preheating system of GPRMS Dillenburg (2019)

4. Evaluation of operating data from the GPRMS Ostheim

The combined low carbon heating system consisting of the CO_2-neutral solar process heating plant and the gas-absorption heat pumps for the GPRMS Ostheim was planned in 2015. Until the start of operation about twelve months passed by, especially due to delays in realizing the GPRMS itself. Since September 2016, the first monitoring data was available. As it was necessary to change the online server of the data logging system due to operational reasons, gaps in the dataset and a new nomenclature for the sensors and therefore the logged monitoring data occurred. But since September 2017 a nearly complete dataset for the whole GPRMS Ostheim is available.

Over the first full 14 months a yearly solar fraction of about 11 % was reached at the GPRMS Ostheim, ranging monthly from 0.1 % in December 2017 up to 63 % in August 2018. In addition, the gas-absorption heat pump cascade (GWP) covered nearly 30 % of the yearly heat demand varying on a monthly basis between 21 % in August 2018 up to 42 % in June 2018. The remaining 59 % (yearly basis) is provided by the natural gas burners. Fig. 10 shows the monthly coverage rates of the three heat sources at the GPRMS Ostheim.

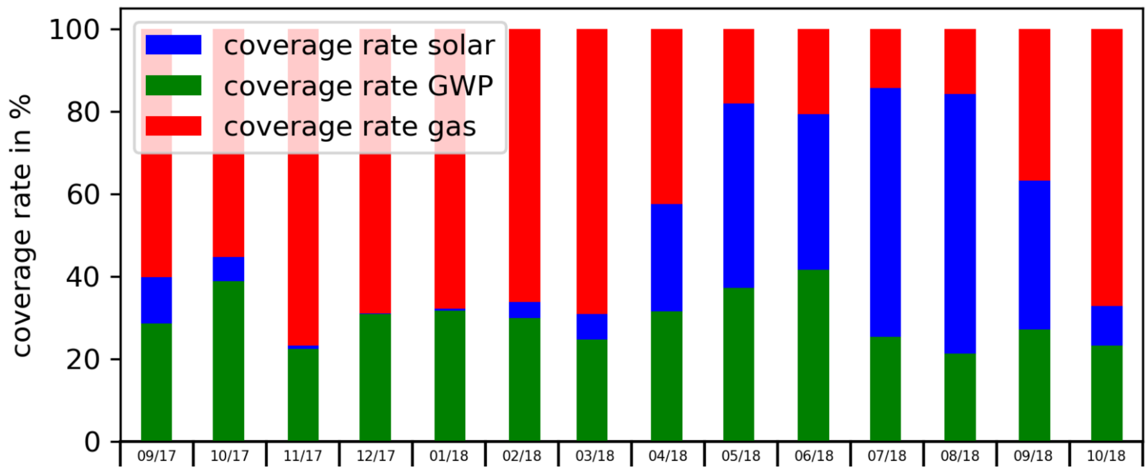


Fig. 10: Overview of monthly coverage rates of the three heat sources in Ostheim from September 2017 till October 2018

During the planning of the solar heating plant, a solar energy yield of 260 MWh/a respectively 620 kWh/m²a (gross) was calculated due to the low temperature demand of the heat sink. The measured data showed that this high yield could not be reached. In the operational year from November 2017 to October 2018 the solar yield reached 191 MWh/a or 455 kWh/m²a, corresponding to a solar utilization ratio of 35,4 %. Although it is still a good yield, it is a quarter below expectations.

A detailed analysis revealed some issues responsible for this reduced solar yield. First, the solar heating plant went into stagnation on a regular basis on sunny days from April till October. Additionally, it could be seen, that on several days the two ground mounted collector rows went into stagnation while the roof collectors were still in operation, as it can be seen in Fig. 11.

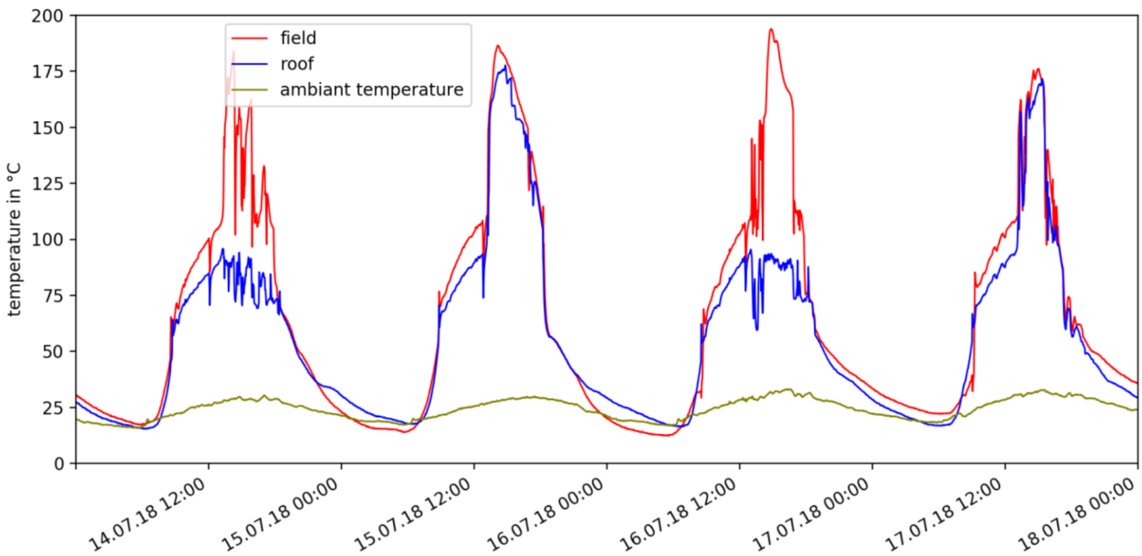


Fig. 11: Consecutive days in July 2018 with partial and full stagnation of the solar heating plant

A detailed analysis of the temperatures, flow rates and system design unveiled two problems. First, the pump of the ground mounted collector field is not able to deliver the planned flow rate because of the pressure drop in the loop. While the collectors on the roof of the GPRMS are operated with a specific flow rate of around 24 l/m²h as designed, the pump of the ground mounted collectors only delivers ~ 15 l/m²h. Therefore, the flow rate of the field collectors with its 224 m² is in the range of 3,3 m³/h while the smaller field on the roof with 198 m² is run through by 4,7 m³/h, which leads to the partial stagnation shown in Fig. 11. The unfavourable connection of the flow and return pipes of each collector row is very likely the cause of the partial stagnation of the solar heating plant. As it can be seen in Fig. 12, both the flow and return pipes are connected on one side of the collector rows. As the two rows consist of 8 and 9 serially connected collectors, each with five segments and five parallel serpentine absorber pipes, equaling 105 and 119 m² of collector area, the pressure drop in the rows is too high to reach a sufficient volume flow rate in the furthest collectors. Connecting the flow and return pipes on the opposite side of each rows would have been necessary to achieve a more uniform flow rate in the collectors.

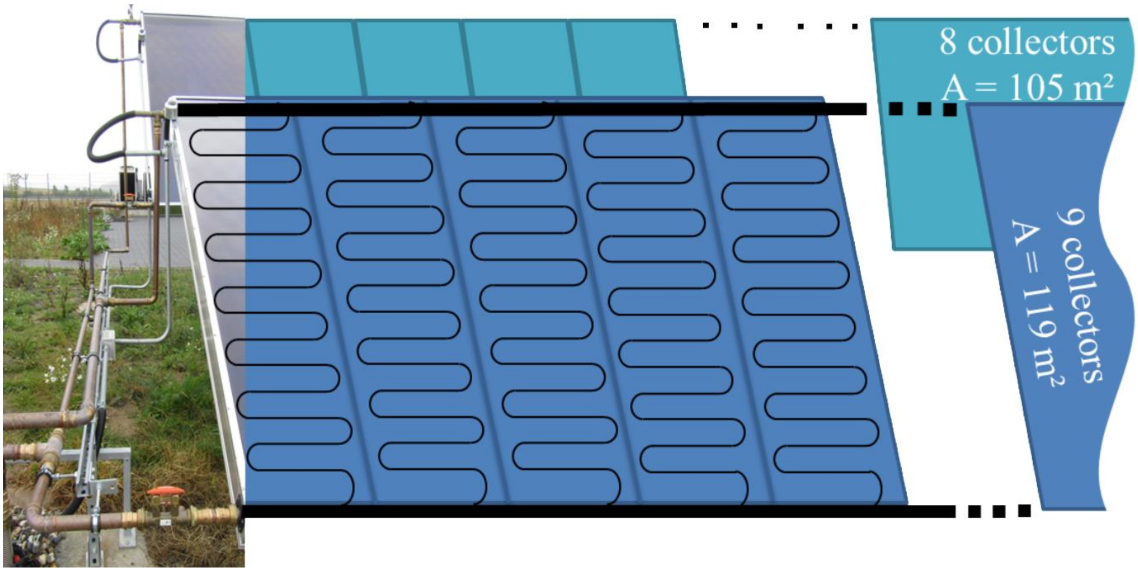


Fig. 12: Scheme of the two ground mounted collector rows with all connection pipes on the left side of the rows

A second problem that could be identified is the high logarithmic temperature difference (ΔT_{log}) of the solar heat exchanger. On sunny days with an irradiation of 800 W/m² or higher, the ΔT_{log} of the solar heat exchanger starts around 5 K in the morning and increases continuously with the irradiance up to 20..25 K before the system goes into stagnation. As the ratio of the capacity flows on the primary and secondary side of the heat exchanger is nearly 1, it is almost certain, that the installed solar heat exchanger does not match the desired heat transfer capacity. Figure 13 shows a summer day with stagnation of the solar heating plant at 2 p.m. (2018, 19th of July), where the increasing ΔT_{log} can be seen. The ΔT_{log} is only presented for times when both the primary and secondary solar pump are running.

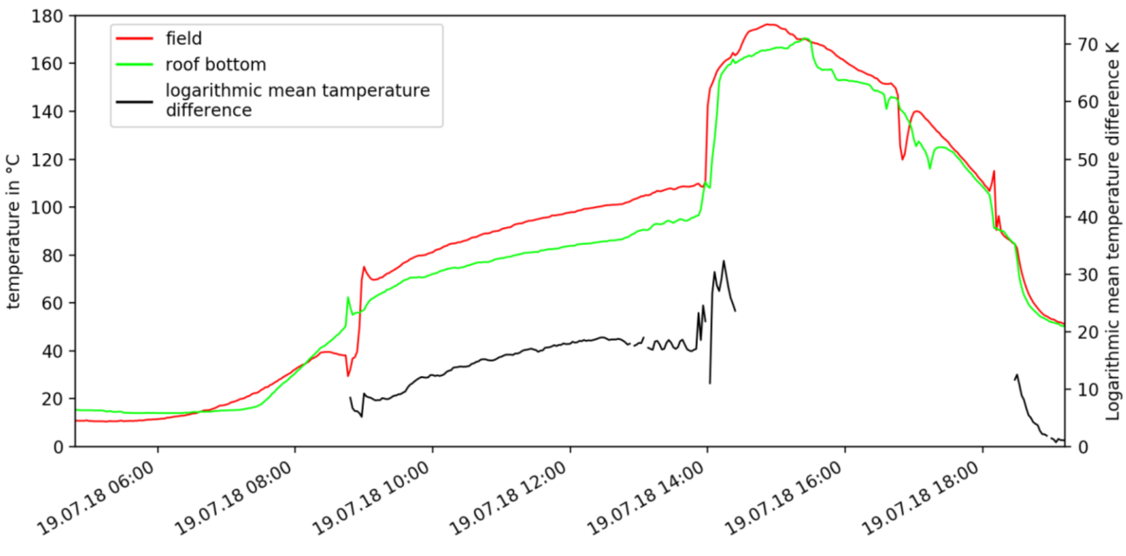


Fig. 13: Collector flow temperatures and logarithmic temperature difference of the solar heat exchanger on a cloudless day in July with high irradiance (up to 1030 W/m² in the collector plane at noon)

Because of the high ΔT_{log} of up to 25 K, the system is frequently going into stagnation while the temperature at the bottom of the storage is still around 60 °C (maximum temperature of storage is 85 °C). Therefore, the storage cannot fully be charged, leading to a higher than necessary heat demand provided by the gas-absorption heat pumps in summer nights, as the stored solar heat is not sufficient until the next morning.

In contrast to the solar heat exchanger for charging the storage, the heat exchanger for the discharge of the storage is working as expected. As it can be seen in Fig. 14, in summer the logarithmic temperature difference is normally below 4 K and in winter it increases up to 6 K corresponding to the increased heat demand of the GPRMS.

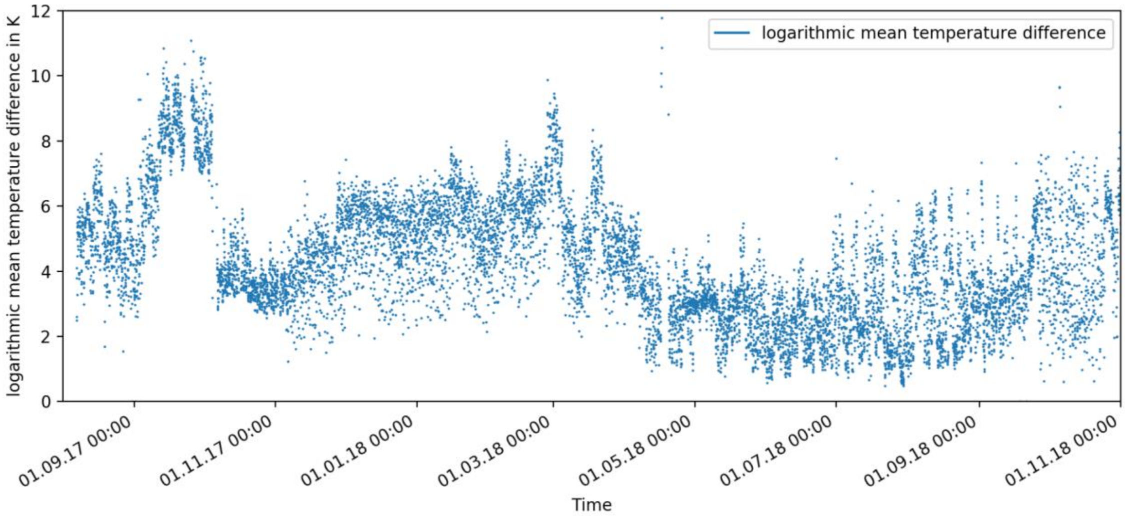
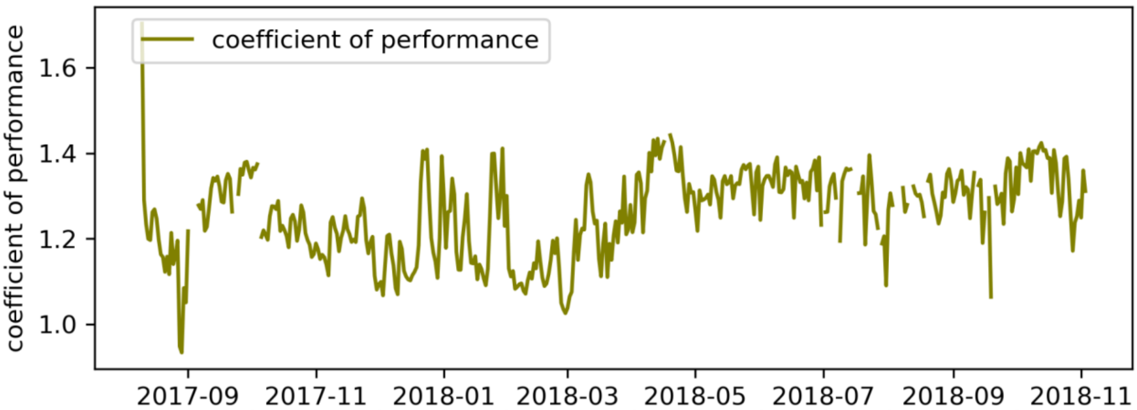


Fig. 14: Logarithmic temperature difference of the heat exchanger for the storage discharge over 15 months of operation

Looking at the gas-absorption heat pumps with ambient air as heat source, a COP of 1,1 up to 1,34 is achieved on a monthly basis according to the measured calorific value of the used natural gas. The COP is calculated on an hourly basis, as the composition and therefore the calorific value of the used natural gas is not constant. Since April 2018 the monthly COP has increased to a rather constant value, between 1,31 and 1,34, as it can be seen in Fig. 15. This can be explained by the installation of a mixing valve increasing the return temperature to the heat pumps to avoid icing on the cold side of the heat pumps.



	09/17	10/17	11/17	12/17	01/18	02/18	03/18	04/18	05/18	06/18	08/18	08/18	09/18	10/18
weighted monthly performance factor	1.33	1.24	1.2	1.16	1.25	1.1	1.19	1.33	1.31	1.34	1.32	1.31	1.33	1.33

Fig. 15: Daily (graph) and monthly (table) COP of the gas-absorption heat pump cascade from September 2017 to October 2018

A comparison of the measured hourly averaged COP values of the heat pump cascade in steady state and the COP values given in the datasheet as a function of the ambient temperature showed a good agreement between 0 °C and 10 °C. Below -5 °C and above 15 °C the discrepancy is increasing but still in an acceptable range. Fig. 16 shows the hourly average COP values of the heat pump cascade in steady state as blue dots and their quadratic interpolation. The heat pump cascade is considered to be in steady state when the heat load varies by less than 10 % from the previous and following hour. The flow and return temperatures of 65 °C and 55 °C used for determining the COP according to the datasheet are in good agreement with values measured at the GPRMS Ostheim.

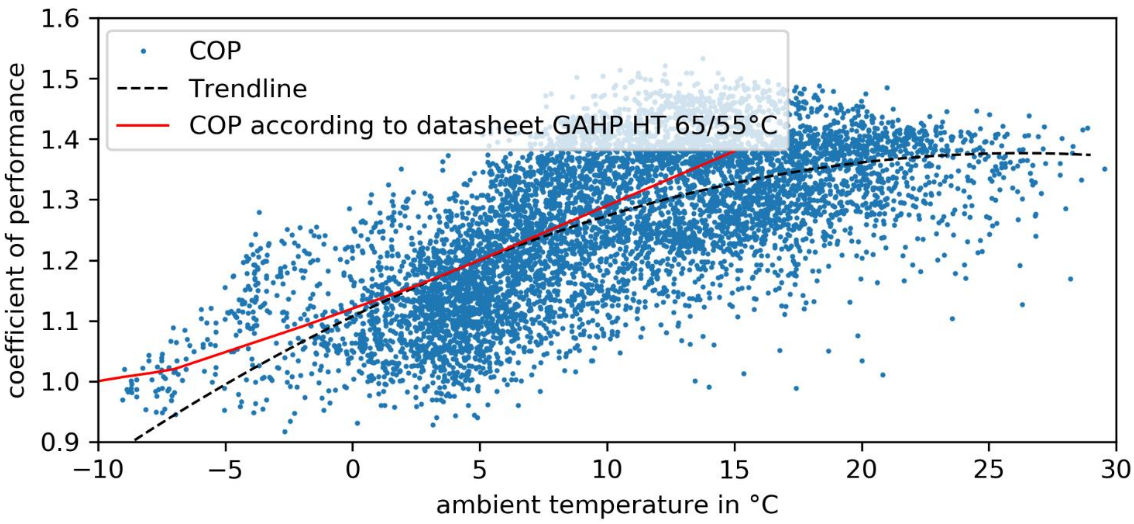


Fig. 16: Comparison of measured COP values and values given in the datasheet for flow temperatures of 65 °C and return temperatures of 55 °C

One aspect, which is currently still under evaluation, is the dimensioning of the heat exchanger for the preheating of natural gas. While the desired flow temperature for the natural gas on the secondary side can be reached, the temperature of the return flow on the primary side of the heat exchanger of about 45 °C is 25 K higher than expected. This also has a strong impact on the solar heat production.

As shown by prior explanations, there is potential to further increase the performance of the currently reasonably performing solar heating plant of the GPRMS Ostheim. At first, the connections of the flow and return pipes to the ground mounted collector rows were changed in August 2019 to achieve an even flow rate in these rows. Additionally, the pump for these rows was changed to reach a higher specific flow rate of 24 l/m²h equal to the one achieved for the roof collector rows. After these changes, a short period is scheduled to evaluate the effects of these optimizations, before replacing the solar heat exchanger, if necessary. Additionally, it will be investigated if it is still possible to achieve balanced capacity flows on the primary and secondary side of the solar heat exchanger after the installation of the stronger pump for the ground mounted collectors. If necessary, the secondary pump for storage charging will be replaced as well.

5. Outlook

It was possible to demonstrate the positive conditions of this niche application in terms of utilizing solar process heat due to a year-round heat demand at a low temperature level and in most cases also a high availability of space for solar thermal equipment. The pilot projects prove that renewable preheating concepts can operate successfully in supplying relevant GPRMS. The aim of further research is to provide planners and operators with appropriate tools to enable even newcomers to the sector to plan and implement integral heat supply concepts with minimum effort. For this purpose, a classification of gas grid structures and a forecast of the seasonal fluctuating gas throughput are subject to further research projects. A model forecasting the daily heat demand based on the forecast daily gas throughput and under consideration of further conditions such as the pressure difference, is currently under development. For this purpose, a freely accessible online tool will be available, which enables an initial estimation based on a few key figures. In addition, various feasibility studies are currently being carried out with other grid operators in Germany with the aim of realizing further prototype plants outside the grid area of EnergieNetz Mitte GmbH in order to ensure market penetration.

6. References

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