UNIPOWER PRO
multivalente Energiefassade

UNIMET , UNGENACH | FIELD REPORT

SMART SKINS | TOP-NOTCH FAÇADES
MULTIVALENT ENERGY FAÇADE

SC – UNIPOWER PRO

HEATING AND COOLING FOR LESS THAN 1 EURO/M²·A

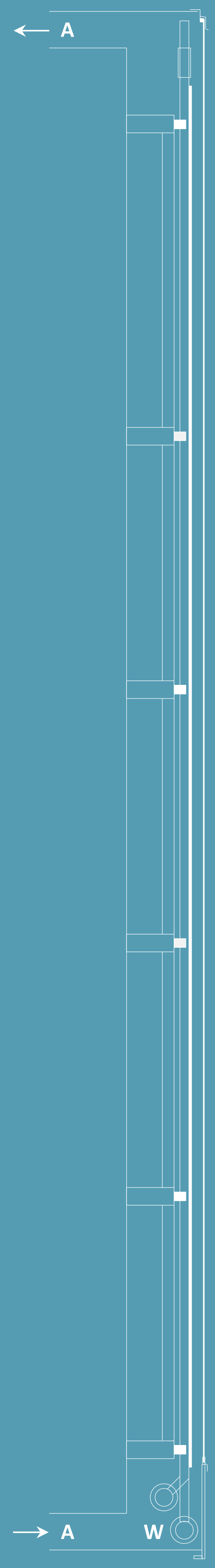
AESTHETICS MEETS GREEN ENERGY

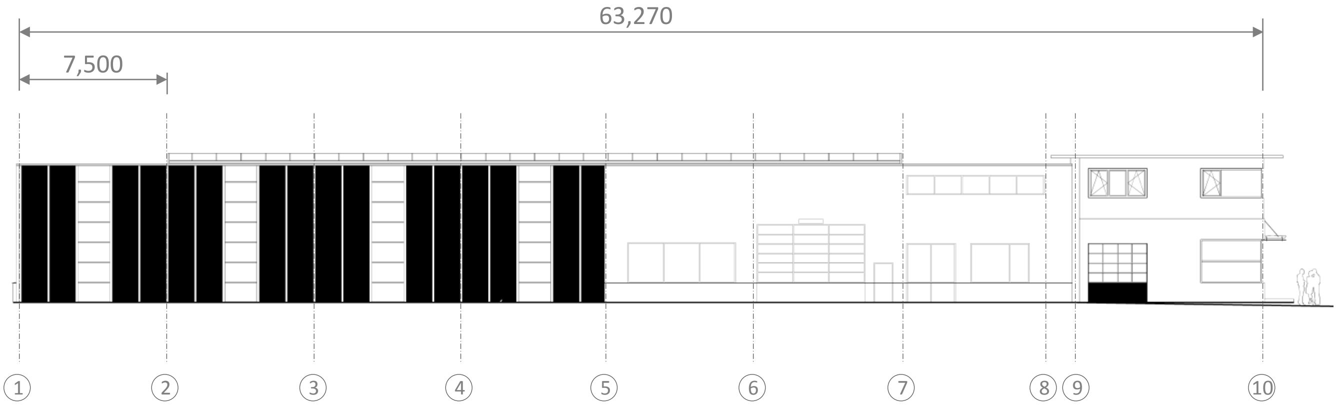
PROJECT: Unimet GmbH & Co KG
LOCATION: Ungenach, Austria
TYPE OF USE: Office & Production Building
OWNER & DEVELOPER: Unimet Metallbau GmbH & Co KG, Ungenach
ARCHITECT: S+C, Weyregg
PROJECT PARTNERS:
- Malli Energietechnik, Vöcklabruck
- ASIC, Austria Solar Innovation Center, Wels
- Denco Happel Austria GmbH, former GEA, Gaspoltshofen

CONTENT

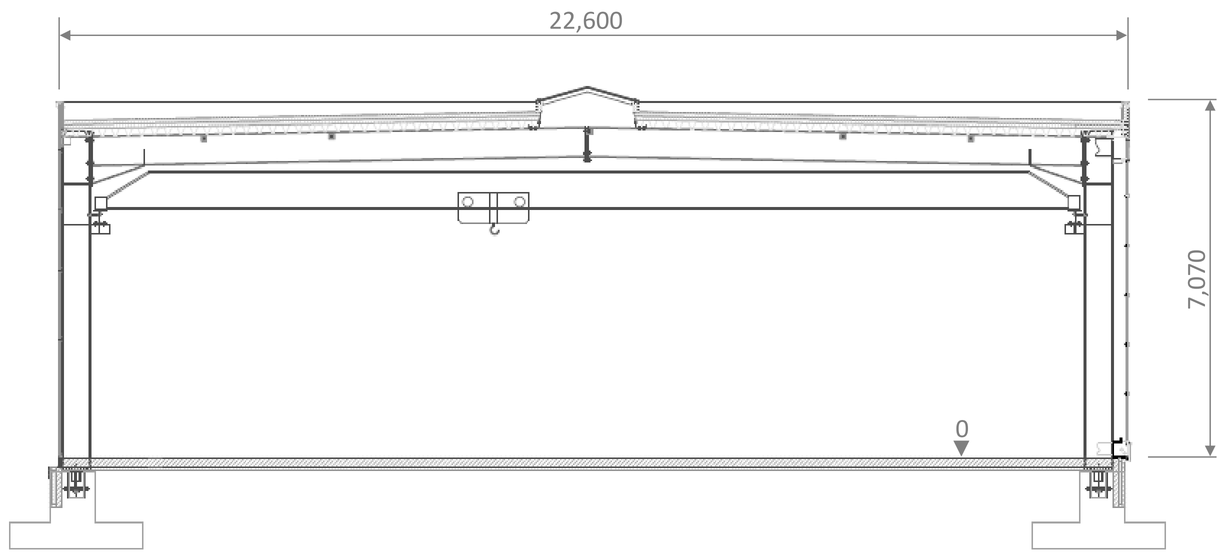
SYSTEM FEATURES

- Formation of a dual, air-water system to make use of low-temperature heat and to improve system response times
- The thermal collector and façade merge into one unit
- Visual appearance that meets architectural requirements
- The façade supplies a large share of the heating energy
- Integration of ventilation by heating the air in winter and cooling in summer
- Areas with natural light are an integral part of the overall concept
- Complete renouncement of fossil fuels for heating and cooling
- Fulfillment of structural-physical building requirements
- No significant thermal load in the summer
- No restrictions on operating times due to snow deposits in winter
- Smooth system operation, low standstill temperatures due to vertical installation
- Storage mass usage through concrete core activation
- Minimal Maintenance
- Durability
- Well-balanced cost-benefit ratio





View South Façade – Thermal absorber surfaces alternate with daylight supply elements.



Vertical Section – The skylight is arranged centrally for symmetrical daylight supply.

CONSTRUCTIONAL FIGURES & OTHER FACTS

- **Building**

Length: 64.8m

Width: 22.6m

Height: 7.1m

Mullion spacing c/w-façade: 1.5m

Production area: 1,400m²

Office area: 200m²

Heating capacity: 100kW (81kW production area ; 19kW offices & workshop)

Commissioning: January 2006

- **Solar façade**

16 off collectors, integrated into post & beam façade

Collector height: 6.0m

Collector width: 1.4m

Collector aperture area: 134m²

Absorber surface area: 130m²

Heating and cooling for less than 1 Euro/m2 per year! All of that by using the resources that Mother Nature gives us both free of charge and free of emissions every single day. This experience report presents facts and data concerning what the builder and developer, Adolf Starlinger, has been compiling over years of self-funded study.

The comprehensive monitoring and data recording that took place from day one of commissioning the energy façade provides all the high-resolution operating data to date. The material now fills folders with selected sensor curves and measurement value tables.

This report outlines the plant description and introduces the innovative concept of the use of thermal solar energy that increases the energy yield at lower temperatures via bivalent thermal operation of water and air. Additionally, this report outlines typical daily sequences of relevant measurement variables.

The report is geared towards anyone who, as builders, architects, specialist planners or those simply interested in the subject, wants to embark on new and unconventional paths in the production of heating and cooling of primarily commercial buildings, as well as anyone who wants to rely on the security of robust data for interpretation and plant performance.

MOTIVATION

It could have been any old run-of-the-mill building. Founded in a typical, commercially used building with conventional technical building equipment, the UNIMET metal construction company was to house both the administration and the machine park. Instead of conventional methods, the builder decided to heat and cool his new premises using a revolutionary concept. The basic idea of using the sun and tapping into its inexhaustible energy is not new. Opting for a different approach, however, was new. The builder was animated by the idea of heating his plant, which was built in 2006, in a regenerative manner with zero use of fossil fuels. The necessary development work had already begun years before. The goal was clearly formulated; an architecturally successful component integration; long lasting and low-maintenance; minimizing energy, but at the same time not leaving out any wishes for additional comfort and room conditions. This all, of course, with a balanced cost-benefit ratio.
After 10 years of operation, we can state that this goal was exceeded by great lengths.

The builder:
"For me, the path was always clear. The only smoke leaving the hall would come from the welding - and even this would be filtered."

CONCEPT

Thermal solar collectors are the primary components for indoor heating. They are architecturally integrated into southern façades. Using a heat pump absorbs the effect of spells of bad weather. Energy for both heating and cooling is generated with a sufficiently dimensioned stratified charge accumulator in combination with a thermally activated concrete floor slab as well as integrated well water use. Contrary to the usual attachment structure, the thermal collectors are embedded in the post and beam façade and thus form an energy-active component that separates the interior from the exterior and fulfills all of the other structural-physical requirements of a primary façade. Collector surfaces alternate visually with daylight and ventilation openings. The post and beam façade mutates into the light, air, and energy manager. It can also be highly flexibly and modularly designed.

The collector assembly is another special feature. This is in bivalent operation with water and air.
The idea: On days when the solar supply is not sufficient to charge the storage tank, the collector generates air temperatures that are used for indoor heating. The collector construction thus increases the energy yield at lower temperatures.

The efficient interaction of the different components ensures a sophisticated control system.

Energy façade – Thermal and daylight elements arranged alternately

Post & beam façade during site assembly

CONSTRUCTION | PROFILE OF REQUIREMENTS

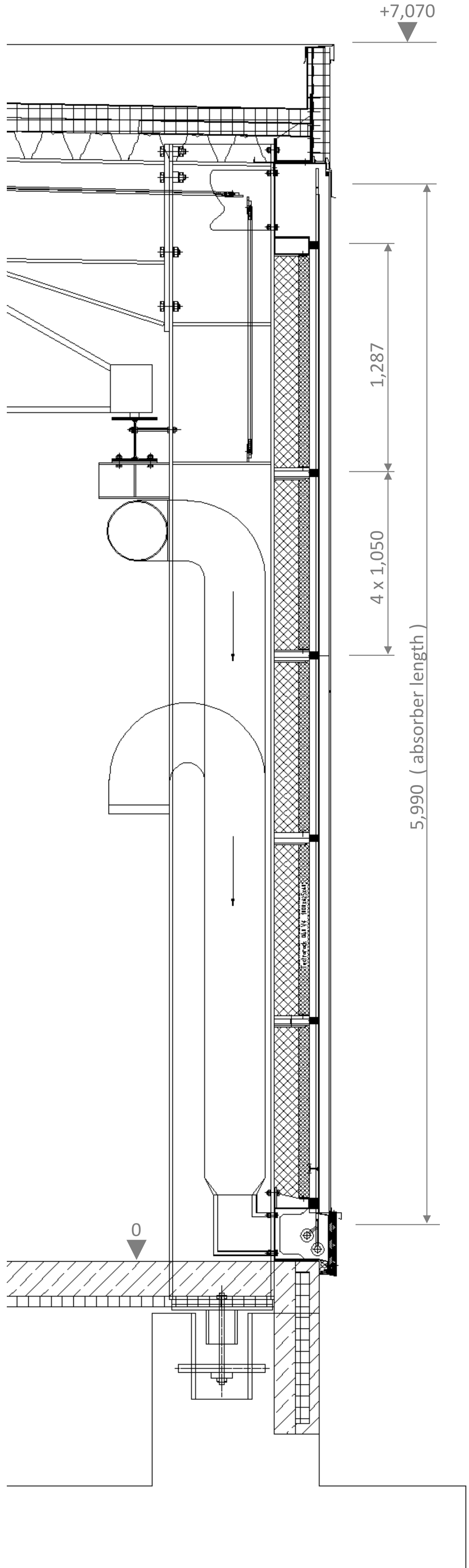
The outward development, which also ensures visibility and acoustics, forms a highly transparent and fully toughened white glass pane. The absorbers are made of extruded, anodized black aluminium. This surface refinement is durable without degrading visually or thermally. Due to a texture with a subsurface structure, the surface area is significantly increased so as to maximize energy transfers. The wing-shaped design with integrated channel flow has been optimized according to thermal factors. The mass usage of aluminum is reduced to a minimum. The absorption of the water-carrying pipe in the extrusion process reduces the transition losses, which are usually encountered when using conventional copper absorbers.

This structure allows for absorber lengths that can extend over two or more floors. Manageability and the large thermal temperature ranges limit the lengths to a reasonable measurement of 7 meters (23ft). The width of the post and beam façade is flexible. The collector assembly is optimized to a low temperature range. High shutdown temperatures are avoided by the vertical orientation of the façade (reduced irradiation in summer), which has a positive effect on the service life of the components.

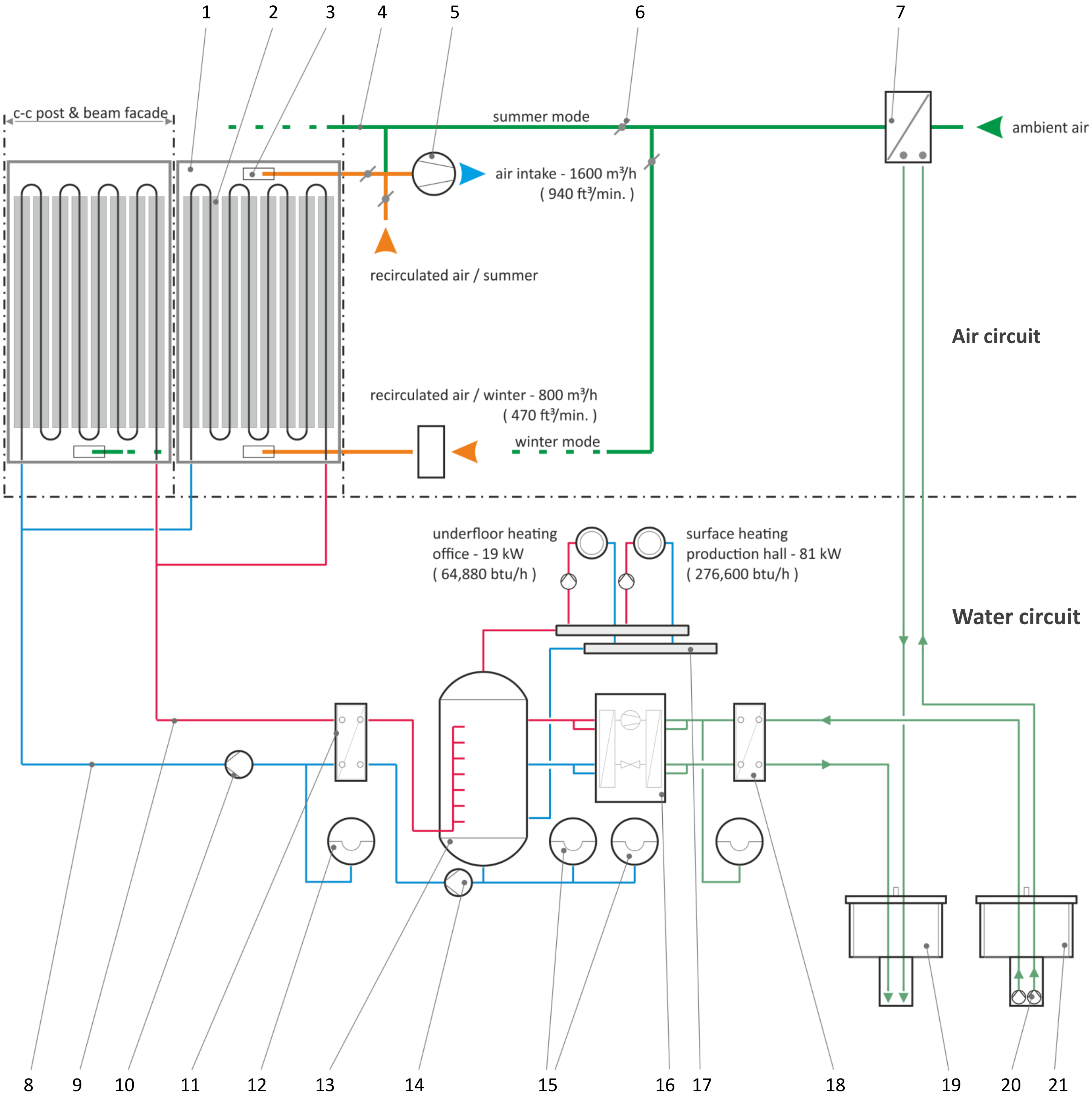
Special attention must be given to the corresponding material pairings. The electrochemical series prohibits the combination of aluminium and copper. Stainless steels are normally used for secondary components.

Profile of Requirements

- Training as a dual system to make use of low-temperature heat and to improve system response time
- The thermal collector and façade merge into one unit
- Visual appearance that meets architectural requirements
- The façade supplies a large share of the heating energy
- Integration of natural light and ventilation surfaces
- The concept provides complete renouncement of fossil fuels for heating and cooling
- Fulfillment of all structural-physical building requirements
- No noteworthy thermal load in the summer
- Cooling in the summer
- No performance reduction due to snow
- Minimal Maintenance
- Smooth plant operation, low standstill temperatures
- Storage mass usage via concrete core activation
- Well-balanced cost-benefit ratio
- Durability



CONFIGURATION DIAGRAM



Simplified Configuration Diagram – Combination of solar thermal façade and heat pump with well water use.

Legend

1 … Thermal bivalent façade collector

2 … Thermal absorber unit

3 … Air duct connection

4 … Air duct system (cascaded)

5 … Supply air terminal (fan silenced)

6 … Switchable flaps in air duct

7 … Heating and cooling unit, air pre-heating resp. cooling due to well water

8 … Primary circuit (solar flow)

9 … Primary circuit (solar return)

10 … Circulating pump (primary circuit)

11 … Plate heat exchanger

12 … Expansion tank (primary circuit)

13 … Stratified charge accumulator – 6400 Liter

14 … Circulating pump (secondary circuit)

15 … Plate heat exchanger (secondary circuit)

16 … Heat pump – Cooling capacity: 81 kW
Heating capacity: 112 kW

17 … Heating Manifold; Office & Production

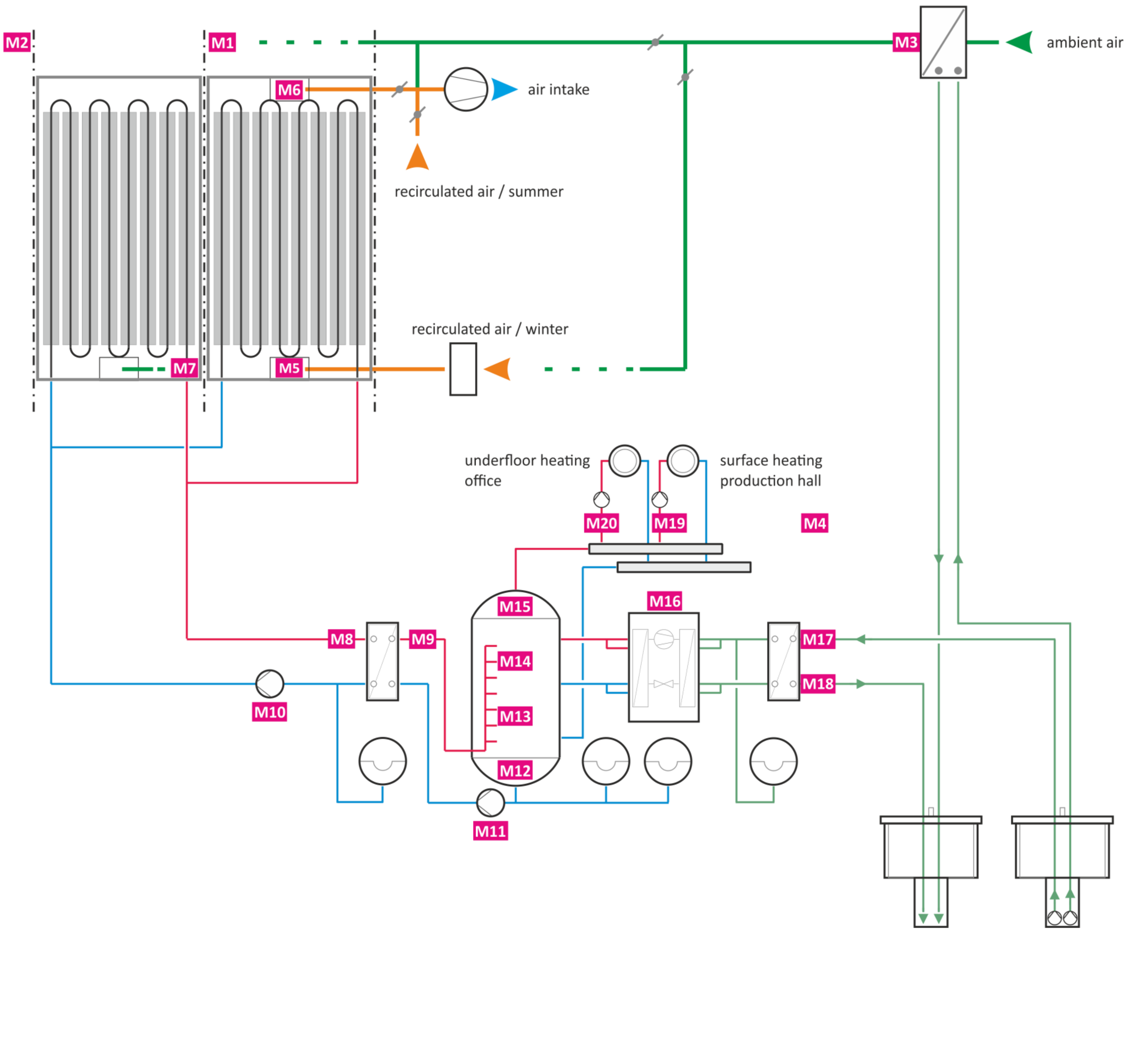
18 … Plate heat exchanger – 81 kW , environmental energy

19 … Discharge Well

20 … Circulating pumps (Intake Well)

21 … Intake Well

MONITORING | MEASURING POINTS



Position of the Sensors – Showing only those measuring points, which are considered in this report.

Legend – Measuring Transducer

M1 … External radiation (South)

M2 … Ambient Temperature, Production Hall (North)

M3 … Supply air temperature output heating / cooling battery

M4 … Hall Temperature, Aluminium Hall, 4m above ground level

M5 … Air temperature inside collector (bottom)

M6 … Air temperature inside collector (top)

M7 … Hot water temperature (collector)

M8 … Solar flow temperature (primary circuit)

M9 … Accumulator charging temperature (secondary circuit)

M10 … Circulating pump, solar flow (switch cycle)

M11 … Accumulator charging pump (switch cycles)

M12 … Storage temperature 1 (bottom)

M13 … Storage temperature 2 (mid bottom)

M14 … Storage temperature 3 (mid top)

M15 … Storage temperature 4 (top)

M16 … Heat pump (switch cycles)

M17 … Supply temperature (intake well)

M18 … Return temperature (discharge well)

M19 … Supply temperature heating circuit (hall)

M20 … Supply temperature heating circuit (office)

The monitoring and measurement system comprises 48 measuring points, such as heat flow meters, temperature and radiation sensors, switching time acquisition for pump and fan operating times and more.

The figure on the left shows the position of the sensors, which are taken into account in the evaluation charts of this study. The data acquisition system has been supplying high-resolution and reliable figures for the operating conditions of the plant for over 10 years.

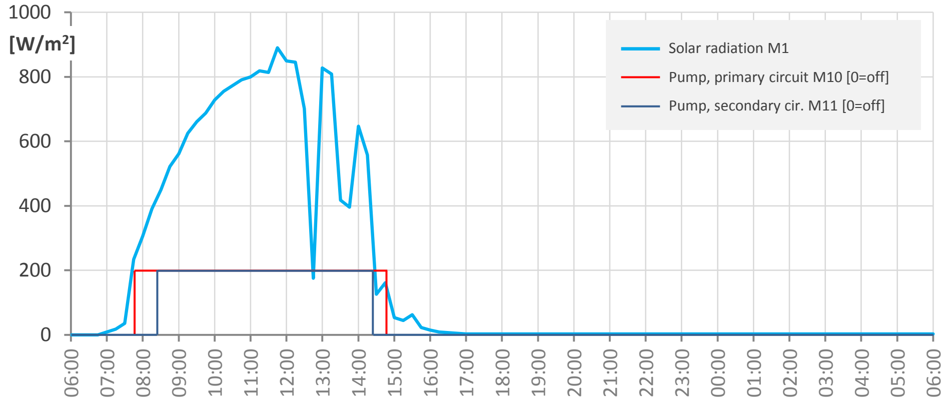
OPERATION – 2016-11-14 | WINTER SCENARIO

- Solar radiation
- Circulating pumps (solar flow)

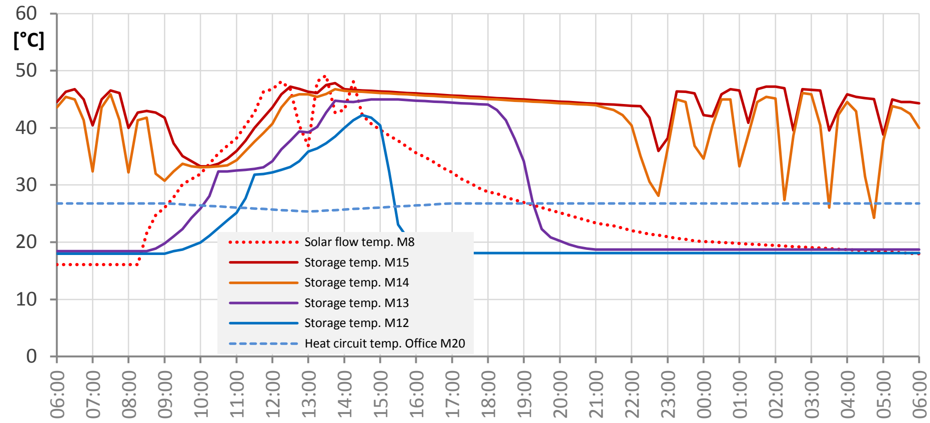
Solar irradiance per day: **548 kWh**
(total area absorber)

Solar heat supply: **250 kWh**

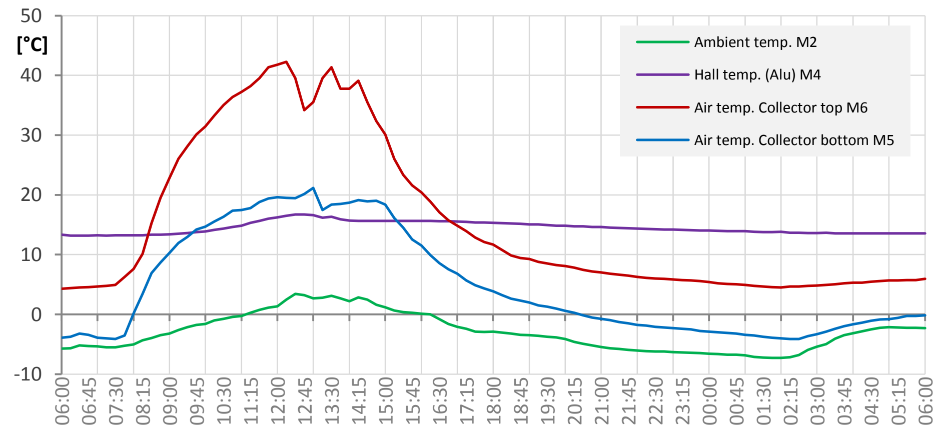
Irradiance / Peak: **802 W/m²**
(converted to vertical plane)



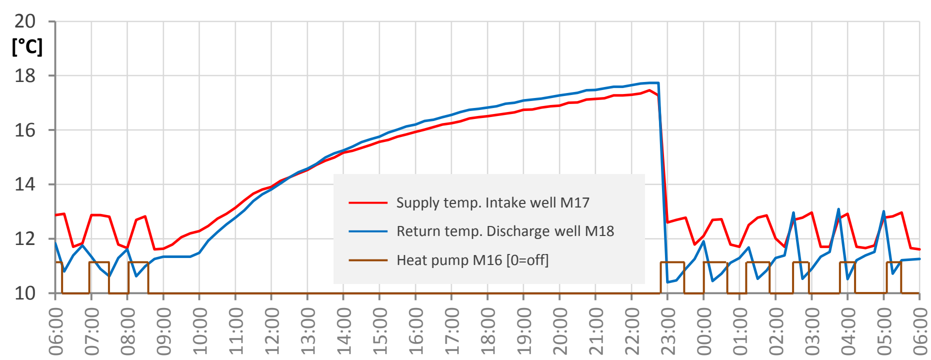
- Storage temperatures
- Solar flow temperature
- Heating circuit temp. (Office)



- Ambient temperature
- Hall temperature
- Air temperatures (Collector)



- Supply temperature (Intake well)
- Return temp. (Discharge well)
- Heat pump (Operation)



OPERATION | ANNOTATIONS

The radiation pattern describes a nice, clear November morning. Radiation peaks reach up to 860 W/m^2. Values such as these can only be achieved in winter on vertical south-oriented surfaces. The measuring sensor is arranged parallel to the edge of the building, though vertically inclined by 10° towards the sun. Around 12:30 PM, clouds were overcasting the sun for a short time, which caused a short-term and partially massive radiation decline below 200 W/m^2.

The solar circuit pump starts the primary circuit until a radiation threshold of 250 W/m^2 is obtained.
The storage loading pump runs based on time and temperature controls.

Four temperature sensors that are installed at different heights in the stratified charge accumulator represent the layering. The heat pump takes over before sunrise for heating requirements and partially discharged storage. For energy-savings, this just feeds the upper storage area and is only driven sequentially. The zigzag pattern indicates partial charges and discharges. In accordance with the level of solar irradiation and the resulting charging temperature, the converted solar energy is shifted into its respective storage layer. Solar energy is continuously supplied to the storage until 2:20 PM. At that same time, heat is extracted from the heating circuits.

After sunset, the discharge curves of the various layers are shown. Energy is supplied to the heating circuit distribution system. The heat pump takes over again just before 11:00 PM. The solar flow temperature exponentially decreases after switching the pump off, which corresponds with natural cooling down behavior. Daily peaks of 50 °C were obtained. The water temperature of the collector climbed up to 57 °C. The heating circuit temperature in the office decreased slightly during the day. This makes the passive solar gains via the windows noticeable. The control system responded correctly and slightly decreased the flow temperature of the heating circuit. This ranged from 25 °C to 27 °C.

The outside temperature remained mostly below 0 °C and only reached values of up to 3.5 °C during the day. The air temperature measurement points in the collector show a maximum spread of just over 20 °C. The profile in the upper measuring point essentially follows the collector water temperature, or more specifically the solar flow temperature. If only positive temperature values occur in the upper collector area, they can drop below freezing in the lower collector area. The increase in the two collector air temperatures from 2:00 AM is due to the rising outside temperature. This energy flow control leads to approx. consistent air temperatures between 14 °C and 18 °C in the hall area. These temperatures are perceived as pleasant room temperatures during physical work. The somewhat higher values during the day are a result of the passive solar gains through the skylight.

To achieve fast response times, heated collector air is channeled directly into the work area. Energy inputs can still be generated via the air, especially with low solar irradiation that is no longer efficient for water heating. The concrete core activated floor slab secures the thermal mass storage tank and, as a result, the naturally inert heat supply.

The temperature curves from the extraction and absorption wells are insightful. These serve as an energy reservoir to the heat pump, and in the summer, they also supply the cooling register for the ventilation circuit. The heat pump is switched into sequences. The temperature difference between flow and return is an indicator of the amount of omitted greenhouse gases. The energy supply for heating is exclusively solar between 8:30 AM and 10:45 PM.

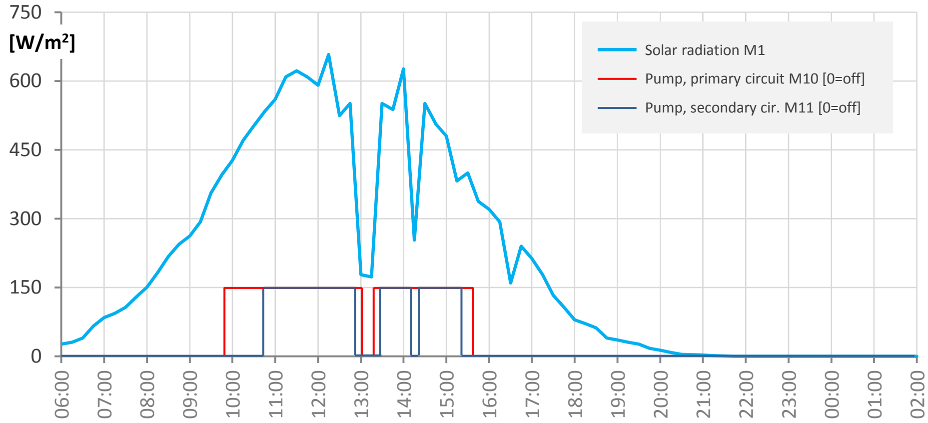
OPERATION – 2015-07-21 | SUMMER SCENARIO

- **Solar radiation**
- **Circulating pumps (solar flow)**

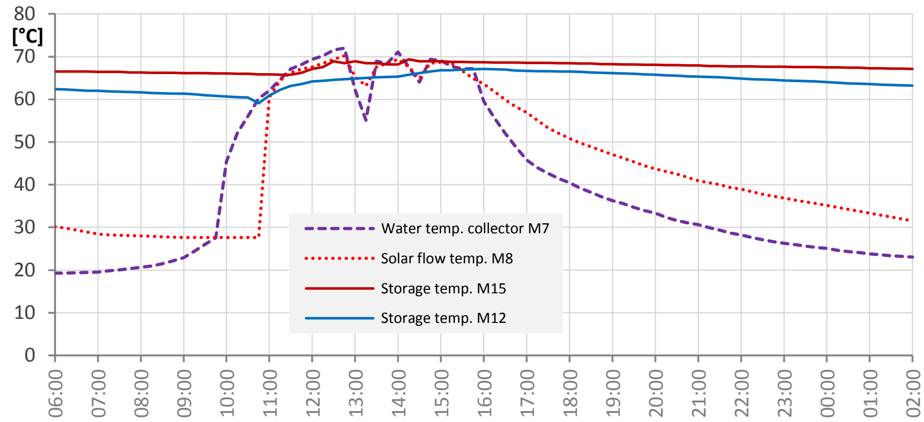
Solar irradiance per day: 422 kWh
(total area absorber)

Solar heat supply: - kWh

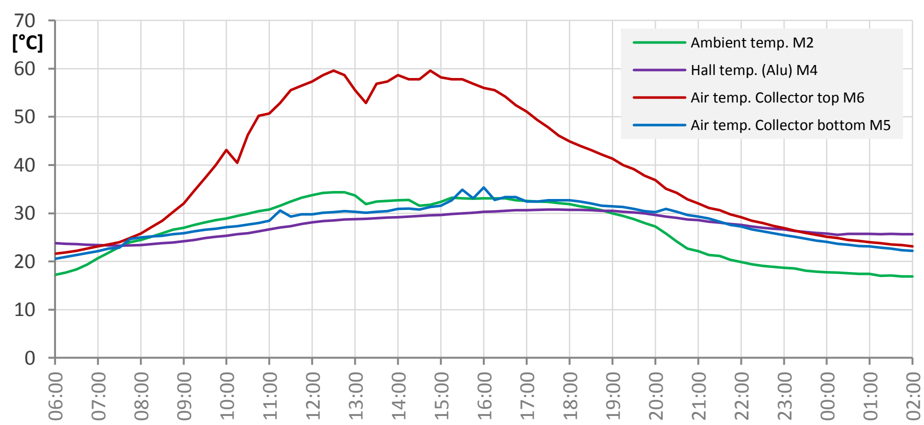
Irradiance / Peak: 526 W/m²
(converted to vertical plane)



- **Storage temperatures**
- **Solar flow temperature**
- **Water temperature (Collector)**



- **Ambient temperature**
- **Hall temperature**
- **Air temperatures (Collector)**



OPERATION | ANNOTATIONS

The diagrams on the left-hand side describe relevant factors during the summer season. The irradiation pattern reflects a beautiful day in July that was overcast with clouds at noon. With peak values well below 600 W/m² (typical for vertical south façades in summer), very moderate solar radiation values are shown. There is, of course, no heating requirement at this time of the year. The collector water circuit is idle.

The pump of the solar primary circuit is switched on at an irradiation threshold of 400 W/m². This serves to dissipate heat from the collector, which then serves to protect the system and significantly extend the service life of system components. Furthermore, the stratified storage tank is kept at storage temperature, so that everything remains pleasantly temperature-controlled on cool summer days, particularly in the office area. This provides temperature control at zero cost.

The system concept shows collector standstill temperatures well below 100 °C. If this is compared with conventional collectors, which exhibit standstill temperatures of 150 °C or more, this results in a greatly reduced thermal load on the implemented components. This is a circumstance that is positively reflected in hardly perceptible wear and the overall longevity of the system.

The charge accumulator shows an almost homogeneous layer profile with temperatures between 60-70 °C. This is fully, thermally charged. Energy can be extracted when required.

Note: The hot water supply is also provided by solar energy via a separate collector circuit.

The long-term operating experience shows that solar yields can be productively fed into the floor slab as early as the end of August. The thermally activated concrete slab is used as a quasi-storage. This results in a high solar coverage rate of the heating requirement for the transition months of September and October.

The outside temperature is very high with peak values of approximately 35 °C. The collector air circuit is not active. The temperature spread of the two curves, in the lower and upper collector area, represents the natural thermal buoyancy. The façade collector serves as a highly efficient thermal skin with a minimal U-value.

Supply air is pre-cooled via the cooling battery and then fed into the halls. If necessary, additional water cooling can be installed via the heat pump and the floor slab.

The room temperature of the hall is between 23 °C (morning) and 31 °C. The main influencing factor here is the skylight. Arranged in the roof area, the hall is not only provided with the required daylight. In the summer, radiation peaks above 900 W/m² can occur during sunny weather. This impacts on the cooling loads, direct or time delayed depending on the heaviness of the construction, and can subsequently lead to an increase in the internal temperature.

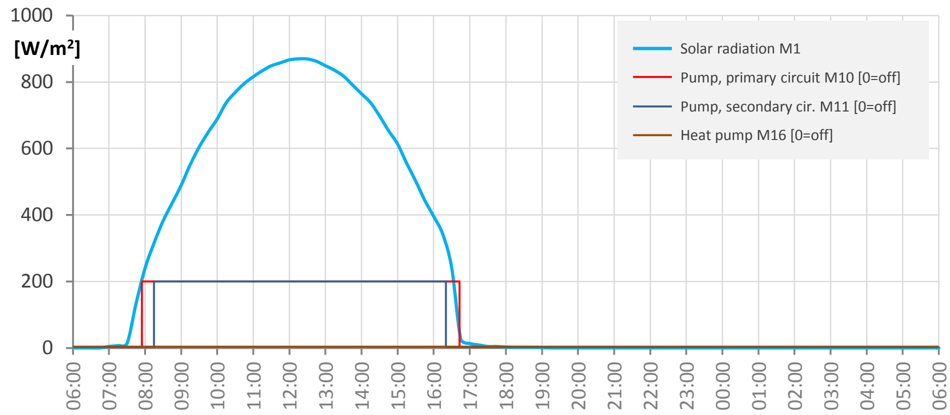
OPERATION – 2015-11-01 | WINTER SCENARIO – TOP YIELD

- **Solar radiation**
- **Circulating pumps (solar flow)**
- **Heat pump (Operation)**

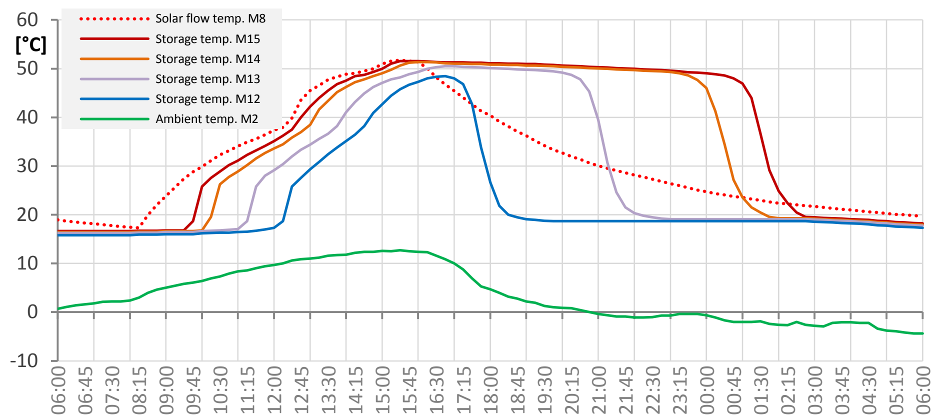
Solar irradiance per day: 705 kWh
(total area absorber)

Solar heat supply: 370 kWh

Irradiance / Peak: 817 W/m²
(converted to vertical plane)



- **Storage temperatures**
- **Solar flow temperature**
- **Ambient temperature**

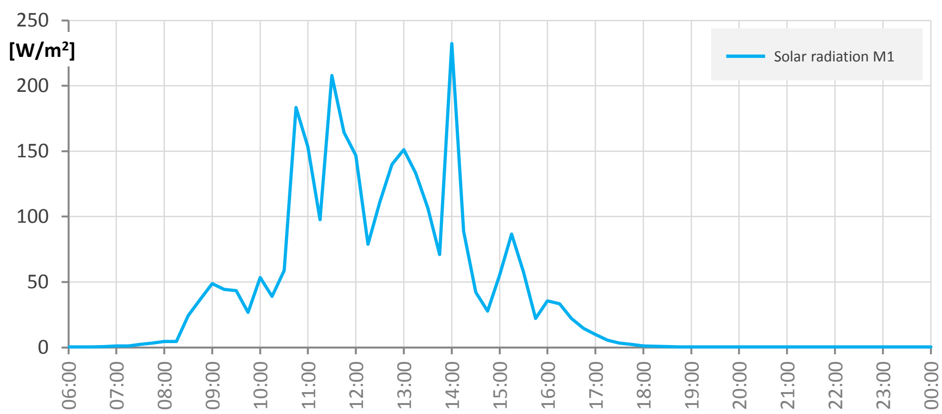


OPERATION – 2015-01-27 | WINTER SCENARIO – CLOUDY DAY

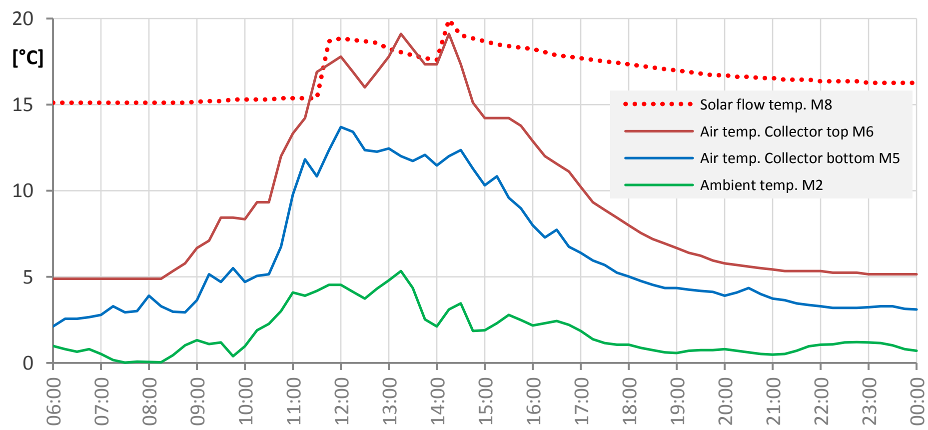
- **Solar radiation**

Solar irradiance per day: 88 kWh
(total area absorber)

Irradiance / Peak: 232 W/m²
(converted to vertical plane)



- **Solar flow temperature**
- **Air temperatures (Collector)**
- **Ambient temperature**



OPERATION | ANNOTATIONS

A Winter Case with Peak Performance:

The 1st of November 2015 was a sunny day, with very little clouding. The solar radiation reaches a maximum value of about 817 W/m^2 (converted to the vertical south façade) at 12:15 PM. The daytime radiation on the collector aperture area shows a cumulative peak of 705 kWh. The solar heat supply via the collector water circuit displays a peak yield of 370 kWh. This makes energy available in the order of magnitude of the solar circuit in such a way that results in a self-contained 24-hour supply of the heating circuits via the thermal energy façade. Despite the relatively low outside temperatures of -3 °C to 12 °C, the heat pump is not used.

The building can be solar-heated during the transition months without sacrificing comfort even on cool, solar-productive days.

The solar circuit pump sets the water circuit in motion at 200 W/m^2 irradiation. The storage loading pump is almost fully active. Between 4-5:00 PM, with sunset at 4:45 PM, an almost homogeneous temperature profile of the load tank is shown with temperatures between 48 and 52 °C. The slight curve deformation of the storage temperatures in the morning is indicative of increased energy dissipation across the air circuit. This curve shape is also reflected in the solar flow temperature. The collector will discernibly detract energy via the air circuit.

A Winter Case with Daylong Cloud Coverage:

January 27 illustrates a fully cloudy day. The maximum irradiation is comparatively low with 232 W/m^2 (converted to the vertical south façade). The achievable and cumulative radiant energy, which at 88 kWh is only 13% compared to the aforementioned peak performance, is even more meaningful. This value depicts the distribution of light of the collector's impinging radiation. This outlines, in the case of non-concentrating solar systems, the maximum available solar energy and thus fixes the theoretically possible upper limit of the solar yield. The solar water circuit was not activated on this day.

The outside temperature ranged from 0 to 5 °C. Collector temperatures of up to 20 °C came as a result despite the excessively diffused and strongly reduced irradiation. This low-temperature potential is accessed and absorbed over the air circuit. The halls are fed directly by the air circuit with preheated collector air. In addition and due to its design, the collector is highly effective as a thermally efficient 'skin'. Common transmission heat losses that occur with conventional post & beam façades in combination with these weather conditions are reduced to a marginal level, and they are even shifted into the energetic profit zone via the ventilation circuit.

MAINTENANCE

10 years of hassle-free operation with minimal maintenance that is limited to:

- 1x Cleaning the Glass Façade
- 2x Replacing the Air Filters
- 1x Replacing the Tubular Entities of the Water-Air Heat Exchanger

Despite the activation of the building envelope, the maintenance costs are hardly worth mentioning.
Conventional fuel oil burner systems lag behind in a different, noticeably higher cost framework.

Component wear and tear due to thermal alternating stresses cannot be detected even after the most recent inspection.

RESULTS

The performance of the system decisively depends on the overall design. The main influencing factors in the winter cases are: the absorber surface, the type and size of the stratified charge accumulator, the mass of the component activation, as well as the sophisticated controls.

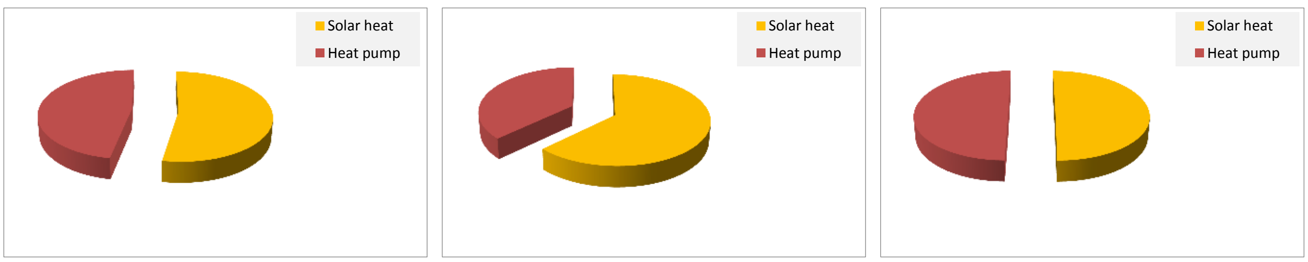
On beautiful winter days, the heat pump can be done away with completely (see Figure 5). Over the year (heating period), the solar system takes over more than 50% of the heat generation. Figures 1-3 also illustrate this ratio. This value varies by daily, monthly, or yearly observations. Comparing the electrically used energy of the heat pump with the total heat nearly results in a 1:4 ratio (see Figure 4).

The air circuit, which was not energetically evaluated in the present study, ensures cool air in the summer and heats the supply air in the winter via solar inputs.

Time period	Mode	Unit	Solar heat supply	Heat pump supply	Heat pump consumption elec.	Floor heat., Office consumption	Heating, Hall consumption
2015-11-01	Daily total	kWh	370	0	0	55	305
2016-11-14	Daily total	kWh	250	223	125	80	380
Nov 1 - 14, 2016		kWh	910	3.820	1.882	830	3.800
October 2016	Monthly total	kWh	2.460	1.453	643	940	2.900
Jan 1 - Nov 14, 16		kWh	22.300	19.751	11.970	8.000	32.900
2015 total	Yearly total	kWh	26.700	26.540	15.430	11.200	40.600
2006 - 2015		kWh	294.600	264.093	147.538	110.320	392.602

Table – Heat flows of the entire system as well as the electric drive energy of the heat pump, pictured for different time periods. Data recorded: November 14, 2016 at 7:00 PM.

Day: November 14, 2016 **Month**: October 2016 **Year**: 2015



Figures 1-3 – Illustration of the heat portions generated by the solar façade and the heat pump for different periods. Gains produced by the air circuit are not considered. Conservative estimates suggest an additional potential savings of up to 15%, achieved through direct or indirect air circuit operation.

The dimensioning of the mass of the component activation is a great influence. In the present case, this would be the concrete base plate, which serves as quasi storage and is dimensioned with a thickness of 250 mm. By the end of August, the solar yield of the façade will be fed into the concrete slab. For the transition months in autumn, this results in exceptionally high solar coverage rates for the heating system.

Even cloudy days lead to collector temperatures of more than 20 °C, which are then directly introduced into the halls via the air circuit while additionally acting as a thermally improved skin on the outside.

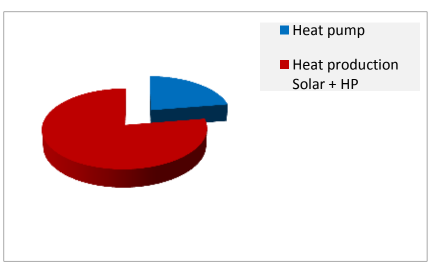


Figure 4 – Shares of heat generation of the solar façade and heat pump (HP) in relation to the electrical energy of the heat pump used.

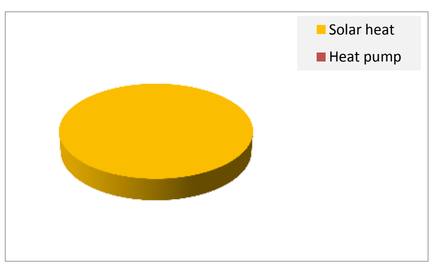
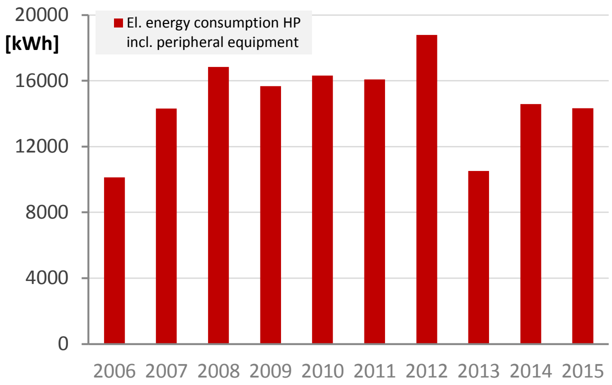
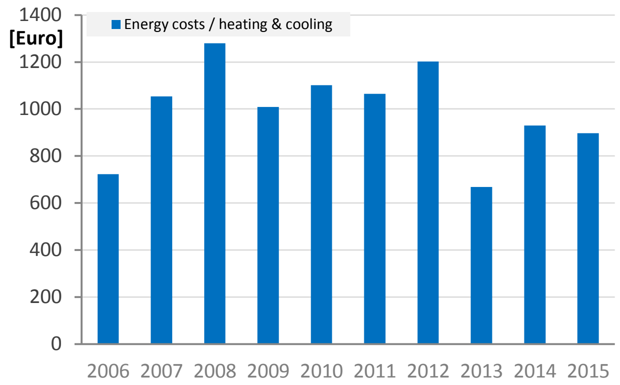


Figure 5 – Building is entirely heated by the energy façade.
High radiation day, November 1, 2015.





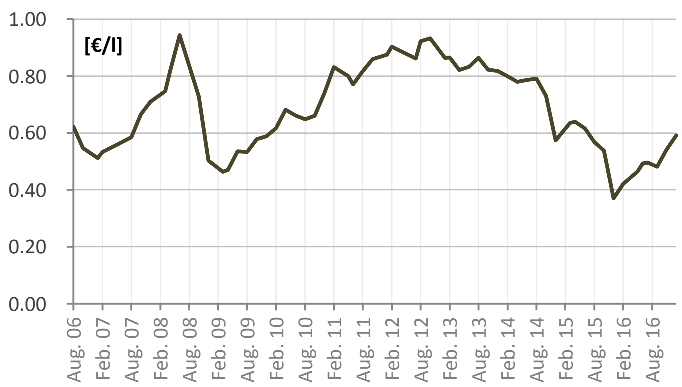
Histograms 1, 2 – Energy costs as well as expended electric total energy for the heating and cooling of the office & production building over a 10-year period.

The 10-year average of electricity consumption for heat pumps and circulating pumps is less than 15,000 kWh/a. In terms of the effective area, this means less than **9.4 kWh/m²/a.** Thermal or visual comfort does not have to be given up. The different years vary quite considerably at times. These are reflected by tougher or milder winters, as well as by winters with comparatively high irradiation levels.

Compared with a conventional oil burner-based heating system with an underlying nominal consumption of 10 liters per m² per year, it results in an energy consumption of a comparative amount of 16,000 liters of oil fuel per year.

This system does not just claim itself to clearly be the better environmental balance. The dependence on oil price development and the reduced monetary input for electrically driven energy are motivating people to depart from burning fossil fuels.

Over a 10-year period of time, CO_2 savings for 160,000 liters of oil fuel add up to 500 tons.



- Source: Esyoil.com
- Based on: 3000 Liter quantity ordered

Figure 6 – Evolution of oil prices between 2006 and 2016

This report was based on UNIMET's (company) documents, drawings, construction of the UNIPOWER PRO system, including specifications, and data that was recorded for over 10 years.

By way of example, individual days were used for the evaluation in order to visualize and quantify the complex interaction of the different structural components.

Despite the great efforts of the EU, as well as of individual EU countries, about 40% of the primary energy is still being used for existing buildings and is largely fossil. In an exemplary manner, UNIMET demonstrates a viable energy management concept that completely avoids the use of fossil, environmentally harmful resources, yet does not compromise the comfort and well being of employees or the durability of the system.

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