Demonstration cases of Solar Energy Buildings

IEA SHC TASK 66 | SOLAR ENERGY BUILDINGS

Technology Collaboration Programme by iea

Demonstration cases of Solar Energy Buildings

This is a report from SHC Task 66: Solar Energy Buildings and work performed in Subtask BC: New and existing buildings and building blocks / communities

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Cover photo credit Jenni Energietechnik AG, 100% solar-heated multi-family building in Oberburg, Switzerland

Technology Collaboration Programme
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Solar Heating & Cooling Technology Collaboration Programme (IEA SHC)

The Solar Heating and Cooling Technology Collaboration Programme was founded in 1977 as one of the first multilateral technology initiatives ("Implementing Agreements") of the International Energy Agency.

Our mission is: *"Through multi-disciplinary international collaborative research and knowledge exchange, as well as market and policy recommendations, the IEA SHC will work to increase the deployment rate of solar heating and cooling systems by breaking down the technical and non-technical barriers."*

IEA SHC members carry out cooperative research, development, demonstrations, and exchanges of information through Tasks (projects) on solar heating and cooling components and systems and their application to advance the deployment and research and development activities in the field of solar heating and cooling.

Our focus areas, with the associated Tasks in parenthesis, include:

- Solar Space Heating and Water Heating (Tasks 14, 19, 26, 44, 54, 69)
- Solar Cooling (Tasks 25, 38, 48, 53, 65)
- Solar Heat for Industrial and Agricultural Processes (Tasks 29, 33, 49, 62, 64)
- Solar District Heating (Tasks 7, 45, 55, 68)
- Solar Buildings/Architecture/Urban Planning (Tasks 8, 11, 12, 13, 20, 22, 23, 28, 37, 40, 41, 47, 51, 52, 56, 59, 63, 66)
- Solar Thermal & PV (Tasks 16, 35, 60)
- Daylighting/Lighting (Tasks 21, 31, 50, 61)
- Materials/Components for Solar Heating and Cooling (Tasks 2, 3, 6, 10, 18, 27, 39)
- Standards, Certification, and Test Methods (Tasks 14, 24, 34, 43, 57)
- Resource Assessment (Tasks 1, 4, 5, 9, 17, 36, 46)
- Storage of Solar Heat (Tasks 7, 32, 42, 58, 67)

In addition to our Task work, other activities of the IEA SHC include our:

- SHC Solar Academy
- *Solar Heat Worldwide*, annual statistics report
- SHC International Conference

Our members

Australia	European Copper Institute	SICREEE
Austria	France	Slovakia
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Contents

1 Executive Summary

A total of 22 demonstration cases of Solar Energy Buildings and Building Blocks inside and outside district heating areas are described.

The demonstration cases are located in Europe, Asia and Australia. The demonstration cases can serve as inspiration in connection with planning of future Solar Energy Buildings and Communities.

Guidelines for monitoring and reporting of Solar Energy Buildings and Communities has been prepared. The guidelines give detailed information on how best to follow the operation of the Solar Energy Buildings and Communities.

The guidelines are of vital importance in connection with evaluation of the different technologies as well as of the combinations of the technologies used in the Solar Energy Buildings.

Stakeholder's viewpoints concerning different aspects on planning and project development of future Solar Energy Buildings and Communities have been gathered and analysed. The viewpoints were selected by means of 309 filled in questionnaires from stakeholders in the field. Viewpoints from Germany, China, Mexico, Denmark, Austria, Switzerland, Slovakia, India, Sweden, Luxembourg, Belgium, the Netherlands and USA were included in the analyses. The most important barriers for a fast spread of Solar Energy Buildings and Communities were identified.

2 Demonstration cases

2.1 Overview of Task 66 demonstration cases

Demonstration cases have been collected from the participating countries. The demonstration cases are listed in Table 1. Most of the demonstration cases have been newly build or newly refurbished. Consequently, measurement programs for these cases have not started yet, or are ongoing. Therefore, not all measured performance data are available at this point in time.

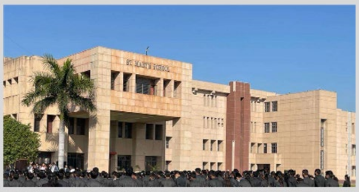
Table 2: Summary of demonstration cases technologies and other details (sorted by European and Asian countries, and Australia).Table 2: Summary of demonstration cases technologies and other details (sorted by European and Asian countries, and Australia).Table 2: Summary of demonstration cases technologies and other details (sorted by European and Asian countries, and Australia). gives an overview of the technologies used and other details. The following sections give detailed descriptions of each demonstration case, focusing on the buildings and the technologies. The demonstration cases include buildings located in district heating areas and individual buildings located outside district heating areas. For buildings connected to an electrical grid, smart interaction with the electrical grid is possible. Buildings located in a district heating area can interact with the thermal grid. The overall purpose of grid interaction is to reduce the energy price for the user whether this is by utilizing low energy prices when they are available or by not using energy from the electrical or thermal grid to reduce peak loads.

Table 1: Demonstration cases overview

Former Industrial complex, Austria *Commercial/Residential*  SEB No. 1	Leh, Ladakh, Himalaya *Kurja Guest House*  SEB No. 2	Kahrener Straße, Cottbus, Germany *Multifamily solar house*  SEB No. 3
LNEG Campus, Lisbon, Portugal *Test Champers*  SEB No. 4	Warsaw, Poland Orphanage  SEB No. 5	Konstanz, Germany *Block of multifamily houses*  SEB No. 6
Reference building, Austria *Multifamily Solar house*  SEB No. 7	Reidberg, Germany *Multifamily houses*  SEB No. 8	Campagne-Reichenau, Austria *Smart City Quarter in Innsbruck*  SEB No. 9
Neue Heimat Tirol, Austria Residential Complex in Rum, Tirol  SEB No. 10	Kochi, India Rajagiri College of Social Science  SEB No. 11	Kochi, India Rajagiri Autonomous Institutions  SEB No. 12

Haryana, India

Educational Institution – St. Mary School



SEB No. 13

Delhi, India

Holy Family Hospital

SEB No. 14

Franz-Mehring-Platz, Freiberg, Germany

Energy-autonomous single-family homes

SEB No. 15

Muehlhaeuserstrasse, Weinstadt, Germany

New residential and service complex

SEB No. 16

Neissestrasse, Ludwigsburg, Germany

New building district

SEB No. 17

East Beisanhuan Road, China

Office building in Beijing

SEB No. 18

Aarhus, Denmark

READY – Resource Efficient Cities Implementing Advanced Smart City Solutions

SEB No. 19

Giggs Place Hilton, Australia

Solar electric single-family home

SEB No. 20

Hunan, Ningxiang City, China

Changeable Inperspace House

SEB No. 21

Gräfelfing, Germany

Refurbishment of an existing building with a new Solar Energy Building

SEB No. 22

Table 2: Summary of demonstration cases technologies and other details (sorted by European and Asian countries, and Australia).

					SEB Technologies														
					Energy source								Energy storage						
					sun			wind	water		earth	air	electrical storage		thermal storage				
Country	District heating network	Measurements	Calculations	Number of technologies used	Photovoltaic	Solar thermal collectors	Solar-air collector	PVT-collectors	Hydropower plant	Groundwater and heat pumps	Geothermal and heat pumps	Air-source heat pumps	batteries	Mobile batteries (E-mobility)	Hot water storage	Thermochemical storage	Ice storage	Thermal mass activation
AT, SEB No. 1			X	7	X				X	X			X	X	X			X
AT, SEB No. 7	X		X	7	X			X			X		X	X	X			X
AT, SEB No. 9	X	X	X	5	X					X		X			X			X
AT, SEB No. 10	X		X	4	X					X			X		X			
DE, SEB No. 6		X	X	4	X						X		X		X			
DE, SEB No. 8		X	X	7	X		X				X		X	X	X		X	
DE, SEB No. 3		X		5	X	X							X	X	X			
DE, SEB No. 15		X		5	X	X							X	X	X			
DE, SEB No. 16	X		X	5				X						X	X		X	X
DE, SEB No. 17	X		X	4	X	X									X		X	
DE, SEB No. 22	X	X	X	5	X	X							X	X	X			
PT, SEB No. 4				2		X									X			
PL, SEB No. 5				4		X					X				X	X		
DK, SEB No. 19	X	X	X	6	X			X		X			X	X	X			
CN, SEB No. 18	X	X	X	3	X								X	X				
CN, SEB No. 21				4		X					X	X			X			
IN, SEB NO. 11				1	X													
IN, SEB No.12				2	X	X												
IN, SEB NO. 13				2	X								X					
IN, SEB No. 14				3	X	X									X			
IN, SEB No. 2		X	X	4	X		X								X			X
AU, SEB No.20		X		6	X	X						X	X	X	X			

It is noticeable that the variability of technologies is greater in the European and Australian solar energy buildings than in the Asian. While, on average, the thirteen European building projects use five different components to ensure a high solar coverage rate, the Asian average is only three. This result is partly influenced by all the European buildings having a hot water tank. In Asia and Australia, there are only three buildings out of seven. Also, Indian and Australian solar energy buildings mostly do not require space heating.

2.1.1 Performance indicators, KPIs

Measured or calculated performance data from the building projects is used to calculate the degree of self-sufficiency for heating, cooling and electricity.

The degree of self-sufficiency is defined as renewable energy consumption (in question) / total energy consumption (in question).

The renewable energy consumption is from the building projects own renewable energy production. The renewable share in the electric and thermal grid from which the building also draws energy is not considered in the degree of self-sufficiency.

2.1.2 SEB No. 1 – Commercial/Residential, Former Industrial Complex, Graz, Austria

Location information
Adress: Puchstrasse 17, 8010 Graz, Austria
Geographic Coordinates: 47.05° N 15.43° E
Climate Zone: Continental climate
Building typology: Commercial/Residential

Autors: Thomas Ramschak (AEE INTEC), Christian Kossegg (BAR)

General Description

The former industrial area for feed production “Tagger-Werk” is located in the southern district of the City of Graz. The owner of the site, which has a gross floor area of around 31,000 m². Since 2012, the former industrial site has been transformed not only from an economic point of view but also from a sustainable point of view into a completely new type of utilization concept. It is particularly important to the owner that the existing building structure is used in the best possible way and that elements of the former industrial area are still visible. The entire energy supply should be based on locally generated energy (solar energy, groundwater, small hydropower) in a unique way. By using innovative elements for load shifting, thermal and electrical storage, user integration, interaction with the higher-level power grid as well as a smart, predictive control, maximum energy flexibility and an energy autonomy level of over 90% should be achieved. A central measure for the entire area is the consequent reduction of CO2 emissions through the use of highly efficient energy system technologies. Furthermore, the integration of e-mobility is an important component in the overall energy concept.

Detailed Description of Key Technologies installed

- One Third (15.660 m²) of gross floor area has already been energy-efficiently renovated to **low-energy building standards**. The declared goal for the other buildings to achieve **passive house standard**
- As groundwater wells are available on the site for energy use, **two groundwater heat pumps with a total capacity of 165 kW** were already installed and support a currently existing gas boiler (400 kW), which should be replaced in medium term by a completely renewable energy supply system.
- Since solar energy plays a central role in the energy supply of the site, **202 kWp of photovoltaics** were already installed. An extension to **365 kWp photovoltaic** surfaces on roofs and facades in planned.
- A small hydropower plant with a capacity of 140 kWp will be built in the Mühlgang (bypass of the river Mur) adjacent to the east.
- In order to improve the flexibility potential in a targeted manner, the use of a battery storage facility with a capacity of 225 kWh is planned.
- The energy flexibilization potential will be maximised by the use of **thermal activation of massive reinforced concrete façade components, decentralised water storage, integration of flexibilization potentials on the side of tenants and users (human centric approach)**.

Selected Performance Indicators[1]

Categorization of energy consumption

Heating: 28,2 kWh/m²a

Electricity: 29,5 kWh/m²a

Renewable Energy Generation

Photovoltaic: approx. 705 kWh/kWp

Hydro power: approx. 1193 MWh/a

degree of self-sufficiency

75%

Table 3: Overview of SEB technologies

	SEB Technologies															
	Energy source										Energy storage					
	sun			wind	water		earth	air	bioenergy		electrical storage		thermal storage			
Technologies	Photovoltaic	Solar thermal collectors	PVT-collectors	Wind turbines	Hydropower plant	Groundwater and heatpumps	Geothermal and heatpumps	Air-source heatpumps	Biomass combustion	Biogas plants	batteries	Mobile batteries (E-mobility)	Hotwater storage	Ice storage	Sorption storage	Thermal mass activation
	x				x	x					x	x	x			x

1 Note: until now only calculated data available

The Building's Special Features

In the H2020 project EXCESS a renovation concept for existing buildings is under development. The concepts will improve of the thermal quality of the building envelope and the implementation of an innovative energy production and energy supply system. Therefore, a prefabricated multifunctional façade element for easing the renovation of existing buildings is under developed. This façade element includes integrated energy producing active elements (PV), insulation and hydraulic activation elements for the use on existing facades as a heat/cold storage and heat dissipation system. In conjunction with the defined energy supply concept in the Demo case, the overall concept transforms the exterior wall into a cost-effective energy storage as well as an interesting element to increase the energy flexibility by storing surplus electricity in the activated element.

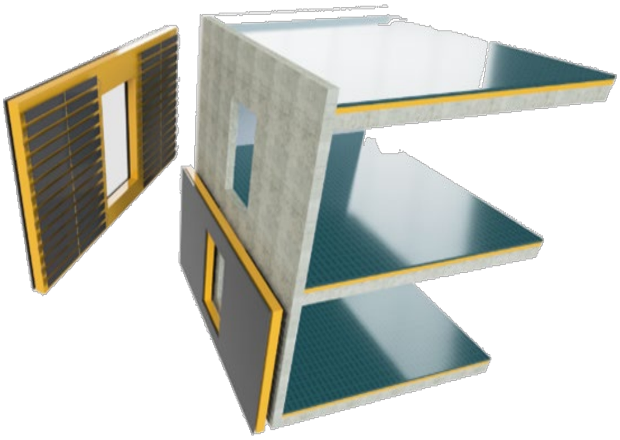


Table 4: Performance indicators

Year of measurements	Simulation	
Solar radiation on horizontal, kWh/(m².a)	1129.1	
Degree days for heating/cooling	3193/27	
Weather data used for calculation	ASHRAE reference climate for Graz-Thalerhof	
Gross Floor Area	31000 m²	
Energy consumption		
Time step used	15 min	
	Total	**Specific**
Heating (SH+DHW)	1734.9 MWh/a	56.0 kWh/m²/a
Cooling	291.5 MWh/a	9.4 kWh/m²/a
Electricity (total)	1879.7 MWh/a	60.6 kWh/m²/a
Electricity (heating+cooling)	967.1 MWh/a	31.19 kWh/m²/a
Renewable energy production		
Time step used	15 min	
Heating (SH+DHW)	HP: 1734.9 MWh/a * 0.9114 = 1581.2 MWh/a 91.14 % of heat from HP is supplied by on site electricity generation	
Cooling	291.5 MWh/a * 0.9570 = 279.0 MWh/a 95.70 % is supplied by on site electricity generation	
Electricity (total)	1709.1 MWh/a	
Renewable energy consumption		
Time step used	15 min	
Heating (SH+DHW)	HP: 1734.9 MWh/a * 0.9114 = 1581.2 MWh/a 91.14 % of heat from HP is supplied by on site electricity generation	
Cooling	291.5 MWh/a * 0.9570 = 279.0 MWh/a 95.70 % is supplied by on site electricity generation	
Electricity (total)	1415.5 MWh/a	
Electricity (heating+cooling)	570.94 MWh/a Used by HP, pumps and HVAC	
Degree of self-sufficiency		
Time step used	15 min	
Heating (SH+DHW)	91.14 %	
Cooling	95.70 %	
Electricity (total)	75.31 %	
Electricity (heating+cooling)	92.74 %	

Main Stakeholders Involved

The Austria demo site in the EXCESS Project (www.positive-energy-buildings.eu) is led and coordinated by AEE INTEC (AEE Institute for Sustainable Technologies) who participated in the development of Tagger-Werk in collaboration with the site owner BAR. Further demo site partners include Thomas Schwarzl IT Consulting and Joanneum Research.

Source: AEE INTEC

2.1.3 SEB No. 2 – Kurja Guest house, Leh, Ladakh, Himalaya

Location information

Adress: Kurja Guest House, Leh, Ladakh

Geographic Coordinates: 34.16°N 77.58°E

Climate Zone: Mountain climate (3.500 m)

Building typology: Residential

Author: Christoph Müller (Simply Solar GbR)

General Description

This robust, low-cost solution allows for traditional homes to be heated reliably and cheaply in challenging high-mountain regions like the Argentinian and Bolivian Altiplano, Ladakh and Kargil in the Himalayas. The described example is a pilot project in Ladakh. Ladakh winters are very cold (as low as -35°C) and long (>6 months heating period) but relatively sunny (Figure 1). Traditional homes only heat the living room, where the whole family is assembled around a Bukari oven.

In the challenging Himalayan climate a basic heat protection of the heated room is required. Based on proven technology our alternative heating solution is a simple solar air heater, with air circulating through a rock bed below the floor in a closed loop. The floor provides underfloor heating, creating an ideal temperature distribution in the room. Due to the big thermal capacity of the rock bed, rooms are heated 24h per day, even during 1-2 days without sun. No more searching for fire wood, or buying gas, no more smoke in the rooms which contributes to respiratory diseases or carbon monoxide incidents.

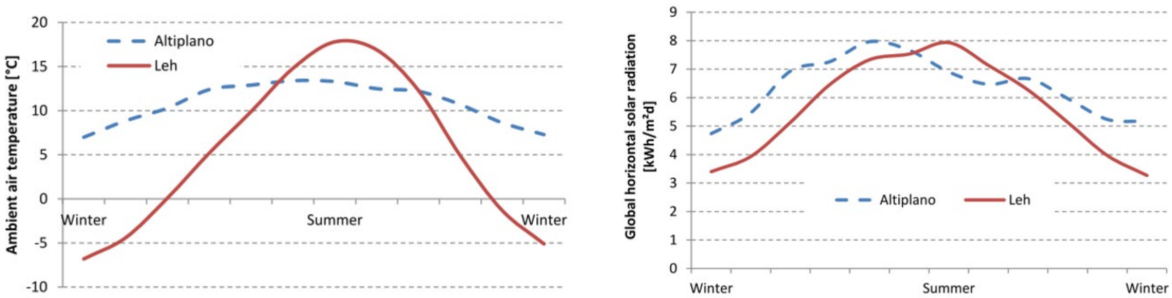


Figure 1: Yearly distribution of temperature (left) and solar radiation(right) in Leh and Altiplano.

The environmental benefits

- Air is used as heat transfer medium - no anti-freezing agent, no pressure at stagnation temperature in summer, no corrosion). Small leakages do not affect performance. No electronics used.
- Modularity allows adaptation to many consumer needs from collector sizes of 2 m² to 120 m²
- Easy to transport and assemble, due to sturdy modular design at low weight. Glass is placed during installation.
- Rocks are available in many regions at low cost which permitting big storage heat capacity, so the heat demand can even be covered for 1-2 days without sun
- Minimal user operation required. Just a on/off switch for the automatic fan operation in heating season.

The financial benefits

- Depending on the region, the system saves up to 90% of the conventional fuel used for space heating, translating to 370 USD per home in Ladakh and Kargil.
- Initial investment is paid off in 4-5 years.
- Locally sourced and produced materials allow for easy maintenance and job creation in the region.

Target group

- Regions with cold but sunny winters, suitable for the proposed technology are often found in southern countries with high mountain regions (Figure 2, pilot projects marked red):

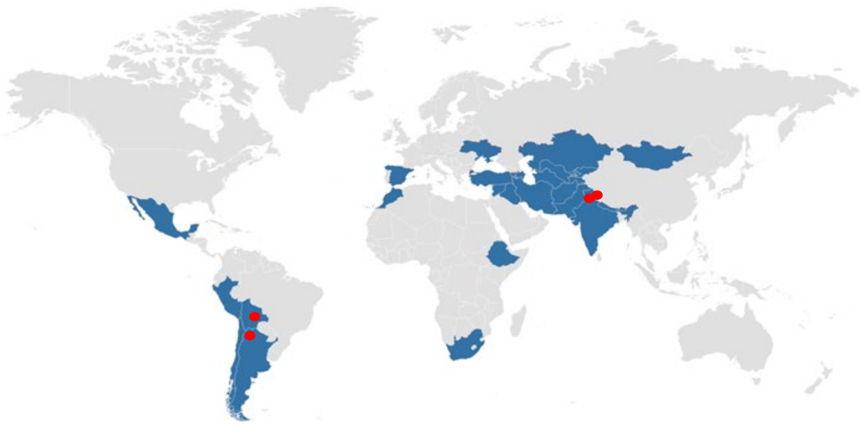


Figure 2: potential project areas and existing pilot projects

Detailed Description of Key Technologies

The system heats up air during sunshine hours; the heated air is circulated inside the building through efficient fans powered by 2 solar photovoltaic panels of 60 Wp each. The hot air circulated is used to heat up the rock bed thermal energy storage under the floor of the heated room (Figure 3). The rock bed serves not only as a heat storage system, but also as an underfloor heating system, and heats the room directly. Once the thermal storage is heated up, the heat is transferred indoors through the floor throughout the whole day.

The heated air can also be circulated from the chimney directly to the room (bypassing pebble bed storage) to warm up instantaneously. To save the energy generated from the sun the house is insulated for protection against external weather resulting in reduction of heat load by ca. 50 percent.

Selected Performance Indicators

Categorization of energy consumption

Heating: 580 kWh/m²a

380 kWh/m²a after basic heat protection.

Renewable Energy Generation

Solar air heater: ~1,4 kWh/m²/d during heating season

Degree of self-sufficiency

95% (measured)

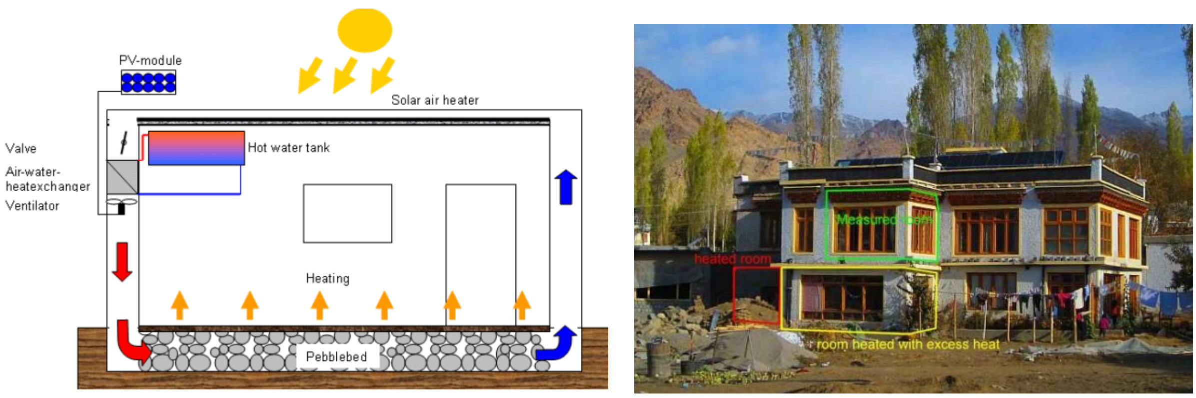


Figure 3: Schematic of heating system and Kurja Guest house with solar air heater on roof

The performance of the Kurja house has been monitored over almost one year. In the diagram below, the course of the ambient, indoor and floor temperature can be seen for a time period of 10.5 months from 26.11.2013 to 10.10.2014. During this time period, the room temperature dropped below 15°C only in 5.7% of the time. The measurement results shown that the average room temperature during the winter months was 15 to 20 K above the average ambient air temperature. It can be deducted from the floor temperature data, that the users switched off the heating system in the beginning of June and started it again for a short 14 day period end of September (Figure 4). The users were so satisfied, that they removed the traditional Bukari oven in the next winter season, as it was not anymore required. Instead, they used the gas oven as back up heater in a few occasions during long bad weather periods. They used 2 gas bottles (12 kg each) for cooking and heating over the heating season. In relation to the delivered heat of the solar air heater this corresponds to 6% of the heating demand, so the solar coverage can be stated with 94%.

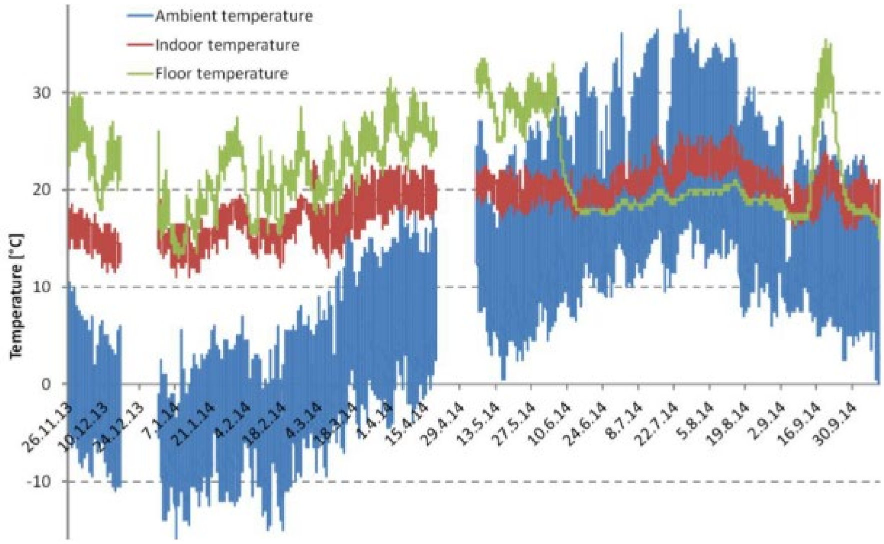


Figure 4: Measured temperatures at Kurja Guest house

Comparison between water- and air-based solar energy system

Solar air systems are not so wide spread and well known as solar water systems. Following table and graphics intend to explain the main differences, advantages and disadvantages of each technology.

	Water based system	Air based system
Heat transfer media capacity	High heat capacity -> only small volume flow (0.03 m³/m²h) in necessary, reducing duct size and insulation effort.	Low heat capacity -> high air volume rates (40 m³/m²h) and **larger channels** are necessary.
Freezing temperatures	**Danger of freezing**, regular control of anti-freezing agent necessary, as system gets damaged otherwise.	No freezing problems.
Stagnation	**High vapor pressure** or high degree of evaporation at stagnation temperature, especially in summer.	No problems of overheating in summer.
Complexity/costs	Usually corrosion resistant materials like copper, aluminum, stainless steel have to be used in solar water systems, which **increase costs**. Evacuated tubes might offer a more economical solution. In all cases many special components are used, which are not available easily.	Simpler and less expensive, locally available materials can be used. Work effort for the ducts and pebble bed storage might be higher, but create more local jobs and value.

Repairs	Repairs of the water circuit need **special know how and tools**.	Reparation of glasses, ducts etc. can often be done by the owner.
Circulation	**AC powered** water pumps dependent on unstable grids or need AC inverters for PV supply.	DC powered fans with direct PV supply -> independent/off-grid, robust.
Leakages	**Sensitive for leakage** in the water circuit – when water is missing in the circuit, operation is impossible.	No problems from leaks, no damage, no environmental or helth hazard risk from spilled heat transfer medium.
Efficiency	The efficiency at higher temperatures is higher than the one of simple air based systems. This makes smaller collector sizes possible (see figure 1-3)	Efficiency is competitive at lower temperatures. At higher temperatures the collector area must be bigger than that of a solar water system to achieve the same energy yield (Figure 5-Figure 6)
Storage	Hot water storage tanks offer a heat capacity of 35 kWh/m³ (dT=30K). Tanks must be made of corrosion resistant material with sacrificial anode, which must be controlled regularly. The anti-freezing/water mixture in the solar circuit must be separated from the storage by a heat exchanger.	Pebble bed occupies about **four times more** volume than a hot water storage with equal energy content. Its construction is completely made with local materials and workers.
Heat distribution to the room	Separate water based under floor heating with **piping and pumps** for circulation is necessary.	Heat is transmitted to the room trough conduction and natural convection as the storage cover is the room floor.
Warm water	Can be provided from the water storage tank.	Warm water can be produced by placing a heat exchanger in the air flow. The warm water system can run without pump and anti-freezing agent.

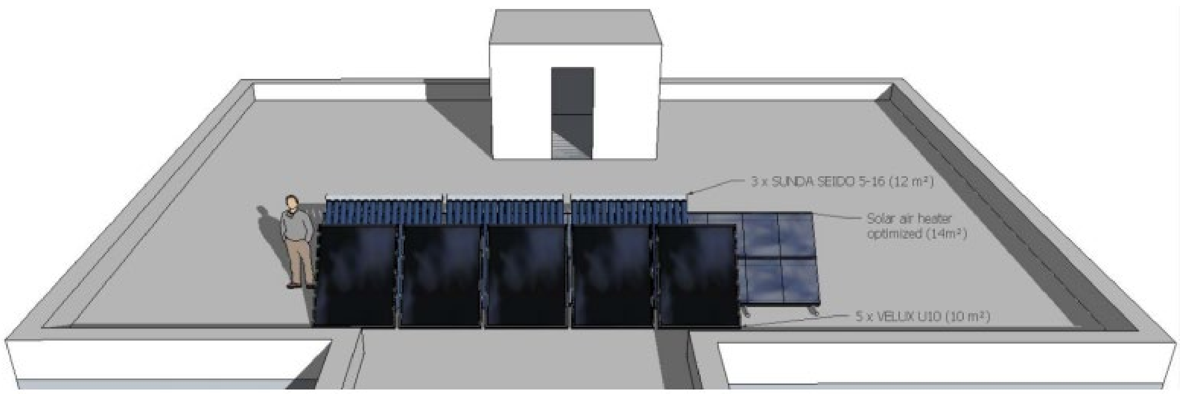


Figure 5: Comparison of practical collector sizes of solar air, flat plate and evacuated tube systems with similar energy output (frontal view)

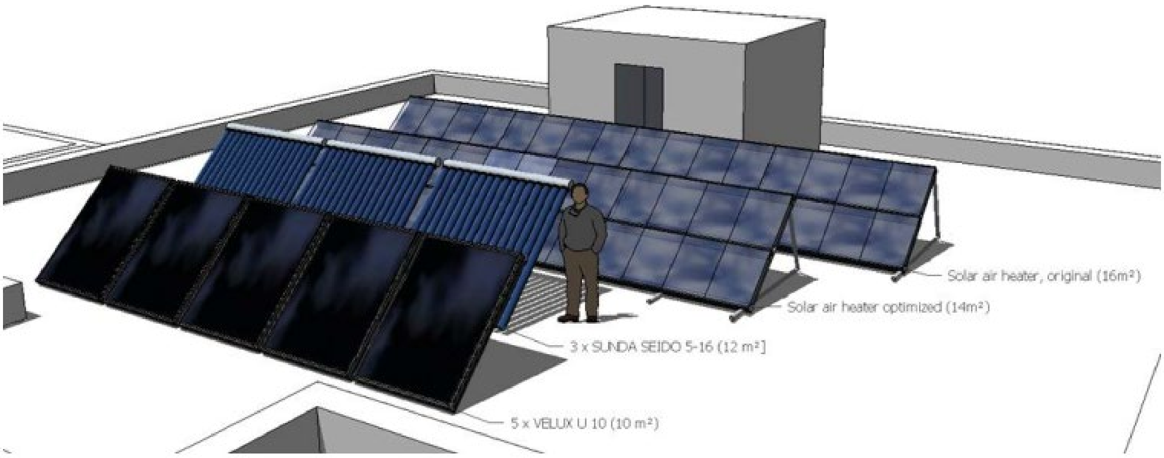


Figure 6: Comparison of practical collector sizes of solar air, flat plate and evacuated tube systems with similar energy output (side view)

Table 5: Overview of SEB technologies

	SEB Technologies															
	Energy source										Energy storage					
	sun			wind	water		earth	air	bioenergy		electrical storage		thermal storage			
Technologies	Photovoltaic	Solar thermal collectors	PVT-collectors	Wind turbines	Hydropower plant	Groundwater and heatpumps	Geothermal and heatpumps	Air-source heatpumps	Biomass combustion	Biogas plants	batteries	Mobile batteries (E-mobility)	Hotwater storage	Ice storage	Sorption storage	Thermal mass activation
	x	x											x			x

Table 6: Performance indicators

Year of measurements	2000-2009	
Solar radiation on horizontal, kWh/(m2·a)	1.686	
Degree days for heating/cooling	4.970 (20/12)	
Weather data used for calculation	Meteonorm 7	
Energy consumption	**Calculated**	**Measured**
Time step used	-	-
Heating (SH+DHW), kWh/a	7.445 (18°C) 5.939 (15°C)	6.193 (fuel year before solar)
Cooling, kWh/a		
Electricity (total), kWh/a		
Electricity (heating+cooling), kWh/a		
Renewable energy production		
Time step used	-	-
Heating (SH+DHW), kWh/a	5.937(18°C) 5.099 (15°C)(used)	5821
Cooling, kWh/a	-	-

Electricity (total), kWh/a		
Electricity (heating+cooling)	PV powered fan	PV powered fan
Renewable energy consumption		
Time step used	-	-
Heating (SH+DHW), kWh/a	5.937(18°C) 5.099 (15°C)(used)	5821
Cooling, kWh/a		
Electricity (total), kWh/a		
Electricity (heating+cooling), kWh/a	PV powered fan	PV powered fan
Degree of self-sufficiency		
Time step used	-	-
Heating, %	79% (18°C) 86%(15°C)	94% (6% gas heater (30kg))
Cooling, %	-	-
Electricity, %	100% (fans for air circuit)	100% (fans for air circuit)

Main Stakeholders Involved

The Kurja demo site together with another 10 pilot installations in Ladakh and Kargil was funded by German Ministry of cooperation (BMZ) and implemented in cooperation with GIZ India, Solar Institut Jülich, IGTE Uni Stuttgart and engineering office hc-solar.

2.1.4 SEB No. 3 - Multifamily solar house, Kahrener Straße, Cottbus, Germany

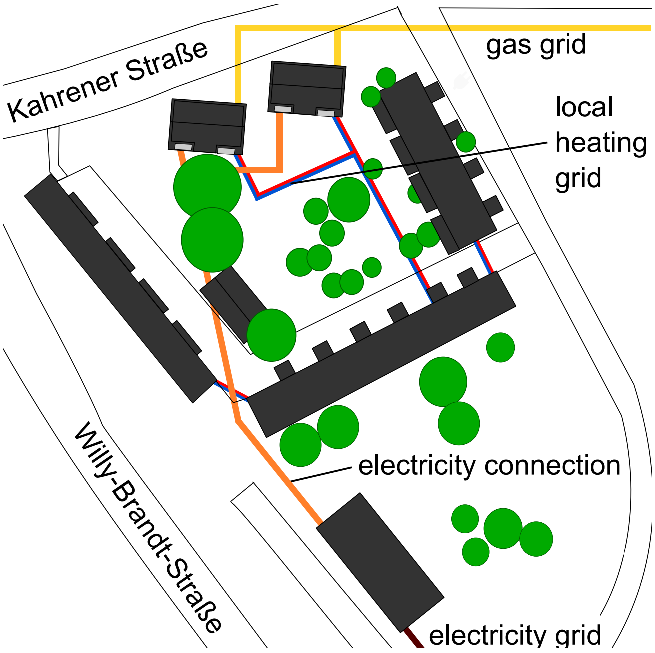
Autors: Lukas Oppelt, Thomas Storch, Andreas Gäbler, Tobias Fieback
(all TU Bergakademie Freiberg)

General Description

In 2019, two highly solar-supplied apartment buildings were completed and energy and sociological monitoring was carried out to evaluate the buildings. The integrated overall concept consists of a massive building envelope in combination with energy technology for high solar self-sufficiency (solar thermal and photovoltaics inclusive storage).

Surpluses of heat and electricity are to be consumed decentrally through networking and sector coupling in the neighbourhood and through the use of e-mobility, thus significantly increasing energy efficiency. In addition, a new type of flat-rate rental model approach is tested for the housing industry and energy supply companies.

The results of the evaluation of the first measurement years show that the solar yield and consumption forecasts for electricity are in good agreement. Self-sufficiency levels of up to 75 % are achieved for one year. It became clear that the installed accumulator is not fully utilized and could be dimensioned smaller for future projects or should communicate with the surrounding houses of the district. Surpluses in electricity actually consumed directly in the district (e.g. office building). Only photovoltaic yields in excess of this are fed into the main grid.



Overview of the buildings considered in the Eversol project (solar-powered buildings (1 and 2), as well as surrounding existing buildings (3-5))
(Image: TU Bergakademie Freiberg)

On the heating side, an unexpected high heating demand was measured due to several boundary conditions:

- First of all this measured demand is the first occupancy directly after the new building was finished,
- Second, there were various incorrect settings in the heating control system.
- Third, the residents have a higher comfort temperature than with the design according to DIN or EnEV.

Nevertheless, a solar fraction of up to 60 % are measured for the heating cycle. Here, too, it is clear that the storage system could be made smaller for future projects; high utilization rates (high charge level) were currently only achieved in summer.

Heat surpluses can be transferred to the surrounding apartment buildings of the district through a local heating network. Thus the degree of utilisation of the solar thermal system can be significantly increased furthermore.

The project also investigated whether an alternative use of photovoltaics plus a heat pump instead of solar thermal energy would be more efficient. The results show that the two systems would be equally efficient with heat pump coefficients of performance between 2.8 and 4.0.

Selected Performance Indicators (measured 2020)

Categorization of energy consumption

Heating: 85 kWh/m_{LA}^2a

Electricity: 29.5 … 32.1 kWh/m²a

Renewable Energy Generation

Photovoltaic: approx. 938 kWh/kWp

Solar thermal energy: approx. 533 kWh/m^2_{STCA} a

degree of self-sufficiency

73% (electricity), 56 % (thermal)

Table 7: Detailed Description of Key Technologies installed

parameter solarhouse	value
Living area (LA)	605 m²
Building usable area (net ground area) (EnEV)	854 m²
Solar thermal collector area (STCA)	100 m²
Heat storage	24,6 m³
Backup heating (gas condensing boiler)	48,2 kW
Photovoltaic power (PV)	29,6 kWp
Power storage (Li-Ion, net)	46,8 kWh
Geothermal collector system for cooling	

Table 8: Overview of SEB technologies

	SEB Technologies															
	Energy source										Energy storage					
	sun			wind	water		earth	air	bioenergy		electrical storage		thermal storage			
Technologies	Photovoltaic	Solar thermal collectors	PVT-collectors	Wind turbines	Hydropower plant	Groundwater and heat pumps	Geothermal and heat pumps	Air-source heat pumps	Biomass combustion	Biogas plants	batteries	Mobile batteries (E-mobility)	Hotwater storage	Ice storage	Sorption storage	Thermal mass activation
	x	x									x	x	x			

Table 9: Performance indicators

Year of measurements	2020-2023	
Solar radiation on horizontal, kWh/(m²·a)	1020	
Degree days for heating/cooling	2434 Kd/a	
Weather data used for calculation	Deutscher Wetterdienst	
Building gross floor area, m²	605	
Energy consumption	**Calculated**	**Measured**
Time step used		Minute
Heating (SH+DHW), kWh/a		75.800
Cooling, kWh/a		3.850
Electricity (total), kWh/a		18.000
Electricity (heating+cooling), kWh/a		-
Renewable energy production		
Time step used		Minute
Heating (SH+DHW), kWh/a		52.400
Cooling, kWh/a		3.850
Electricity (total), kWh/a		27.500
Renewable energy consumption		
Time step used		Minute
Heating (SH+DHW), kWh/a		52.400
Cooling, kWh/a		3.850
Electricity (total), kWh/a		13.500
Electricity (heating+cooling), kWh/a		-
Degree of self-sufficiency		
Time step used		Minute
Heating (SH+DHW), %		56 %
Cooling, %		100 %
Electricity (total), %		73 %
Electricity (heating+cooling), %		-

SH = Space heating, DHW = Domestic hot water

The Building's Special Features

The monthly rent consists of a fixed amount of 10.50 €/m² fixed over a longer period of time, which also includes heating, cooling and electricity in addition to the basic rent:

- Rental model development: Content-related and calculatory design and subsequent review of flat-rate rental model approaches.
- Quantification of the price effects of introducing a flat-rate rental model
- Sociological studies on the effects of a flat-rate rent

Initial evaluations of the measurement results show no significant increased energy consumption due to the flat-rate rent model. Some residents are even more economical than planned.

Main Stakeholders Involved

The Eversol-Project (eversol.iwtt.tu-freiberg.de) is led and coordinated by TU Bergakademie Freiberg (chair of technical thermodynamics). Other participants in the project are the house owner: eg Wohnen 1902, the Freiberg Institute for Networked Energy Self-Sufficiency, mensura Immobilienservice GmbH, helma Eigenheimbau AG, VSWG - Verband sächsischer Wohnungsgenossenschaften e.V., GdW- Bundesverbamd deutscher Wohnungs- und Immobilienunternehmen e.V., Fa. Timo Leukefeld. Thanks go to the German Federal Ministry for Economic Affairs and Climate Action (BMWK) and the Project Management Jülich / Research Centre Jülich for their financial support of the project.

2.1.5 SEB No. 4 – Test Champers, LNEG Campus, Lisbon, Portugal

Location information

Adress: LNEG Campus, Lisbon, Portugal

Geographic Coordinates: 38.77° N 9.18° W

Climate Zone: Mediterranean climate

Building typology: Test Chambers

Autor: Jorge Facão (LNEG)

General Description

A new testing capacity was installed in Laboratory of Solar Energy at LNEG. The facility is composed by two modules for testing new building façades: one with the south façade with masonry wall behave as a reference and another with the south façade with new building wall. The first new building element developed was a dynamic thermo-regulative wall with nanofluids (water with cooper nanoparticles) implemented in south façade. The two cells are made of two galvanized steel sheets lacquered with 0.50 mm thickness, and 40 mm of insulation in rigid polyurethane foam injected with density 40 kg / m3. The south-facing masonry is composed by double wall with brick of 11 cm, 4 cm of XPS thermal insulation, plaster, and white painting.

The nanofluid façade has thermo-regulative behaviour with help of two submersible pumps installed in the inner and the outer cavities. The wall is made in transparent acrylic sheets and with 50 mm of thermal insulation with agglomerated cork. The thickness of the fluid wall is 120 mm.

The cells are instrumented with temperature sensors, pyranometer and anemometer. All the sensors are connected to a Keysight data logger. The test cells could be used to test other solar building façades using one as a reference.

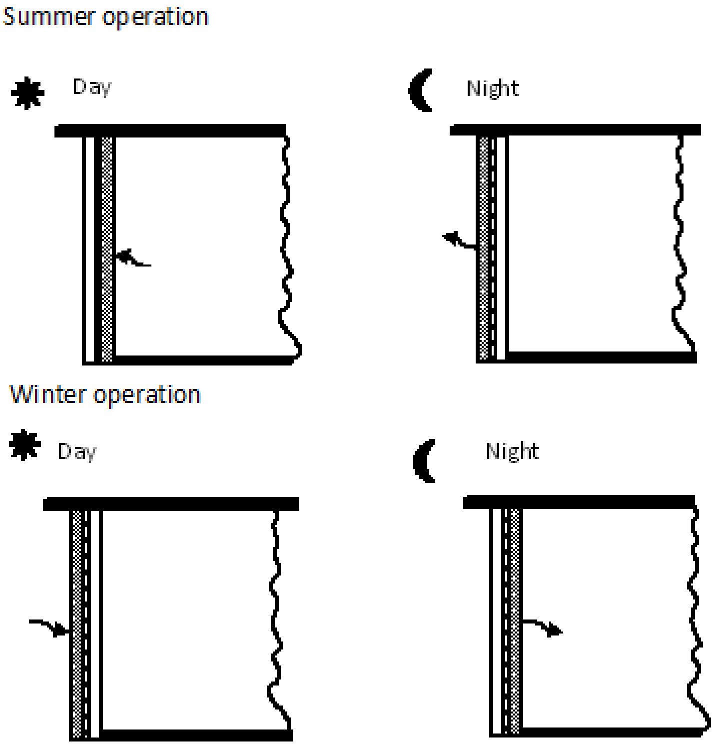
Thermoregulation

An animal's metabolic activity is linked to its body temperature. Low body temperatures make high metabolic rates unfeasible, as enzymatic reactions depend on temperature. High metabolic rates can lead to overheating and produce lethal effects on molecular structure. Several strategies have been developed to optimize metabolic energy expenditure or savings across different animal lifestyles.

Starfish to avoid overheating during low tide fills with water during sea beach. Alligators stay in the sun in the morning to raise their body temperature with their mouths open. At dusk they are in the water because the outside air temperature is higher.

The new dynamic building façade are inspired by nature having a thermoregulation operation– biomimetic element.

In Summer, during the day, the fluid is in the interior cavity, absorbing heat from the space and promoting cooling. Overnight the fluid is transferred to the outer cavity to release heat. For this dynamic behaviour 2 small pumps are used to control the fluid flow between the inner and outer cavities. During winter, the fluid is in the outer cavity during the day absorbing solar radiation volumetrically and transferred to the inner cavity at night to release heat and warm the space.



Façade energy balance performance metrics

The standard way to evaluate the performance of façades as U-value, G-value, and so on, is that the presented metrics cannot be calculated directly from physical characteristics of the materials adopted and do not have a general physical meaning.

Instead, these metrics are derived from either experimental or numerical datasets, with the aim to quantify the performance of the system to achieve a certain objective. The metrics are defined as dimensionless efficiencies or ratios over known quantities, which could be calculated based on boundary conditions and other physical parameters.

The main differences between the novel metrics are related to the dynamic nature of the adaptive system to be characterised. This can be divided into: i) short-term (sub-hourly or hourly metrics), related to the performance of fast reactive system; ii) mid-term (daily metrics), related to the performance of systems that are storing and exchanging energy with the indoor environment over a daily cycle (mainly related to solar daily cycle and charge and discharge period of solar energy in the thermal mass of the building envelope); iii) long-term (monthly and seasonal metrics), adopted to normalise a certain metric over the boundary conditions of a longer period (heating or cooling season). Nevertheless, in order to provide a useful insight into the performance of dynamic façade systems and be normalised over a certain range / distribution of boundary conditions, short- and mid-term metrics can also be evaluated over a longer period, considering their cumulative distribution. With the mid-term metrics, particular attention should be paid to the starting and ending time of the integration of the heat flows, as these depend on the starting and ending time of the charge / discharge cycles and/or of the solar daily cycle (which is seasonally dependent). Moreover, for long-term metrics, the definition of the baseline temperature of the HDD (heating degree days) and CDD (cooling degree days) could depend on the type of climate (amount of available solar radiation as compared to the seasonal temperature variation), type of building (mainly related to the amount of internal thermal mass and endogenous occupation loads) and type / dynamics of the HVAC system adopted.

Detailed description of key technologies installed

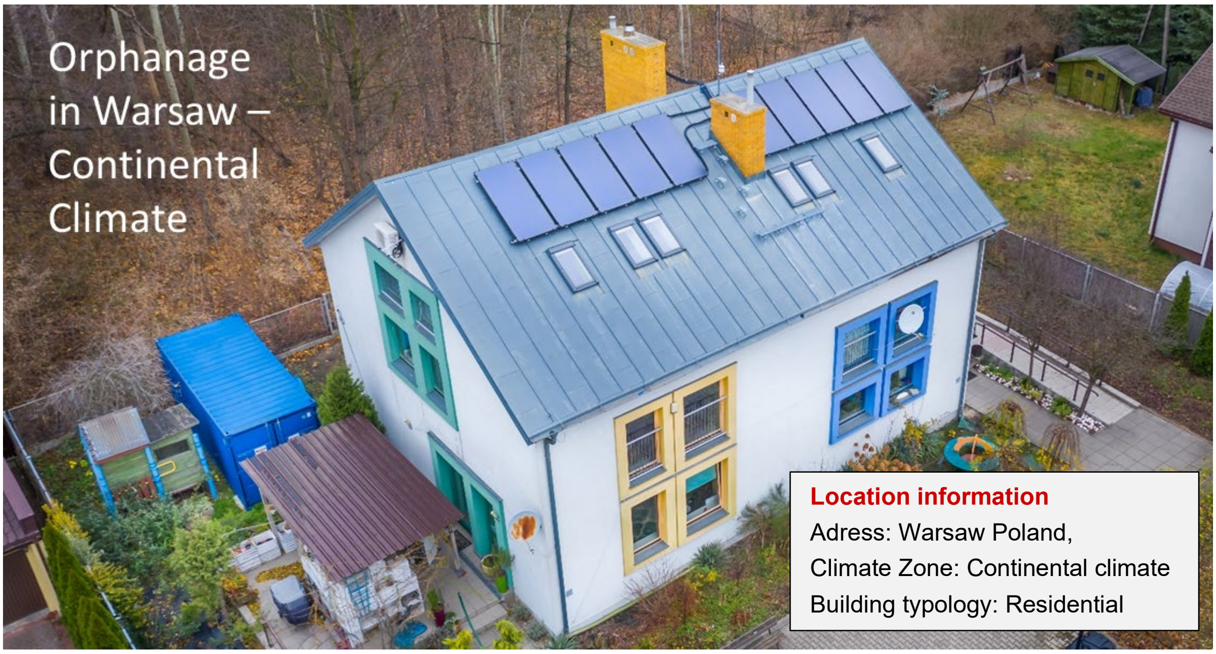
Table 10: Overview of SEB technologies

	SEB Technologies															
	Energy source										Energy storage					
	sun			wind	water		earth	air	bioenergy		electrical storage		thermal storage			
Technologies	Photovoltaic	Solar thermal collectors	PVT-collectors	Wind turbines	Hydropower plant	Groundwater and heatpumps	Geothermal and heatpumps	Air-source heatpumps	Biomass combustion	Biogas plants	batteries	Mobile batteries (E-mobility)	Hotwater storage	Ice storage	Sorption storage	Thermal mass activation
		x											x			

Main Stakeholders Involved

This infrastructure is in the framework of by national programme FCT/MCTES (PIDDAC) and European Regional Development Fund (ERDF) of Lisbon Regional Operation Programme, NZEB_LAB, Research Infrastructure on Integration of Solar Energy Systems in Buildings, NZEB_LAB (Refª. LISBOA-01-0145-FEDER-022075).

2.1.6 SEB No. 5 – Orphanage, Warsaw, Poland



Location information

Adress: Warsaw Poland,

Climate Zone: Continental climate

Building typology: Residential

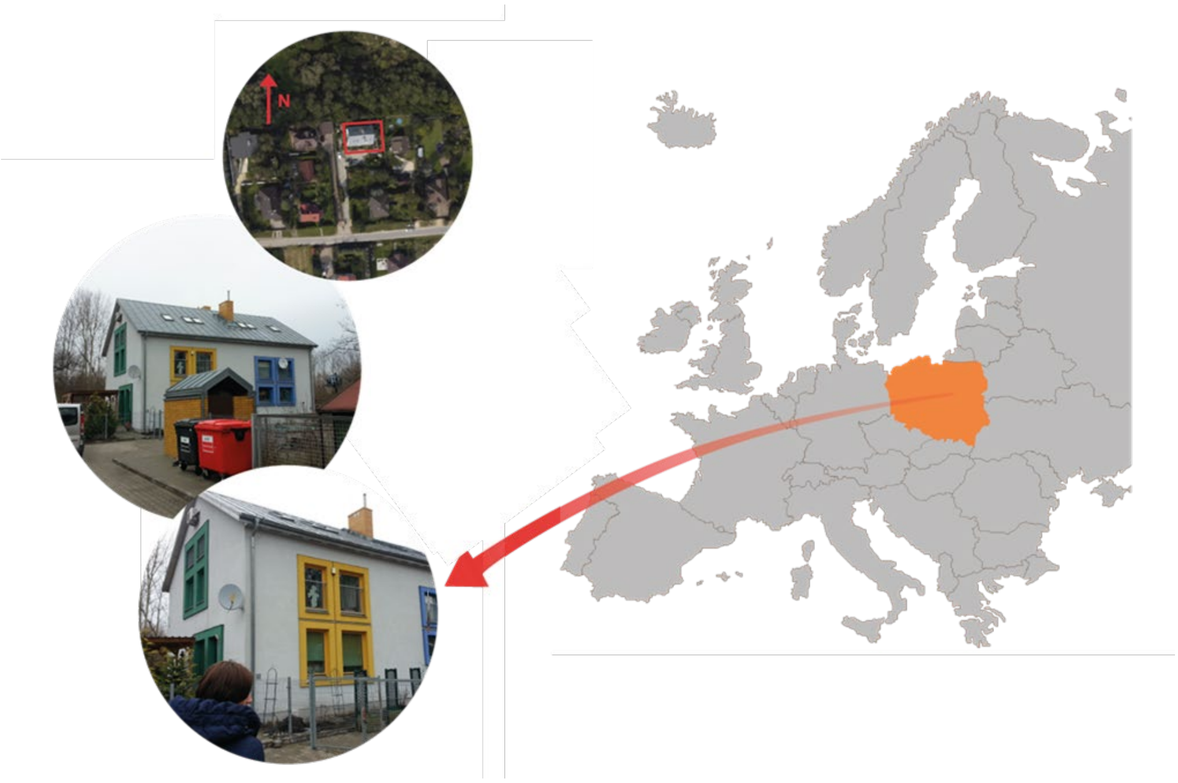
Autors: Samuel Knabl (AEE INTEC), Wim van Helden (AEE INTEC)

General Description

The CREATE (Compact REtrofit Advanced Thermal Energy storage) project was a research project funded by the European Commission under the Horizon 2020 programme. The consortium consisted of eleven partners from eight different European countries and was led by AEE INTEC. The main aim was to develop and demonstrate a heat battery, i.e. an advanced thermal storage system based on thermochemical materials (TCMs), that enables economically affordable, compact and loss-free seasonal storage of heat in existing buildings.

The developed CREATE system features a modular prismatic storage module design, optimised towards compactness allowing the use of available volume in a building up to 21% more effectively than with currently used cylindrical modules. The storage material used is granulated potassium carbonate (K2CO3) and in the scope of the project a full system with three modules and a total of 1,250 liters of K2CO3 with a storage capacity of around 182kWh was built and experimentally evaluated.

The main project's achievements revolved around (i) improvement of the salt performance such as power, stability and energy density; (ii) development and optimization of a prismatic shaped absorber vessel to improve stacking and space requirements; (iii) development and optimization of low-cost evaporator / condenser; and (iv) optimization of the full-scale system on basis of lab experiments and annual system simulations.



Demonstration

Implementation of the CREATE concept took place place in a typical European dwelling. To demonstrate the applicability of the thermochemical storage solution and its operation in real-life conditions as well as to receive an early user feedback, the CREATE system was installed in full-scale at an orphanage in Warsaw, Poland. The climate at the location can be characterized by cold winters and warm summers. The demonstration lasted from summer 2019 till summer 2020.

Detailed Description of Key Technologies installed

Table 11: Overview of SEB technologies

	SEB Technologies																
	Energy source											Energy storage					
	sun			wind	water		earth	air	bioenergy		electrical storage		thermal storage			
Technologies	Photovoltaic	Solar thermal collectors	PVT-collectors	Wind turbines	Hydropower plant	Groundwater and heatpumps	Geothermal and heatpumps	Air-source heatpumps	Biomass combustion	Biogas plants	batteries	Mobile batteries (E-mobility)	Hotwater storage	Ice storage	Thermochemical storage	Thermal mass activation
		x					x						x		x	

The building is made from traditional brick with a total floor area of 446.8 m2. It has 2 floors and an attic. Twelve persons lived in the building at the beginning of the demonstration activities in 2019. The heating system is a conventional water, pump driven system designed for an indoor temperature of 20°C. The designed temperatures of heating water (working fluid) are 75/65°C, and the design heat demand is 20.4kW. Heating and domestic hot water is prepared in a combi condensing gas boiler with a nominal power of 31 kW (De Dietrich SBK M-5 Diematic). The system is equipped with a 200 l water buffer and has a weather regulation.

Gas boiler, DHW boiler and other crucial elements of the heating and DHW systems are located in the boiler room of approx. 7m² area. The centrepiece of the CREATE heat storage which is placed in a container on the outside of the building is the so-called CREATE Heat Battery: It is the seasonal compact thermo chemical storage, which is based on the hydration respectively dehydration of salt hydrates as loss-free chemical storage mechanism. Furthermore, he CREATE Heat Battery includes the central evaporator/condenser incl. process water tank, the vapor channel and electro pneumatic storage valves. A scheme of the overall demo system design is presented in Figure 7. The part limited by the red line is located in the container, the rest is located inside the house or in the garden. The main elements of the system are: solar collectors, two water buffers of 500 dm³ volume each, gas boiler, ground heat exchangers, heat pump and all elements placed in the container

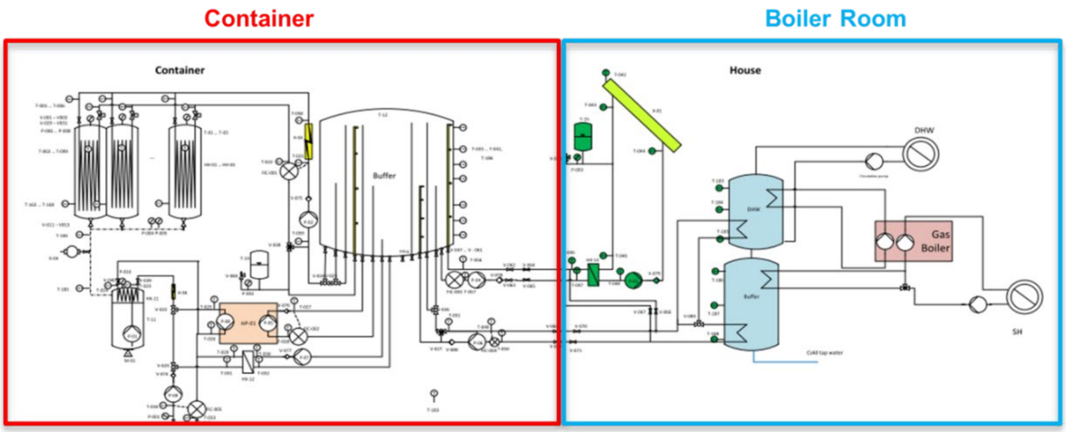


Figure 7: System design final version.

Experimental results measured showed a power output, depending on the module inlet temperature of up to 1.93 kWh owed at 30°C and storage density of around 128 kWh/m³ on module level and in general a high cycling stability of the system.

Main Stakeholders Involved

The Warsaw demo site in the CREATE Project (http://www.createproject.eu/) is led and coordinated by AEE INTEC (AEE Institute for Sustainable Technologies). Further demo site partners include TNO (NL), TU Eindhoven (NL), Vaillant (GER), EDF (FR), RINA (IT), FENIX (CZ), DOW (GER), Caldic (GER), Polar Kältetechnik (GER) and Mostostal (PL).

2.1.7 SEB No. 6 - Multifamily houses, Konstanz, Germany

Authors: Franziska Bockelmann and Marcus Peter (SIZ energieplus)

General description

North of Constance (Germany), the two buildings in solid construction, each with three full stories and six residential units (NFA in total 1,100 m²), were built in 2016. Access to the flats per building is via an internal staircase. The two apartment buildings are connected by an underground car park, which is the basement. The storage and technical rooms are also located there.

Two ground-coupled heat pumps are planned to supply heat to the houses. The first serves the heating circuit in the low temperature range and the second, as a high temperature heat pump, provides hot water for the bathroom and kitchen. Each of the two heat pumps is connected to two separate buffer tanks. A decentralized exhaust air system increases the living comfort. Natural ventilation via the windows is possible at any time. Photovoltaic modules on the roof complete the energy concept.

For multi-family houses, the implemented energy concept consisting of a ground-coupled heat pump and photovoltaics is now a common supply concept. Nevertheless, optimizations and standards for planning can be derived from the results and findings for future buildings and systems that are to be implemented especially for social housing. The concept for the apartment building can be seen as a multiplier in terms of construction and supply technology.

Detailed description of key technologies installed

- Both buildings meet the "**KfW Efficiency House 70**" standard and the **EnergiePLUS** standard is to be achieved, too.
- Two ground-coupled **heat pumps (30 kWth + 27 kWth)** are designed to supply the floor heating and to provide domestic hot water as well as supports the low temperature circuit.
- The geothermal system consists of nine borehole heat exchanger, each 100 m long.
- Since solar energy plays a central role in the energy supply, **59,2 kWp of photovoltaics** were already installed. With 29.6 kWp on each roof and a module orientation to the west and east.
- In order to improve the flexibility potential in a targeted manner, the use of a **battery storage** facility with a capacity of **30 kWh (Lithium-ion)** is integrated.

Table 12: Overview of SEB technologies

	SEB Technologies																
	Energy source										Energy storage						
	sun			wind	water		earth	air	bioenergy		electrical storage		thermal storage				
Technologies	Photovoltaic	Solar thermal collectors	PVT-collectors	Wind turbines	Hydropower plant	Groundwater and heat pumps	Geothermal and heat pumps	Air-source heat pumps	Biomass combustion	Biogas plants	Batteries	Mobile batteries (E-mobility)	Hot water storage	Ice storage	Sorption storage	Thermal mass activation	
	x						x				x		x				

Table 13: Performance indicators

Year of measurements	Since 2016			
Solar radiation on horizontal, kWh/(m²·a)	1,180 – 1,200 Source: DWD- 30-year average from 1991 to 2020			
Degree days for heating/cooling	long term mean: GTZ 20/15 – 3370 Kd GTZK 20/22 – 91 Kd Source: IWU Degree days (Excel-Tool)			
Weather data used for calculation	Reference climate according to German EnEV / GEG			
Building gross floor area, m²	1,100			
Energy consumption	**Calculated**	**Measured 2017**	**Measured 2018**	**Measured 2019**
Time step used	15 Min	15 Min	15 Min	15 Min
Heating (SH+DHW), kWh/a	66,451	111,100	102,100	106,300
Cooling, kWh/a	-	-	-	-
Electricity (total), kWh/a	27,246	61,768	61,416	60,350
Electricity (heating), kWh/a	n.a.	29,420	27,218	25,939
Renewable energy production				
Time step used	15 Min	15 Min	15 Min	15 Min
Heating (SH+DHW), kWh/a	n.a. (heat production via heat pumps with PV)	26,666	18,713	20,881
Cooling, kWh/a	-	-	-	-
Electricity (total), kWh/a	51.000 (Photovoltaic)	57,900	53,900	53,200
Renewable energy consumption				
Time step used	15 Min	15 Min	15 Min	15 Min
Heating (SH+DHW), kWh/a	n.a. (heat production via heat pumps with PV)	26,666	18,713	20,881

Cooling, kWh/a	-	-	-	-
Electricity (total), kWh/a	n.a.	20,276	19,508	19,890
Electricity (heating), kWh/a	n.a.	5,132	4,435	4,663
Degree of self-sufficiency	n.a.			
Time step used	15 Min	15 Min	15 Min	15 Min
Heating (SH+DHW), %	n.a.	24	18	20
Cooling, %	-	-	-	-
Electricity (total), %	n.a.	33	32	33
Electricity (heating), %	n.a.	17	16	18

SH = Space heating, DHW = Domestic hot water

Main stakeholders involved

The German demo site in the R&D Project “SolSys” is led and coordinated by TU Braunschweig IGS (Institute für Gebäude- und Solartechnik) who participated in the monitoring phase in collaboration with the site owner WOBAK. Further demo site partners include EGSplan and Stadtwerke Konstanz.

2.1.8 SEB No. 7 - Multifamily house, reference building, Austria

Location information

Adress: 8010 Graz, Austria

Geographic Coordinates: 47.05° N 15.43° E

Climate Zone: Continental climate

Building typology: Residential

Authors: Thomas Ramschak, Michael Gumhalter (AEE INTEC)

General description

Solar Energy Buildings' different concepts for renewable energy supply systems are evaluated based on annual dynamic simulations. For these system simulations, a reference Building is defined as a test environment in order to ensure common boundary conditions and comparable results. Additionally, the transferability of the developed energy concepts to other building standards will be evaluated by performing a sensibility study on physical building parameters.

This report describes the definition of the reference building for Austria, the loads and the components of the energy generation and distribution system. Details of the general boundary conditions, such as climatic properties, domestic hot water load, electricity consumption profile, and further relevant inputs for the simulation, are presented in the Subtask A -Report.

Starting from the geometry of a multifamily residential building that is typical for new construction in Austria, two variants with different energetic performance have been defined. These buildings are named Austria_MFH-10 and Austria_MFH-35 according to their space heating energy demand which is approximately 10.43 and 35.51 kWh/m²a (735.8 m² heated floor area) in the climate of the city Graz

Building geometries and thermal properties

A general view of the building geometry and its orientation (given for the northern hemisphere) is shown in Figure 8. The common geometrical structure of the buildings is fixed by inside measures. The different buildings are then derived by applying the different insulation thicknesses. The total net floor area for all three floors of the buildings is 842.4 m² with an inner (air) volume of 2021.6 m³. Due to a centrally located unheated area (stairway), the heated area of the nine apartments is 735.8 m². The material specific properties of opaque areas and the arrangement of the windows is shown in Table 14.

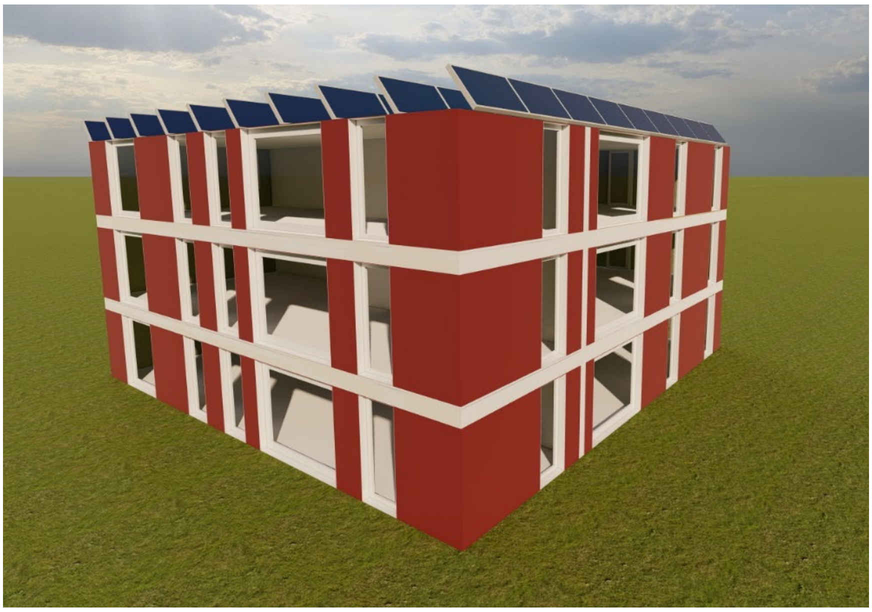


Figure 8: Simple view of the multifamily house (showing South and East facades)

Table 14: Material properties and arrangements

	External wall		Windows			Top floor ceiling	
orientation	Area [m²]	U-value construction [W/m²K]	Area [m²]	U-value tot [W/²K]	g-value	Area [m²]	U-value construction [W/m²K]
North	88	0,116	35.1	0.75	0.49	280	0.114
East	83		40.4				
South	75		48.7				
West	60		65.4				

Loads

Ventilation

Air exchange is performed by a mechanical ventilation which is equipped with an air-to-air heat recovery with an efficiency of 80%. A design air exchange rate of 0.3 h^{-1} with an additional infiltration rate of 0.05 h^{-1} is used. The control of the mechanical ventilation system is based on the CO_2 level in the rooms.

Shading

All windows in the buildings are equipped with blinds. Those are activated, if the irradiation is greater than 100 W/m² on the window surface.

Internal loads

Three time dependent, internal gains are added to the building, on the one hand caused by inhabitants and on the other hand by electric equipment and lighting. The occupant profile and the specific values of the people are described in SIA 2024 (2015) and plotted in Figure 9. With a total number of 30 occupants the gains correspond to 7.94 MWh/a. Thermal gains caused by the waste heat of electrical equipment are given by a daily periodic profile (Figure 10). These electrical gains sum up to 10.48 MWh/a. Lighting is shown in Figure 11 and is responsible for 2.99 MWh thermal gains per year

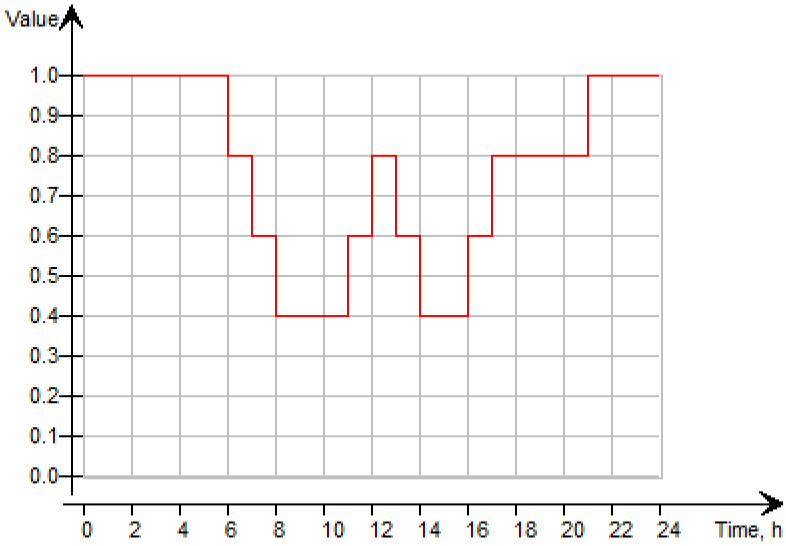


Figure 9: Occupancy profile

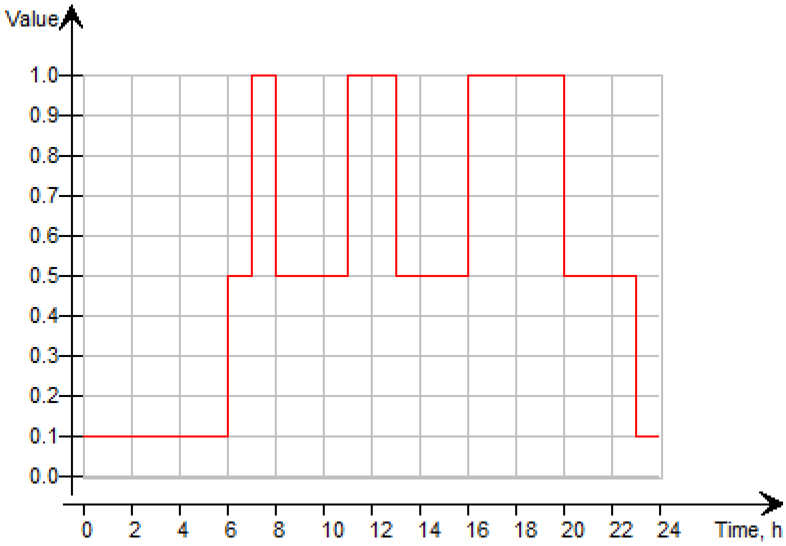


Figure 10: Equipment profile

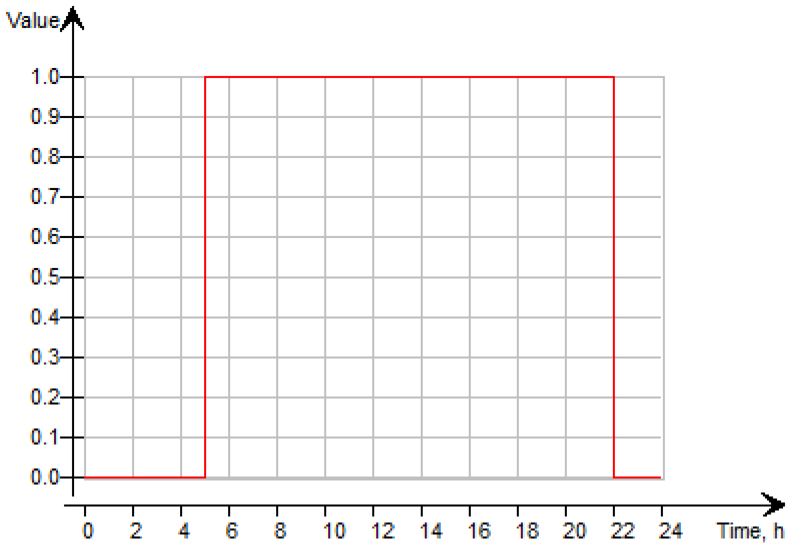


Figure 11: Lighting profile

Domestic hot water loads

The hot water demand profiles are based on SIA 2024 (2015), corresponding to an average draw off of 30 L/d at 45 °C (cold water 10 °C) per person or in total 17.76 MWh/a. The tapping profile is identical for every day and is shown in Figure 12.

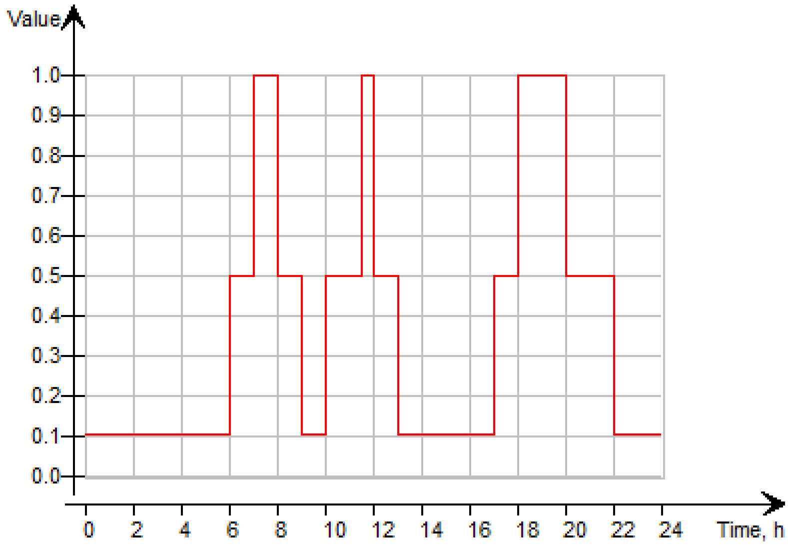


Figure 12: DHW profile

Description of key technologies

The central objective is to develop highly integrated overall energy supply systems that can ensure sustainable reliability of supply to meet the heating and electricity requirements of multi-storey residential buildings. Potential system combinations will be elaborated in detail and optimized with respect to technical, economic and control issues. The focus is on the local use of renewable energy generators in combination with highly efficient storage solutions. Central components are covered PVT-collectors, PV-modules, ground source heat pumps, thermal water storages and the thermal activation of building mass. To increase the self-sufficiency battery storage is investigated.

Table 15: Overview of SEB technologies

	SEB Technologies															
	Energy source										Energy storage					
	sun			wind	water		earth	air	bioenergy		electrical storage		thermal storage			
Technologies	Photovoltaic	Solar thermal collectors	PVT-collectors	Wind turbines	Hydropower plant	Groundwater heat pumps	Geothermal heat pumps	Air-source heat pumps	Biomass combustion	Biogas plants	Batteries	Mobile batteries (E-mobility)	Hot water storage	Ice storage	Sorption storage	Thermal mass activation
	x		x				x				x	x	x			x

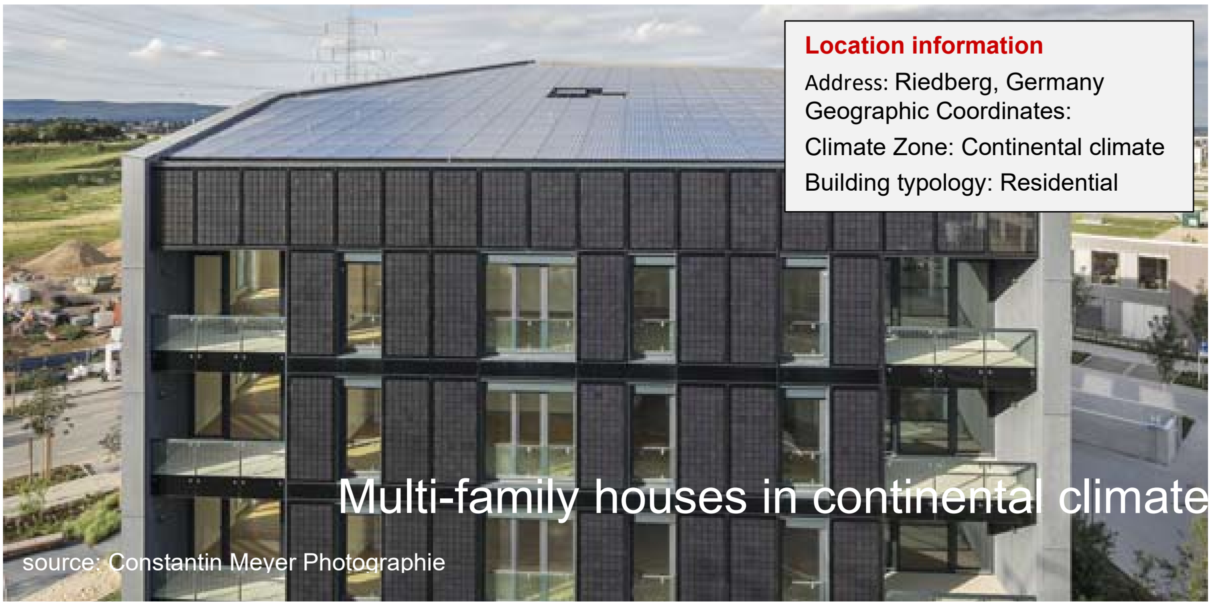
Table 16: Performance indicators

Year of measurements	Simulation	
Solar radiation on horizontal, kWh/(m²·a)	1129.1	
Degree days for heating/cooling	3193/27	
Weather data used for calculation	ASHRAE reference climate for Graz-Thalerhof	
Gross Floor Area	735.8 m²	
Energy consumption		
Time step used	15 min	
	Total	**Specific**
Heating (SH+DHW)	23616.6 kWh/a	32.1 kWh/m²/a
Cooling	12428.8 kWh/a	16.9 kWh/m²/a
Electricity (total)	19836.3 kWh/a	27.0 kWh/m²/a
Electricity (heating+cooling)	6379.4 kWh/a	8.7 kWh/m²/a
Renewable energy production		
Time step used	15 min	
Heating (SH+DHW)	PVT: 13669.5 kWh/a HP: 9947.1 kWh/a * 0.7236 = 7197.7 kWh/a 72.36 % of heat from HP is supplied by on site electricity generation	
Cooling	Free Cooling: 12428.8 kWh/a * 0.9947 = 12362.9 kWh/a 99.47 % of pumping electricity for free cooling is supplied by on site electricity generation	
Electricity (total)	26647.59 kWh/a	
Renewable energy consumption		
Time step used	15 min	
Heating (SH+DHW)	PVT: 13669.5 kWh HP: 9947.1 kWh/a * 0.7236 = 7197.7 kWh/a 72.36 % of heat from HP is supplied by on site electricity generation	
Cooling	Free Cooling: 12428.8 kWh/a * 0.9947 = 12362.9 kWh/a 99.47 % of pumping electricity for free cooling is supplied by on site electricity generation	
Electricity (total)	12320.28 kWh/a	
Electricity (heating+cooling)	4616.6 kWh/a Used by HP, pumps and HVAC	
Degree of self-sufficiency		
Time step used	15 min	
Heating (SH+DHW)	84.89 %	
Cooling	99.47 %	
Electricity (total)	62.11 %	
Electricity (heating+cooling)	72.36 %	

Acknowledgement

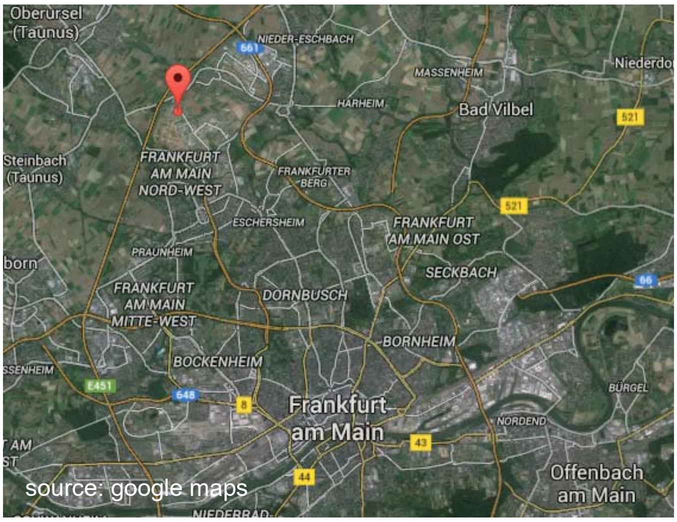
The Austrian reference building has been defined within the Sol4City project, supported by the Austrian Federal Ministry of Climate Action, Environment, Energy, Mobility Innovation and Technology (project number FO999886948).

2.1.9 SEB No. 8 - Multifamily houses, Reidberg, Germany



Authors: Franziska Bockelmann and Marcus Peter (SIZ energieplus)

General description



In 2015 the five-storey multi-family residential building (17 apartments, NFA 1,600 m²) was initially taken into service. The only electric building is equipped with an electric brine-water heat pump that uses a solar absorber in addition to an ice storage as source. After the heating period, the regeneration of the ice storage is carried out by means of the solar ambient air absorbers, which otherwise cover the heat demand of the building. The ice storage is only operated at outside temperatures that no longer permit extraction via the outside air. The heat is generated by a brine-to-water heat pump and conducted via two temperature levels, on the one hand in the floor heating system and on the other hand for the preparation of hot water by means of a fresh water station for each flat. The fresh water stations are heat exchangers that use a higher flow temperature from the heat pump. Central mechanical ventilation with heat recovery (84 %) reduces heat loss in winter and increases living comfort. Natural ventilation via the windows also remains possible here at all times. To provide a balance-sheet excess of electricity, PV modules on the roof and on the façade are installed.

The concept of generating more energy than the residents need for heat and household electricity has already been tested in single-family houses and was implemented here in a multi-family building. The surplus energy is used on site and charges electric cars and e-bikes in the building's underground car park, which is shared by the tenants.

Detailed description of key technologies installed

- The multi-family house meet the EnergiePLUS standard.
- One **brine-water heat pump with a total capacity of 50 kWth** is installed. The sources of its energy supply are either **11 solar ambient air absorber** on the roof **(85 m²)** under the PV-modules or an **ice storage** with a volume of about **100 m³**. The regeneration of the ice storage after the heating period takes

place via heat conduction from the ground and through the air collectors, as well as through free cooling in summer.

- Since solar energy plays a central role in the energy supply, **99 kWp of photovoltaics** were already installed. With **84 kWp on the roof** and **15 kWp on the south façade**.
- In order to improve the flexibility potential in a targeted manner, the use of a **battery storage** facility with a capacity of **59,4 kWh (Lithium-ion)** is integrated.
- Special feature is the combination of PV and battery: The components are connected on the DC side. There is only one inverter that converts direct current from the battery or PV system to alternating current. The battery has no connection to the public grid and accordingly cannot be charged from the grid.

Table 17: Overview of SEB technologies

	SEB Technologies															
	Energy source										Energy storage					
	sun			wind	water		earth	air	bioenergy		electrical storage		thermal storage			
Technologies	Photovoltaic	Solar thermal collectors *(solar-air-absorber)*	PVT-collectors	Wind turbines	Hydropower plant	Groundwater and heat pump	Geothermal and heat pump	Air-source heat pump	Biomass combustion	Biogas plants	Batteries	Mobile batteries (E-mobility)	Hotwater storage	Ice storage	Sorption storage	Thermal mass activation
	x	x					x				x	x	x	x		

Table 18: Performance indicators

Year of measurements		Since 2016			
Solar radiation on horizontal, kWh/(m²·a)		1,100 – 1,120 Source: DWD- 30-year average from 1991 to 2020			
Degree days for heating/cooling		longterm mean: GTZ 20/15 – 2967 Kd GTZK 20/22 – 137 Kd Source: IWU Degree days (Excel-Tool)			
Weather data used for calculation					
Building gross floor area, m²		1,600			
Energy consumption	**Calculated**	**Measured 2016**	**Measured 2017**	**Measured 2018**	**Measured 2019**
Time step used	15 Min	15 Min	15 Min	15 Min	15 Min
Heating (SH+DHW), kWh/a	45,412	116,690	93,666	103,040	101,145
Cooling, kWh/a	n.a.	9,498	7,432	8,423	8,926
Electricity (total), kWh/a	61,860 (without e-mobility)	116,490	124,620	124,885	122,690
Electricity (heating+cooling), kWh/a	n.a.	40,729	40,739	46,238	47,427
Renewable energy production					
Time step used	15 Min	15 Min	15 Min	15 Min	15 Min
Heating (SH+DHW), kWh/a	n.a. (heat production via heat pumps with PV)	34,210	26,370	26,804	22,568
Cooling, kWh/a	n.a. (free cooling via ice storage)	9,498	7,432	8,423	8,926
Electricity (total), kWh/a	86,500 (Photovoltaic)	87,940	95,640	103,810	99,410
Renewable energy consumption					
Time step used	15 Min	15 Min	15 Min	15 Min	15 Min
Heating (SH+DHW), kWh/a	n.a.	34,210	26,370	26,804	22,568
Cooling, kWh/a	n.a.	9,498	7,432	8,423	8,926
Electricity (total), kWh/a	n.a.	53,197	51,273	52,049	58,411
Electricity (heating+cooling), kWh/a	n.a.	20,182	15,536	18,587	22,665
Degree of self-sufficiency					
Time step used	15 Min	15 Min	15 Min	15 Min	15 Min
Heating (SH+DHW), %	n.a.	29	28	26	22
Cooling, %	n.a.	100	100	100	100
Electricity (total), %	n.a.	46	41	42	48
Electricity (heating+cooling), %	n.a.	50	38	40	48

SH = Space heating, DHW = Domestic hot water

Main stakeholders involved

The German demo site in the R&D Project "SolSys" as well as "Effizienzhaus Plus FFM Riedberg" is led and coordinated by TU Braunschweig IGS (Institute für Gebäude- und Solartechnik) who participated in the design and monitoring phase in collaboration with the site owner Nassauische Heimstätte Wohnungs- und Entwicklungsgesellschaft mbH. Further demo site partners include EGSplan and HHS Architekten.

2.1.10 SEB No. 9 - Smart City Quarter, Campagne-Reichenau, Innsbruck, Austria

Location information
Adress: Radetzkystraße, 6020 Innsbruck, Austria
Geographic Coordinates: 47.27° N 11.42° E
Climate Zone: Continental climate
Building typology: Residential / Commercial

Authors: Fabian Ochs, Elisa Venturi (UIBK)

General description

A Smart City quarter (of approximately 84,000 m²) is being created in the east of Innsbruck. Approximately 1,100 new apartments, numerous local supply and service facilities as well as sports fields and a club are planned. A cooperative planning process involved neighboring residents as well as local clubs, schools, and kindergartens in the development of the master plan.

The Campagne-Reichenau is to become a best-practice example for the creation of sustainable and cost-effective living space in Passive House standards. The focus is on energetic and economic optimization in combination with mobility solutions in the new smart city quarter. The goal is to develop the area into a "Zero Emission Urban Region" and integrate it into the urban planning concept of the city of Innsbruck as well as into the Energy Strategy Tyrol 2050. Important aspects are the reduction of greenhouse gas emissions, social sustainability, highest energy efficiency, ecological quality and renewable energy as an essential part of the energy supply.

Detailed description of key technologies installed

- A **groundwater heat pump** provides the heat to supply the space heating demand.
- In every building, the distribution system for space heating is **floor heating**.
- Domestic hot water is provided by **district heating** (from the regional district heating supplier IKB). The district heating has a high proportion of **industrial waste heat and bioenergy**.
- **Photovoltaic panels** are installed on top of the roof.
- Planned sustainable **mobility solutions**
- Goal to have a **new smart city quarter**

A **detailed monitoring** system has been installed. Space heating and domestic hot water demand on **building- and apartment-level** are monitored. Several meters along the entire distribution system measure mass flow, pressure, temperature and energy of the water flux. **Energy production, energy consumption and distribution losses** can be investigated. Moreover, temperature, humidity and CO_2 concentration in some of the apartments will be monitored.

Table 19: Overview of SEB technologies

	SEB Technologies																
	Energy source										Energy storage						
	sun			wind	water		earth	air	bioenergy		electrical storage		thermal storage				
Technologies	Photovoltaic	Solar thermal collectors	PVT-collectors	Wind turbines	Hydropower plant	Groundwater and heat pumps	Geothermal and heat pumps	Air-source heat pumps	Biomass combustion	Biogas plants	batteries	Mobile batteries (E-mobility)	Hotwater storage	Ice storage	Sorption storage	Thermal mass activation
	x					x		x					x			x

Table 20: Performance indicators

Year of measurements	2023	
Solar radiation on horizontal, kWh/(m²·a)	1190 kWh/(m²·a)	
Degree days for heating/cooling	3497 / 0 Kd/a	
Weather data used for calculation	Innsbruck	
Building gross floor area, m²	22277	
Energy consumption	**Calculated**	**Measured**
Time step used	Monthly calculation	15 min
Heating (SH+DHW), kWh/a	SH (UE): 377 130 kWh/a DHW (UE): 449 623 kWh/a Total (UE): 826 753 kWh/a	SH (FE): 487 655 kWh/a (thermal) DHW (FE): 1 004 784 kWh/a Total (FE): 1 492 439 kWh/a
Cooling, kWh/a	Not available	105 321 kWh/a (thermal)
Electricity (total), kWh/a	Appliances: 160 447 kWh/a Auxiliaries: 421 253 kWh/a Total: 581 699 kWh/a	Not available
Electricity (heating+cooling), kWh/a	SH: 73 591 kWh/a	SH: 96 336 kWh/a
Renewable energy production		
Time step used	Monthly calculation	
Heating (SH+DHW), kWh/a	-	-
Cooling, kWh/a	-	-
Electricity (total), kWh/a	53 002 kWh/a	PV monitoring data are not available
Renewable energy consumption	(Considering only own renewable energy production. The renewable share in the electric and thermal grid is not considered).	
Time step used	Monthly calculation	
Heating (SH+DHW), kWh/a	-	-
Cooling, kWh/a	-	-
Electricity (total), kWh/a	53 002 kWh/a	-
Electricity (heating+cooling), kWh/a	53 002 kWh/a	-
Degree of self-sufficiency		
Time step used	Monthly calculation	
Heating (SH+DHW), %	-	-
Cooling, %	-	-
Electricity (total), %	7 %	-
Electricity (heating+cooling), %	33 %	-

SH = Space heating, DHW = Domestic hot water

Main stakeholders involved

The project is led by Neue Heimat Tirol (NHT) and additional information can be found on the NHT website (https://www.neueheimat.tirol/projekte/geplante-wohnbauprojekte/innsbruck-campagne-1ba). University of Innsbruck collaborates with NHT to investigate alternative solutions by means of dynamic simulations.

NHT universität innsbruck

2.1.11 SEB No. 10 - Residential Complex, Neue Heimat, Rum, Tirol, Austria

Location information

Adress: Steinbockallee, 6063 Rum, Austria

Geographic Coordinates: 47.27° N 11.45° E

Climate Zone: Continental climate

Building typology: Residential

Authors: Fabian Ochs, Elisa Venturi, Mara Magni, Alice Tosatto (UIBK)

General description

Neue Heimat Tirol (NHT) built a residential complex with 132 rental apartments in Rum, which is a town in Tyrol (Austria) on the eastern border of Innsbruck.

Five buildings are designed according to the Passive House Plus standard. Generous open spaces are created between the buildings. The entire residential complex is heated through the waste heat network of the Tirol Kliniken (company of all provincial hospitals in the Austrian state of Tyrol). The heat is provided to the apartments through a floor heating system. Moreover, a mechanical ventilation heat recovery system is installed in the buildings. One of the key points of the project is the so-called booster heat pump to provide domestic hot water and designed to maximize the PV self-consumption.

Photovoltaic panels are installed on the building roofs for a total of 710 m². The energy generated is made available for the decentralized water heating and building services. Saltwater batteries are installed to store the excess of energy produced by the renewable source to increase the energy self-consumption.

Detailed description of key technologies installed

- Five buildings according to the **Passive House plus standard**. The buildings are slightly different in height and number of apartments.
- For example, one of the buildings is composed of 7 floors and 35 apartments. The floor area of the building is 412 m2 and the total heated area is 2209 m2.
- Heating energy is provided by the **waste heat network** of the Tirol Kliniken in combination with booster heat pumps. A 1000 l **central storage tank** is placed in the building and heated by the heating network. The central storage tank supplies the underfloor heating circuit and the booster heat pumps for water heating in each apartment in parallel.
- **Booster heat pumps** are installed in the apartments. Domestic hot water is supplied by a smaller decentralised tank (e.g. 150 l) in the apartments.
- **Mechanical ventilation with heat recovery system**
- **Photovoltaic system** for the electricity needs of the building and the surplus is fed into the grid.
- **Saltwater batteries** are installed with the aim of maximizing the self-consumption of PV for the electricity needs of the common areas.

Table 21: Overview of SEB technologies

	SEB Technologies																
	Energy source										Energy storage						
	sun			wind	water		earth	air	bioenergy		electrical storage		thermal storage				
	Photovoltaic	Solar thermal collectors	PVT-collectors	Wind turbines	Hydropower plant	Groundwater and heat pumps	Geothermal and heat pumps	Air-source heat pumps	Biomass combustion	Biogas plants	batteries	Mobile batteries (E-mobility)	Hotwater storage	Ice storage	Sorption storage	Thermal mass activation
Technologies	x					x					x		x				

Table 22: Performance indicators

Year of measurements	2024-2025 (monitoring data not yet available)	
Solar radiation on horizontal, kWh/(m²·a)	1090	
Degree days for heating/cooling	3643/0 Kd/a	
Weather data used for calculation	Innsbruck	
Building gross floor area, m²	Building: 2209.4, Flat: 86.4	
Energy consumption	**Calculated-Building (PHPP)**	**Calculated-Flat (Simulated)***
Time step used	Monthly calculation	Variable time step, output saved every 10 min
Heating (SH+DHW), kWh/a	<u>SH</u>: 25187 kWh/a <u>DHW</u>: 9381 kWh/a <u>Total</u>: 54568 kWh/a	<u>SH</u>: not simulated <u>DHW</u>: 2154 kWh/a
Cooling, kWh/a	No cooling	No cooling
Electricity (total), kWh/a	<u>Appliances</u>: 45505 kWh/a <u>Total</u>: 57258 kWh/a	-
Electricity (heating+cooling), kWh/a	0	0
Renewable energy production		
Time step used	Monthly calculation	Variable time step, output saved every 10 min
Heating (SH+DHW), kWh/a	-	-
Cooling, kWh/a	-	-
Electricity (total), kWh/a	24880 kWh/a	801 kWh/a
Renewable energy consumption		
Time step used	Monthly calculation	Variable time step, output saved every 10 min
Heating (SH+DHW), kWh/a	-	<u>SH</u>: 0 kWh/a <u>DHW</u>: 97 kWh/a
Cooling, kWh/a	-	-
Electricity (total), kWh/a	24880 kWh/a	701 kWh/a
Electricity (heating+cooling), kWh/a	-	-
Degree of self-sufficiency		
Time step used	Monthly calculation	Variable time step, output saved every 10 min
Heating (SH+DHW), %	-	3%

Cooling, %	-	-
Electricity (total), %	43%	25%
Electricity (heating+cooling), %	-	-

* Flat of interest: the biggest flat of the building, having 3 sleeping rooms and an area of 86.4 m^2

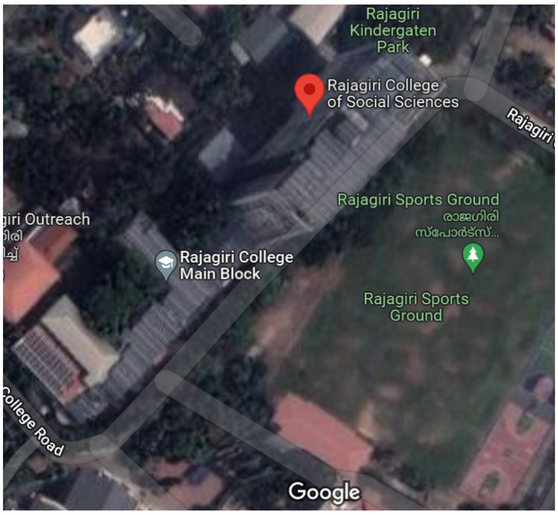
Main stakeholders involved

The project is led by Neue Heimat Tirol (NHT) and additional information can be found on the NHT website (https://www.neueheimat.tirol/projekte/neubauprojekte/rum-steinbockallee). University of Innsbruck collaborates with NHT to investigate alternative solutions by means of dynamic simulations.

2.1.12 SEB No. 11 - Rajagiri College of Social Science, Kochi, India,

Author: Dr. Arun Kumar V

General description



Rajagiri College of Social Sciences (Autonomous) was established as a result of the indefatigable industry and foresight of the CMI. The various axioms of the insitution maintain the axiomatic spirit of Rajagiri - 'Relentlessly Towards Excellence'. The Hill Campus at Kalamassery is having residential facility for students. The campus of Rajagiri College of Social Sciences is spread over an area of around 29 acres.

An educational institute has been considered which has load peaking from the morning and low loads in the evenings. The objective of the optimization is to have an asset which enables RCSS microgrid to be self-sustained. Another key requirement is to have an asset configuration that gives overall net energy required throughout the year from RE. Here combine cooling, heat and power (CCHP) load is present.

The objective of the institution is to use maximum green energy possible. The techno-economic optimization with maximizing the solar energy utilization is the key objective. By using innovative and smart energy integration system the main objective can be achieved with reduction of CO_2 emissions.

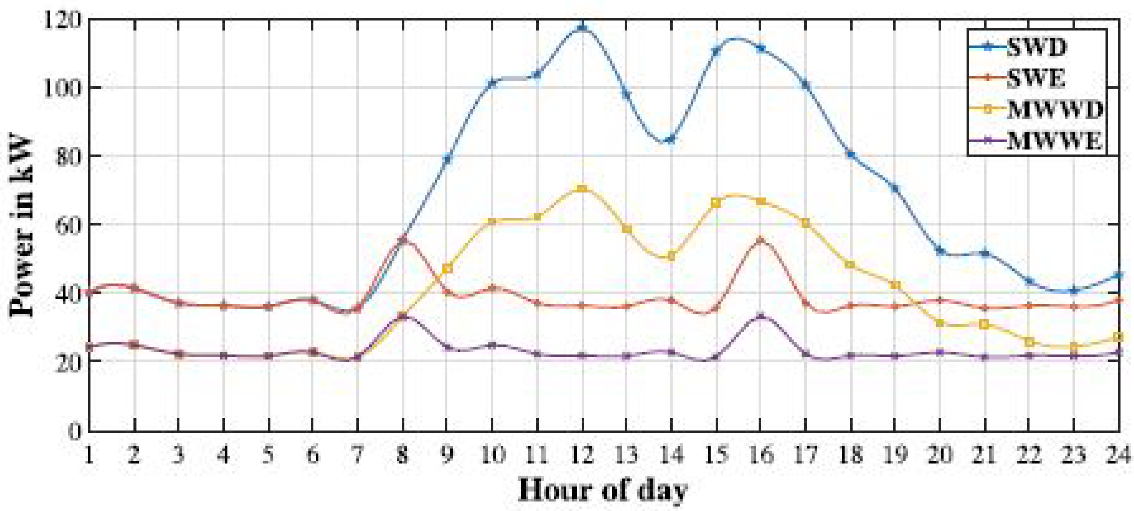
Detailed description of key technologies installed

- Solar energy is the only possible green power and plays a vital role in the energy supply of the site, **267 kWp of photovoltaics** system is already installed.
- The other sources of power are
    - 2 Nos. of redundant grid supply,
    - 3 Nos. of Diesel generator

Table 23: Overview of SEB technologies

	SEB Technologies															
	Energy source										Energy storage					
	sun			wind	water		earth	air	bioenergy		electrical storage		thermal storage			
Technologies	Photovoltaic	Solar thermal collectors	PVT-collectors	Wind turbines	Hydropower plant	Groundwater and heat pumps	Geothermal and heat pumps	Air-source heat pumps	Biomass combustion	Biogas plants	batteries	Mobile batteries (E-mobility)	Hotwater storage	Ice storage	Sorption storage	Thermal mass activation
	x															

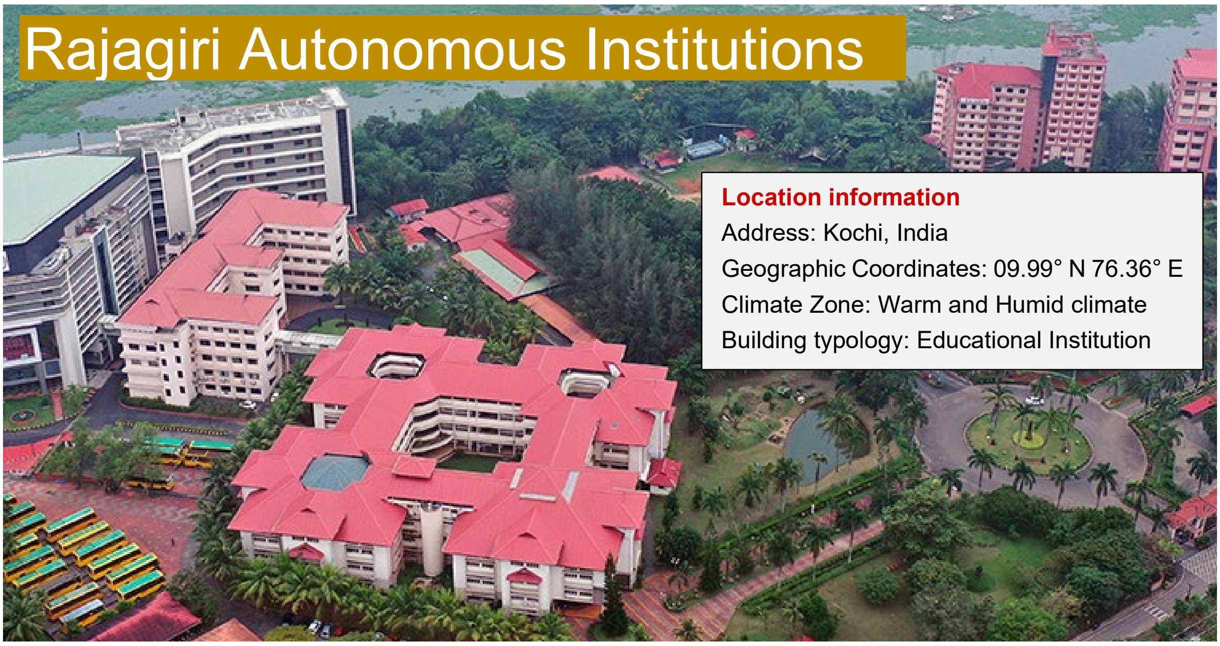
Figure 13: Performance indicators



- SWD-Summer Week Day
- SWE- Summer Weekend
- MWWD-Monsoon Winter Week Day
- MWWE- Monsoon Winter Weekend

Main stakeholders involved

2.1.13 SEB No. 12 - Rajagiri Autonomous Institutions, Kochi, India



Author: Dr. Arun Kumar V

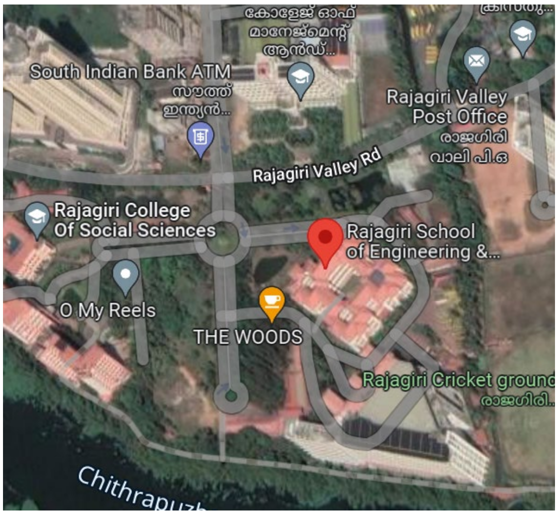
General description

The Rajagiri institutions in Rajagiri valley (RV) constitutes of four major entities and has a 90-acre (360,000 m2) campus on the banks of the Chitrapuzha river.

- Rajagiri School of Engineering & Technology (RSET) - Autonomous, Kakkanad, Kochi, is a premier educational institution offering excellence in engineering education and research.
- Rajagiri College of Management and Applied Sciences
- Rajagiri College Of Social Sciences
- Rajagiri Business School
- Rajagiri Christu Jayanthi Public School

These institutions have different load pattern based on working and non working day and also has high load peaking from the morning and low loads in the evenings. The objective of the optimization is to have an asset which enables RV microgrid to be self-sustained. Another key requirement is to have an asset configuration that gives overall net energy required throughout the year from RE. Here combine cooling, heat and power (CCHP) load is present.

The objective of the institution is to use maximum green energy possible. The techno-economic optimization with maximizing the solar energy utilization is the key objective. By using innovative and smart energy integration system the main objective can be achieved with reduction of CO_2 emissions.



Detailed description of key technologies installed

- Solar energy is the only possible green power and plays a vital role in the energy supply of the site, **717 kWp of photovoltaics** system is already installed.
- The other sources of power are
  - 2 Nos. of redundant grid supply,
  - 3 Nos. of Diesel generator

Table 24: Overview of SEB technologies

	SEB Technologies															
	Energy source										Energy storage					
	sun			wind	water		earth	air	bioenergy		electrical storage		thermal storage			
Technologies	Photovoltaic	Solar thermal collectors	PVT-collectors	Wind turbines	Hydropower plant	Groundwater and heat pumps	Geothermal and heat pumps	Air-source heat pumps	Biomass combustion	Biogas plants	batteries	Mobile batteries (E-mobility)	Hotwater storage	Ice storage	Sorption storage	Thermal mass activation
	x	x														

Main stakeholders involved

2.1.14 SEB No. 13 - Educational Institution, St. Mary School, Haryana, India

Location information

Address: Haryana, India

Geographic Coordinates: 28.91° N 76.48° E

Climate Zone: Composite climate

Building typology: Educational

Author: Dr. Arun Kumar V

General description

St. Mary's Sr. Sec School is located in Bahu Akbarpur of Rohtak District, Haryana. It is a Christian (Catholic) Missionary school run's by the Delhi Catholic Archdiocese (DCA). St. Mary's Sr. Sec. School, Rohtak can proudly boast of being the first environment friendly school, to use solar energy for the entire school, ensuring inexhaustible supply of lighting and heating throughout the year. In a residential school the load variation has two complementary patterns - one for the teaching block and the other for the hostel. During the daytime the load for the teaching block is high and that of the hostel is low and vice versa during the night time and early morning hours. St. Mary school has approximately 900 students and the average load during working hours is approximately 9 kW. The hostel has a facility for 150 students. However, approximately 50 students are on board at present and the average load is approximately 5 kW. In this case the grid is available for only 2 h during the daytime and intermittently during the night. The BESS in case of hostel works on time shift mode of operation whereas in the teaching block it operates as per requirement. Here combine heat and power (CHP) load is present.

The objective of the school is to use maximum use of green energy possible. The techno-economic optimization with maximizing the solar energy utilization is the key objective. By using innovative and smart energy integration system the main objective can be achieved with reduction of CO_2 emissions.

Detailed description of key technologies installed

- Solar energy is the only possible green power and plays a vital role in the energy supply of the site, **20 kWp of photovoltaics with 72kWh BESS** system at school and **20 kWp of photovoltaics with 72kWh BESS** system at hostel is already installed.
- The other sources of power are
  - Grid supply (Unreliable)
  - 2 Nos. of Diesel generator

Table 25: Overview of SEB technologies

	SEB Technologies															
	Energy source										Energy storage					
	sun			wind	water		earth	air	bioenergy		electrical storage		thermal storage			
Technologies	Photovoltaic	Solar thermal collectors	PVT-collectors	Wind turbines	Hydropower plant	Groundwater and heat pumps	Geothermal and heat pumps	Air-source heat pumps	Biomass combustion	Biogas plants	batteries	Mobile batteries (E-mobility)	Hotwater storage	Ice storage	Sorption storage	Thermal mass activation
	x										x					

Figure 14: Performance indicators

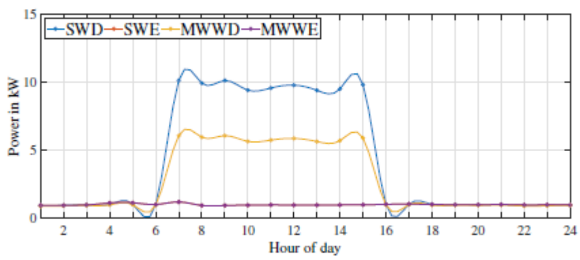


Figure: Load Pattern of School

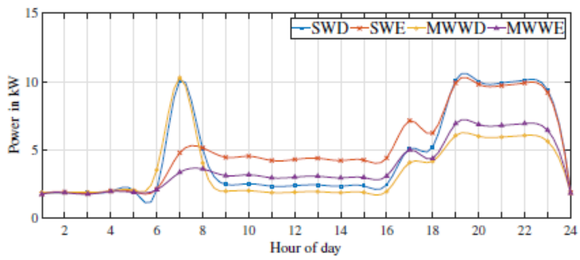


Figure: Load Pattern of Hostel

- SWD-Summer Week Day
- SWE- Summer Weekend
- MWWD-Monsoon Winter Week Day
- MWWE- Monsoon Winter Weekend

Main stakeholders involved

2.1.15 SEB No. 14 - Holy family hospital, Delhi, India

Location information

Address: Delhi, India

Geographic Coordinates: 28.56° N 77.27° E

Climate Zone: Composite climate

Building typology: Hospital

Author: Dr. Arun Kumar V

General description

Holy Family Hospital, New Delhi is a 345 bedded multi-specialty hospital run by the New Delhi Holy Family Hospital Society and managed by the Delhi Catholic Archdiocese. The Hospital is spread over a green campus of 23 acres. The hospital is equipped with modern infrastructure with 30 Emergency beds, 52 beds at ICU, 7 Operation Rooms, CCU, Dialysis, Maternity LR, IPCU, NICU and 37 Outpatient Department Clinics. Apart from specialized services, the Hospital has strong support services such as In-House Blood Bank, Food Services, Medical Records, Pharmacy, Physiotherapy, Pastoral Care, Maintenance, IT, Laundry and Housekeeping. The load of Hospital is having two components. The first part is base load and the other is peaking load. Generally, the base load is easy to handle but it is difficult to cater to the peaking load as it is fluctuating in nature. Redundancy of power is mandatory in case of hospital as it comes under emergency. Here combine cooling heat and power (CCHP) load is present.

The objective of the hospital is to use maximum green energy possible. The techno-economic optimization with maximizing the solar energy utilization is the key objective. Another important factor is redundancy in power which provides uninterrupted 24/7 power supply. By using innovative and smart energy integration system the main objective can be achieved with reduction of CO_2 emissions.

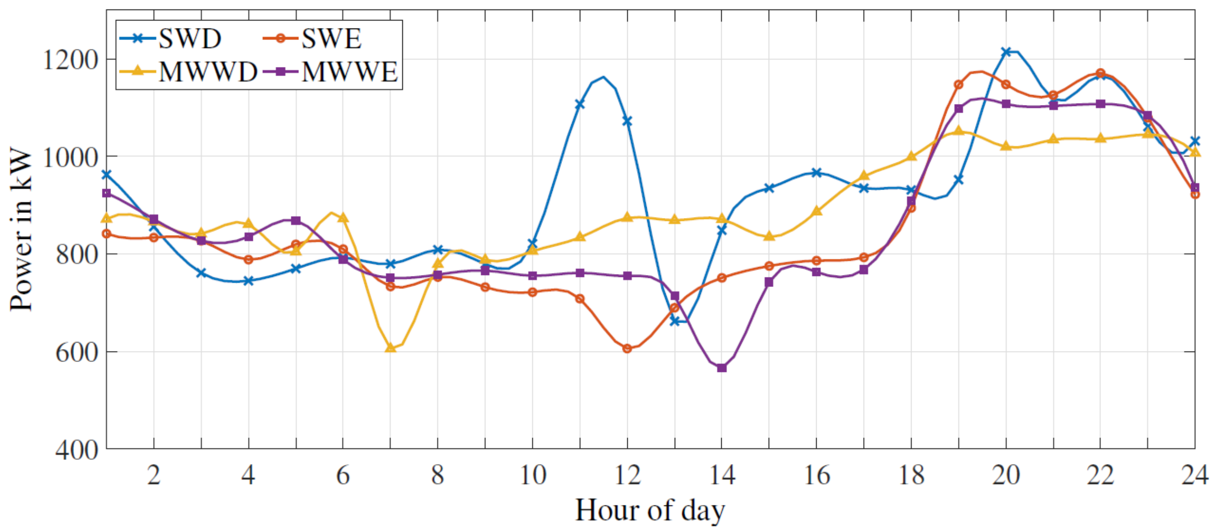
Detailed description of key technologies installed

- Solar energy is the only possible green power and plays a vital role in the energy supply of the site, **300 kWp of photovoltaics** system is already installed.
- Water heating solar collector is also installed with integrated electric boilers for hot water requirement in hospital.
- The other sources of power are
    - 2 Nos. of redundant grid supply,
    - 3 Nos. of Diesel generator

Table 26: Overview of SEB technologies

	SEB Technologies																
	Energy source										Energy storage						
	sun			wind	water		earth	air	bioenergy		electrical storage		thermal storage				
Technologies	Photovoltaic	Solar thermal collectors	PVT-collectors	Wind turbines	Hydropower plant	Groundwater and heat pumps	Geothermal and heat pumps	Air-source heat pumps	Biomass combustion	Biogas plants	batteries	Mobile batteries (E-mobility)	Hotwater storage	Ice storage	Sorption storage	Thermal mass activation
	x	x											x				

Figure 15: Performance indicators



- SWD-Summer Week Day
- SWE- Summer Weekend
- MWWD-Monsoon Winter Week Day
- MWWE- Monsoon Winter Weekend

Main stakeholders involved

2.1.16 SEB No. 15 - Single-family homes, Franz-Mehring-Platz, Freiberg, Germany

Location information

Adress: Franz-Mehring-Platz 12d, 09599 Freiberg, Germany

Geographic Coordinates: 50.9022° N 13.343° E

Climate Zone: Continental climate

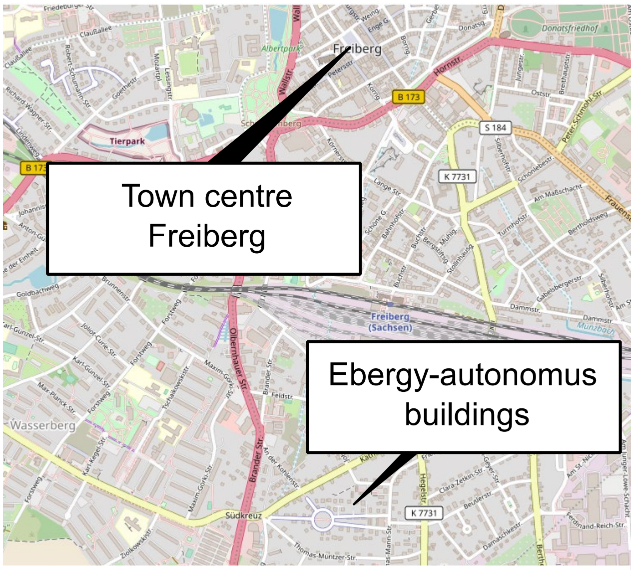
Building typology: Commercial/Residential

Autors: Lukas Oppelt, Thomas Storch, Andreas Gäbler, Tobias Fieback (all TU Bergakademie Freiberg)

General Description

The CO_2-neutral self-supply of heat and electric energy is an important objective for new and existing buildings in the future. The energy autonomous house is one advanced nearly zero-energy building, which is independent of fossil fuels and energy from the electricity grid. It has a planned annual primary energy consumption of approx. 7 kWh/m². The autarky can be achieved by using solar energy in combination with an efficient building shell and sufficiently large heat and electricity storages. Within the framework of the research project "EAHplus Monitoring" two in Freiberg located energy autonomous single-family houses were evaluated between 2013 and 2017.

The second partially self-sufficient single-family houses in Freiberg are used in different ways. One building serves as a residential building (RB), the other is used as an office building (OB). Within the framework of the monitoring, two different usage profiles could thus be analysed. The monitoring of the heating and cooling supply showed, among other things, that:



Location of the energy self-sufficient houses in Freiberg (Map:OpenStreetMap, Image: TU Bergakademie Freierg)

- The heat demand was 16-33 % higher than the planning data, but still exceeded the planning data for self-sufficiency (65 %) every year.
- The solar thermal utilisation rate was increased to over 27% (2016) by heating a pool for the residents.
- Summer cooling of the residential building via a geothermal probe measurably increases user satisfaction and consequently living comfort, so it was also added for the office building.

For the power supply, the aim was to achieve complete self-sufficiency. In addition to the PV array, the buildings therefore have large lead-gel accumulators. To increase the self-consumption share of the residential building, an electric car was also integrated into the system. In summary, the results showed that:

- 100 % self-sufficiency in electricity in the first two years due to below-average irradiation values average irradiation values, but with a solar coverage of 99.6 % in 2016, the degree of solar coverage of 99.6 % was almost achieved in 2016.
- The self-consumption quota in 2014 was 36 % and could be increased by integrating additional consumers such as solar panels consumers such as an electric car to an annual rate of up to 53 % (2016) 53 % (2016) could be achieved.
- Electricity self-sufficiency depends largely on the battery system used and the defined maximum depth of discharge maximum depth of discharge

Selected Performance Indicators (measured 2014-2017)

Categorization of energy consumption

Heating:	Electricity:
48 kWh/m$_{LA}$²a (RB)	11 kWh/m²a (RB)
44 kWh/m$_{LA}$²a (OB)	15 kWh/m²a (OB)

Renewable Energy Generation

Photovoltaic: approx.	Solar thermal energy: approx.
925 kWh/kWp (RB)	310 kWh/m²$_{STCA}$ a (RB)
890 kWh/kWp (OB)	230 kWh/m²$_{STCA}$ a (OB)

Degree of self-sufficiency

approx. 94% (electricity), 70 % (thermal)

Table 27: Detailed Description of Key Technologies installed

parameter solarhouse	value
Living area (LA)	206 (RB), 162 (OB) m²
Solar thermal collector area (STCA)	46 m²
Heat storage	9,1 m³
Backup heating (stove)	25 kW
Photovoltaic power (PV)	8,4 kWp
Power storage (Lead-gel)	58 kWh
Electric vehicle	Mitsubishi i-MieV / 16 kWh
Geothermal collector system for cooling	

Table 28: Overview of SEB technologies

	SEB Technologies															
	Energy source										Energy storage					
	sun			wind	water		earth	air	bioenergy		electrical storage		thermal storage			
Technologies	Photovoltaic	Solar thermal collectors	PVT-collectors	Wind turbines	Hydropower plant	Groundwater and heat pumps	Geothermal and heat pumps	Air-source heat pumps	Biomass combustion	Biogas plants	batteries	Mobile batteries (E-mobility)	Hotwater storage	Ice storage	Sorption storage	Thermal mass activation
	x	x									x	x	x			

Table 29: Performance indicators

Year of measurements	2014-2017	
Solar radiation on horizontal, kWh/(m²·a)	1020	
Degree days for heating/cooling	1875 Kd/a	
Weather data used for calculation	Test reference years (Deutscher Wetterdienst)	
Building gross floor area, m²	368	
Energy consumption	**Calculated**	**Measured**
Time step used		Minute
Heating (SH+DHW), kWh/a		8.500
Cooling, kWh/a		1.700
Electricity (total), kWh/a		3.700 (inkl. E-mobility)
Electricity (heating+cooling), kWh/a		-
Renewable energy production		
Time step used		Minute
Heating (SH+DHW), kWh/a		7.700
Cooling, kWh/a		1.700
Electricity (total), kWh/a		15.300
Renewable energy consumption		
Time step used		Minute
Heating (SH+DHW), kWh/a		3.500
Cooling, kWh/a		1.700
Electricity (total), kWh/a		13.500
Electricity (heating+cooling), kWh/a		-
Degree of self-sufficiency		
Time step used		Minute
Heating (SH+DHW), %		70 %
Cooling, %		100 %
Electricity (total), %		94 %
Electricity (heating+cooling), %		-

SH = Space heating, DHW = Domestic hot water

The Building's Special Features

To increase the self-consumption rate, an electric vehicle was used that can be charged with electricity from the public grid or with PV yields from the apartment building. The extent to which an intelligent charging control system can be used was investigated. The aim was to charge the electric vehicle as much as possible using PV yields alone. Weather forecasts were also taken into account, and it became clear that intelligent charging control results in added value, as:

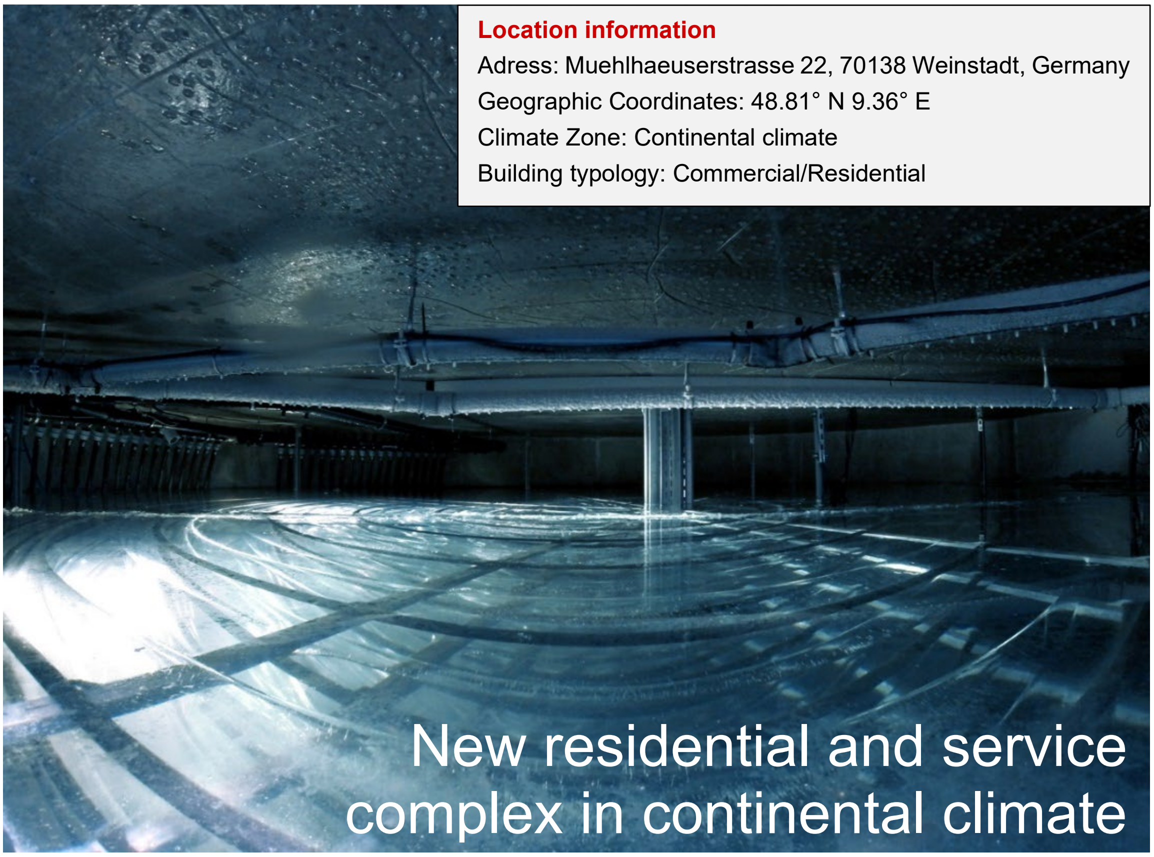
- the self-consumption rate was increased
- The amount of electricity drawn from the grid was reduced, while the minimum range was always ensured.
- the house battery was spared
- a possible shutdown of the PV system was avoided

Without the charging control, electricity was drawn from the public grid in at least 45 % of cases in winter. With the charging control, the probability of drawing electricity from the grid during charging was only 22 %.

Main Stakeholders Involved

The project was led and coordinated by TU Bergakademie Freiberg (chair of technical thermodynamics). Other participants in the project are the house owner: Fa. Timo Leukefld, MR SunStrom GmbH, Helma Eigenheimbau AG, EnviaM/ Mitteldeutsche Netzgeselschaft Strom mbH, Heizung Sanitär Klein and the Institute of Electrical Engineering of TU Bergakademie Freiberg. Thanks go to the German Federal Ministry for Economic Affairs and Climate Action (BMWK) and the Project Management Jülich / Research Centre Jülich for their financial support of the project.

2.1.17 SEB No. 16 - New residential and service complex, Muehlhaeuserstrasse, Weinstadt, Germany



Location information

Adress: Muehlhaeuserstrasse 22, 70138 Weinstadt, Germany

Geographic Coordinates: 48.81° N 9.36° E

Climate Zone: Continental climate

Building typology: Commercial/Residential

Authors: Stefanie Lott, Harald Drück (University of Stuttgart, Institute of Building Energetics, Thermotechnology and Energy Storage (IGTE), Germany), Bernd Hafner (Viessmann Climate Solutions SE, Germany)

General description

The building complex in Weinstadt, 20 km east of Stuttgart, designed as a plus-energy house, is a sustainable building project pre-certified by the German Sustainable Building Council (DGNB). The new residential and service complex was built with the aim of enabling different generations to live together in a modern, sustainable way. The residential and service complex with a floor space of 1,240 m² distributed over three floors includes 10 residential units, a physiotherapy practice and a diaconia station. The first floor also includes an underground garage with electrified parking spaces and wall boxes for a car-sharing station. The planning team assumed an annual heating demand of 87.3 MWh/a and a cooling energy demand of 9.7 MWh/a. Since fall 2020, the residential and service complex has been completed and occupied. The heating and cooling supply is based on an anergy network for a central heat pump in combination with a central latent heat store with the storage medium water as well as photovoltaic-thermal sun-air collectors.

Detailed description of key technologies installed

- With a flow temperature of 28 °C and a return temperature of 24 °C, low-temperature heating ceilings **heat** the attic and concrete core-activated ceilings heat the ground and upper floors of **the building complex**.
- For **building cooling or tempering**, the forward flow temperature is 16 °C and the return flow temperature is 19 °C.
- The **domestic hot water** is produced by means of **electric instantaneous water heaters**.
- The solar energy supply concept is based on a central brine-to-water heat pump, a central ice store and photovoltaic-thermal sun-air collectors (PVT-SLK). The heat pump is operated bivalent to an **electric resistance heating** system with a thermal capacity of **9.28 kW**. The **ice store** with a **water volume of 196 m³** and the four **PVT collector** fields with **a total area of 238 m²** (13° and 24° inclination angle, southern orientation) serve as heat sources of the heat pump. The **nominal thermal power** of the **heat pump** is **42.8 kW** at a brine temperature at the evaporator of 0 °C and a water temperature at the condenser of 35 °C (operating point B0/W35).
- The maximum electrical power of the four PVT collector fields is in total **44.8 kWp**.
- **Novel control:** Simplified, there are the following main operating modes. In the so-called direct mode, the heat pump uses the solar thermal gains of the PVT collector fields on the source side to heat the building on the sink side or to charge a buffer tank. As soon as the collector outlet temperature falls below a switchover temperature of -4 °C, for example, or rises above the maximum permissible evaporator inlet temperature of 20 °C, for example, the system control automatically switches to another operating mode. If the collector outlet temperature falls below or exceeds the switchover temperatures, a so-called mixed-absorber-discharging mode takes place in which both heat sources - ice store and PVT collectors - can be used. A three-way mixer is then used to set the switchover temperature.
  The system is designed in such a way that in the winter period direct, mixed-absorber-discharging or discharging mode and regeneration mode can take place. During the latter, the PVT collector fields are used to charge the ice store, which allows heating or liquefaction of the storage medium. The same applies to the so-called natural-cooling mode: An additional heat exchanger uses the ceiling and concrete core-activated ceiling heating systems of the building as a heat source and the ice store as a heat sink. In this way, the building can be cooled in the summer months. At the beginning of the summer, the ice store should therefore be iced up to a maximum. For this reason, icing is deliberately implemented in the transition months. This is done by covering the remaining heating demand preferably via discharging mode, in which the heat pump discharges the ice store to heat the building. Depending on the initial charge status of the ice store and the thermal energy discharged, icing of the storage medium can thus take place. In addition, no regeneration mode takes place during the transition months.

Table 30: Overview of SEB technologies

	SEB Technologies																	
	Energy source											Energy storage						
	sun			wind	water		earth	air	bioenergy		electrical storage		thermal storage			
Technologies	Photovoltaic	Solar thermal collectors	PVT-collectors	Wind turbines	Hydropower plant	Groundwater and heat pumps	Geothermal and heat pumps	Air-source heat pumps	Biomass combustion	Biogas plants	batteries	Mobile batteries (E-mobility)	Hotwater store	Ice store and heat pumps	Sorption store	Thermal mass activation
			x									x	x	x		x

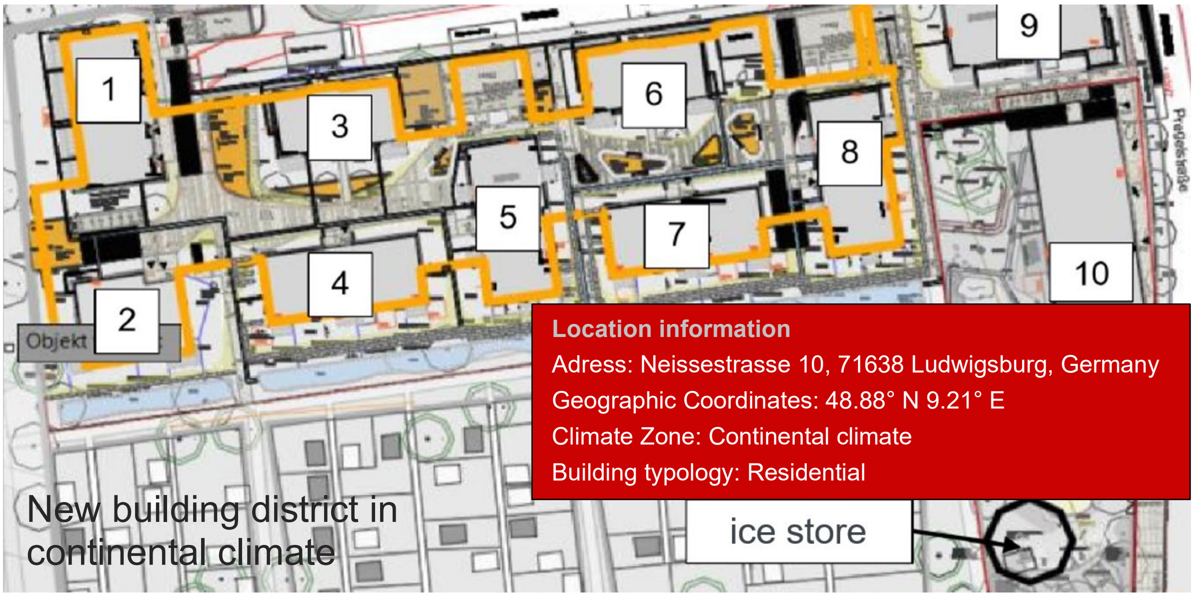
Table 31: Performance indicators

Year of measurements	2023	
Solar radiation on horizontal, kWh/(m²·a)	1,090	
Degree days for heating/cooling	2789/26	
Weather data used for calculation	Meteonorm version 6, Stuttgart	
Energy consumption	**Calculated**	**Measured**
Time step used	-	5 min
Heating (SH), kWh/a	87,350	58,004
Cooling, kWh/a	9,664	11,790
Electricity (HP and consumer), kWh/a	82,206	No data available
Renewable energy production		
Time step used	-	-
Heating (PVT collectors and ice store), kWh/a	70,151	No data available
Cooling (PVT collectors and ice store), kWh/a	3,696	No data available
Electricity (PVT), kWh/a	45,425	No data available
Renewable energy consumption		
Time step used	-	-
Heating (SH), kWh/a	70,151	No data available
Cooling, kWh/a	3,696	No data available
Electricity, kWh/a	Not determined	No data available
Degree of self-sufficiency		
Heating, %	80.3	-
Cooling, %	38.2	-
Electricity, %	Not determined	-

Main stakeholders involved

The new residential and service complex was realized by the consulting and planning company KOP. The technology for heat and cold supply was designed and delivered by Viessmann Climate Solutions SE. The monitoring of the system is carried out by the Institute for Building Energetics, Thermotechnology and Energy Storage (IGTE) of the University of Stuttgart in cooperation with Viessmann.

2.1.18 SEB No. 17 - New building district, Neissestrasse, Ludwigsburg, Germany



Authors: Stefanie Lott, Harald Drück (University of Stuttgart, Institute of Building Energetics, Thermotechnology and Energy Storage (IGTE), Germany), Bernd Hafner (Viessmann Climate Solutions SE, Germany)

General description

The newly built district in Ludwigsburg, about 15 km north of Stuttgart, consists of nine multi-family houses and a kindergarten with three residential units above. The unheated underground floors contain an underground car park as well as cellar and other ancillary rooms. In total, the district with 107 residential units offers a heated floor space of 8,567 m². The district was completed in May 2022, and the commissioning of the heating and cooling supply system with metering technology started in summer 2022.

For the design of the system components as well as an anergy network, an annual heating demand of 508 MWh and a cooling energy demand of 167 MWh is assumed. Furthermore, a simultaneity factor for the heat supply of 0.5 is taken into account.

The solar heating and cooling supply is based on an anergy network for building-wise decentral heat pumps in combination with a central latent heat store with the storage medium water as well as with thermal sun-air collectors.

Detailed description of key technologies installed

- The district is heated via **underfloor heating** with a forward temperature of 35 °C and a return temperature of 28 °C, while the **building is cooled or tempered** with a forward temperature of 17 °C and a return temperature of 20 °C. The **bathrooms** are equipped with **low-temperature radiators**. The **domestic hot water** is produced by **electric instantaneous water heaters**.
- Each of the ten buildings is equipped with a **decentralized brine-to-water heat pump** with a nominal thermal output of 29 kW to 138 kW, **in total 428 kW at operating point B0/W35** which uses energy from a **central ice store** with a water volume of **660 m³** and a central collector field with a total area of **137 m²** via an anergy network. The **thermal sun-air collectors** installed there are not equipped with PV modules, so they do not generate solar-electric energy. However, additional **photovoltaic (PV) modules** with a total area of **1085 m²** (12 ° inclination angle, east/west orientation) are installed. The maximum electrical power of the PV collector fields is in total **220 kWp**. Also on a building-by-building basis, additional heat exchangers are used to implement natural cooling operation.
- **Novel control:** Simplified, there are the following main operating modes. In the so-called absorber-direct mode, the heat pump uses the solar thermal gains of the collector field on the source side to heat the building on the sink side or to charge a buffer tank. As soon as the collector outlet temperature falls below

a switchover temperature of -4 °C, for example, or rises above the maximum permissible evaporator inlet temperature of 20 °C, for example, the system control automatically switches to another operating mode. If the collector outlet temperature falls below or exceeds the switchover temperatures, a so-called mixed-absorber-discharging mode takes place in which both heat sources - ice store and thermal sun-air collectors - can be used. A three-way mixer is then used to set the switchover temperature.
The system is designed in such a way that in the winter period direct, mixed-absorber-discharging or discharging mode and regeneration mode can take place. During the latter, the thermal collector field is used to charge the ice store, which allows heating or liquefaction of the storage medium. The same applies to the so-called natural-cooling mode: An additional heat exchanger uses the underfloor heating system of the building as a heat source and the ice store as a heat sink. In this way, the building can be cooled in the summer months. At the beginning of the summer, the ice store should therefore be iced up to a maximum. For this reason, icing is deliberately implemented in the transition months. This is done by covering the remaining heating demand preferably via discharging mode, in which the heat pump discharges the ice store to heat the building. Depending on the initial charge status and the thermal energy discharged, icing of the storage medium can thus take place. In addition, no regeneration operation takes place during this transition period.
If the storage medium in the ice store is already completely liquid before the end of the cooling period and the average ice store temperature is above the set forward temperature of 17 °C for tempering, the ice store is discharged during passive-pre-cooling mode via the thermal sun-air collectors. In this case, the lower outdoor temperatures during summer nights are used to lower the collector outlet temperature and thus discharge the ice store. The active-cooling mode is used when the temperature level in the network can no longer be sufficiently lowered in summer by the natural-cooling and passive-pre-cooling modes. In this case, the most powerful heat pump in the district uses the anergy network as a heat source and thus cools it down. The heat is released via the collector field as a heat sink.

Table 32: Overview of SEB technologies

	SEB Technologies															
	Energy source										Energy storage					
	sun			wind	water		earth	air	bioenergy		electrical storage		thermal storage			
Technologies	Photovoltaic	Solar thermal collectors	PVT-collectors	Wind turbines	Hydropower plant	Groundwater and heat pumps	Geothermal and heat pumps	Air-source heat pumps	Biomass combustion	Biogas plants	batteries	Mobile batteries (E-mobility)	Hotwater store	Ice store and heat pumps	Sorption store	Thermal mass activation
	x	x											x	x		

Table 33: Performance indicators

Year of measurements	2023	
Solar radiation on horizontal, kWh/(m²·a)	1,090	
Degree days for heating/cooling	2804/29	
Weather data used for calculation	Meteonorm version 6, Stuttgart	
Energy consumption	**Calculated**	**Measured**
Time step used	-	10 min
Heating (SH), kWh/a	508,000	484,680
Cooling, kWh/a	167,000	No data available
Electricity (HP and consumer), kWh/a	363,203	No data available
Renewable energy production		
Time step used	-	-
Heating (SH), kWh/a	398,995	No data available
Cooling, kWh/a	55,244	No data available
Electricity (PV), kWh/a	197,689	No data available
Renewable energy consumption		
Time step used	-	-
Heating (SH), kWh/a	398,995	No data available
Cooling, kWh/a	55,244	No data available
Electricity, kWh/a	Not determined	No data available
Degree of self-sufficiency		
Heating, %	78.5	-
Cooling, %	33.1	-
Electricity, %	Not determined	-

Main stakeholders involved

The new residential and service complex was realized by the residential housing company of the city of Ludwigsburg, Wohnungsbau Ludwigsburg GmbH. Stadtwerke Ludwigsburg (SWLB), the public utility of Ludwigsburg, financed and operates the complex. The technology for heat and cold supply was designed and delivered by Viessmann Deutschland GmbH. The monitoring of the system is carried out by the Institute for Building Energetics, Thermotechnology and Energy Storage (IGTE) of the University of Stuttgart in cooperation with Viessmann Climate Solutions SE.

2.1.19 SEB No. 18 - Office building, East Beisanhuan Road, China

Location information

Address: CABR ZEB (No.30 East 3rd Ring Road, Beijing, China)

Geographic Coordinates: 39.96° N, 116.41° E

Climate Zone: temperate monsoon climate

Building typology: Office

Authors: Xinyu Zhang, Wenbo Cai (CABR, CN)

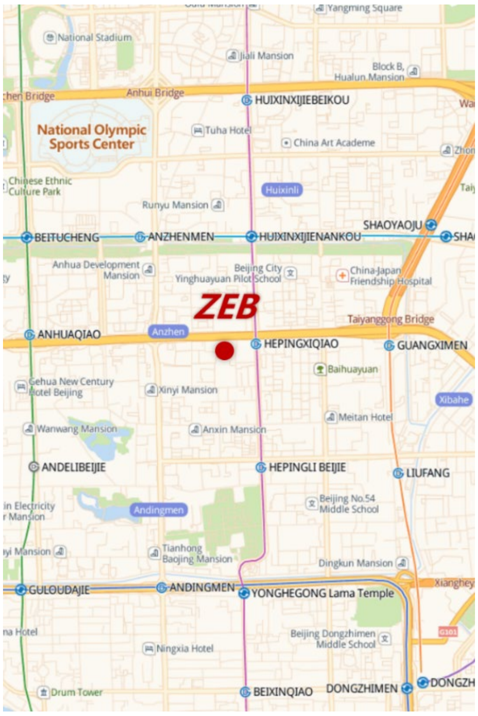
General description

The ZEB (Zero-Energy Building) is located in the office parks of CABR (China Academy of Building Research). The original building, which was built in 1970s, is a brick-concrete building and has 2 layers. The building area is 3,000 m^2.

The building is cooled by split air conditioner and heated by connecting to municipal thermal grid. The heating period is from mid-November to mid-March the next year.

The ZEB was converted from the original office building by installing PV modules and replacing high-performance doors and windows. The renovation project began since August, 2021 and came into operation in December, 2021.

The sc-Si cells and thin-film CdTe cells was used in roof and elevation. The total installed capacity is 235 kWp, and the PV system can provide 20,000 kWh of electricity per year according to the simulation result by TRNSYS. This can ensure that the PV power generation meet ZEB energy consumption needs, and supply the surrounding buildings in the same park. DC electrical equipment, which can be driven directly by PV power, are used in partial room.



Detailed description of key technologies installed

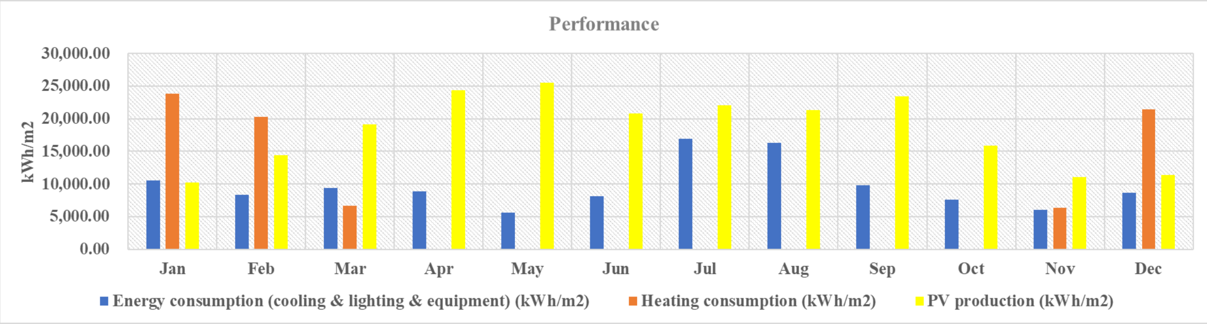
- The PV system installed area is 1,500 m^2.
- The installed capacity of sc-Si cells is 115 kWp.
- The installed capacity of thin-film CdTe cells is 118 kWp.
- PV curtain wall (thin-film CdTe cell) is used with installed capacity of 2.2 kWp.
- Facade PV modules act as exterior sunshade.
- A flexible charging pile was installed for E-mobilities.
- DC electrical equipment, which can be driven directly by PV power, are used in partial room.

Table 34: Overview of SEB technologies

Technologies	SEB Technologies																
	Energy source										Energy storage						
	sun			wind	water		earth	air	bioenergy		electrical storage		thermal storage				
	Photovoltaic	Solar thermal collectors	PVT-collectors	Wind turbines	Hydropower plant	Groundwater and heat pumps	Geothermal and heat pumps	Air-source heat pumps	Biomass combustion	Biogas plants	batteries	Mobile batteries (E-mobility)	Hotwater storage	Ice storage	Sorption storage	Thermal mass activation
	x										x	x				

Table 35: Performance indicators

Year of measurements	2022	
Solar radiation on horizontal, kWh/(m²·a)	1,378	
Degree days for heating/cooling	120	
Weather data used for calculation	EnergyPlus weather database	
Building gross area, m²	3,000.00	
Energy consumption	**Calculated**	**Measured**
Time step used	1hr	1hr
Heating (SH+DHW), kWh/a	132,878	78,485 (only SH)
Cooling, kWh/a	87,292	/
Electricity (total), kWh/a	135,800	116,041
Electricity (heating+cooling), kWh/a	33,574 (only cooling)	/
Renewable energy production		
Time step used	1hr	1hr
Heating (SH+DHW), kWh/a	/	/
Cooling, kWh/a	/	/
Electricity (total), kWh/a	211,826	219,561
Renewable energy consumption		
Time step used	1hr	1hr
Heating (SH+DHW), kWh/a	/	/
Cooling, kWh/a	/	/
Electricity (total), kWh/a	100,079	67,744
Electricity (heating+cooling), kWh/a	30,873 (only cooling)	/
Degree of self-sufficiency		
Time step used	1hr	1hr
Heating (SH+DHW), %	/	/
Cooling, %	/	/
Electricity (total), %	100,079/135,800=73.7%	67,744/116,041=58.4%
Electricity (heating+cooling), %	30,873/33,574=92% (only cooling)	/



Main stakeholders involved

The ZEB project is led by China Academy of Building Research (CABR) and Jianke EET Co., Ltd.(EET).

中国建研院 EET 环能科技

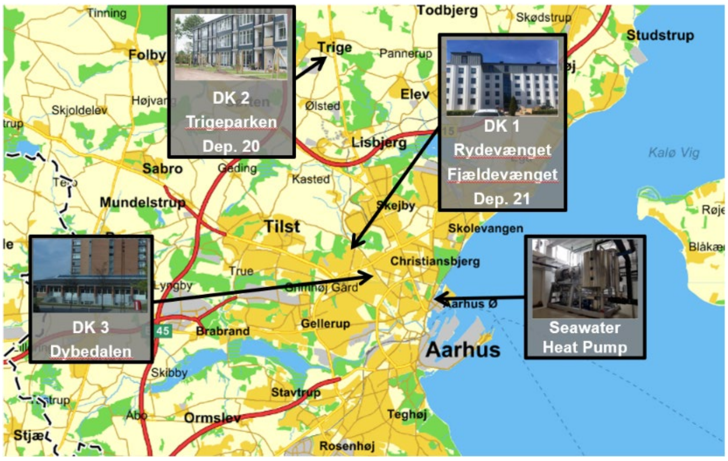
2.1.20 SEB No. 19 - Solar energy communities, Aarhus, Denmark

READY - Resource Efficient Cities **Implementing Advanced Smart City** Solutions

Authors: Elsabet Nielsen (DTU), Simon Furbo (DTU), Reto M. Hummelshøj (COWI A/S)

General description

The READY project (December 2014 – November 2020) is supported by the European Community, FP7-SMARTCITIES-2013, Demonstration of optimized energy systems for high performance energy districts. The project focuses on the combination of energy efficient buildings and use of renewable energy sources in cities. READY includes demonstration projects in two European countries, Denmark and Sweden. The project has 25 project partners, including industries, utilities, housing companies, universities, consultants and other organizations. Here the demonstration projects in the community of Aarhus in Denmark are included.



Overview map of demonstration cites in Aarhus community in Denmark [1].

The project focuses on energy efficiency established through energy refurbishment of buildings, installation of renewable energy supply systems with batteries to increase the self-consumption and the energy flexibility of the grids supplying the communities, smart energy flexible solutions in buildings, and introduction of renewable energy and heat recovery technologies.

During the project period multifamily buildings of 47,442 m^2 and one office building of 1,448 m^2 were energy refurbished, leading to energy reduction in the range of 69%.

In Aarhus, the renewable share in district heating (DH) is 80% while the renewable share in electricity production is 66%. Consequently, the renewable share in the buildings in the area is already high and the main focus in the project is to reduce energy consumption. Further district heating is cheap, and it is therefore extremely difficult to get a competitive economy in renewable heating systems.

The new seawater heat pump will increase the renewable share in the district heating system somewhat, however it is not considered in the following tables.

Table 36: Overview of demonstration sites

BEI: Building Energy Improvement, VENT: Balanced ventilation with heat recovery, PV: Photovoltaic, WW-HR: Wastewater Heat Recovery, PVT: Photovoltaic Thermal, BESS: Battery Energy Storage System.

	Measures	Gross floor area	PV	Heat pump	Solar thermal PVT
		m^2	kWp	kW	m^2
DK1 Fjældevænget	BEI, VENT, PV*	14,151	153*		
DK1 Rydevænget	BEI, VENT, PV, WW-HR	14,151	157	2	
DK2 Trigeparken	BEI, VENT, PVT, PV, BESS, WW-HR	19,140	140**	44	743
DK3 Dybedalen	BEI, VENT, PV	1,446	24.8		
Seawater heat pump				1,000	
Total		48,888	479	1,046	743

*No measurements available

**Inclusive PVT contribution

Detailed description of key technologies installed

- All the buildings are energy refurbished including improved building envelope, new 3-layer energy windows and upgrading of heating and ventilation systems (balanced ventilation with heat recovery).
- Since solar energy plays a central role in the energy supply of the sites, **479 kWp of photovoltaics (PV)** (DK1: Rydevænget 157 kWp ~ 844 m^2 and Fjældevænget 153 kWp ~ 822 m^2 + DK2: Trigeparken 143 kWp ~ 743 m^2 + DK3: Dybedalen 24.8 kWp ~ 128.5 m^2) and **743 m^2 combined solar thermal and PV (PVT)** (DK2: Trigeparken 743 m^2 ~ 143 kWp) were installed.
- Thermal energy from the PVT panels supply heat to (3 x 12 kW) 36 kW PVT heat pumps for DHW production. The DHW is stored in (3 x 800 l) 800 l storage tanks (DK2: Trigeparken), see Figure 16 .
- Integration of surplus/waste heat recovery technologies from wastewater. Installation of 18 food waste disposers in the multifamily buildings along with waste sorting facilities and terrain. Since wastewater heat is available on the site for energy use, **two wastewater heat recovery pumps with a total capacity of 10 kW** (DK2: Trigeparken 8 kW + DK1: Rydevænget 2 kW) were installed and support the currently existing DH, see Figure 17.
- To improve the flexibility potential in a targeted manner by optimizing the electricity utilization from the PV system and increase the network flexibility, **new and second life batteries storage technology and controls with a capacity of 114 kWh** were integrated. The battery storage system comprises a central 40 kW inverter connected to two battery racks, one with four new Nissan cells with a total capacity of 79 kWh, and one rack with 2'nd life cells (GEN 1) with a total capacity of 35 kWh (DK2: Trigeparken).
- Surplus energy is shared with the grids supplying the community. Intelligent 2-way energy metering, information, and control equipment keep track of the energy flows.
- A 1 MW Seawater heat pump feeds heat into the district heating grid.
- 54 intelligent electrical vehicles (EV) chargers, each with two sockets of 11 kW with a strategic perspective in interaction with public transportation solutions, were installed.

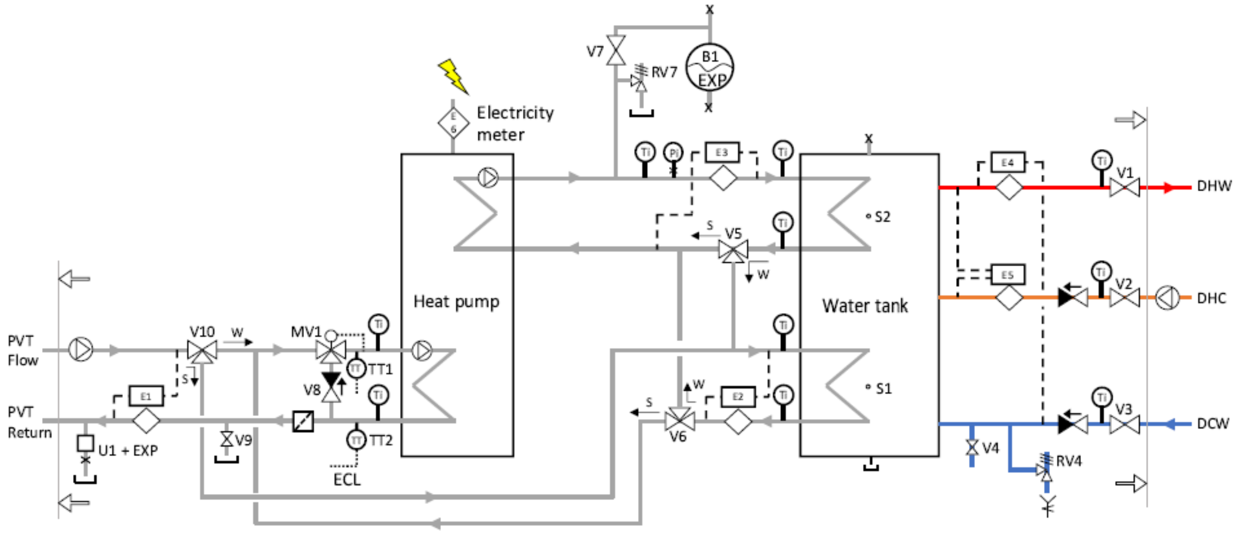


Figure 16: Principle diagram for utilzation of PVT for DHW preparation (DK2: Trigeparken) [2].

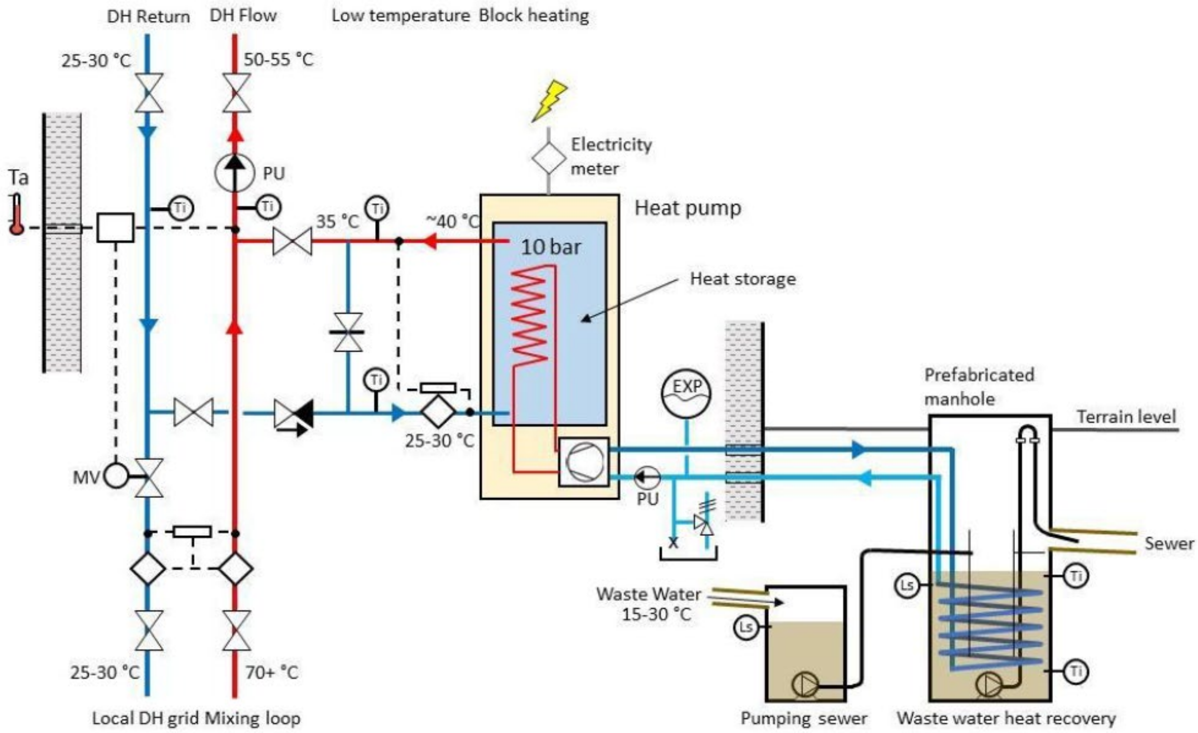


Figure 17: Principle diagram of the WW-HR facility (DK2: Trigeparken) [2].

Table 37: Overview of SEB technologies

	SEB Technologies															
	Energy source										Energy storage					
	sun			wind	water		earth	air	bioenergy		electrical storage		thermal storage			
Technologies	Photovoltaic	Solar thermal collectors	PVT-collectors	Wind turbines	Hydropower plant	Wastewater and heat pumps	Geothermal and heat pumps	Air-source heat pumps	Biomass combustion	Biogas plants	batteries	Mobile batteries (E-mobility)	Hotwater storage	Ice storage	Sorption storage	Thermal mass activation
	x		x			x					x	x	x			

Table 38: Performance indicators, DK1: Rydevænget

Year of measurements	2020		
Solar radiation on horizontal, kWh/(m²·a)	1020		
Degree days for heating/cooling	2529		
Weather data used for calculation	2001-2016		
Building gross floor area, m²	14,151		
Energy consumption	**Calculated, before renovation**	**Calculated, after renovation**	**Measured**
Time step used	0.5 hour	0.5 hour	10 minutes
Heating (SH+DHW), kWh/a	2,745,294	1,037,174	908,494
Cooling, kWh/a	-	-	-
Electricity (total), kWh/a	1,259,405	373,586	278.775
Electricity (heating), kWh/a	-	-	-
Renewable energy production			
Time step used	-	-	10 minutes
Heating (SH+DHW), kWh/a	-	-	-
Cooling, kWh/a	-	-	-
Electricity (total), kWh/a	-	-	144,449*
Renewable energy consumption			
Time step used	-	-	10 minutes
Heating (SH+DHW), kWh/a	-	-	-
Cooling, kWh/a	-	-	-
Electricity (total), kWh/a	-	-	82170*
Electricity (heating), kWh/a	-	-	-
Degree of self-sufficiency			
Time step used	-	-	10 minutes
Heating (SH+DHW), %	-	-	-
Cooling, %	-	-	-
Electricity (total), %	-	-	29.5%
Electricity (heating+cooling), %	-	-	-

SH = Space heating, DHW = Domestic hot water

Calculations adjusted for measured degree days.

*The self-consumption of electricity is estimated since the PV system was not fully operational until July 2020 due to construction work.

The calculated energy quantities for Fjældevænget are similar to the quantities in the Table 38 and no measurements are available.

Table 39: Performance indicators, DK2: Trigeparken

Year of measurements	2020		
Solar radiation on horizontal, kWh/(m²·a)	1020		
Degree days for heating/cooling	2529		
Weather data used for calculation	2001-2016		
Building gross floor area, m²	19,140		
Energy consumption	**Calculated, before renovation**	**Calculated, after renovation**	**Measured**
Time step used	0.5 hour	0.5 hour	10 minutes
Heating (SH+DHW), kWh/a	3,464,340	1,339,800	717,256
Cooling, kWh/a	-	-	-
Electricity (total), kWh/a	1,952,280	1,090,980	366.498 243,892*
Electricity (heating), kWh/a	-	-	-
Renewable energy production			
Time step used	-	-	10 minutes
Heating (DHW), kWh/a	-	-	-
Cooling, kWh/a	-	-	-
Electricity (total), kWh/a	-	-	59,170*
Renewable energy consumption			
Time step used			10 minutes
Heating (SH+DHW), kWh/a	-	-	-
Cooling, kWh/a	-	-	-
Electricity (total), kWh/a	-	-	33,349*
Electricity (heating), kWh/a	-	-	-
Degree of self-sufficiency			
Time step used	-	-	10 minutes
Heating (SH+DHW), %	-	-	-
Cooling, %	-	-	-
Electricity (total), %	-	-	13.7%
Electricity (heating+cooling), %	-	-	-

SH = Space heating, DHW = Domestic hot water

Calculations adjusted for measured degree days.

*Electricity consumption/production is for the period May - December.

Table 40: Performance indicators, DK3: Dybedalen

Year of measurements	2020		
Solar radiation on horizontal, kWh/(m²·a)	1020		
Degree days for heating/cooling	2529		
Weather data used for calculation	2001-2016		
Building gross floor area, m²	1,446		
Energy consumption	**Calculated, before renovation**	**Calculated, after renovation**	**Measured**
Time step used	0.5 hour	0.5 hour	10 minutes
Heating (SH+DHW), kWh/a	200,994	88,206	83,579
Cooling, kWh/a	-	-	-
Electricity (total), kWh/a	127,248	65,070	66,805
Electricity (heating), kWh/a	-	-	-
Renewable energy production			
Time step used	-	-	10 minutes

Heating (SH+DHW), kWh/a	-	-	-
Cooling, kWh/a	-	-	-
Electricity (total), kWh/a	-	-	28,057
Renewable energy consumption			
Time step used	-	-	10 minutes
Heating (SH+DHW), kWh/a	-	-	-
Cooling, kWh/a	-	-	-
Electricity (total), kWh/a	-	-	21037
Electricity (heating), kWh/a	-	-	-
Degree of self-sufficiency			
Time step used	-	-	10 minutes
Heating (SH+DHW), %	-	-	-
Cooling, %	-	-	-
Electricity (total), %	-	-	31,5%
Electricity (heating+cooling), %	-	-	-

SH = Space heating, DHW = Domestic hot water

Calculations adjusted for measured degree days.

*Electricity consumption/production is for the period May - December.

Main stakeholders involved

The Danish part of READY is led and coordinated by COWI A/S. Further Danish demo site partners include Aarhus Municipality incl. AffaldsVarmeAarhus (AVA), Aarhus University, Boligforeningen Ringgården AmbA, KAMSTRUP A/S, Racell Saphire ApS, Danfoss A/S, Danish District Heating Association (Grøn Energi), Lithium Balance A/S, and E.ON Denmark.

References

[1] Ready – Resource Efficient Cities Implementing Advanced Smart City Solutions, Final publishable summary report – full duration of project, Deliverable 9.3.5, January 2021.

[2] Ready – Resource Efficient Cities Implementing Advanced Smart City Solutions, Evaluation of the operational monitoring data of the demonstration projects, Deliverable 7.3, November 2020.

2.1.21 SEB No. 20 – Josh's House – Gigg Place Hilton, Australia

Location information

Address: 2/19 Grigg Place Hilton WA 6163 Australia

Geographic Coordinates: -32.07° S, 115.78° E

Climate Zone: Warm temperate (NCC Zone 5)

Building typology: Residential/Single Dwelling

Authors: Rebecca Yang (RMIT), Chengyang Liu (RMIT)

General description

Josh's House was built in 2013 as a national exemplar of energy efficient dwelling design for the volume market, and the lessons learned have been widely disseminated via Dr Josh Byrne's research efforts with Curtin University and the CRC for Low Carbon Living. With the addition of an electric vehicle (EV) and a recent update to the solar energy system (mid-2018), this applied study will continue in conjunction with local business partners. The original gas-boosted solar hot water system was replaced with an electric heat pump, and the gas stove was replaced with an induction cooktop, making the home totally solar-electric. The new appliances, as well as the EV charging station, are metered, and the data provides useful insights into the effect of auto charging on a solar-electric household. Josh's House received 10/10 stars for the Nationwide House Energy Rating Scheme (NatHERS) and is net energy exporters. It collects and recycles most of its own water and landscaping includes food production, wildlife habitat and play spaces. The interiors incorporate 'Healthy Homes' (indoor air quality) and 'Livable Homes' (universal access) principles.

Detailed description of key technologies installed

- A 6.4 kWp PV array (SunPower X-Series) was installed on 2018, with a 5 kWp inverter (Fronius Symo 5.0).
- The Josh's House was equipped with a 10 kWh LiPO Battery System (LG Chem Resu 10), which supplies to the household usage as well as the electric vehicle (Mitsubishi iMiev).
- Working in conjunction with the PV system, the Josh's House was renovated with a heat pump hot water system and induction cooktop, which reduces the reliability for natural gas.
- Josh's House has several features for reducing the energy consumption and carbon emission along with the water consumption. It has an integrated water system in conjunction with UV disinfection system which can collect up to 32,000 litres of rainwater. This will meet the demand for internal purposes for up to 8 months.
- To fully utilise the greywater, Josh's House uses the Grey Flow Diversion Device to process and collect the greywater generated from laundry and bathroom for irrigation usage.
- Josh's House has been upgraded with smart metering systems, solar irradiance sensor, wind speed & direction sensor and temperature & humidity sensors (including slabs, wall, ceiling and roof in-built sensors) for a continuous monitoring of the house's energy performance.

Table 41: Overview of SEB technologies

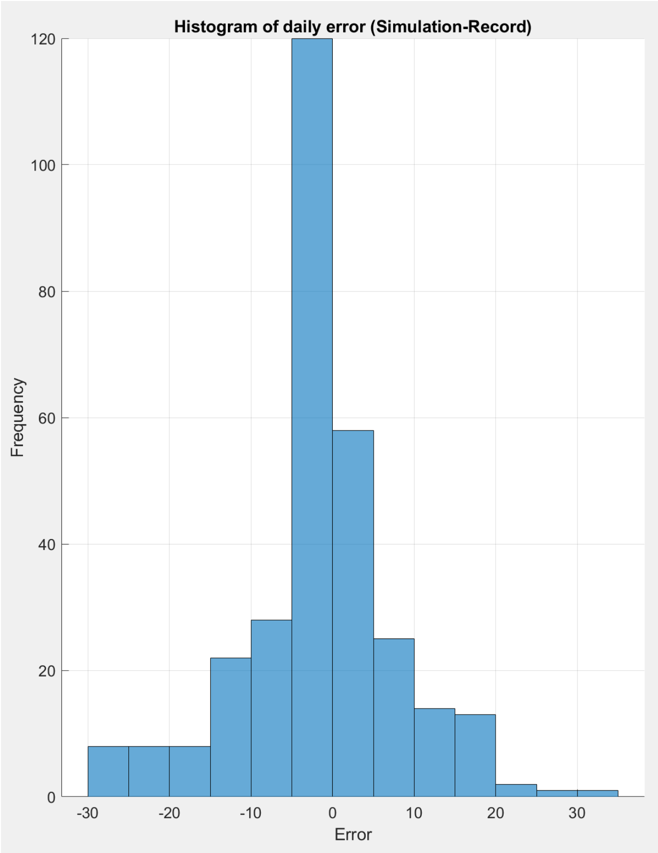
Technologies	SEB Technologies															
	Energy source										Energy storage					
	sun			wind	water		earth	air	bioenergy		electrical storage		thermal storage			
	Photovoltaic	Solar thermal collectors	PVT-collectors	Wind turbines	Hydropower plant	Groundwater and heatpumps	Geothermal and heatpumps	Air-source heatpumps	Biomass combustion	Biogas plants	batteries	Mobile batteries (E-mobility)	Hotwater storage	Ice storage	Sorption storage	Thermal mass activation
	x	x						x			x	x	x			

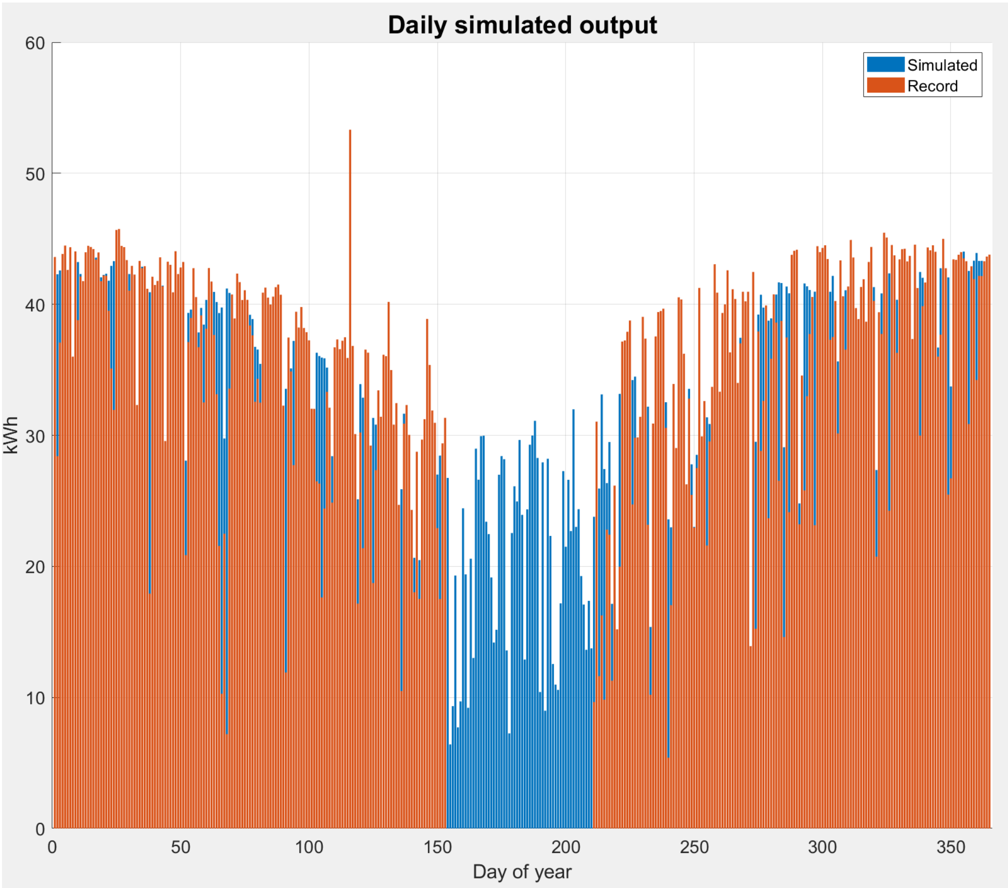
Table 42: Performance indicators

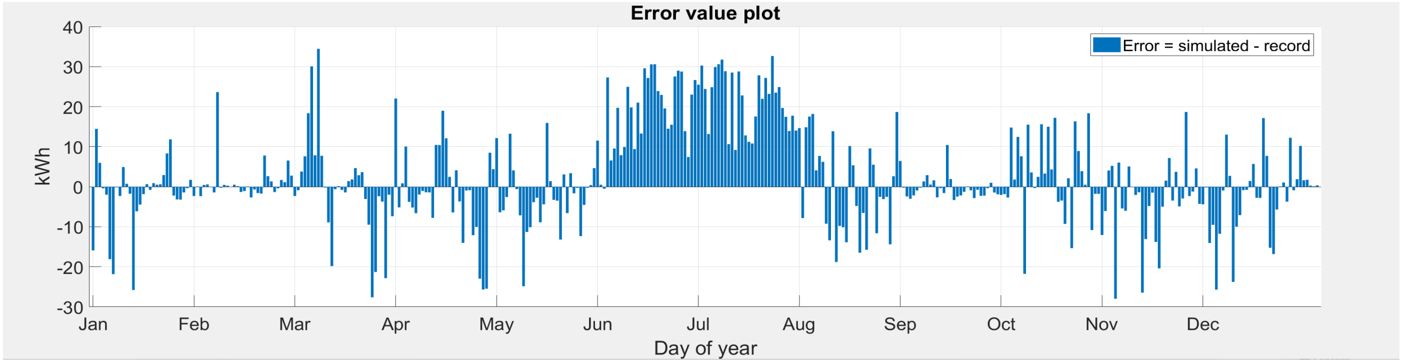
Year of measurements	2018	
Solar radiation on horizontal, kWh/(m^2·a)	12,525	
Degree days for heating/cooling		
Weather data used for calculation	BoM Australia – Perth Airport - Perth WA, Australia	
Energy consumption	**Calculated**	**Measured**
Time step used		Yearly
Heating (SH+DHW), kWh/a		1156
Cooling, kWh/a		N/A
Electricity (total), kWh/a		6040.6
Electricity (heating+cooling), kWh/a		
Renewable energy production		
Time step used	Hourly	Hourly
Heating (SH+DHW), kWh/a		
Cooling, kWh/a		
Electricity (total), kWh/a	11,815	10,782
Renewable energy consumption		
Time step used		
Heating (SH+DHW), kWh/a		
Cooling, kWh/a		
Electricity (total), kWh/a		5376
Electricity (heating+cooling), kWh/a		
Degree of self-sufficiency		
Time step used		
Heating (SH+DHW), %		
Cooling, %		
Electricity (total), %		89%
Electricity (heating+cooling), %		

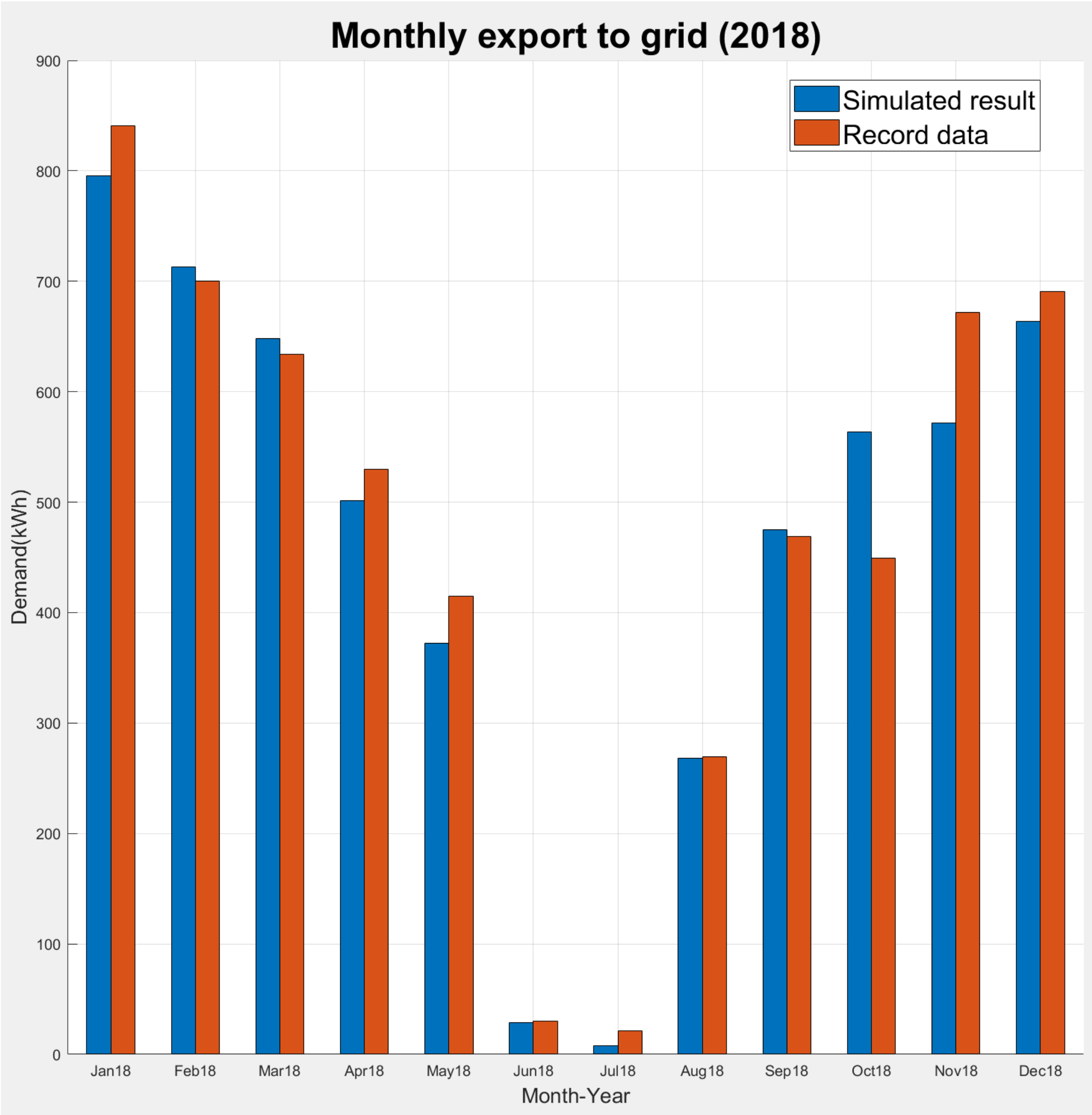
Comparison between Simulated PV generation and on-site measurement

Simulated using the MATLAB and Simulink models developed by Solar Energy Application Lab, RMIT


Histogram of daily error (Simulation-Record)
Frequency
Error
120
100
80
60
40
20
0
-30
-20
-10
0
10
20
30


Daily simulated output
Simulated
Record
kWh
Day of year
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350


Error value plot
Error = simulated - record
kWh
40
30
20
10
0
-10
-20
-30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Day of year


Monthly export to grid (2018)
Simulated result
Record data
Demand(kWh)
900
800
700
600
500
400
300
200
100
0
Jan18
Feb18
Mar18
Apr18
May18
Jun18
Jul18
Aug18
Sep18
Oct18
Nov18
Dec18
Month-Year

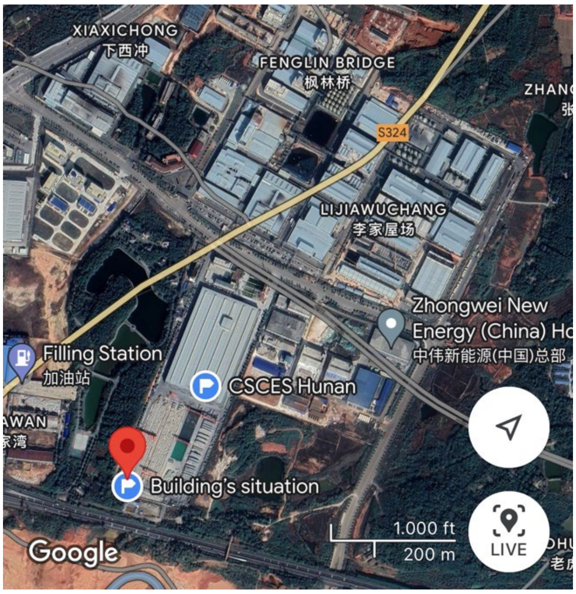
2.1.22 SEB No. 21 – CSCES's Changeable Interspace House, Changsha, China

Authors: Yuexiang Zhu (Hunan University, China)

General description

The CI HOUSE (Changeable Interspace House) in the southwest of China Construction Technology Hunan Co., LTD is designed for a new prefabricated building demonstration by China Construction Fifth Engineering Division Corp., LTD. The construction of the three-story edifice, standing at a height of 11.25 meters and encompassing a footprint of 123.91 square meters, was completed in 2020. The structure boasts a cumulative floor area of 418.62 square meters.

In the design of the integrated energy system, solar collectors are installed on the top floor and their pipes extend down to the equipment room in the basement. The principal apparatus located in the basement comprises a lithium bromide absorption chiller, a high-temperature air-source heat pump, chilled water storage and thermal storage tanks, an air handling unit, a pretreatment pipeline from VEAHE (Vertical Earth-Air Heat Exchanger), and essential water pumps.



The first floor serves as a showcase for renewable energy technologies, demonstrating cooling and heating provisions. During summer, solar-powered air conditioning facilitates cooling, with the high-temperature air-source heat pump providing auxiliary heat. In contrast, winter heating is achieved through the air-source heat pump, while tunnel wind from EAHE is utilized for fresh air pretreatment throughout the year. The building's second and third floors predominantly display the standard modular shear wall architecture. The second floor employs a split-type air conditioning system for energy supply, while the third floor, unfinished and undecorated, is reserved for structural display purposes.

Detailed description of key technologies installed

- The solar collector array is configured in three parallel rows, with the respective row comprising seven, six, and seven units. The array consists of a total of twenty sets, each with an active light-harvesting area of **1.98 m^2**.
- A single-effect lithium bromide absorption chiller, with a rated cooling capacity of **11.5 kW** is installed.
- The solar collectors provide the thermal medium required for the operation of the lithium bromide unit. In instances of insufficient heat generation, a high-temperature air source heat pump (**19.2 kW)** is employed for auxiliary heating.
- The lithium bromide absorption chiller can provide cold water to supply the space cooling demand. Also, the air source heat pump can meet the space heating demand in winter.
- The system includes a hot water tank for storing water heated by the collectors and a cold water tank for the chilled water from the chiller.
- The VEAHE provides pre-treats fresh air, which is then channeled to the air handling unit. The VEAHE consists of one U-type pipe, the diameter of which is 219 mm, and they are installed at a depth exceeding 15 meters.

Table 43: Overview of SEB technologies

	SEB Technologies																			
	Energy source												Energy storage							
	sun			wind	water		earth	air	bioenergy		electrical storage		thermal storage			
Technologies	Photovoltaic	Solar thermal collectors	PVT-collectors	Wind turbines	Hydropower plant	Groundwater and heat pumps	Geothermal and heat pumps	Air-source heat pumps	Biomass combustion	Biogas plants	Batteries	Mobile batteries (E-mobility)	Hot water storage	Ice storage	Sorption storage	Thermal mass activation
		x					x	x					x			

Main stakeholders involved

The project was led and coordinated by China State Construction Engineering Corporation（CSCEC）, China Construction Fifth Engineering Division Corp., LTD, and Hunan University.

2.1.23 SEB No. 22 – Singlefamily Solar House, Gräfelfing, Germany

Author: Gerhard Mengedoht (Technical University of Applied Sciences Ulm, THU (until 08/2023, since 09/2023 Steinbeis Transfer Centre for Solar Building & Refurbishment, Gräfelfing), all photos & pictures: Gerhard Mengedoht

General Description

The 'Sonnenhaus Gräfelfing' is located in Gräfelfing, a suburb near Munich in Germany. In 2011, the owner needed more living and usable space for his occupied single-family house with an integrated home office.

The expansion of the usable floor space was also to result in a significant reduction in energy consumption for heating and electricity.

The main focus was on using solar thermal energy, including a stratified storage tank and photovoltaics. Initially, an approach was pursued to expand the existing building to a passive house standard.

For reasons of cost and energy efficiency, the usable floor space was expanded by an innovative new building as a solarhouse concept. The new part of the solar energy building was erected as a separate building

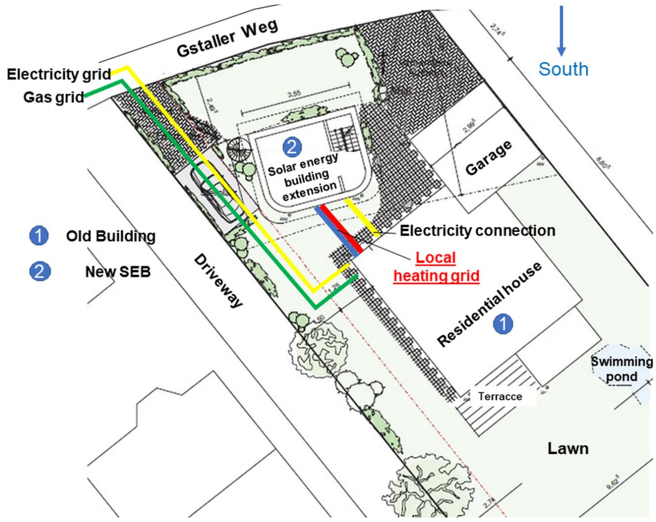


Figure 18: Overview of the existing building No. ① and the new solar- house No. ②, connected by a local heating grid.

away from the building line and thus oriented more to the south (*Figure 18*).

Despite tall trees and without additional thermal insulation of the existing building (construction standard EnEV 2002, year of construction 2002/2003), the new construction of a solarhouse more than halved the energy consumption for gas and electricity for both buildings (existing building and new solarhouse) through the use of solar thermal energy and photovoltaics.

After approx. 11 years of operation, the following conclusion can be drawn: Regarding this application (energy-efficient refurbishment of an old building plus extension of usable space), the solarhouse concept is clearly superior to insulating the existing building to passive house standard, both in terms of investment costs and energy savings per euro invested. The annual energy cost savings of € 1063 per year with the solarhouse concept are significantly higher than those of insulating the existing building to passive house standard at € 182 per year. The investment costs per energy saved are € 0.08/kWh for the solarhouse concept and € 0.79/kWh for the façade insulation of the existing building. This means that the Solar Energy Building concept is approx. 10 times more cost-efficient per kWh than the subsequent insulation of the existing building (assuming heating costs with gas at 7 € cent/kWh, today approx. 11 € cent/kWh). The measurements taken since 2013 have been confirmed in subsequent years and vary slightly depending on the climate. Continuous monitoring has enabled further optimizations.

Tabel. 1: Detailed Description of Key Technologies installed

Parameter	**Value**
Building gross floor area (NFA)	356 m² (267 + 89) m²
Building usable area (net ground area) (EnEV)	440.5 m² (321.6 + 118.9) m²
Solar thermal collector area (STCA)	38.46 m² (30.96 + 7,50) m²
Heat storage	7.75 m³ (7.25 m³ for SH + 0,5 m³ for DHW)
Backup heating (gas condensing boiler)	8.0 - 11,0 kW
Photovoltaic power (PV) PV-1 since 2013 Photovoltaic power (PV) PV-2 since 2023	2,45 kWp 11.75 kWp (PV-1 + 9,30 kWp)
Power storage (Li-Ion, net)	12.3 kWh
Power storage for electric vehicle (eMini Cooper SE, Li-Ion)	32.0 kWh

Selected Performance
Indicators (measured 2013/14, 2017/18 – 2022/23, 2023)
Categorization of energy consumption

Heating :	23.18 … 39.76 kWh/(m_{NFA}^2a)
Electricity :	11.8 … 16.1 kWh/(m²a)

Renewable Energy Generation

Photovoltaic (PV-1) :	1,074.1 … 1,144.9 kWh/kWp
Photovoltaic (PV-2) :	781.0 kWh/kWp **
Solar thermal energy (old + new system) :	406.96 … 562.06 kWh/(m^2_{STCA} a)
Solar thermal energy (old system) :	214.40 … 305.32 kWh/(m^2_{STCA} a)
Solar thermal energy (new system) :	537.07 … 627.48 kWh/(m^2_{STCA} a)

degree of self-sufficiency

Heating (SH+DHW)	58,8 … 68,8 %
Electricity PV-1	24,5 … 29,9 %
Electricity PV-2	64,8 %

** The influence of the tall trees on the new monocrystalline PV-system PV-2 is clearly visible (Module efficiency 21,5 %)

Detailed Description of Key Technologies installed

The centerpiece of the new solar house is the 7,250-litre stratified water storage tank. A stratification lance is used to build up and maintain thermal stratification in the tank. The tank is integrated into the building, and serves purely as a heating buffer (for both buildings). This buffer storage tank is connected to the existing building via a local heating network. From an architectural point of view, it was a challenge to integrate the large storage tank and the necessary solar technology surfaces (approx. 50 m²) into the relatively small solar house, which has a small floor area (floor slab 39.5 m²) (Figure 20).

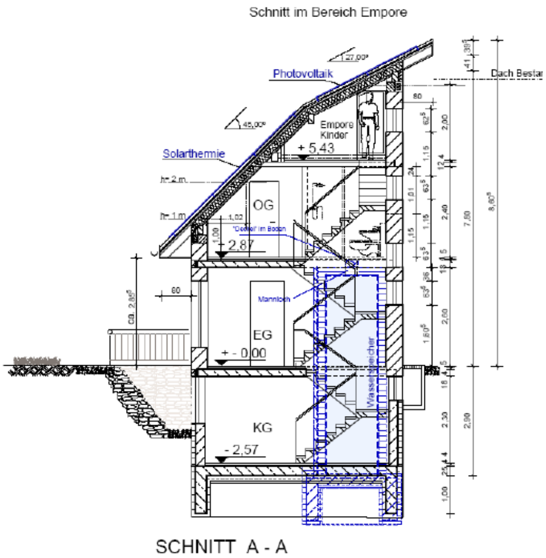


Figure 20: Cross-section of the solarhouse with stratified heat storage

Figure 19: South view of SEB Gräfelfing

The solarhouse itself has only one heat generator, the 33.68 m² new solar thermal system integrated into the roof (45° inclination). A chimney and a fossil fuel heating system are no longer needed. The solar heat from the six large-area solar thermal collectors is transferred to other zones in the existing building that require heating (living rooms, basement rooms), thereby increasing the efficiency of the solar thermal system in the solarhouse.

For exergetic reasons, the domestic hot water is heated centrally in a 500-liter hot water tank that was already present in the existing building. When the large heating buffer storage tank is empty in winter, a gas-condensing boiler in the existing building is used. The 22-year-old 7.5 m² solar thermal system (30° inclination) on the existing building, which is partially shaded by tall trees, was also integrated into the control concept.

The solarhouse concept is also usefully complemented by a 16.7 m² photovoltaic system for solar power (nominal output 2.45 kWp). The PV inverter supplies the solarhouse and the existing building with electricity as needed and feeds any surplus electricity into the grid.

Since 2023, an additional 9.30 kWp PV system has been installed on the SE and NW roof of the existing building 1 (increased to 10.92 kWp in June 2024). The electrical system was supplemented by an electricity storage unit (12.3 kWh) and a wall bo.

The building's structural design is characterized by a south-facing office space optimized for daylight and triple glazing with a high g-value and high τ_{vis}-value. A highly effective adjustable external solar shading system, including light control (Figure 19), helps to prevent overheating in summer.

The construction is better than a 3-litre house (primary energy $q_P \leq 34$ kWh/(m²a) for both buildings) and is ventilated exclusively via windows. Increased room temperatures due to the upper area of the thermal store, which can reach 95°C in summer, did not occur due to a very well insulated store shell (30 cm) and special passive shaft ventilation (chimney effect via annular gap and stairwell, Figure 20 and Figure 22).

Since summer 2015, a heat exchanger has been used to transfer the solar surplus that may occur in the solarhouse heat storage tank to a swimming pond (Figure 23). This increases the efficiency of the solar thermal system.

Figure 22: North view of the Gräfelfing solarhouse

Figure 23: Natural swimming pond

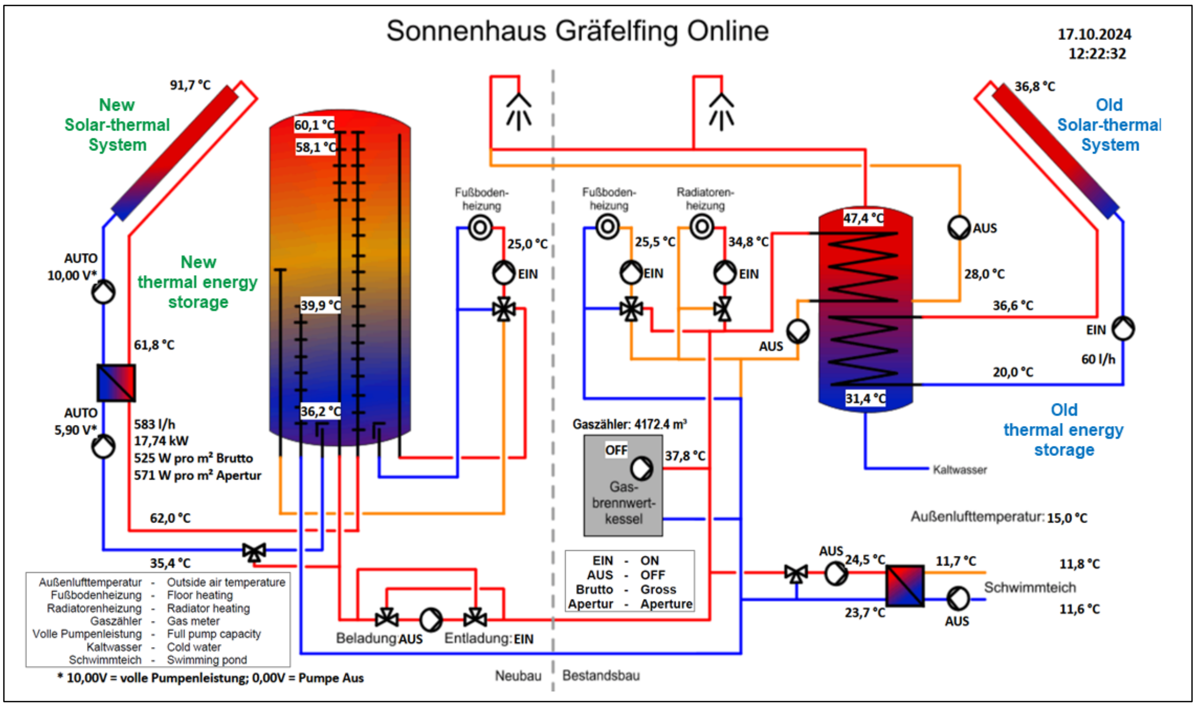


Figure 21: Plant schematic and visualization of measurement data for solar thermal heat supply (snapshot: swimming pond being heated around midday)

The system schematic and an online visualisation (http://www.sonnenhaus-graefelfing.de) of the measurement data for the solar thermal heat supply (solarhouse new building on the left, an an existing building on the right) are shown in Figure 21. Part of the summer solar heat surplus is transferred to the swimming pond (40 m³, max. water temperature 25°C).

The various operating phases of the hydraulic system shown in Figure 21 are as follows:

- Solar energy is fed from the new solar thermal system (33.68 m², aperture 30.96 m²) shown on the left via six (selectively coated) large-area collectors through a solar heat transfer station into the stratified buffer storage (7.25 m³) and stratified lance storage and buffered.
- The rooms in both buildings are heated by a large-area low-temperature surface heating system from the middle area of the temperature-stratified buffer storage tank. A 4-way mixing valve in the heating circuit station optimizes the flow temperature of the surface heating and only takes as much heat as is needed from the buffer storage tank at the lowest possible heating water temperature.

- The old solar thermal system (8.17 m², aperture 7.50 m²) shown on the right in Figure 21 only charges the domestic hot water storage tank (0.5 m³). This tank supplies domestic hot water for both buildings 1 and 2.
- An additional gas condensing boiler can be used to heat the stratified buffer storage tank and the domestic hot water storage tank if the weather remains poor.

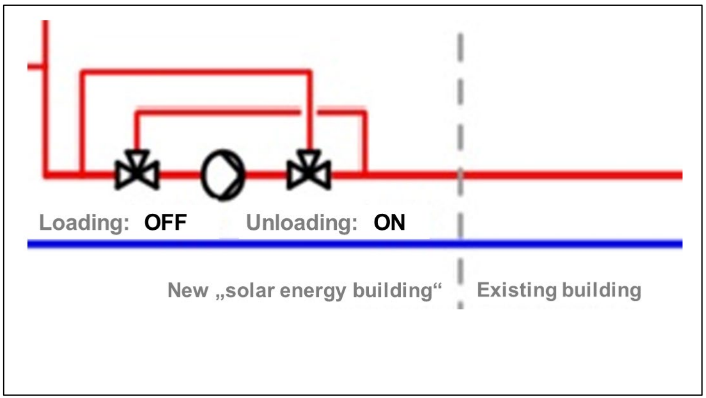


Figure 24: Hydraulic section with the transfer pump for charging and discharging the stratified heat storage tank with layer-type heat exchangers

Figure 25: Transfer pump in operation

Figure 24 shows the transfer pump (4 - 7 W) as a central component of the system hydraulics. This transfer pump (Figure 25), which is crucial for the entire system, realizes the targeted charging and discharging of the stratified lance heat storage tank for the various operating conditions as follows:

1. The provision of heat energy from solar energy and natural gas for both buildings, which are connected via a local heating network
2. When the stratification lance storage tank can no longer absorb solar energy in summer (95°C in the upper area), this solar excess heat is used to heat damp, cold cellar rooms, if desired.
3. In addition, excess heat is released into a swimming pond via a heat exchanger in summer.
4. These two excess functions prevent stagnation in the large-scale solar thermal energy system

Table 44: Overview of SEB technologies

	SEB Technologies															
	Energy source										Energy storage					
	sun			wind	water		earth	air	bioenergy		electrical storage		thermal storage			
Technologies	Photovoltaic	Solar thermal collectors	PVT-collectors	Wind turbines	Hydropower plant	Groundwater and heatpumps	Geothermal and heatpumps	Air-source heatpumps	Biomass combustion	Biogas plants	batteries	Mobile batteries (E-mobility)	Hotwater storage	Ice storage	Sorption storage	Thermal mass activation
	x	x									x	x	x			

Table 45: Performance indicators, 2 solar thermal systems with PV-System 1 (2,45 kWp)

Year of measurements	2013/2014 (21.5. - 20.5.)		2017/2018 – 2022/23 (1.6. - 31.5.)	
Solar radiation on horizontal, kWh/(m^2·a)	1,238		∅ 1,278.7	
Degree days for heating/cooling, Kd/a	3,550		∅ 3,502.5	
Weather data used for calculation	German Meteorological Service			
Building gross floor area (NFA), m^2	356 (Building 1: 267 + Building 2: 89)			
Energy consumption	**Measured 1 year**		**Measured 6 years**	
Time step used	15 Minutes		15 Minutes	
Heating (SH+DHW), kWh/a, kWh/(m^2a)	10,224	28.72	∅ 11,171	∅ 31.38
Cooling, kWh/a, kWh/(m^2a)	-	-		
Electricity (total), kWh/a, kWh/(m^2a)	4,430	12.44	∅ 5,228	∅ 14.69
Electricity (heating+cooling), kWh/a	-		-	
Renewable energy production				
Time step used	15 Minutes		15 Minutes	
Heating N-ST (SH+DHW) kWh/a, kWh/(m^2_{STCA} a)	15,179.1	490.3	∅ 18,505	∅ 597.7
Heating O-ST (SH+DHW) kWh/a, kWh/(m^2_{STCA} a)	2,087.7	278.4	∅ 2,027	∅ 270.3
Cooling, kWh/a, kWh/(m^2a)	-		-	
Electricity (total), kWh/a (PV-System 1)	2,711.0		∅ 2,722.2	
Renewable energy consumption				
Time step used	15 Minutes		15 Minutes	
Heating N-ST (SH+DHW) kWh/a, kWh/(m^2_{STCA} a)	15,179.1	490.3	∅ 18.505	∅ 597.7
Heating O-ST (SH+DHW) kWh/a, kWh/(m^2_{STCA} a)	2,087.7	278.4	∅ 2.027	∅ 270.3
Cooling, kWh/a	-		-	
Electricity PV-System 1 (total), kWh/a	1,273.6		∅ 1,451.3	
Electricity (heating+cooling)			-	
Degree of self-sufficiency				
Time step used	15 Minutes		15 Minutes	
Heating (SH+DHW), %	62.8		∅ 65.0	
Cooling, %	-		-	
Electricity PV-System 1 (total), %	28.7		∅ 27.9	
Electricity (heating+cooling), %	-		-	

SH = Space heating, DHW = Domestic hot water, ∅ - mean value,
N-ST = New solar-thermal system 33.68 m^2 (aperture 30.96 m^2),
O-ST = Old solar-thermal system = 8.71 m^2 (aperture 7.50 m^2), PV-System 1: 2.45 kWp.

Table 46: Performance indicators, 2 solarthermal systems with PV-System 2 (2,45 kWp + 9,30 kWp)

Year of measurements	2023 (1.1. - 31.12.)	
Solar radiation on horizontal, kWh/(m^2·a)	1,257	
Degree days for heating/cooling, Kd/a	3,247	
Weather data used for calculation	German Meteorological Service	
Building gross floor area (NFA), m^2	356 (Building 1: 267 + Building 2: 89)	
Energy consumption	**Measured 1 year**	
	1.1.2023 – 31.12.2023	
Time step used	15 Minutes	
Heating (SH+DHW), kWh/a, kWh/(m^2a)	9,693	27.23
Cooling, kWh/a, kWh/(m^2a)	-	-
Electricity (total), kWh/a, kWh/(m^2a)	5,575	15.66
Electricity (heating+cooling) kWh/a	-	
Renewable energy production		
Time step used	15 Minutes	
Heating N-ST (SH+DHW) kWh/a, kWh/(m^2_{STCA} a)	17,367	560.9
Heating O-ST (SH+DHW) kWh/a, kWh/(m^2_{STCA} a)	1,566	208.8
Cooling, kWh/a, kWh/(m^2a)	-	-
Electricity (total), kWh/a	9,177	

Renewable energy consumption		
Time step used	15 Minutes	
Heating N-ST (SH+DHW) kWh/a, kWh/(m²$_{STCA}$ a)	17,367	560.9
Heating O-ST (SH+DHW) kWh/a, kWh/(m²$_{STCA}$ a)	1,566	208.8
Cooling, kWh/a, kWh/(m²a)	-	-
Electricity PV-System 2 (total) kWh/a	3,614	
Electricity (heating+cooling) kWh/a	-	
Degree of self-sufficiency		
Time step used	15 Minutes	
Heating (SH+DHW), %	66.1	
Cooling, %	-	
Electricity PV-System 2 (total), %	64.8	
Electricity (heating+cooling), %	-	

SH = Space heating, DHW = Domestic hot water, PV-System 2: (2.45+9.30) kWp, Battery+Wallbox,
N-ST = New solar-thermal system 33.68 m² (aperture 30.96 m²),
O-ST = Old solar-thermal system 8.71 m² (aperture 7.50 m²).

Main Stakeholders Involved

The "Sonnenhaus-Gräfelfing" project (http://www.sonnenhaus-graefelfing.de) was privately managed, conceptualised and financed by Gerhard Mengedoht.

Other project participants are: Lebensraum Eva Prignitz, Wolfgang Hilz, Achim Fregin, Gunter Lindemann (THU), Mariner Wohnbau GmbH, Generation Solar - Solar und Heizungstechnik GmbH, Adsol GmbH.

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3 Guideline for monitoring and reporting

3.1 Purpose of a monitoring

Monitoring can play a key role in the entire life cycle of existing and future buildings as well as their energy supply systems.

With the data available with monitoring, buildings and energy supply systems can be made transparent for planners, operators and users. This transparency can already be used during the commissioning of the building and energy supply system to significantly shorten the time until fully functional operation. Based on a transparent data situation, measures can be derived for the building and the energy supply system which, in addition to optimized, energy-efficient, sustainable and demand-oriented operation, can also be used to influence user behavior and thus reduce not only the energy sources used but also the operational and demand-related costs for the energy supply.

In addition, the documentation of the monitoring data can be used for efficient and sustainable maintenance and repair measures as well as for adaptations of future energy supply systems.[1] [2]

3.1.1 Current status of monitoring from the point of view of IEA SHC Task 66 participants

Today detailed monitoring is unfortunately only common for buildings related to research or demonstration projects, as stated by an international report of IEA SHC Task 40.[3] To gain more information about the situation in different countries the international participants of IEA SHC Task 66 had been involved in a short survey about the current and future status of monitoring in their countries.

In India for example major energy supply systems are monitored but single or multi-family buildings are monitored only for billing purpose, with the minimum number of required measuring equipment. The future is seen in a decentralized energy supply (electricity, heating, cooling), in which prosumers are gaining in importance. For this purpose, a high optimization potential arises through more detailed monitoring concepts.

In Denmark, it is common practice to monitor heating and electricity for billing purposes and to inform residents about their consumption. Similar to India, monitoring in the future will support the creation of virtual heating and power plants consisting of many individual buildings connected to one smart district.

The current and future status regarding monitoring in Germany reflects a similar situation to India and Denmark. As mentioned above, monitoring for buildings has been implemented almost exclusively in scientific projects for decades. Although the service was evaluated in numerous studies as essential for achieving the energy and functional goals of the buildings, it was hardly ever transferred into practice. In recent years, "technical monitoring" has been introduced into the German construction industry as a performance profile through various regulations (VDI 6041[1], AMEV Recommendations [4] [5]). The importance of monitoring is increasing significantly due to the growing interest and relevance of CO_2 emissions and the desire to reduce them, as well as the goal of implementing climate-neutral or greenhouse gas-neutral buildings including their energy supply. For example, the EU taxonomy (to be applied from 01.01.2023) states that, among other things, consumption data of buildings in terms of performance will determine their rating as "green". In addition, numerous services such as energy management and monitoring, among others, are assessed as green activities. At the EU level, the EPBD offers the option of implementing monitoring instead of regular energy inspections of facilities. At the federal level, the topic of monitoring has meanwhile been included in the German building energy act GEG and the federal subsidies for efficient buildings BEG, where it is required as a basis or promoted with subsidies. Various sustainability certifications, e.g. DGNB or LEED, also require monitoring during operation or award points for it. Finally, the new requirements for the mandatory use of building automation anchored in the EU Directive EPBD also require the use of monitoring. At this point, it should be pointed out that in the course of monitoring, it is often possible to gain very deep insights into user behavior, which can in principle be assigned to groups of people and even to individual persons. This allows conclusions to be drawn about private life. In view of the European General Data Protection

[1] Cf. VDI 2017
[2] Cf. Plesser et al. 2019
[3] Cf. Noris et al. 2013
[4] Cf. AMEV 2017
[5] Cf. AMEV 2020

Regulation on the protection of individuals with regard to the processing of personal data, on the free movement of data, the associated legal aspects must be taken over by a lawyer.

Based on the qualified assessments of the IEA SHC Task 66 participants from India, Denmark and Germany, it would make sense to implement a more detailed monitoring concept in addition to the minimum for billing purposes, not only for the optimized, energy-efficient, sustainable and demand-oriented operation of the energy supply systems.

Especially with regard to the energy supply with high solar fractions of the "city of the future", in which, among other things, decentralized prosumers want to be used in combination with renewable energies as virtual power plants, a detailed monitoring concept with transparent data knowledge about currently retrievable heat and electricity capacities, quantities and also storage capacities, is gaining in importance.

Thus, a detailed monitoring concept for individual buildings as well as for building blocks and communities in existing and new buildings holds high optimization potentials and thus potentials for energy savings, as well as for current and future supply security.

3.1.2 Focus of the guideline

An important part of the implementation of the solar energy buildings of the "city of the future" considered in IEA SHC Task 66 is the monitoring of the realized and future solar energy supply concepts and their target values, as described in chapter 3.2. Since the solar supplied "city of the future" will continue to consist of a mixture of existing and new buildings, this guideline describes monitoring concepts for both building structures. It is particularly important to monitor existing buildings, as this is still insufficient or almost non-existent, depending on the country under consideration. In particular, the different integration into the planning process must be taken into account. Starting from a basic monitoring variant, different extensions for more detailed investigations are described.

In order to understand the guideline, chapter 3.3 starts with a definition and a chronological classification of different kinds of monitoring. Information on the preparation of a monitoring concept to be taken into account in the early planning phases is provided in chapter 3.4 by listing monitoring parameters and their assignment to the kinds of monitoring and different balancing boundaries as well as brief description of possible associated measurement systems and references on data evaluation and analysis. Chapter 3.5 concludes with information on the preparation of reports. In addition, a high application reference is to be created with an example monitoring report in Annex 0.1.

3.2 Target values regarding Task 66

In detail, this guideline for monitoring and reporting of the IEA SHC Task 66 on solar energy buildings “focuses on the development of economic and ecologic feasible solar energy supply concepts with high solar fractions for new and existing single buildings and building blocks or communities”, as stated in the annex plan of IEA SHC Task 66.[6] Major boundary conditions for the central European climate conditions are solar fractions of at least 85 % of the heat demand, 100 % of the cooling demand and at least 60 % of the electricity demand for households and e-mobility. This guideline therefore provides information on monitoring and reporting, which can be used to verify the target values for solar fractions for both existing and new buildings, building blocks and communities.

3.3 Kinds of monitoring

In the process of the life cycle of a building and in the different planning, construction and use phases, various monitoring measures can be implemented to ensure quality and to control the planned efficiencies and performance of the building and the energy supply systems.

The overall monitoring is the technical monitoring (TMon), which is already integrated in the planning phase and continues until the phase of use. Further monitoring is only implemented from or during the commissioning of the building or the energy supply systems (see Figure 26).[1]

The following continues to provide more detail on each type of monitoring. [1 2 5 7]

[6] Cf. Drück 2020

[7] Cf. Erhorn-Kluttig 2017

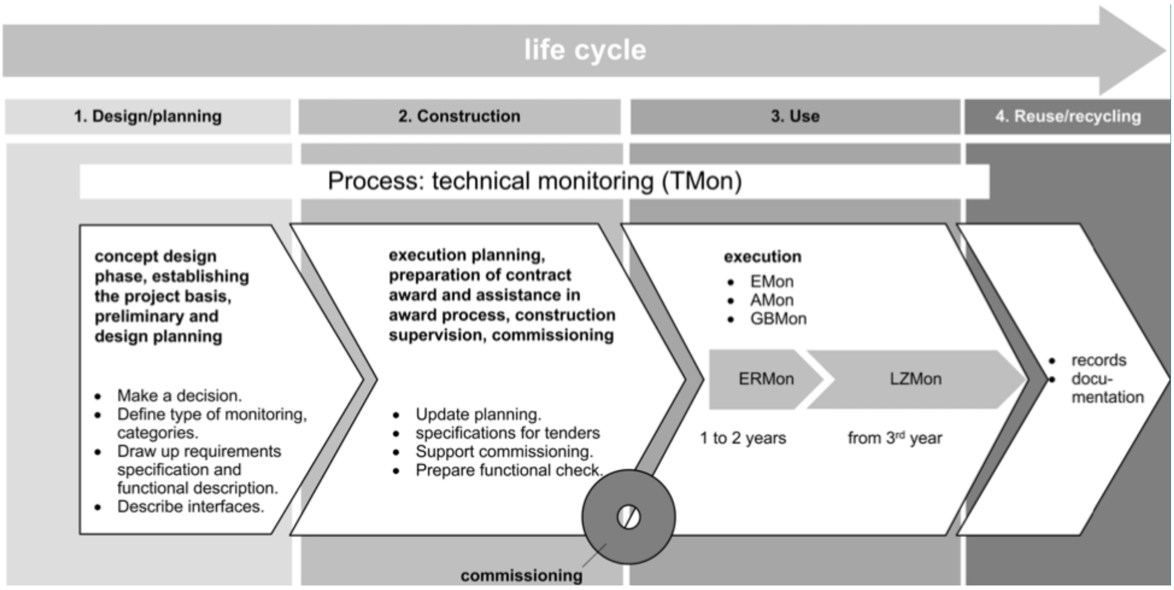

Figure 26: Integration and implementation of the different types of monitoring[1]

3.3.1 Technical Monitoring (TMon)

Technical Monitoring (TMon) is a quality management process for new buildings as well as comprehensive renovations and refurbishments for the specification and testing of the functions of the buildings and facilities, which is provided by an independent third party. The TMon is supported by the building owner during project realization as well as by the personnel responsible for operation during the initial phase of use.

TMon helps to ensure that at the interfaces between the planning and construction phase and the first phase of use, the desired quality is achieved with regard to the originally planned project goals, especially for the building services, and that the prerequisites for energy-efficient, functional and demand-oriented building operation are created. TMon is an important instrument for quality assurance in the construction process and thus makes a decisive contribution to economic, energy-efficient and functional and demand-oriented building operation.

The classification of TMon within the phase of use is based on the process of building and energy supply system operation. While energy monitoring (EMon) is the initial subarea, the behavior of the components and the energy supply system itself is examined in more detail with system monitoring (AMon). With the building and comfort monitoring (GBMon) the building and room climatic conditions in the buildings resulting from the technical building equipment, the system, are examined in detail.

3.3.1.1 Differentiation of TMon from commissioning management (commissioning)

The TMon is neither a planning nor an installation service, but rather a service for testing the functional objectives of buildings and facilities and serves exclusively to ensure the desired quality (in particular building services engineering) within the planning, construction and initial phase of use. The TMon can support the commissioning through supplementary commissioned partial services, but in no case represents a fully comprehensive commissioning.

3.3.1.2 Tasks of a TMon

- Verification of the intended performance of the building, the energy supply system and the measurement system
- Testing of the operation of the building and individual components or total energy supply systems with regard to the properties aimed for in the planning or owed by the builder (trial operation)
- Identification of characteristic values (e.g. key performance indicators (KPIs)), among other things, on the basis of the planning for comparative analysis and further operational optimization (adjustment phase)
- Regular or continuous monitoring of the permanent compliance with the intended properties of the building
- Checking the function of the energy supply system and its components, e.g. circulation pumps or valves, as well as checking the operating modes and control strategies of the energy supply system, e.g. on the basis of heating or cooling curves, without intervening structurally or technically in the building or the energy supply system

- Query or record and document the required target values from the planning in the form of testable target values for individual test values
- Establish appropriate procedures and corresponding technical and organizational requirements to verify the achievement of targets
- Recording or receiving operating values from building operation (from building automation or other measurement systems)
- Comparison of target values and operating data for defined test parameters in order to determine whether the targets have been achieved
- Communication of a corresponding evaluation to the building owner, planners, constructors and operators as a starting point for optimizing operations or knowledge for follow-up projects

3.3.2 Commissioning management (commissioning)

In contrast to the TMon, the commissioning is a planner and installer service that is at least partially included in the basic services of the official German scale of fees for services by architects and engineers (HOAI) as well as in the German construction contract procedures (VOB) as part of the joint responsibility for functioning facilities. In order to ensure the functioning of the facilities, more detailed services of the commissioning management should be commissioned to service providers, planners or execution companies, especially for technically demanding projects.

Services are to be awarded to third parties for organizing the commissioning of a building with a focus on a cross-trade perspective. Whereby the commissioning management is divided into three main levels - commissioning, trial operation, acceptance - and is limited to cost groups for building and technical facilities as well as for external facilities and open spaces. The aim of commissioning management is to ensure an orderly commissioning within a specified time and cost frame and enables the handover of a fully functional building and energy supply system to the user. [8]

3.3.3 Adjustment Monitoring (ERmon)

The monitoring phases in the life cycle of a building can be differentiated between adjustment and long-term monitoring.

The adjustment phase begins with the initial use of the building or the energy supply system and spans over a period of at least two years after the handover of the building. The adjustment phase must be distinguished from the commissioning management of the energy supply systems during the construction phase described in the previous chapter. During acceptance and commissioning, often only the elementary functions of the energy supply systems are checked and the operator is instructed. This is followed by adjustment monitoring, in which the analysis of the function and performance of the energy supply system, as energy demand and energy consumption of the user, creates the basis for an adaption of original planning specifications (e.g. setpoints) which can vary for actual building and system operation.

The aim is to achieve the operating optimum of the building and system technology as well as characteristic and setpoint values for continuous operation. Energy consumption, performance and function are included in the monitoring and analysis. The resulting characteristic and setpoint values, measured under real conditions with user influence, are the comparative variables for further monitoring.

3.3.4 Long-term Monitoring (LZMon)

Long-term monitoring (LZMon) aims to preserve the operating optimum achieved in the adjustment phase as well as fault-free and efficient system operation. In contrast to the adjustment phase, the time intervals at which the data is analyzed are significantly longer. The LZMon starts at the end of the adjustment phase and can last until the end of the building's or of the energy supply systems phase of use. Adjustments due to changes in use and system modifications can thus be monitored, analyzed and evaluated.

3.3.5 Energy Monitoring (EMon)

Energy monitoring (EMon) deals with the continuous recording and evaluation of energy and media consumption data as well as with the recording and evaluation of performance and volume flows, such as by gas meters, heat

[8] Cf. VDI 2011

or cold meters, electricity meters and water meters. Figure 27 schematically illustrates the link between these parameters. The EMon forms the basis for optimization measures related to the building, the energy supply system operation and/or the user behavior.

The energy flow to be captured in the building begins with the supply of final energy at the building and includes generation, storage, distribution and transfer. A clear allocation of the final energy sources used to the different consumers (e.g. space heating, cooling, etc.) is necessary for a simple evaluation of the energy consumption of a building.

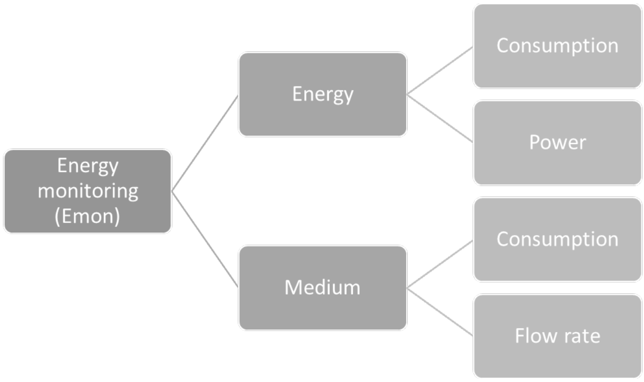

Figure 27 Test scope and parameters of an energy monitoring (EMon)

The EMon can be equated in large parts with a monitoring system for billing purposes. If it is a residential building, the individual energy consumption of the flats is recorded and used for billing purposes. Thus, monitoring for billing purposes is included in the EMon, but is usually supplemented by other measurement technology if other consumers or subgroups are to be evaluated metrologically.

3.3.6 System Monitoring (AMon)

System monitoring (AMon) covers the recording and evaluation of the operating states of the technical systems by measuring systems and analysis instruments, such as building automation and control systems (BACS). This can involve both permanently installed or mobile measuring systems as well as manual recording and reading. Possible parameters are, as shown in Figure 28 for example, switching states, operating times, temperatures, differential pressures as well as volume flows and operating modes (full/partial load).

In contrast to energy monitoring, individual components and system parts are considered and evaluated here.

The AMon thus provides the basis for functional testing and monitoring as well as operational optimization. The recorded data are the basis for fault analyses, which in turn have an effect on energy consumption and therefore on the energy monitoring.

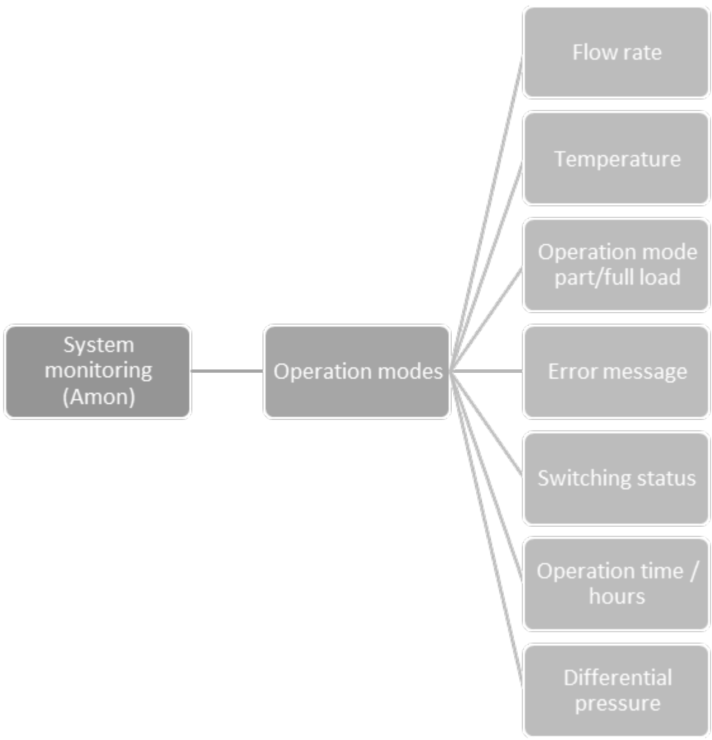

Figure 28 Test scope and parameters of a system monitoring (AMon)

3.3.7 Building and Comfort Monitoring (GBMon)

Building and comfort monitoring (GBMon) essentially looks at room conditioning and building physics. Figure 29 shows the main parameters of the GBMon. Besides room conditioning parameters, such as temperature, brightness, humidity and CO_2 concentration, user perception (comfort) and user behavior (ventilation behavior, occupancy data, etc.) are also recorded.

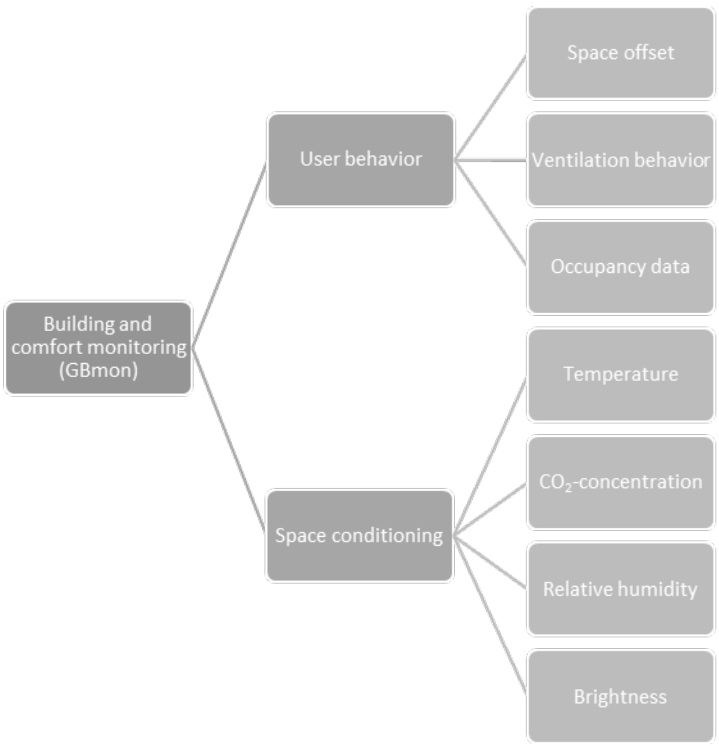

Figure 29 Test scope and parameters of a building and comfort monitoring (GBMon)

While indoor climate is usually measured at random for at least two rooms or for 10 % of rooms from 20 rooms upwards, survey methods are used to record user behavior and comfort. An example questionnaire for a spot-monitoring survey can be found in Annex 2.2.

3.4 Monitoring concept and parameters

The aim of a monitoring concept is to describe and define the organizational and content-related tasks to be carried out. The concept must at least contain the following information and descriptions:

- Relevant targets to be met by the system
- Monitoring schedule showing the work packages, the planned test operations and reporting cycles, the tasks of the service provider and the other project participants, as well as the processing times or periods for the individual services
- List of the systems to be measured with the monitoring parameters and the required data points (sensors, actuators, physical and virtual data points; see chapter 3.4.1 and 0),
- Identification of the measuring points relevant for monitoring in the planning documents or other suitable drawings
- List of target values submitted by the specialist planners and presentation of the evaluation methodology (calculation bases, e.g. for weather adjustment, for calculating an efficiency factor or for defining tolerances, as mentioned in chapter 3.4.3)
- Requirements for measurement and data technology as specifications for the technical planners (see chapter 3.4.1)
- Presentation of the prerequisites for carrying out test operations (availability of corresponding planning documents, functional descriptions, operating data from the building automation system, etc.) as well as specifications for the implementation (e.g. the creation of special load situations). It must be shown whether and, if so, how the operator can continue to use the hardware and software used for monitoring

The particular degree of complexity of the kinds of monitoring can be described using the categories listed below. It is intended to help in the planning phase to adapt the effort to the energetic relevance of the different components (Cf. Figure 26).

- Cat. 1 - Low: Minimal technical effort, use of mainly existing data from monitoring for billing purposes and those from system control.
- Cat. 2 - Medium: Additional sensors, e.g. for single components, are used to a small extent, which allows a significant increase in the informational value.
- Cat. 3 - High: The energy supply system has its own sensors that allow a more in-depth analysis of the energetic behaviour. For accumulated parameters, e.g. energy consumption, the instantaneous value of the power should also be recorded. The instantaneous values can be more helpful for evaluation.

Further, even for a simple evaluation of the energy consumption of a building by measuring energy quantities, a clear assignment of the final energy sources used to the energy consumers recorded and to be evaluated is necessary. If, for example, there is a storage tank or a longer distribution line in the system, it must be clear to which energy consumer the corresponding losses are to be assigned. It should be noted that appropriate sub-meters must be provided for the individual energy consumer or energy consumer group. Only by choosing an energy balance boundary corresponding to the energy consumer is it possible to determine descriptive parameters for the evaluation.

For a comprehensive energy and operation monitoring, volume flows, valve positions, switching and operating states of energy generators and circulation pumps as well as temperatures at characteristic points in the energy supply system (e.g. supply temperature and return temperature) must be recorded in addition to the energy quantities. For operational monitoring and optimization, in addition to the energy quantities, operating status of the system as well as switching and control states must be continuously recorded.

Therefore, the actual energy and operation monitoring is preceded by a comprehensive system analysis as well as the preparation and implementation of a measurement concept. Each building and each system has unique characteristics, which must be considered in detail. A corresponding concept should be developed at the earliest possible planning stage and integrated into the implementation process, as mentioned in chapter 3.3.

In order to be able to carry out a check of the operation of the building and energy supply system, on which is the focus in this guideline, control and regulation concepts should also be known and shown in a functional description.

They are directly related to the use of the building, to usage or opening times, to setpoints for the indoor climate and to the user's options for exerting influence.

Further recommendations to be considered regarding the preparation of a monitoring concept are presented below.

Recommendations during the planning phases

a. If the building is still under construction: an active part in the construction meetings should be taken. It is always an advantage to be involved in communication and for all parties to know faces, names and functions. This way a quick reaction to changes in the implementation is possible. Whereby special care should be taken that the sensors and cabling are installed in a timely, professional and cost-effective manner and become an integral part of the building.

b. Additional measurements for project-specific research tasks (e.g. in GBMon) require a longer lead time.

In the following technical recommendations and typical time intervals for data acquisition are described first. Typical components and systems for the energy supply and corresponding monitoring parameters to be taken into account are shown in chapter 0, including individual additional parameters that may be useful for data analysis. Not shown are supplementary measurement, control and regulation parameters that are required for the operation, control and regulation of the individual energy supply systems. Supplementary information on exemplary evaluation variables and their calculation from the monitoring parameters defined below can furthermore be found in chapter 3.4.3.

3.4.1 Data acquisition

In general, data from the building and energy supply system can be collected in different ways. It is not necessary for data to be collected and transmitted online. A common method is to collect data on site with regular forwarding via modem or e-mail. Whereby The data should be transmitted by BMS independently via email but not by remote access of the monitoring system (Caution liability). Data that accumulates in the building management system (BMS) can be stored there or recorded centrally via an interface.

If data from the building management system is used, investment costs for additional measurement technology of a monitoring system independent of the BMS can be saved. At the same time, however, the independent use of monitoring system and BMS (non-reactive, no interactions) is advantageous. Since in this way the data can be viewed in more detail, easily accessible and in particular independent of third parties. This can reduce waiting times for data, if necessary. In addition, by using both systems independently, for example, the measurement frequency can be increased to respond to faulty data transmission. Thus, in the best case the monitoring system should be planned in such a way that successful implementation does not depend on the reliability of the building management system. Whereby additional data from the building management system is a useful addition. Here, depending on the objectives and available investment capital, a sensible compromise must be found. Manual recording through depreciation is also possible.

The technical effort for continuous data collection and forwarding for monitoring can be considerable and requires - depending on the size of the system - infrastructure (e.g. BACnet). In many buildings, as already mentioned, external access to the data network is not permitted for security reasons, which makes online data collection difficult. Here, too, it makes sense to adapt the technical requirements to the general level of the monitoring system:

- Var. 1: Manual or electronic data collection with decentralized data storage
- Var. 2: Predominantly electronic data collection on site with central data storage in the building
- Var. 3: Online data transmission via external server. Data provision and evaluation via web service (cloud)

For data acquisition systems with internet access, the monitoring system and involved servers have to be protected against portscans by an intrusion prevention system as e.g. “fail2ban”, which is written in the open source software Python. Whereby open source software is generally suggested to save licensing costs. Furthermore, the monitoring system must be able to continue to operate fully even when disconnected from the Internet. Therefore, it is recommended not to use any software whose function depends on an active internet connection.

The measurement data must be resolved as finely as possible in terms of time. Instantaneous values with a 15-minute measurement interval have proven to be a good compromise between informative value and data processability for the analysis of heating and cooling systems for building air conditioning (shorter data logging cycles if possible and manageable). Depending on the task, hourly, daily or monthly totals can also be useful.

At a relatively early stage, it can be determined whether individual variables must be stored only as cumulative totals or as instantaneous values. In the case of instantaneous values, the recording speed depends on the fluctuation of the variable, whereas cumulative data can still be evaluated meaningfully even at low data logging frequencies.

A data logger can be used to monitor and record the data, and the memory capacity can be chosen by the desired sample rate.

Days, weeks, months or years can be selected as the reporting period. This is to be clarified in consultation with the client and implemented depending on the selected kind of monitoring. Usual time intervals for reporting or evaluating data can be found in Table 3-1.

Table 3-1: Usual reporting intervals

KIND OF MONITORING	REPORTING PERIOD
Energy monitoring (EMon)	3 month or annual
System monitoring (AMon)	3 month
Building and comfort monitoring (GBMon) – long-term – fixed sensors	3 month or annual
Building and comfort monitoring (GBMon) – short-term – mobile sensors	measurement once per season – reporting after measurement
Adjustment monitoring (ERMon)	3 month
Long-term monitoring (LZMon)	annual (one year)

3.4.2 Monitoring parameters and measurement equipment

In Figure 30 to Figure 37, the parameters to be monitored, the associated measurement equipment, and information on the installation of the measurement equipment, are defined for the following listed balancing boundaries.

- Building (basic monitoring parameters)
- Heating and cooling generator
- Heating and cooling consumer and stores
- Ventilation systems
- Indoor climate (GBMon)

In addition to the assignment of the measurement parameters to the balancing boundaries, the monitoring parameters are also assigned to the types of monitoring defined in chapter 3.3 by means of a color marking in the left margin. If a monitpring parameter is not marked in color, it does not have to be considered in the corresponding type of monitoring.

The monitoring parameters compiled in Figure 30 to Figure 37 must be processed for all buildings or existing energy supply systems for which monitoring is to be carried out. Depending on the application, supplementary measurement parameters must also be defined in an appropriate manner for energy supply systems that are not listed.

Since this monitoring guideline focuses on the solar energy supply of buildings, in Table 3-2 additionally the most important information especially for the measurement equipment and information on the installation of the measurement equipment to monitor parameters of solar thermal systems is summarized.

Building (part 1/2)

EMon	AMon	GBMon	ERMon	LZMon	monitoring parameter	comparative value with planned target value	way of parameter recording	parameter unit	measurement equipment	installation information measurement equipment	annotation
					Ambient temperature	-	Measurement	°C	temperature sensor	Be located in solar radiation shields which are ventilated to permit free passage of ambient air and to avoid effect of thermal source or sinks.	Possibly additional conversion for controls, e.g. as moving average
					Electr. energy from the grid	Maximum value per year	Meter reqading	kWh	power meter	Be mounted in the circuit for system and each subsystems.	Measurement per feed-in
					Electr. energy feed in to the grid	Minimum value per year	Meter reading	kWh			Measurement per feed-in
					Total elektr. energy consumption	Maximum value per year	Calculation	kWh			Sum of all individual measurements
					a) Consumption without elektr. energy useres (auxillary energy)	Maximum value per year	Meter reading	kWh			(optional) central systems (ventilation, elevators, etc.)
					b) Consumption from elektr. energy useres (houshold, …)	Maximum value per year	Meter reading	kWh			(optional) without central systems (office lighting, -equipment, etc.)
					c) Consumption of induvidual subsystems	Maximum value per year	Meter reading	kWh			(optional) per unit, e.g. bulk consumers, research, e-car charging stations
					Total elektr. energy generation	Minimum value per year	Calculation	kWh			Sum of all individual measurements
					a) from CHP	Target value per year	Meter reading	kWh			(optional) per unit
					b) from PV	Minimum value per year	Meter reading	kWh			(optional) per unit (unadjusted and adjusted to solar raditation)
					c) from other installations	Target value per year	Meter reading	kWh			(optional) per unit
					Heat from the grid	Maximum value per year	Meter reading	kWh	temperature sensor + flow meter or thermal meter (for liquid heating system)	a. The temperature sensor should be mounted at the supply and return pipe work; b. The insulation shall be placed around the pipe both supply and return of the temperature sensor; c.The heat / cooling energy can also be measured by thermal meter directly, and the quantity of heat/cooling can be evaluated by the temperature difference and flow rate of supply and return water.	-
						Peak value per year	average 1/4-hourly load	kW			Measurement at the transfer unit
					Heat feed into the grid	Minimum value per year	Meter reading	kWh			-
					Total heat consumption	Maximum value per year	Calculation	kWh			Sum of all individual measurements, weather-adjusted
					a) Heating	Maximum value per year	Meter reading	kWh			(optional) per unit, weather-adjusted
					b) Domestic hot water	Maximum value per year	Meter reading	kWh			(optional) per unit
					c) Users and processes	Maximum value per year	Meter reading	kWh			(optional) per unit
					Total heat generation	Minimum value per year	Calculation	kWh			Sum of all individual measurements
					a) Generator 1	Minimum value per year	Meter reading	kWh			(optional) per unit
					b) Generator n	Minimum value per year	Meter reading	kWh			(optional) per unit

Figure 30
Monitoring parameters and information on corresponding measurement equipment for basic monitoring on building level (part 1/2)

Building (part 2/2)

EMon	AMon	GBMon	ERMon	LZMon	monitoring parameter	comparative value with planned target value	way of parameter recording	parameter unit	measurement equipment	installation information measurement equipment	annotation
					Cooling energy intake from the grid	Maximum value per year	Meter reading	kWh	temperature sensor + flow meter or thermal meter (for liquid heating system)	a. The temperature sensor should be mounted at the supply and return pipe work; b. The insulation shall be placed around the pipe both supply and return of the temperature sensor; c.The heat / cooling energy can also be measured by thermal meter directly, and the quantity of heat/cooling can be evaluated by the temperature difference and flow rate of supply and return water.	-
					Cooling energy input to the grid	Minimum value per year	Meter reading	kWh			-
					Total cooling energy consumption	Maximum value per year	Meter reading	kWh			(optional) per unit, weather-adjusted
					a) room cooling	Maximum value per year	Meter reading	kWh			(optional) per unit
					c) process cooling	Maximum value per year	Meter reading	kWh			(optional) per unit
					Total cold generation	Minimum value per year	Meter reading	kWh			Sum of all individual measurements
					a) Generator 1	Minimum value per year	Meter reading	kWh			(optional) per unit
					b) Generator n	Minimum value per year	Meter reading	kWh			(optional) per unit
					Total fuel consumption	Maximum value per year	Calculation	kWh			Sum of all individual measurements, weather-adjusted (the net and gross calorific values of fuels have to be declared for the calculation depending on system type)
					a) Gas	Maximum value per year	Meter reading	m³	gas meter	Be mounted in the pipe work	Weather-adjusted for heating purposes, independent measurements for separate Useres
					b) Heating oil	Maximum value per year	Meter reading	l	manual record		Weather-adjusted
					c) Wood / pellets	Maximum value per year	Meter reading	kg	manual record		Weather-adjusted
					d) Other	Maximum value per year	Meter reading	...			Weather-adjusted
					Drinking water intake from the grid	Maximum value per year	Meter reading	m³	water meter	Be mounted in the pipe work	-
					Total drinking water consumption	Maximum value per year	Meter reading	m³			Sum of all individual measurements

Figure 31
Monitoring parameters and information on corresponding measurement equipment for basic monitoring on building level (part 2/2)

Figure 32
Monitoring parameters and information on corresponding measurement equipment for indoor climate

EMon	AMon	GBMon	ERMon	LZMon	Indoor climate monitoring parameter	comparative value with planned target value	way of parameter recording	parameter unit	measurement equipment	installation information measurement equipment	annotation
					(Samples for at least 2 rooms, or for 10 % of rooms from existing 20 rooms)						
					Ambient temperature	-	Measurement	°C	temperature sensor	Be located in solar radiation shields which are ventilated to permit free passage of ambient air and to avoid effect of thermal source or sinks.	Possibly additional conversion for controls, e.g. as moving average
					Indoor air temperature	Dependent on concept: - min./max. values - permitted shortfall/ excess hours	Measurement	°C h/a	temperature sensor	Be mounted more than 40 cm away from wall an more than 50 cm away from ground.	Random mobile measurements, if no measuremnts available in building automation system
					Relative humidity	Dependent on concept: - min./max. values	Measurement	%	hygrometer	a. Be mounted at the height and location which are representative of the indoor condition b. To avoid the effect of dust pollution, etc.	(optional) Random mobile measurements, if no measuremnts available in building automation system
					CO_2-concentration	Maximum value	Measurement	ppm	capnometer	The wall-mounted sensor should be 0.3-1.8m above the ground.	(optional) Only for single room control and available recording via building automation system
					Presence in room	-	Measurement	0/1	-	-	(optional) Only for single room control and available recording via building automation system
					Window contact	-	Measurement	0/1	-	-	(optional) Only for single room control and available recording via building automation system
					Target room temperature - standard-guideline	-	Single room control data point	°C	temperature sensor	Be mounted more than 40 cm away from wall an more than 50 cm away from ground.	(optional) Only for single room control and available recording via building automation system
					Position of individual setpoint adjusters	-	Single room control data point	K	-	-	(optional) Only for single room control and available recording via building automation system

Heat and cold generators (part 1/2)

EMon	AMon	GBMon	ERMon	LZMon	monitoring parameter	comparative value with planned target value	way of parameter recording	parameter unit	measurement equipment	installation information measurement equipment	Gas condensing boiler	Heat pump (reversible)	Combined heat and power plant	district heating / cooling	direct electr. heating	Compression chiller	Absorption chiller	Recooling plant (cooling tower)	Solarthermal system	Geothermal system (geothermal	Photovoltaic system	annotation
											parameter X should be monitored for corresponding energy generator or energy generation system											
					Utilisation ratio / Performance factor / Coefficient of performance	Minimum value	Calculation	-	-	-	x	x	x (total, for electr. and thermal)	-	-	x	x	-	-	-	-	Evaluation as daily, monthly and anual values (Gas boiler: refering to the net or gross calorific values)
					Ambient temperature	-	Measurement	°C	temperature sensor	Be located in solar radiation shields which are ventilated to permit free passage of ambient air and to avoid effect of thermal source or sinks.	x	x	x	x	x	x	x	x	x	-	x	Possibly additional conversion for controls, e.g. as moving average
					Global radiation	Maximum value	Measurement	W/m²	pyronometer	a. Be installed such as to receive the same levels of direct, diffuse and reflected solar radiation as are received by the plane; b. Mounts on support structure or another structure that is aligned parallel to the plane, with a tolerance of <1° with the plane; c. To avoid shading impact from local surroundings, from sunrise to sunset; d. Do not cast a shadow onto the plane area at any time during the monitor period.	-	-	-	-	-	-	-	-	x	-	x	-
					Supply temperature - primary	Setpoint and tolerance	Measurement	°C	temperature sensor	a.The temperature sensor should be mounted at the supply and return pipe work; b.The insulation shall be placed around the pipe both supply and return of the temperature sensor.	-	x	-	x	-	x	x	-	x	x (ground side)	-	Setpoint possibly as characteristic curve with tolerance
					Return temperature - primary	Setpoint and tolerance	Measurement	°C			-	x	-	x	-	x	x	-	x	x (ground side)	-	
					Supply temperature - secondary	Setpoint and tolerance	Measurement	°C			x	x	x	x	x	x	x	x		x	-	
					Return temperature - secondary	Setpoint and tolerance	Measurement	°C			x	x	x	x	x	x	x	x		x	-	
					Average temperature after solar collector	Maximum value	Measurement	°C			-	-	-	-	-	-	-	-	x	-	-	-
					Supply temperature - desorber	Setpoint and tolerance	Measurement	°C	temperature sensor	Be mounted in the pipe work.	-	-	-	-	-	-	x	-	-	-	-	Setpoint possibly as characteristic curve with tolerance
					Return temperature - desorber	-	Measurement	°C			-	-	-	-	-	-	x	-	-	-	-	(optional)
					Exhaust temperature	Maximum value	Measurement	°C			x	-	-	-	-	-	-	-	-	-	-	(optional) Evaluation per day

Figure 33 Monitoring parameters and information on corresponding measurement equipment for heat and cold generators (part 1/2)

EMon	AMon	GBMon	ERMon	LZMon	Heat and cold generators (part 2/2) monitoring parameter	comparative value with planned target value	way of parameter recording	parameter unit	measurement equipment	installation information measurement equipment	Gas condensing boiler	Heat pump (reversible)	Combined heat and power plant	district heating / cooling	direct electr. heating	Compression chiller	Absorption chiller	Recooling plant (cooling tower)	Solarthermal system	Geothermal system (geothermal source)	Photovoltaic system	annotation
					Flow rate - primary	Setpoint and tolerance	Measurement	m³/h	flow meter	Be mounted in or on the pipe work.	-	x	-	-	-	x	x	-	-	x (ground side)	-	(optional)
					Flow rate - secondary	Setpoint and tolerance	Measurement	m³/h			-	x	-	-	-	x	x	x	-		-	(optional)
					Gas consumption	Maximum value	Meter reading	m³	gas meter	Be mounted in the pipe work.	x		x	-	-	-	-	-	-	-	-	Evaluation as monthly and annual values
					Electr. energy consumption (circulation pumps, …)	Maximum value per year	Meter reading	kWh	power meter	Be mounted in the circuit of system and each subsystem.	x	x	x	x	x	x	x	x	x	x	-	Evaluation as montly or annual values
					Electric fan power	Maximum value	Measurement	kW			-	-	-	-	-	-	-	x	-	-	-	-
					Generated electric power	Minimum value	Measurement	kW			-	-	x	-	-	-	-	-	-	-	x	-
					Generated electric energy	Minimum value Target value per year	Meter reading	kWh			-	-	x	-	-	-	-	-	-	-	x	-
					Generated heat/cold / transfered heat/cold quantity	Maximum value (CHP: targetvalue per year)	Meter reading	kWh	temperature sensor+flow meter or thermal meter(for liquid system) or orifice plate flowmeter/vortex street flowmeter(for air heating system)+air mass flowmeter	See Figure 2-2	x	x	x	x	x	x	x (to desorber and by evaporator)	x	x (from collector circuit to storage)	x	-	Evaluation as monthly and anual values
					Operation message (- circulation pump for Geothermal System	-	Measurement	0/1	-	-	x	x	x	-	-	x	x	x	x	x	-	(optional)
					Operating hours	Maximum value	Meter reading	h	-	-	x	x	x	-	-	x	x	-	-	-	-	(optional) Evaluation as montly and annual values
					Operating starts	Minimum value	Meter reading	number	-	-	x	-	x	-	-	x	x	-	-	-	-	(optional) Evaluation as daily, montly and annual values
					Operating mode (cooling, heating, …)				-	-	-	x	x	-	-	-	-	-	-	-	-	-
					Amount of condensation	Minimum value	Meter reading	l	-	-	x	-	-	-	-	-	-	-	-	-	-	(optional) Evaluation per day in l/kWh
					Operation hours per start	Minimum value	Calculation	-	-	-	x	-	x	-	-	-	-	-	-	-	-	(optional) Evaluation per week, month and year
					Full load hours - electrical	Maximum value	Calculation	h	-	-	-	-	x	-	-	-	-	-	-	-	-	(optional) Evaluation as montly or annual values
					Full load hours - thermal	Maximum value	Calculation	h	-	-	-	-	x	-	-	-	-	-	-	-	-	

Figure 34 Monitoring parameters and information on corresponding measurement equipment for heat and cold generators (part 2/2)

Consumer and stores

monitoring parameter	comparative value with planned target value	way of parameter recording	parameter unit	measurement equipment	installation information measurement equipment	parameter X should be monitored for corresponding consumer or store: Heating circuit	Cooling circuit	Thermal store	Elect. Store (battery)	annotation
Ambient temperature	-	Measurement	°C	temperature sensor	Be located in solar radiation shields which are ventilated to permit free passage of ambient air and to avoid effect of thermal source or sinks.	x	x	x	-	Possibly additional conversion for controls, e.g. as moving average
Supply temperature	Setpoint an tolerance	Measurement	°C		Be mounted in the pipe work.	x	x	-	-	Setpoint possibly as characteristic curve with tolerance
Return temperature	Setpoint an tolerance	Measurement	°C			x	x	-	-	
Upper storage temperature	Setpoint and tolerance	Measurement	°C	temperature sensor	Be mounted at the place which are representative to the condition.	-	-	x	-	
Lower storage temperature	Setpoint and tolerance	Measurement	°C			-	-	x	-	
Other storage temperature	Setpoint and tolerance	Measurement	°C			-	-	x	-	(optional) Setpoint possibly as characteristic curve with tolerance
Soil / gound water temperature	Min./Max. value	Measurement	°C			-	-	-	-	-
Flow rate	Setpoint and tolerance	Measurement	m³/h	flow meter	a. A bend in the pipe work, an orifice or a fluid-mixing device shall be placed upstream of the sensor. b. The installation distance of the flow sensor should be the straight pipe section with no valves, elbows and diameters, etc. within 10 times of the straight pipe diameter in the upstream and 5 times of the straight pipe diameter in the downstream. c. The flow sensor should be avoided at the highest points of piping system. d. The flow sensor probe shall point upstream and in a pipe where the flow is rising (to prevent air from being trapped near the sensor).	x	x	-	-	-
Transfered heat / cold quantity	Maximum value	Meter reading	kWh	power meter	Be mounted in the circuit	x	x	x (input and output)	x (electr. input and output)	(optional)
Electr. energy consumption circulation pump	Maximum value per year	Meter reading	kWh			(x)	(x)	-	-	Evaluation as montly or annual values
Operation message - circulation pump	-	Measurement	0/1	-	-	x	x	x	-	(optional) Audit of continous operation and/or missing heating threshold
Control signal (Three-way) control valve	-	Measurement	%	-	-	x	x	-	-	(optional) Actuator: weather sensitive valve openeing: adding return flow, manually or via

Figure 35
Monitoring parameters and information on corresponding measurement equipment for energy consumer and stores

Ventilation system (part 1/2)

monitoring parameter	comparative value with planned target value	way of parameter recording	parameter unit	measurement equipment	installation information measurement equipment	parameter X should be monitored for corresponding ventilation system: with **heat recovery** and air heater	**Partial air conditioning** system, heat recovery, air heater/ cooler and mixed air operation	**Full air conditioning** system, heat recovery with bypass, air heater/ cooler, humidifier, reheater	annonation
Specific fan performance supply/return air	Maximum value	Calculation	W/(m³ s)	-	-	x	x	x	Evaluation according to classifications DIN EN 16798-3
Degree of temperature change through heat recovery	Setpoint	Calculation	-	-	-	x	x	x	Calculation according to EN 308
Ambient temperature	-	Measurement	°C	temperature sensor	Be located in solar radiation shields which are ventilated to permit free passage of ambient air and to avoid effect of thermal source or sinks.	x	x	x	Weather station; possibly additional conversion for controls, e.g. as moving average
Supply/return duct pressure	Setpoint and tolerance	Measurement	Pa	air pressure gauge	Be mounted in the duct.	x	x	x	Setpoint possibly as characteristic curve with tolerance
Flow rate supply/return air	Setpoint and tolerance	Measurement	m³/h	orifice plate flow meter	Be mounted far away from air interference sources.	x	x	x	
Supply air temperature	-	Measurement	°C	temperature sensor	Be mounted in the duct.	x	x	x	
Supply air temperature after heat recovery	Min./max. value	Measurement	°C	temperature sensor	Be mounted in the duct.	x	x	x	
Return air temperature	Setpoint and tolerance	Measurement	°C			x	x	x	
Outdoor air temperature	-	Measurement	°C			x	x	x	-
Exhaust air temperature	Min./max. value	Measurement	°C			x	x	x	Setpoint possibly as characteristic curve for temperature difference
Outdoor temperature before heat recovery	-	Measurement	°C	temperature sensor	Be mounted in the duct.	x	-	-	(optional)
Return air temperature before heat recovery	-	Measurement	°C			-	x	x	(optional)
Supply temperature of air heater	Setpoint and tolerance	Measurement	°C	temperature sensor	Be mounted in the duct.	x	x	x	(optional) Setpoint possibly as characteristic curve with tolerance
Return temperature of air heater	Setpoint and tolerance	Measurement	°C			x	x	x	
Supply temperature of air cooler	Setpoint and tolerance	Measurement	°C	temperature sensor	Be mounted in the duct.	-	x	x	
Return temperature of air cooler	Setpoint and tolerance	Measurement	°C			-	x	x	
Supply temperature of reheater	Setpoint and tolerance	Measurement	°C	temperature sensor	Be mounted in the pipe work.	-	-	x	
Return temperature of reheater	Setpoint and tolerance	Measurement	°C			-	-	x	
Control signal supply/return air fan	Setpoint and tolerance	Measurement	%	-	-	x	x	x	
Control signal of mixed air damper	Setpoint and tolerance	Measurement	%	-	-	-	x	-	-

Figure 36 Monitoring parameters and information on corresponding measurement equipment for ventilation systems (part 1/2)

Ventilation system (part 2/2)

EMon	AMon	GBMon	ERMon	LZMon	monitoring parameter	comparative value with planned target value	way of parameter recording	parameter unit	measurement equipment	installation information measurement equipment	parameter X should be monitored for corresponding ventilation system: with **heat recovery** and air heater	**Partial air conditioning** system, heat recovery, air heater/ cooler and mixed air operation	**Full air conditioning** system, heat recovery with bypass, air heater/ cooler, humidifier, reheater	annonation
					Relative humidity of supply air	Dependent on concept: - min./max. values	Measurement	%			-	x	x	(optional) Setpoint possibly as characteristic curve with tolerance; for air cooler with dehumidification function
					Relative humidity of supply air after heat recovery	Min./max. value	Measurement	%	hygrometer	Be mounted in the duct.	-	x	x	(optional) For air cooler with dehumidification function; for humidity control
					Relative humidity of return air	Dependent on concept: - min./max. values	Measurement	%			-	x	x	(optional) Setpoint possibly as characteristic curve with tolerance; for air cooler with dehumidification function
					Relative humidity of outdoor air	-	Measurement	%	hygrometer	Be mounted at the height and location which are representative of the indoor condition and to avoid the effect of dust pollution, etc.	-	x	x	(optional) for heat recovery system with rotary heat exchanger
					Control signal air heater valve	-	Measurement	%	-	-	x	x	x	(optional)
					Control signal of bypass damper heat recovery	Setpoint and tolerance	Measurement	%	-	-	-	-	x	-
					Control signal air cooling valve	-	Measurement	%	-	-	-	x	x	(optional)
					Control signal - reheater	-	Measurement	%	-	-	-		x	(optional)
					CO_2-concentration of return air	Setpoint and tolerance	Measurement	ppm	capnometer	Be mounted in the duct.	x	x	x	(optional) Applikation when controled via CO_2 concentration
					Operation message/signal - heat recovery	-	Measurement	0/1	-	-	x	x	x	(optional)
					Operation message/signal - air heater pump	-	Measurement	0/1	-	-	x	x	x	(optional) Audit of continous operation
					Operation signal - exhaust damper	-	Measurement	0/1	-	-	x	x	x	(optional)
					Operation signal - air cooler (pump)	-	Measurement	0/1	-	-	-	x	x	(optional) Audit of continous operation
					Operation signal - reheater	-	Measurement	0/1	-	-	-	-	x	(optional) Audit of continous operation
					Operation signal humidifier	-	Measurement	0/1	-	-	-	-	x	(optional)
					Fan power supply/return air	Maximum value	Measurement	kW	power meter	Be mounted in the system.	x	x	x	-
					Electr. energy consumption fan of supply/return air	Maximum value	Meter reading	kWh	power meter	Be mounted in the circuit.	x	x	x	Evaluation as montly or annual values
					Thermal energy - air heater	Minimum value	Meter reading	kWh	power meter	Be mounted in the circuit of the system.	x	x	x	(optional)
					Thermal energy - air cooler	Maximum value	Meter reading	kWh	power meter	Be mounted in the circuit of the system.	-	x	x	(optional)
					Thermal energy - reheater	Maximum value	Meter reading	kWh	power meter	Be mounted in the circuit of the system.	-	-	x	(optional)

Figure 37 Monitoring parameters and information on corresponding measurement equipment for ventilation systems (part 2/2

Table 3-2: Measurement equipment and installation information for monitoring of a solar thermal system

	measurement equipment	installation information measurement equipment
SOLAR THERMAL SYSTEM	Temperature sensor and flow meter Or Thermal meter (for liquid system) or Orifice plate flowmeter/vortex street flowmeter (for air heating system) and air mass flowmeter	***For liquid heating system:*** 1. the temperature sensor should be mounted at no more than 200 mm from the collector inlet and outlet 2. the insulation should be placed around the pipe work both upstream and downstream of the sensor 3. a bend in the pipe work, an orifice or a fluid-mixing device shall be placed upstream of the sensor 4. the installation distance of the flow sensor should be the straight pipe section with no valves, elbows and diameters, etc. within 10 times of the straight pipe diameter in the upstream and 5 times of the straight pipe diameter in the downstream 5. the flow sensor should be avoided at the highest points of piping system 6. the flow sensor probe shall point upstream and in a pipe where the flow is rising (to prevent air from being trapped near the sensor) 7. the heat gain can also be measured by thermal meter directly ***For air heating system:*** 1. the temperature sensor should be mounted at no more than 200 mm from the collector inlet and outlet 2. the insulation shall be placed around the ducts both upstream and downstream of the sensor 3. the orifice plate flowmeter / vortex street flow meter should be mounted far away from air interference sources 4. the air mass flow meter should be kept away from interference sources which can cause mechanical vibration of pipes 5. the air mass flow meter should keep away from electromagnetic interference sources

3.4.3 Evaluation variables and analyses

In order to be able to carry out an evaluation of a building or an energy supply system, definitions of evaluation variables or so-called *key performance indicators*, as well as the associated target values, are required. In the following, some of these evaluation variables are listed as examples. It may be useful to define variable target values for different operating conditions, times of day or seasons. In addition, the target values should be presented as absolute as well as specific values in order to enable comparability with other buildings, among other things. Whereby for the specific values in particular the definition of the reference values must be specified. For example, for the area-specific heating demand of a building, the reference area, e.g. the heated floor space, must be defined.

Energy consumption (primary, final, useful)

- Energy production
- CO_2-emissions
- COP, performance factor
- Load cover factors
- Supply cover factors
- Solar fraction
- Share of renewable

A detailed definition and calculation of necessary key performance indicators (KPI) for solar energy buildings out of the in chapter 0 defined monitoring parameters can be find in the document “Task66-A_KPIs.pdf “.

Monitoring has the fundamental objective of comparing planning values (target values) with the consumption arising during operation (actual values) in order to find out whether a building and its systems are operated according to plan and whether the building complies with the efficiency standards. The evaluation of the measurement data must clarify the question of whether the target values of the planning are achieved or maintained in operation.

Energy consumption is influenced from year to year by different climatic and user-dependent conditions and therefore turns out to be higher or lower than assumed in the planning. In order to be able to compare the measured values and KPIs of the different years or different locations with the target values defined in the planning, the energy consumption must be weather-adjusted or usage-adjusted. A direct comparison can only be made if values are derived from the same basis (boundary conditions).

With regard to primary energies and CO_2 emissions, the country-specific/national factors should be applied. To ensure a comparison among countries, uniform values, such as an EU mix, would have to be used. Otherwise, comparability is not given here either, as the basis of the evaluation is not the same.

3.5 Monitoring report

Monitoring reports document the results of the application of the monitored parameters in comparison to the target values and operating data of the building and its energy supply systems (instantaneous values). The central statement of the reports must be whether the target values of the planning were achieved or met during operation.

The monitoring report is used for permanent monitoring in the form of a target-actual comparison. With selected and defined benchmarks (characteristic values, KPIs), a performance comparison and evaluation of buildings or energy supply systems can be made between recording intervals (test periods), other buildings or specific characteristic values from the literature.

Monitoring reports must contain at least the following information for the respective test period:

- Information on the scope of the monitoring (building, installations, balancing boundaries) and on the course of the monitoring (period, participants, additional work, special features ...)
- List of the monitoring parameters for the building and/or the energy supply system, including the target values submitted by the specialist planners and the actual values determined
- List of the systems and components (see balancing boundaries in chapter 3.4) with the monitoring parameters for system monitoring, including the target values handed over by the specialist planners and the corresponding actual values,
- Quantitative evaluation of the achievement or non-achievement of target values within the test period (e.g. "Target not achieved, as target value not met by 47 %", "Target achieved, as compliance at 87 % of the test points" for a target value > 80 %).
- A monitoring report must clearly and comprehensibly show the client whether a target value was achieved or not. In addition, a monitoring report should contain concrete information on how to eliminate quality deficits and gaps. The final report should contain recommendations for the further continuation of monitoring in an adapted scope.

The operating data are analyzed to identify optimization potential and to analyze deviations between target and actual values. For this operational analysis, operating states, energy flows in the building and building automation data (system temperatures, operating states, valve positions, etc.) are recorded. The data is evaluated, compared with the planning targets and analyzed with regard to further operational optimization.

Example monitoring report

As already mentioned in the focus of the guideline for a high application reference, in Annex 0.1, an example monitoring report is given. Monitoring reports are in general prepared within a specified time interval. The content of the reports is the knowledge gained from the monitoring of the system and comfort status as well as the optimization measures concluded for the system technology. Furthermore, the energy balances are presented in the reports and a cross comparison is made with the planning specifications.

The optimization measures implemented in each case are documented and evaluated in terms of the energy saving potentials achieved. Recommendations for further possible measures are made in the reports.

Within the framework of quality control, any deficiencies detected by the monitoring process are documented by the control technology implemented. The client is thereby supported in the elimination of deficiencies towards the executing trades.

The basis of the monitoring is the recording of the total consumption of electricity, heating and cooling. The specific indicators resulting from these consumption data enable an evaluation of the energy standard and a comparison with other buildings and/or energy supply systems. Besides the total consumption, consumer groups and representative individual consumers are analyzed separately.

The structure and contents of a monitoring report are shown in Annex 0.1. Whereby, the report can be divided into the following chapters:

1. SUMMARY

1.1 FINAL AND USEFUL ENERGY

1.1.1 ELECTRICITY

1.1.2 HEAT

1.1.3 COOLING

1.2 PRIMARY ENERGY AND CO2 REDUCTION

1.3 HEAT PUMP OPERATION (OTHER GENERATORS AND CO.)

1.4 ROOM COMFORT

1.5 OUTLOOK

2. INTRODUCTION

1.6 TASK

1.7 BRIEF DESCRIPTION OF THE BUILDING AND THE ENERGY CONTROL CONCEPT

3. AIMS AND METHODOLOGY OF MONITORING

4. DATA CHECK

5. TO-DO CHECKLISTE

6. BUILDING LEVEL

1.1 ELECTRICITY CONSUMPTION

1.1.4 PHOTOVOLTAIC ENERGY YIELD

1.2 HEATING CONSUMPTION

1.3 COOLING CONSUMPTION

7. PRIMARY ENERGY AND CO2 EMISSIONS

8. SYSTEM LEVEL

1.4 HEAT PUMP

1.5 ADDITIONAL COMPONENTS

9. ROOM LEVEL - COMFORT

1.6 INDOOR AIR QUALITY - ROOM TEMPERATURE / HUMIDITY / CO_2-CONCENTRATION

1.7 OVERHEATING AND UNDERCOOLING

In the process, information is given on the corresponding points of descriptions and analysis (italic text sections). In addition, text templates as well as figure variants for the results are presented. The example figures can be used for all consumption, temperature or operational analyses. The presentation of the results should always be in the form of an illustration and a table for understanding the values.

3.6 Nomenclature

ABBREVIATION	NOTATION
AMon	system monitoring
AMEV	research group for mechanical and electrical technology, national and communal administration
BACnet	building automation and control network
BACS	building automation and control system
BEG	federal subsidies for efficient buildings
BMS	building management system
Cat.	category
CHP	combined heat and power generation
CO_2	carbon dioxide
COP	coefficient of performance
DNGB	German sustainable building council
EMon	energy monitoring
EPBD	energy performance of buildings directive
ERMon	adjustment monitoring
EU	European union
GBMon	building/comfort monitoring
GEG	German building energy act
HOAI	official German scale of fees for services by architects and engineers
HVAC	heating, ventilation and air conditioning
IEA SHC	international energy agency, solar heating and cooling program
KPI	key performance indicators
LEED	leadership in energy and environmental design
LZMon	long-term monitoring
PV	photovoltaic
TMon	technical monitoring
Var.	variant
VDI	association of German engineers
VOB	German construction contract procedures

3.7 References

AMEV (2017): Technical Monitoring 2017 - Technical Monitoring as an Instrument for Quality Assurance; Research Group for Mechanical and Electrical Technology, National and Communal Administration (AMEV); Berlin

VDI (2017): VDI 6041 - Facility-Management - Technical monitoring of buildings and building services; Association of German Engineers (VDI); Berlin

Plesser, S. et al. (2019): REVHA Guidebook NO. 29 - Quality Management for Buildings - Improving Building Performance through Technical Monitoring and Commissioning; Federation of European Heating, Ventilation and Air Conditioning Associations (REHVA); ISBN 978-2-930521-24-4; Brussels

Noris, F. et al. (2013): Measurement and Verification protocol for Net Zero Energy Buildings - A report of Subtask A - IEA Task 40/Annex 52 Towards Net Zero Energy Solar Buildings; Eurac research; Bolzano

Drück, H. (2020): Task 66 Solar Energy Buildings - Integrated solar energy supply concepts for climate-neutral buildings and communities for the "City of the Future" - Annex Plan; University of Stuttgart, Institute for Building Energetics, Thermotechnology and Energy Storage (IGTE); Stuttgart

AMEV (2020): Technisches Monitoring 2020 - Technisches Monitoring als Instrument zur Qualitätssicherung -Empfehlung Nr. 158; Research Group for Mechanical and Electrical Technology, National and Communal Administration (AMEV); Berlin

Erhorn-Kluttig, H. et al. (2017): Messleitfaden EnOB / EnEff:Stadt - Neuer gemeinsamer Messleitfaden für Demonstrationsvorhaben im Bereich „Energie in Gebäuden und Quartieren“; EnergieWendeBauen, Fraunhofer Institute for Building Physics (IBP); Stuttgart

VDI (2011): VDI 6039 - Facility-Management - Managing of building commissioning – Methods and procedures for building-services installations; Association of German Engineers (VDI); Berlin

Annex 0.1 – Example monitoring report

Monitoring report

[Project, location]

1. Monitoring-report

Monitoring period: [xx.xx.2022 – yy.yy.2022]

Client	[Name] [Address]
Contract	12345
Editor	[Name] [Address]
Status	[Date]

1. SUMMARY

The most important points from the energy monitoring are listed in this report; more detailed descriptions can be found in the respective chapters.

In the following report, the energy quantities, outputs, flow and return temperatures, as well as operating states of the generators and the heating and cooling transfer systems recorded via the building management system [adjust for data acquisition] are graphically prepared and analyzed.

This report documents and comments on the building operation regarding selected technical equipment and rooms for the year [specify year] / for the reporting period [specify reporting period].

The operating data are analyzed to identify optimization potential and to detect deviations between target and actual values. For this operational analysis, operating states, energy flows in the building and building automation data (system temperatures, operating states, valve positions, etc.) are recorded with a time sequence of 15 minutes [adjust recording interval]. The data is evaluated, compared with the planning targets and analyzed regarding further operational optimizations.

In the corresponding chapters, the analyses and advices are listed in detail and the optimization potentials as well as recommendations for action with regard to the operation are compiled.

1.1 Final and useful energy

1.1.1 Electricity

- *Total electricity consumption in the monitoring period (absolute and specific value)*
- *Distribution among individual consumers (percentage, absolute, specific values)*
- *Comparison to target values and other monitoring periods, e.g. previous year*
- *Analysis result - optimization results*

1.1.2 Heat

- *Total heat supply in the monitoring period (absolute and specific value) as well as distribution to the individual generators (percentage, absolute, specific values)*
- *Distribution to individual consumers (percentage, absolute, specific values)*
- *Comparison to target values and other monitoring periods, e.g. previous year*
- *Analysis result - optimization results*

1.1.3 Cooling

- *Total cooling supply in the monitoring period (absolute and specific value) as well as distribution to the individual generators (percentage, absolute, specific values)*
- *Distribution to individual consumers (percentage, absolute, specific values)*
- *Comparison to target values and other monitoring periods, e.g. previous year*
- *Analysis result - optimization results*

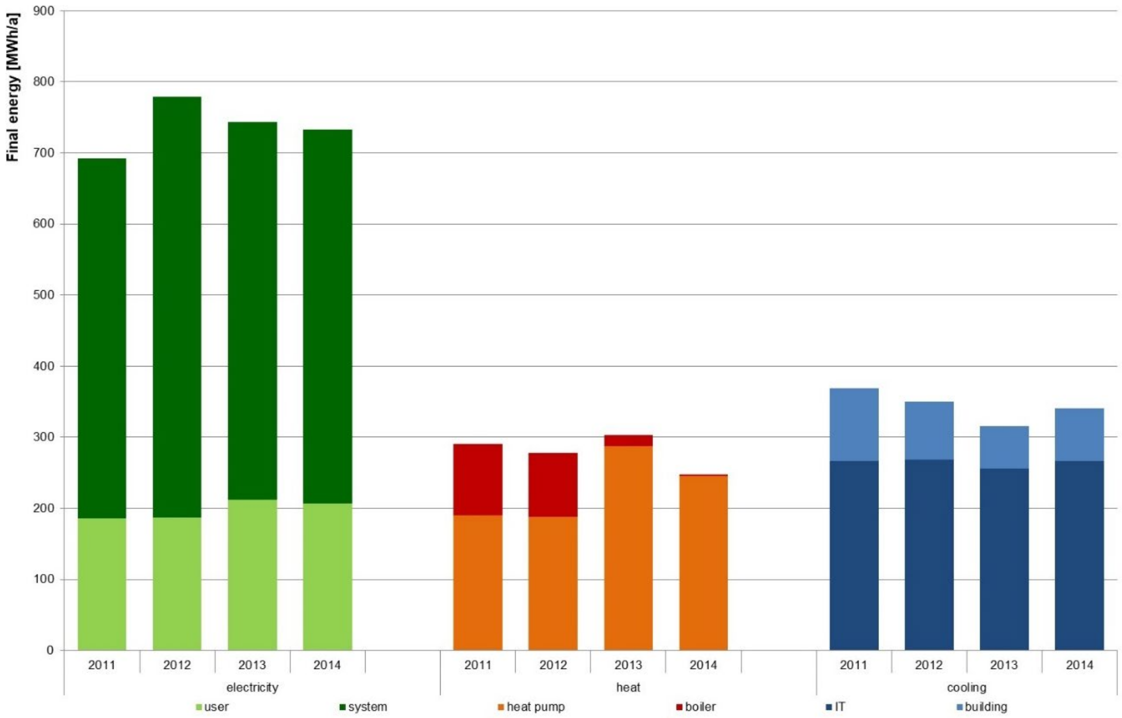

Figure 1: Example of a summary of final energy consumption as an overview

1.2 Primary energy and CO_2 reduction

- *Primary energy consumption in the monitoring period (absolute and specific values)*
- *Reduction in CO_2 emissions due to optimizations / CO_2 increase*
- *Comparison with target values and other monitoring periods, e.g. previous year*

1.3 Heat pump operation (other generators and co.)

- *Annual COP or efficiency*
- *Comparison to target values and other monitoring periods, e.g. previous year*

1.4 Room Comfort

- *Room temperatures, humidity, CO_2 concentration*
- *Overheating hours*
- *Comparison to target values and other monitoring periods (e.g. previous year), as well as deviations*
- *Air velocity flow (in GBMon – short-term – mobile sensors)*

1.5 Outlook

- *What is the result of the monitoring so far? Description of what can / should be changed or optimized.*

2. INTRODUCTION

2.1 Task

Within the framework of monitoring over a period of [years, month, …], an evaluation of the energy efficiency as well as the functionality of the energy and comfort concept is to be carried out by checking individual measuring technique and control technology parameters of the building control system as well as the user comfort. Based on the measurement data provided and on-site visits, recommendations for optimizing the building operation in terms of energy efficiency and user comfort are to be presented, as well as verifying the planning target of a primary energy requirement of [value] kWh/(m²*a).

2.2 Brief description of the building and the energy control concept

- *Representation and description of the building*
- *Description of the energy concept/energy supply on building and room level*
- *Description of the control concept and design data*

Figure 2: Site map of the building / Map of the location with the building marked

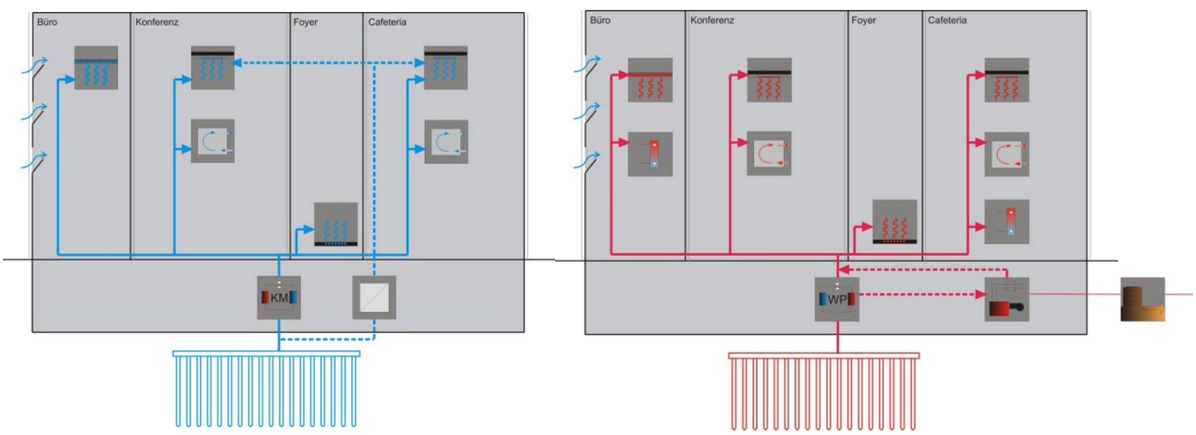

Figure 3: Example for the illustration / visualization of the heating and cooling concept (heating mode on the right and cooling mode on the left)

The most important parameters of the plant system are listed below:

Building:
- Gross floor area (GFA): m²
- Net floor area (NFA): m²
- Total heating capacity: kW
- Heating capacity [single units]: kW
- Heating demand building: MWh/a
- Cooling capacity building: kW
- Cooling capacity [single units]: kW
- Cooling demand building MWh/a

Design temperatures heat generation and distribution:

- Heat pump: °C
- Gas boiler: °C
- Radiator: °C
- Floor heating: °C
- Concrete core activation: °C
- Heating ceiling: °C
- Ventilation heating coil: °C

Design temperatures cooling generation and distribution:

- Reversible heat pump: °C
- Chiller °C
- Floor cooling: °C
- Concrete core activation: °C
- Cooling ceiling: °C
- Ventilation cooling coil: °C

Regulation static / dynamic heating

- xx

Regulation cooling

- xx

3. AIMS AND METHODOLOGY OF MONITORING

3.1 Energetic optimization of the building operation

It aims to analyze the operating characteristics and record the relevant consumption values by monitoring the energy consumption. Possible optimization potentials will be uncovered and implemented during operation. The following procedure should be used:

- Consumption data of the building are determined separately for cooling, heat and electricity. The resulting performance data will be used to monitor the success of the project in relation its targets and will also form the basis for identifying potential energy savings in the operation of the building. In this context, the planned control technology is evaluated and possible execution or design errors are detected. An energetic comparison with other innovative buildings can thus be realized.
- Attention should also be paid to the monitoring of consumption values as well as operating states. Through the monitoring, system-specific efficiency parameters are to be developed and an optimization of the overall system in operation is to be created.
- From the beginning of the measurement campaign, measurement accompaniment is provided during the start-up of the system. In this way, the integral interaction of all participants is intended to achieve rapid implementation of the projected energy concept by adapting the building's control and regulation technology. With the aim of maintaining the achieved standard in the long term, a recommendation for action for the further operation of the building will be given in the final report at the end of the project. The building manager should be kept up to date with the measurement and test results.

3.2 User comfort

The comfort of the users is a decisive criterion for the perception of the quality of the building. Experience has shown that even modern buildings are problematic in terms of user comfort, especially during the adjustment phase. Comfort monitoring in reference rooms is intended to identify problems and their causes at an early stage so as to considerably shorten the adjustment phase. In addition, the comfort conditions will be permanently monitored and suggestions for improvement will be developed for the areas investigated.

3.3 Monitoring of control technology

Faulty operation or incorrect control of the system can result in additional energy consumption and thus the planned consumption parameters cannot be achieved. For this reason, during the monitoring phase, temperatures of the air and water, as well as control states of valves and pumps are registered.

The results of the monitoring will then be incorporated into possible optimization strategies for an improved control of the plants in the future.

3.4 Monitoring aims

The monitoring basically pursues the following purposes:

1. Comparison of the planning targets in operation
2. Collection and presentation of energy consumptions
3. Collection and presentation of functional sequences of the energetically relevant energy consumers and generators of the technical supply system
4. If necessary, hints for operation optimization (detailed coordination necessary before)

The energy target values are mainly:

- Cooling demand$_{FE}$ xx kWh/a
- Heating demand$_{FE}$ xx kWh/a
- Domestic hot water demand$_{FE}$ xx kWh/a
- Electricity demand xx kWh/a
- Heating load xx W/m²·a
- Cooling load xx W/m² a
- Primary energy xx kWh/m²·a
- CO_2 emissions xx kg/m²·a

With index FE as final energy

4. DATA CHECK

In order to obtain a better overview of the anomalies and changes in the data recording and operation of the systems, the points are collected and listed in the following table.

MONITORING PERIOD	DATA POINT	CONSPICUOUSNESS / NOTE
01.01.2022 – 15.01.2022	WMZ2 heat pump	No data available
…	…	…

The table should list if e.g.

- *No current or valid data have been transmitted from installations to be inspected.*
- *No or incomplete data are transmitted - measurement data failures*
- *Irregularities in data recording, e.g. too high temperatures.*

In addition, information should be provided on how to determine the missing data, e.g.

"Due to a defective heat meter, the energy quantities consumed can only be recorded since August 2011. From October 2010 to August 2011, the share of heat energy is therefore calculated from the difference between the other heat meters."

5. TO-DO CHECKLIST

In order to obtain a better overview of the individual open points or conspicuities as well as optimizations, the points are collected and listed in the following "To-Do Checklist". All measures, changes and settings can be documented and listed here.

NO.	WHAT	WHO	UNTIL	COMMENTS
1	Increasing the heating curve	HVAC installer	…	…
2	Control of flow rate floor heating	…	…	…
…	…	…	…	…

6. BUILDING LEVEL

In this chapter, the total building balances for electricity, heating and cooling are shown and evaluated.

6.1 Electricity consumption

The total energy consumption of the building is made up of the electricity consumption of [include all consumer]. Within the scope of the commissioned monitoring, only [list of consumers covered] is recorded in detail and balanced according to Figure 4. All other electricity consumption is not separately recorded and cannot / will not be included in the monitoring.

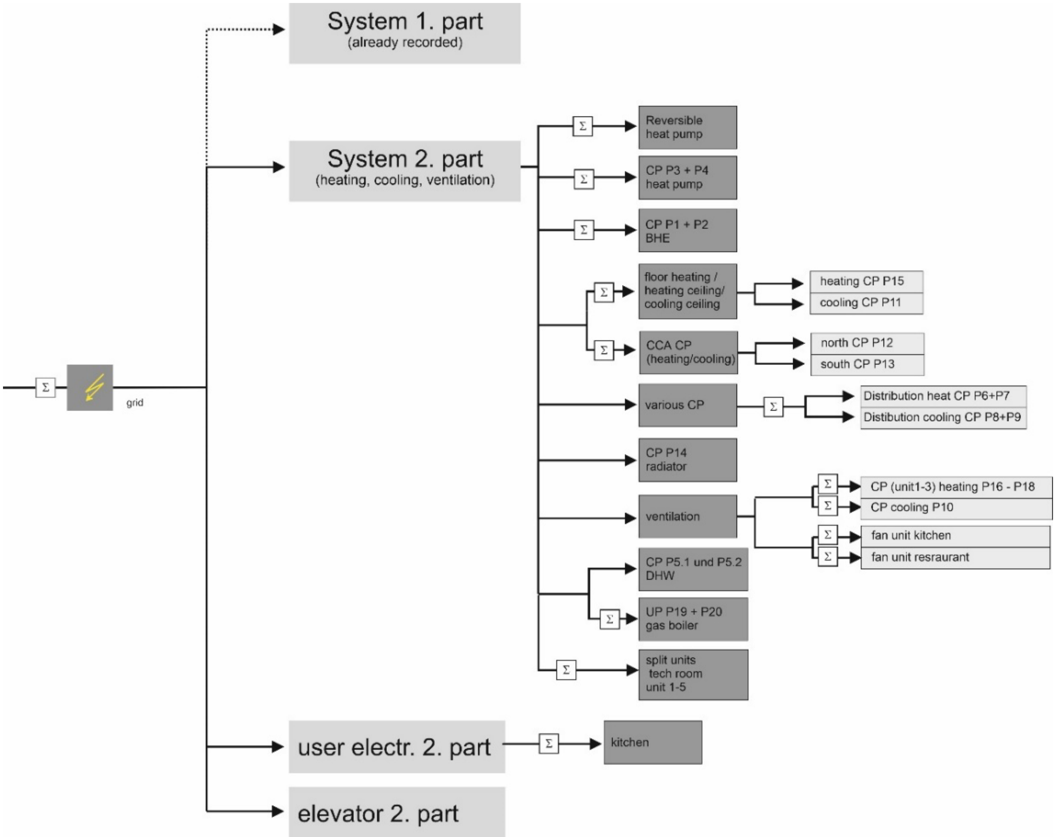

Figure 4: Example of a scheme of the meter structure for electricity (simplified)

Evaluation and analysis of

- *Total electricity consumption in the monitoring period (absolute and specific values) as well as distribution*
- *Distribution to individual consumers (percentage, absolute, specific data)*
- *Comparison to target values and other monitoring periods, e.g. previous year*
- *Analysis results - Optimization results*

The results and optimization measures are to be listed in a summary table.

TARGET VALUE	COMMENT/ RATING	RECOMMENDATIONS FOR ACTION AND IMPACT
XXX	*xx*	*xx*

Presentation options:

- *Annual and monthly balance sheets*
- *Bar charts, pie charts*
- *Carpetplots/Heatmaps: the date is plotted on the x-axis and the time is plotted on the y-axis. In this diagram, operating times and outliers or deviating time programs can be recognized during operation.*
- *Line graphs show the electricity load as daily minimum, average and maximum. It is possible to read out the base load (usually at night) and the daily peaks.*

The meter totals for electricity consumption are made up of the actual meter groups and the virtual remainder. They are presented as piled up monthly bars for a period of one year each.

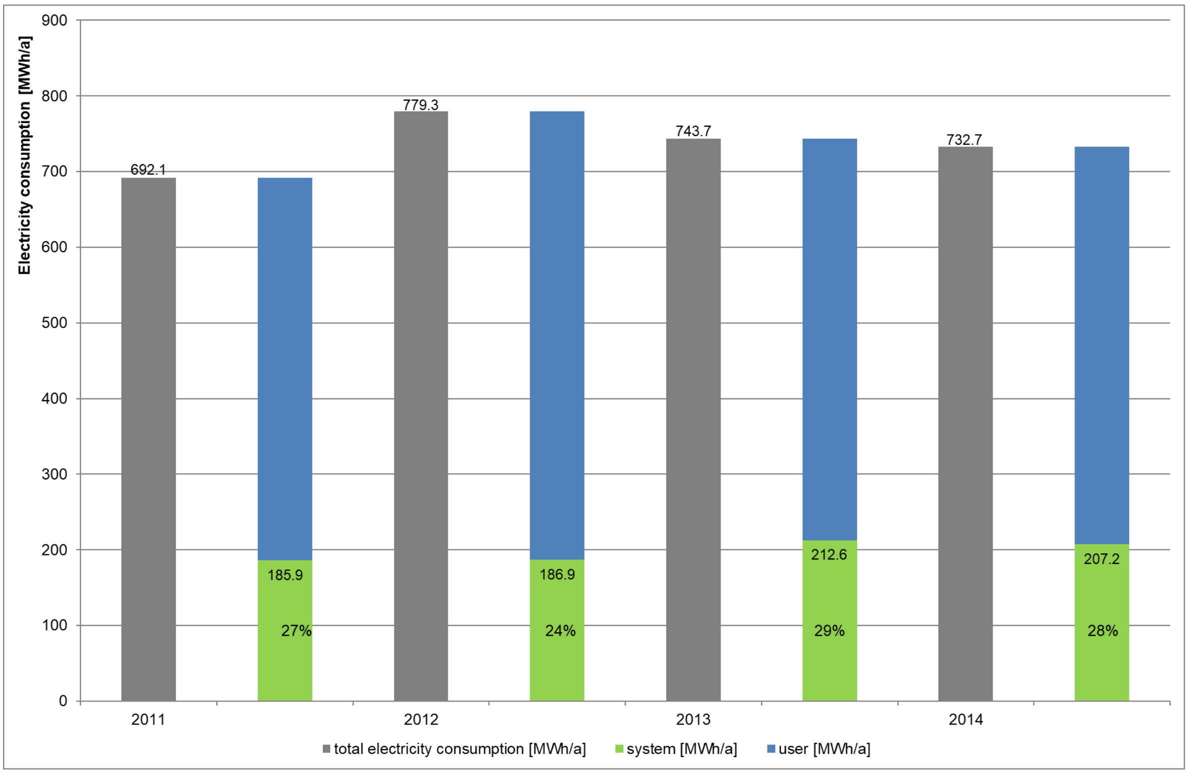

Figure 5: Example: Total electricity consumption of building and system share

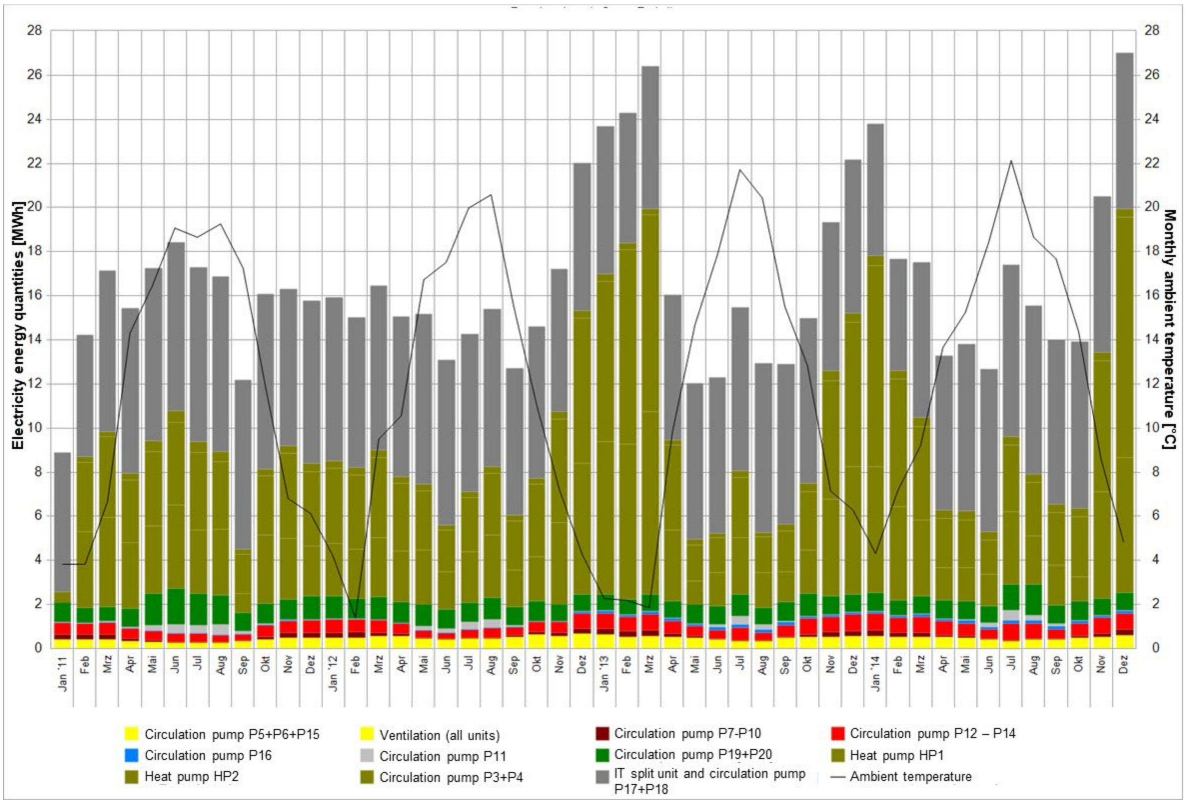

Figure 6: Example: Monthly energy consumption electricity systems (electricity consumption groups) (piled up)

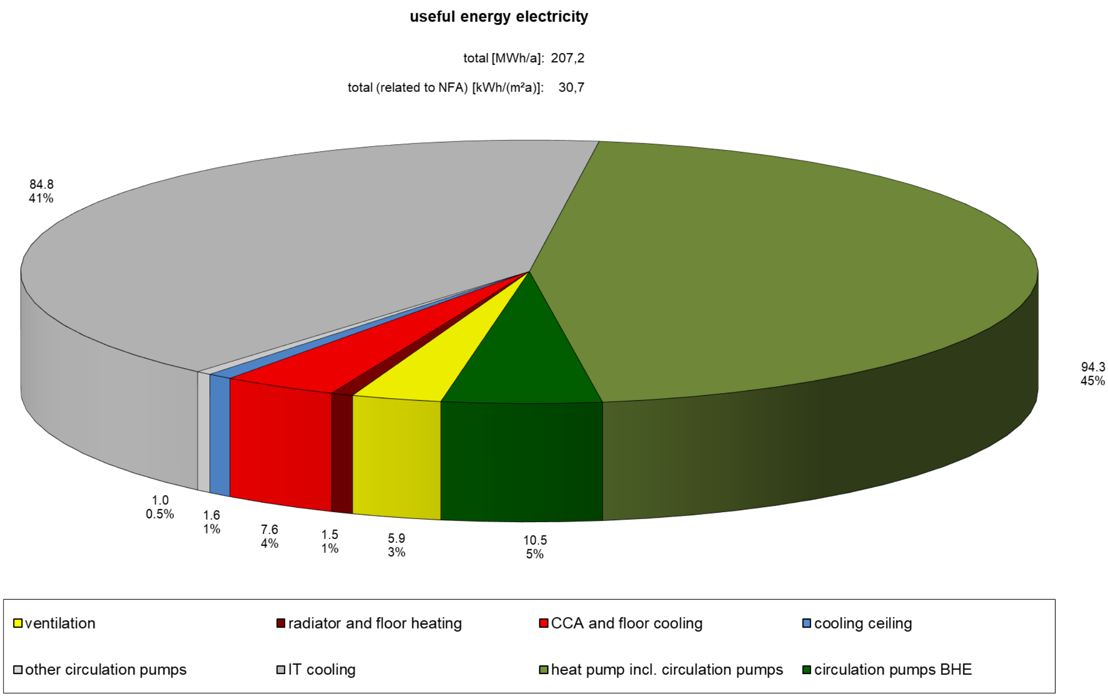

Figure 7: Example: Annual consumption of electricity for systems (electricity consumption groups)

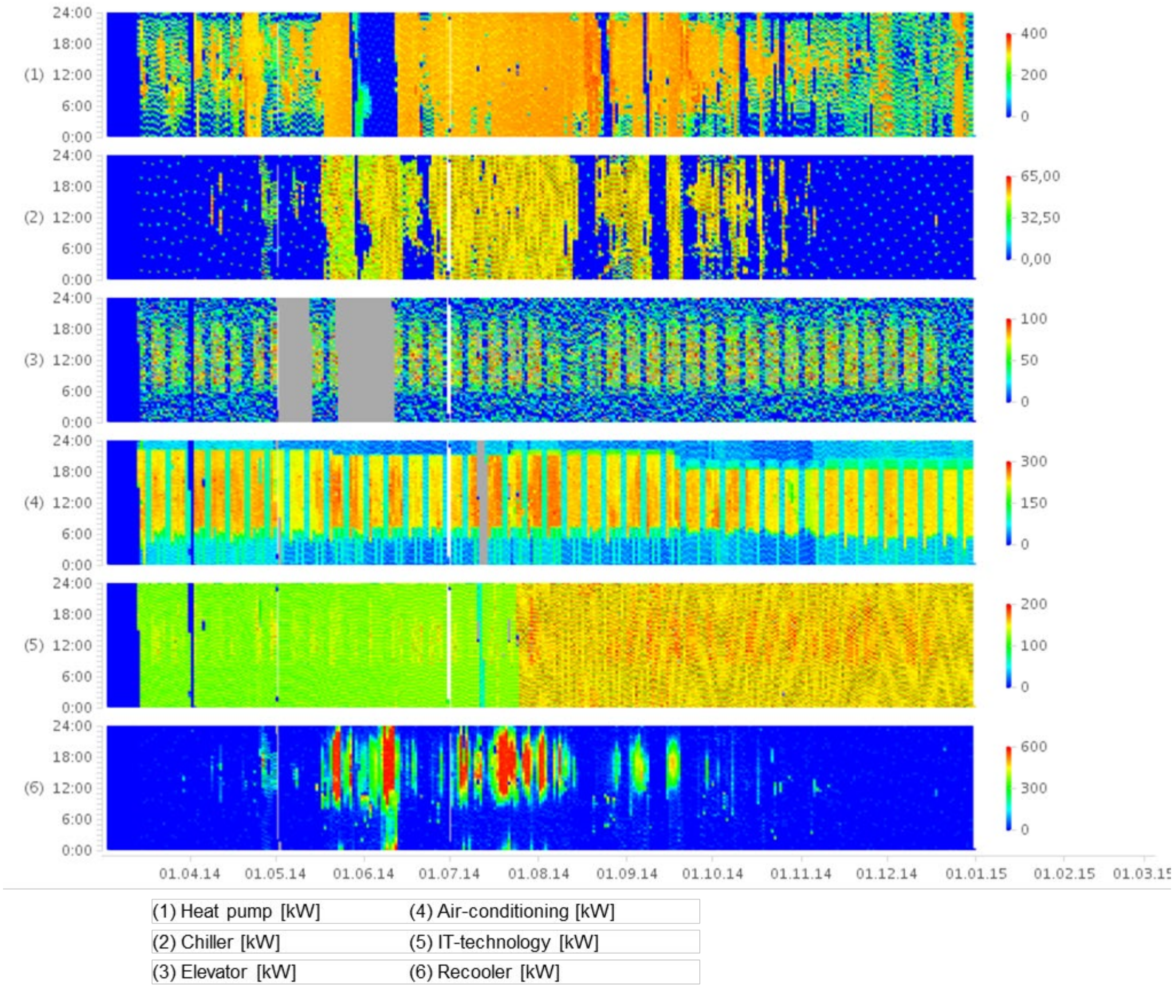

Figure 8: Example: load profile building power groups

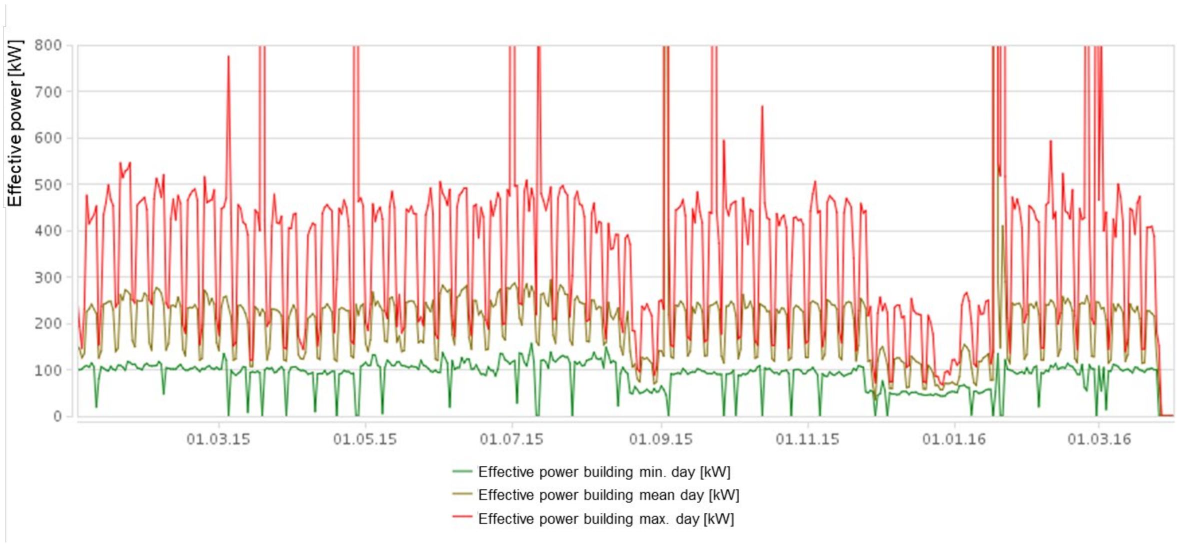

Figure 9: Base, mean and peak load building efficiency

6.1.1 Photovoltaic energy yield

Figure 10 shows the monthly as well as the annual energy yield of the photovoltaic system. The total yield in [year] is [value] MWh/a ([value] kWh/(m²PVa)), which is about [value]% below the planning value of [value] MWh/a.

The reduction to [year] can be seen due to the climatic irradiation. The PV system had not shown any failures or repairs.

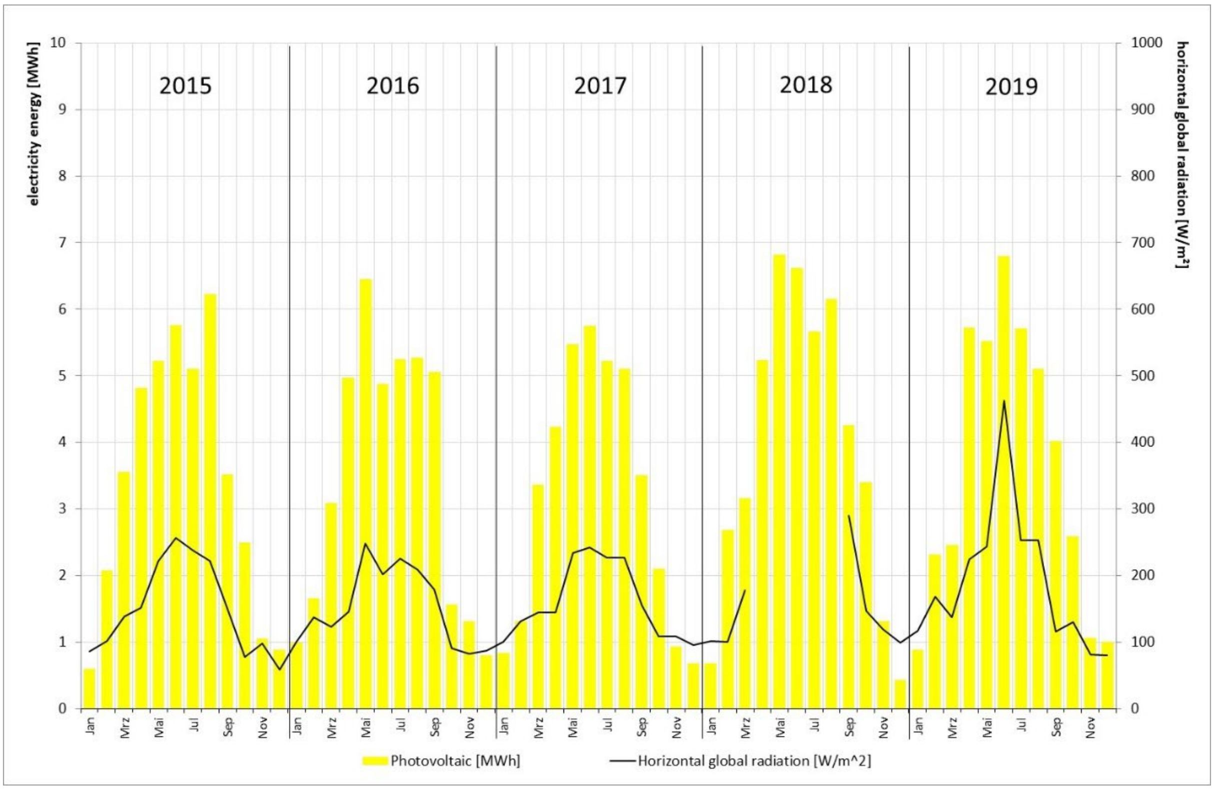

Figure 10: Example: Monthly energy yield and average global radiation of the photovoltaic system

6.2 Heating consumption

To record the heat and cooling consumption, a distinction must be made between winter and summer operation. Figure 11 shows the structure of the building's heating and cooling supply as well as the installation locations of the heat and cooling energy meters. Both the heat quantities of the energy supply systems and the heat and cooling consumption are recorded. Using the heat and cooling energy meters, closed heat and cooling balances of the building or individual system parts can be generated.

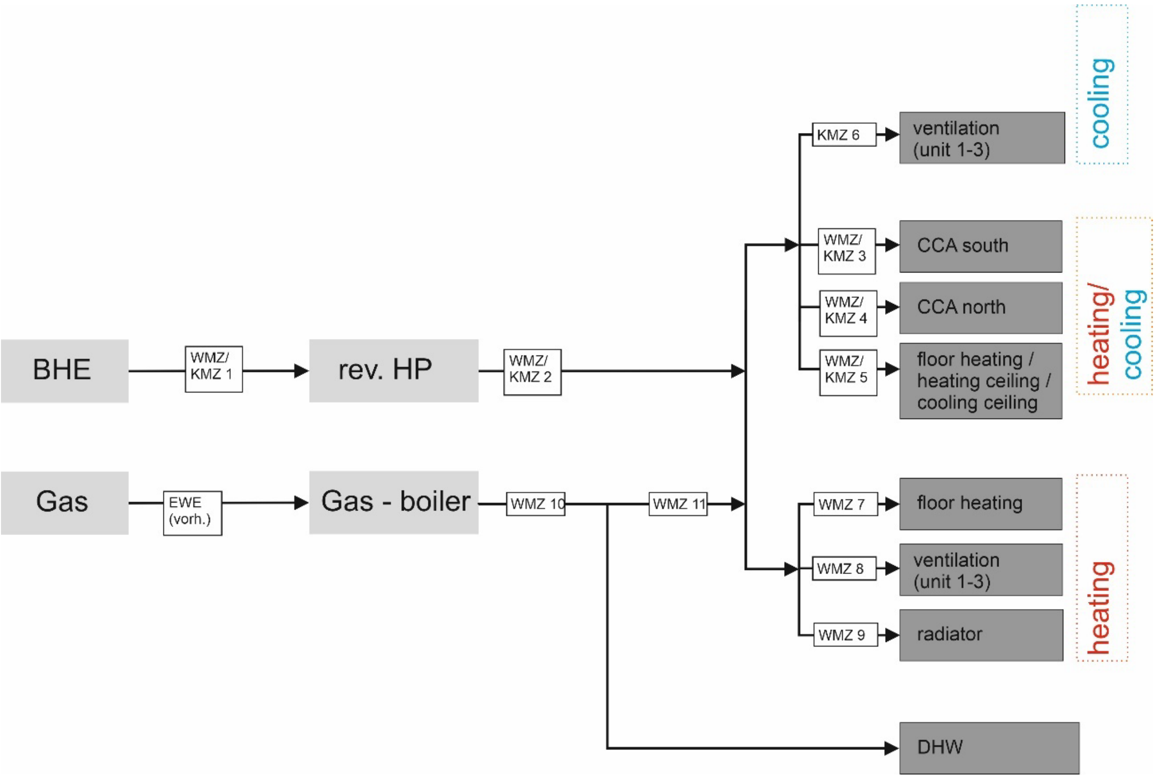

Figure 11: Example: Scheme of the meter structure for heat and cold energy

Evaluation and analysis of

- *Total heat supply in the monitoring period (absolute and specific values) (if necessary also weather-adjusted) as well as distribution to the individual generators (percentage, absolute, specific values)*
- *Distribution to individual consumers (percentage, absolute, specific values)*
- *Comparison to target values and other monitoring periods, e.g. previous year*
- *Analysis result - Optimization results; explanation of differences, etc.*

Presentation options (see chapter 6.1 for the possible figures):

- *Annual and monthly balance sheets*
- *Bar charts, pie charts*
- *Carpetplots/Heatmaps: the date is plotted on the x-axis and the time is plotted on the y-axis. In this diagram, operating times and outliers or deviating time programs can be recognized during operation.*
- *Line graphs show the electricity load as daily minimum, average and maximum. It is possible to read out the base load (usually at night) and the daily peaks.*

The meter totals for heat consumption are made up of the actual meter groups and the virtual remainder and are shown as picked up monthly bars for a period of one year. In addition, the average daily outdoor temperature is plotted as a black line to show any correlations with the weather.

The weather-adjusted heat supply is based on the factor of the ratio of degree-day number of the considered year of [location] (by zip code [no]) related to the long-term average of degree-day number of [reference location] ([no] Kd, as of [year]). The weather-adjusted heat supply amounts to between [value] and [value] MWh (~[value] kWh/m²a) in recent years.

The results and optimization measures are to be listed in a summary table.

TARGET VALUE	COMMENT/ RATING	RECOMMENDATIONS FOR ACTION AND IMPACT
XXX	*xx*	*xx*

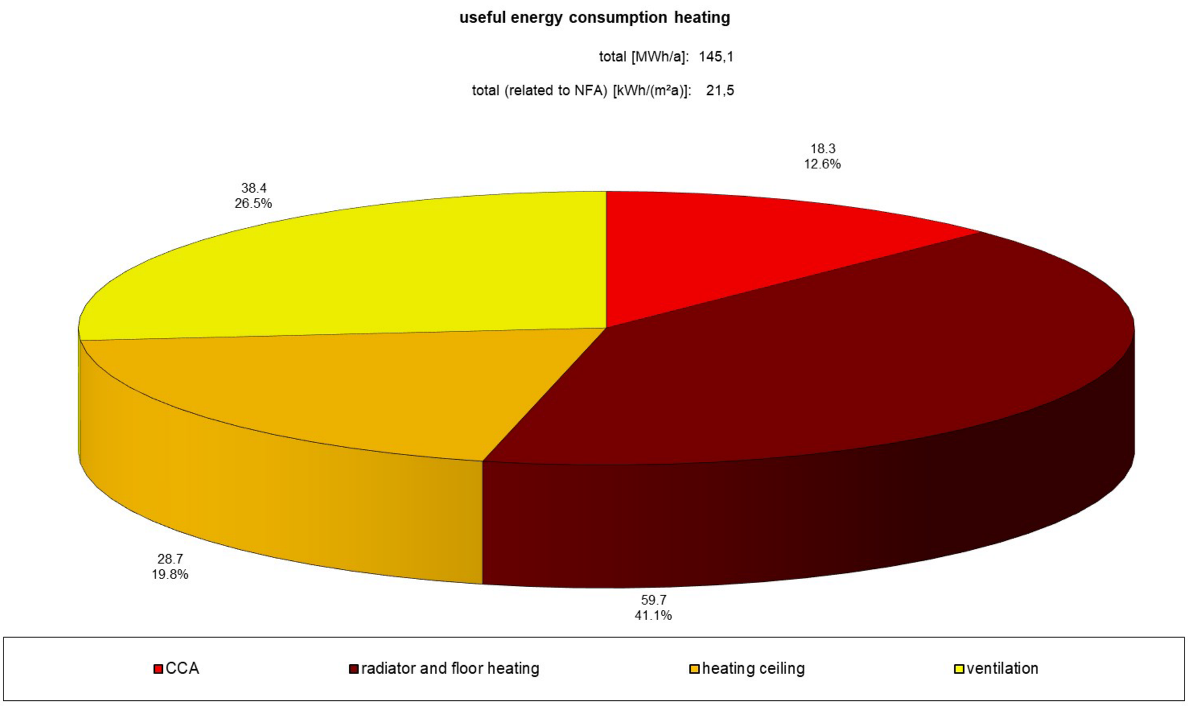

Figure 12: Example: Useful energy consumption heating

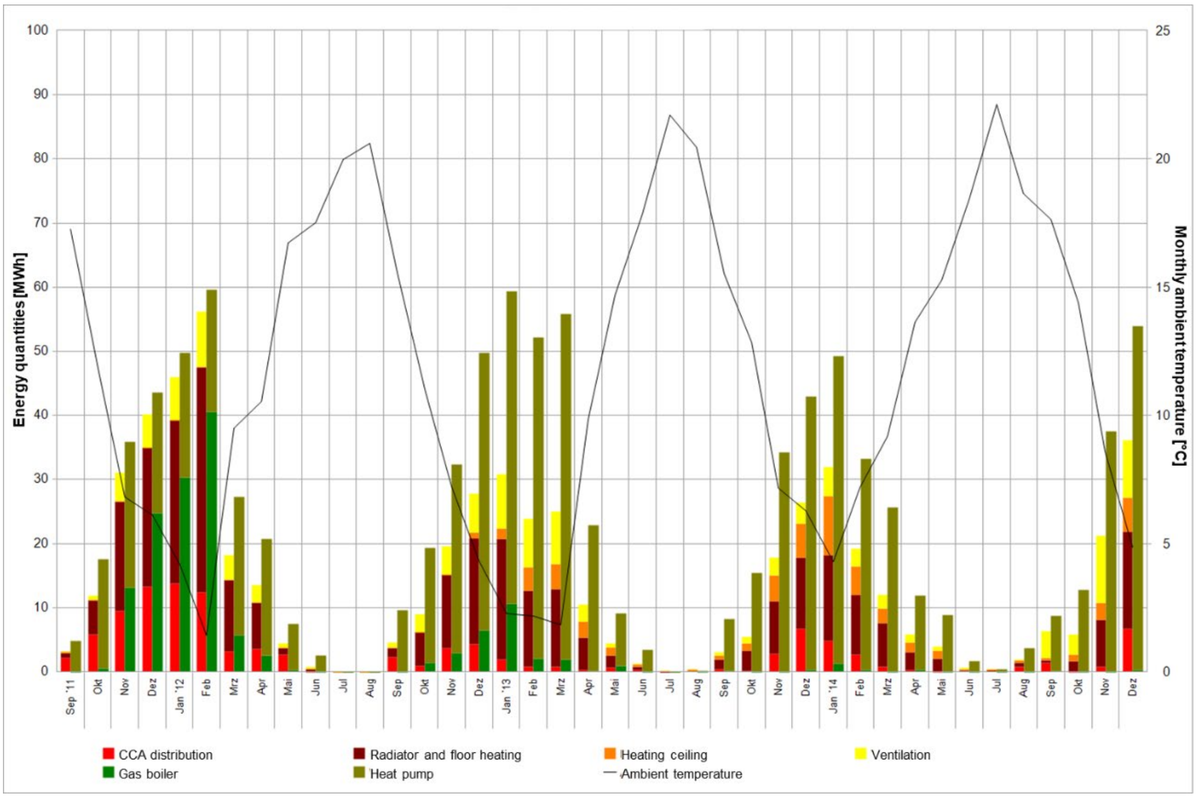

Figure 13: Example illustration: Monthly energy quantities of heat consumers and heat supply (stacked)

6.3 Cooling consumption

The cooling supply as well as the cooling consumption of the building will be recorded according to figure 11.

Evaluation and analysis of

- *Total cooling supply in the monitoring period (absolute and specific values) (if necessary, also weather-adjusted) as well as distribution to the individual generators (percentage, absolute, specific values)*
- *Distribution to individual consumers (percentage, absolute, specific values)*
- *Comparison to target values and other monitoring periods, e.g. previous year*
- *Analysis result - Optimization results; explanation of differences, etc.*

Presentation options (see chapter 6.1 and chapter 6.1.1 for the possible figures):

- *Annual and monthly balance sheets*
- *Bar charts, pie charts*
- *Carpetplots/Heatmaps: the date is plotted on the x-axis and the time is plotted on the y-axis. In this diagram, operating times and outliers or deviating time programs can be recognized during operation.*
- *Line graphs show the electricity load as daily minimum, average and maximum. It is possible to read out the base load (usually at night) and the daily peaks.*

Meter totals for cooling consumption are composed of actual meter groups and the virtual remainder and are presented as stacked monthly bars for a one-year period.

The results and optimization measures are to be listed in a summary table.

TARGET VALUE	COMMENT/ RATING	RECOMMENDATIONS FOR ACTION AND IMPACT
XXX	*xx*	*xx*

7. PRIMARY ENERGY AND CO_2 EMISSIONS

- *Explanation of what is included in primary energy consumption*
- *e.g. "A target value for primary energy consumption of < 100 kWh/(m²a) for heating, cooling and ventilation as well as lighting was defined in the planning."*
- *Specification of primary energy (PE) factors*
- *Comparison of target value with measured value and e.g. to previous year*

TARGET VALUE	COMMENT/ RATING	RECOMMENDATIONS FOR ACTION AND IMPACT
XXX	*xx*	*xx*

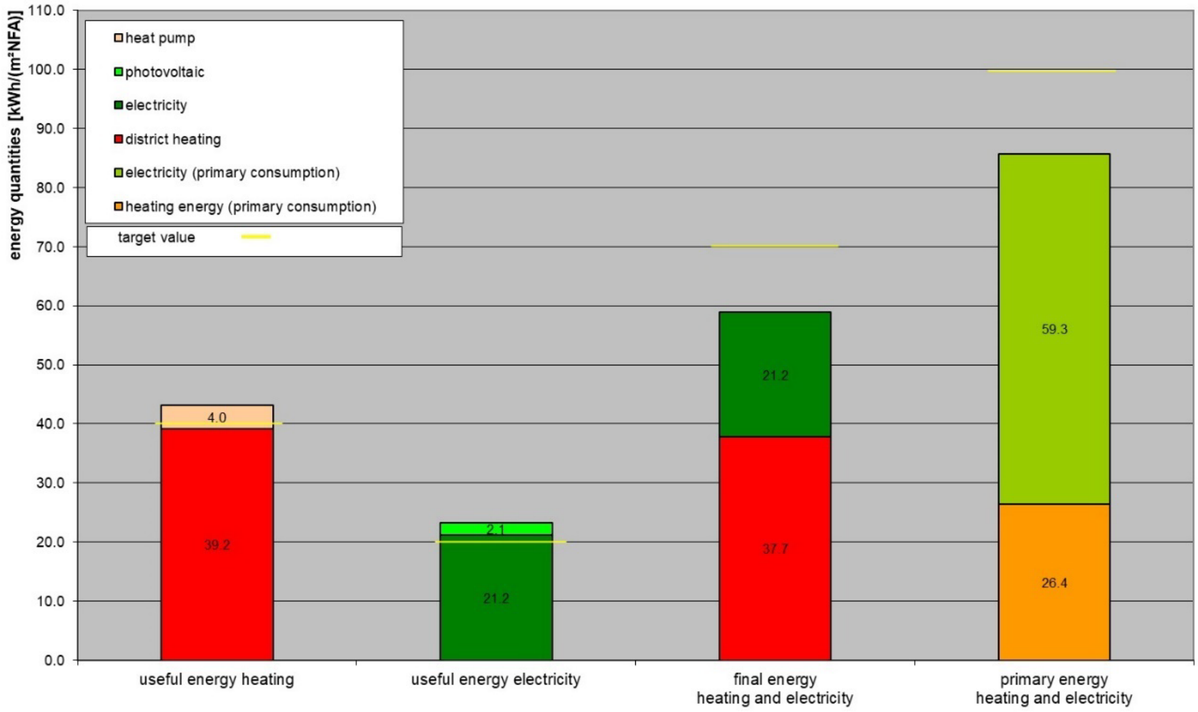

Figure 14: Example: Useful, final and primary energy consumption of the building (stacked) as well as the target values

- *Explanation of what is included in CO_2 emissions*
- *Details to the CO_2 equivalents*
- *Comparison of target value with measured value and e.g. to previous year*

TARGET VALUE	COMMENT/ RATING	RECOMMENDATIONS FOR ACTION AND IMPACT
XXX	*xx*	*xx*

8. SYSTEM LEVEL

In this chapter, individual components of the technical building equipment are presented and evaluated. A TARGET/ACTUAL comparison of (energy-related) key figures is also carried out here.

8.1 Heat pump

The annual performance factors (APF) can be determined from the values of the electricity meters for the heat pumps and the records of the energy quantities from the heat and cooling energy meters on the secondary side of the heat pump.

$$APF = \frac{heat\ and\ cooling\ energy\ produced\ [MWh\ ]}{Purchased\ electricity\ energy\ [MWh]}$$

- *Presentation of monthly, annual and seasonal performance factors*
- *Explanation of the curves*
- *Comparison with data sheets / interpretation and e.g. previous years or other systems in other buildings*

TARGET VALUE	COMMENT/ RATING	RECOMMENDATIONS FOR ACTION AND IMPACT
XXX	*xx*	*xx*

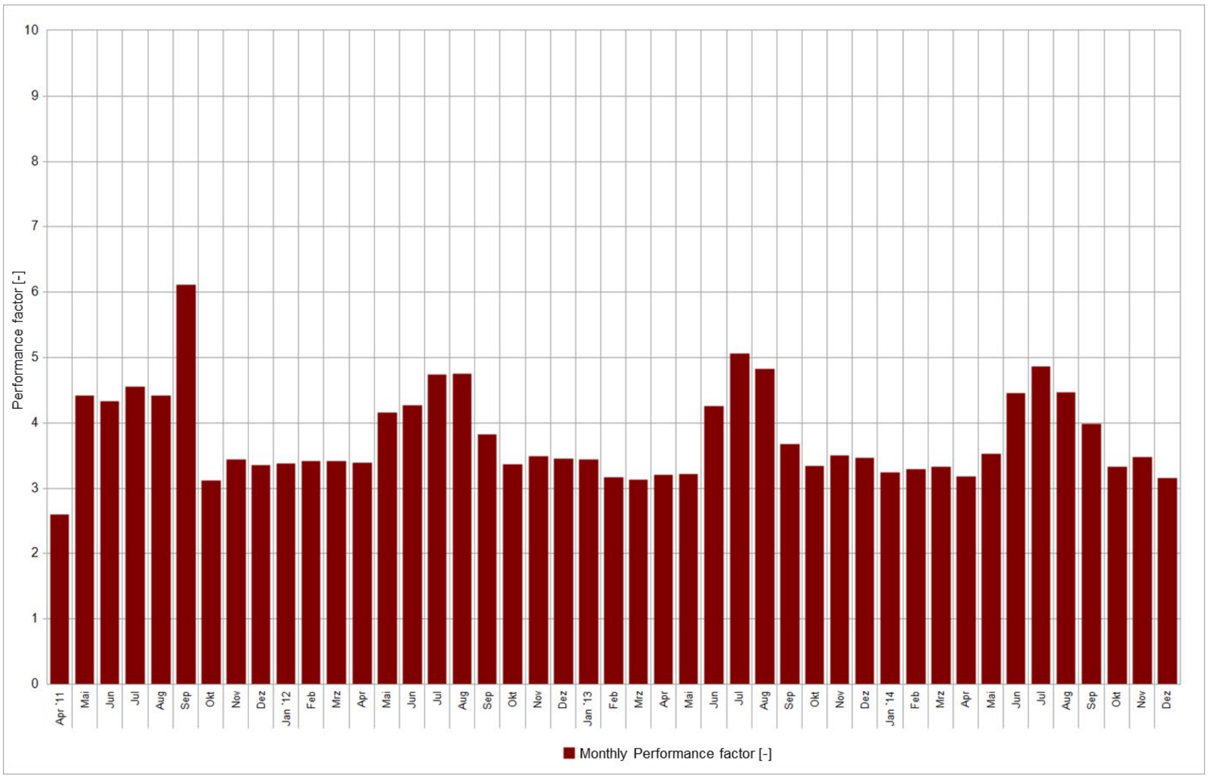

Figure 15: Example: Monthly performance factor of heat pump

8.2 Additional components

Evaluation and analysis for all other energy generators and consumers integrated in the building, e.g. chiller, gas condensing boiler, heating and cooling circuits, and ventilation system.

- *Evaluation of the SPF / utilization factors / efficiencies*
- *Flow and return temperature TARGET and ACTUAL comparison*
- *Comparison with heating/cooling characteristics*
- *Comparison with target values and planning / dimensioning*

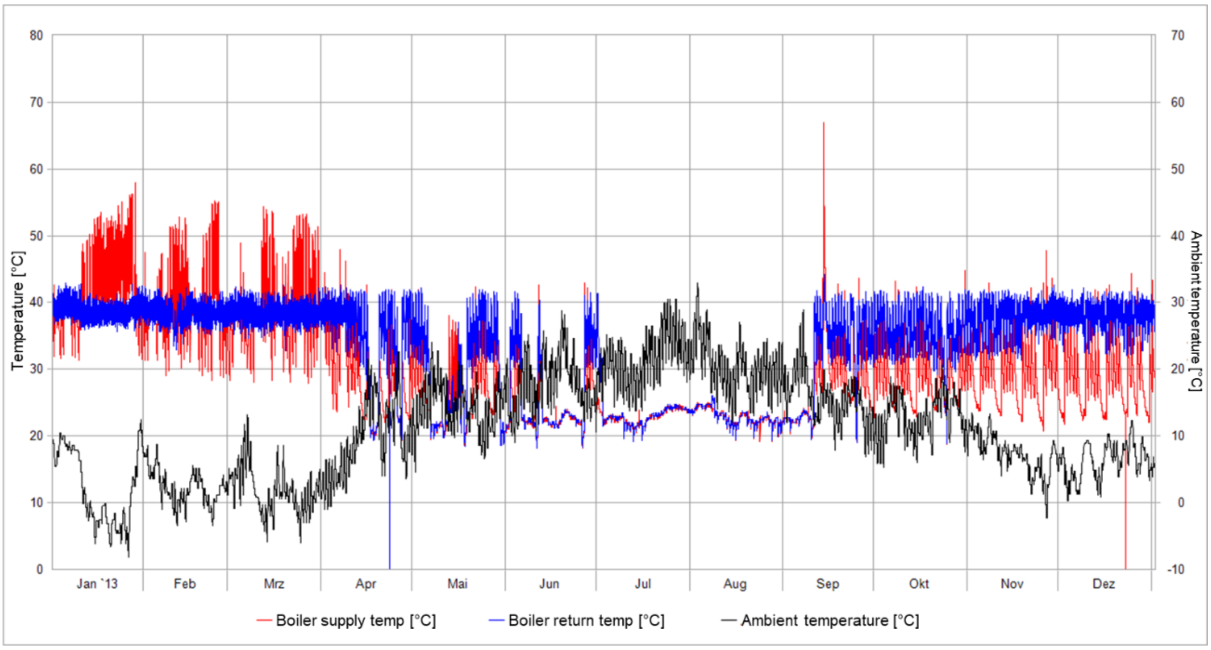

Figure 16: Example: 15-min-values for the supply and return temperature of the gas boiler

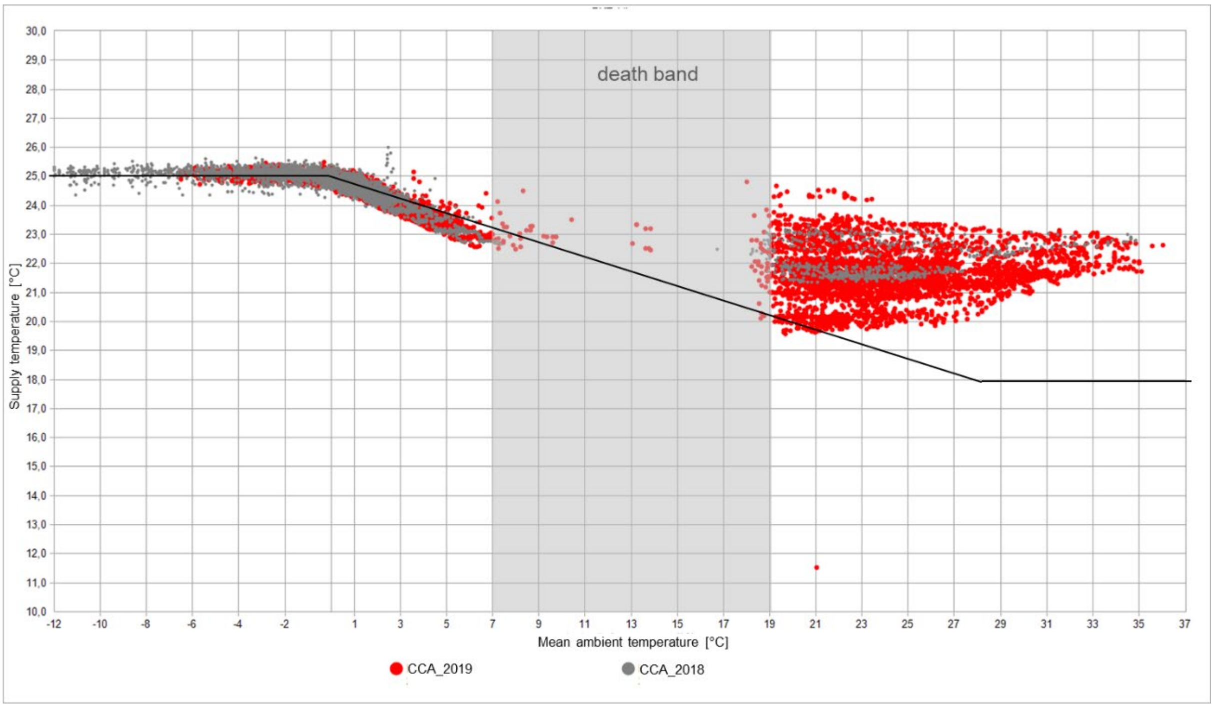

Figure 17: Example: 15-min values of the supply temperature and the heating curve; comparison of setpoint and actual heating curve of a concrete core activation system consisting of value pairs of supply and mean ambient temperature

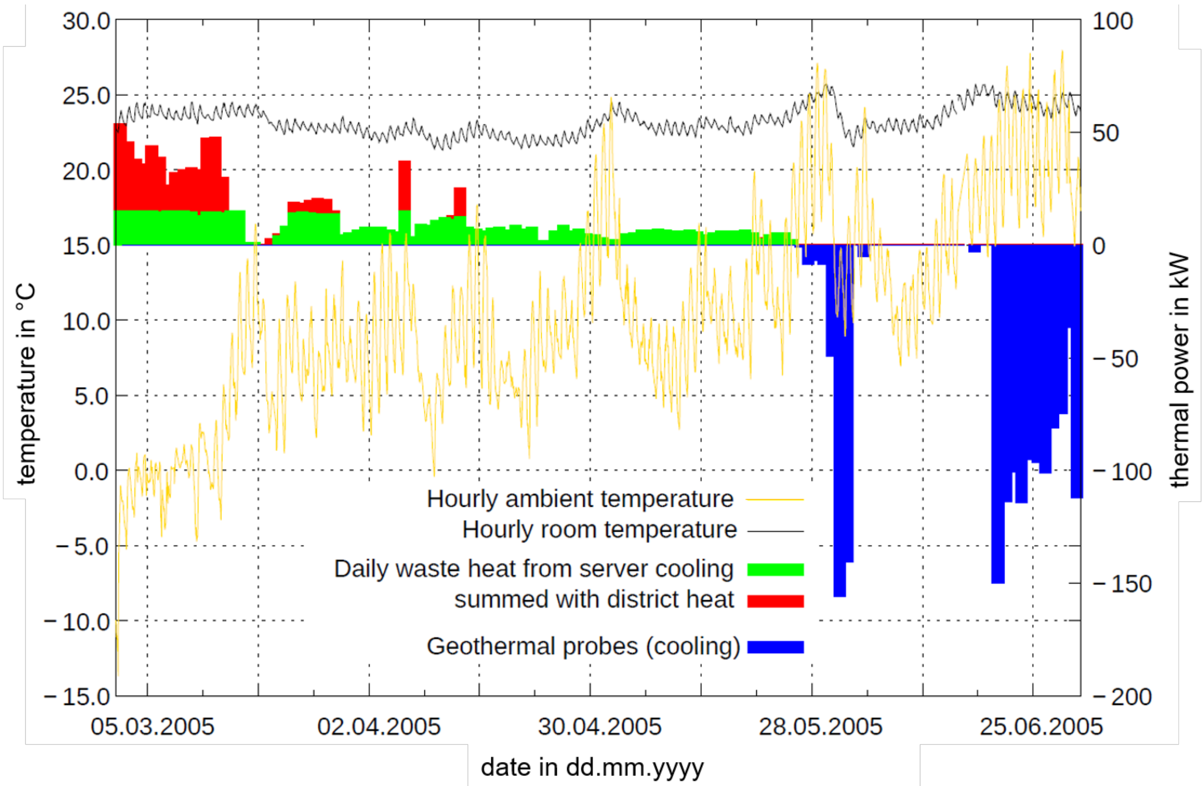

Figure 18: Example: Parameters for heating and cooling of a thermally active concrete core

TARGET VALUE	COMMENT/ RATING	RECOMMENDATIONS FOR ACTION AND IMPACT
XXX	*xx*	*xx*

9. ROOM LEVEL - COMFORT

Mark reference rooms under consideration plan view

9.1 Indoor air quality - room temperature / humidity / CO_2-concentration

- *Show boundary conditions and target values of room comfort*
- *What are the reference values or which room temperatures and humidity must be maintained?*
- *Show boundary conditions and target values of room comfort*
- *What are the reference values or what CO2 levels must be maintained?*

For each room investigated, the mean hourly relative humidity is plotted against the mean hourly room temperature within the period of use and divided into three categories according to DIN EN ISO 7730 and DIN EN 15251:2007. And the temperature range of indoor air to be maintained as a function of the outdoor air temperature. The conditions that actually exist are shown as colored dots for each year.

The figures on room comfort clearly show that this is distributed widely from good to limited. With regard to relative humidity, it can be clearly seen that the relative humidity varies from good to limited - too humid. The CO2 concentration is on average in good ranges (< 800 ppm), but is also clearly exceeded and reaching up to 2,000 ppm.

It should be noted that

- No cooling operation was implemented during the monitoring period.
- No humidification or dehumidification was installed in the ventilation systems. The existing fluctuations are based on the use and occupancy of the rooms as well as on the prevailing humidity of the outside air and the fluctuating air temperatures in the building.
- There is no mechanical ventilation.

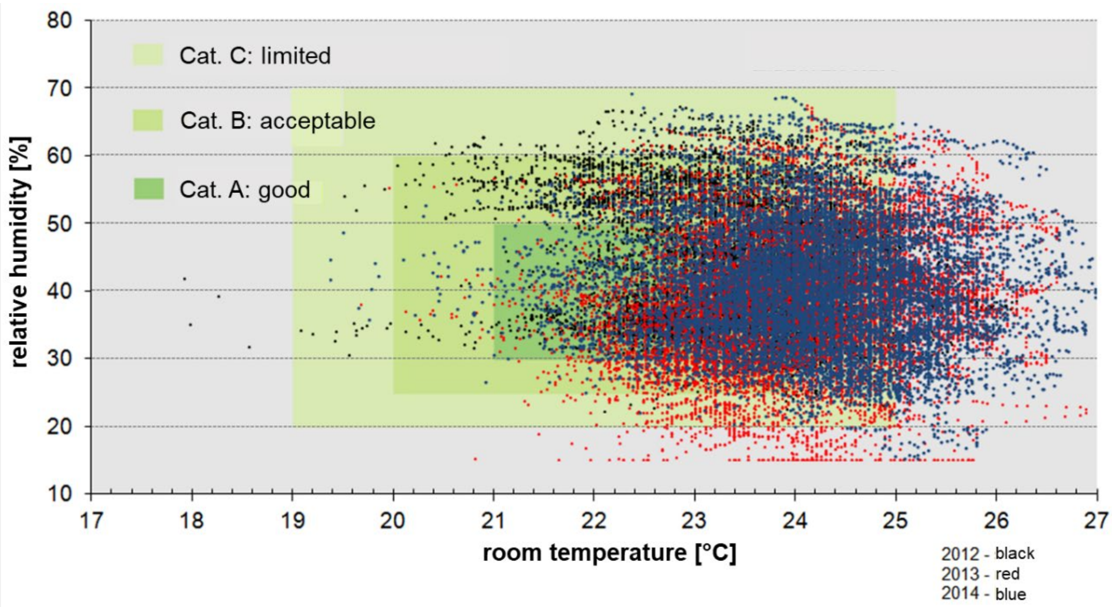

Figure 19: Example: Temperature-humidity ratio

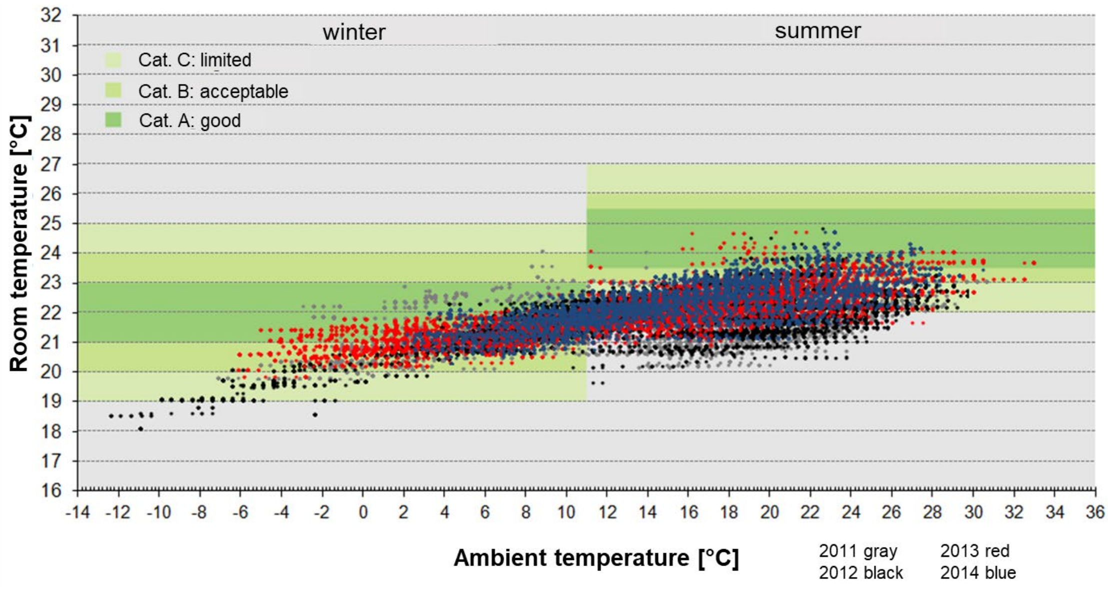

Figure 20: Example: Room temperature according to DIN EN ISO 7730 (15-min-values)

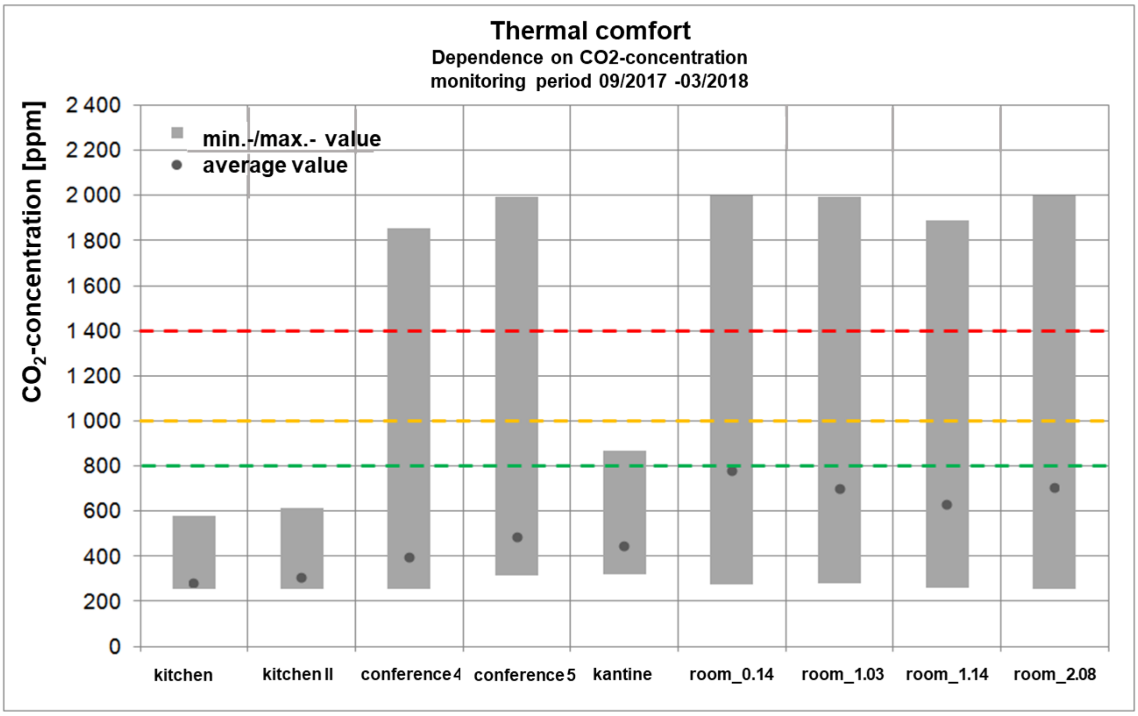

Figure 21: Example: CO2 concentration room

TARGET VALUE	COMMENT/ RATING	RECOMMENDATIONS FOR ACTION AND IMPACT
XXX	*xx*	*xx*

9.2 Overheating and undercooling

- *Show limiting conditions and target values of room comfort*
- *What are the reference values or which overheating hours / undercooling must be maintained?*

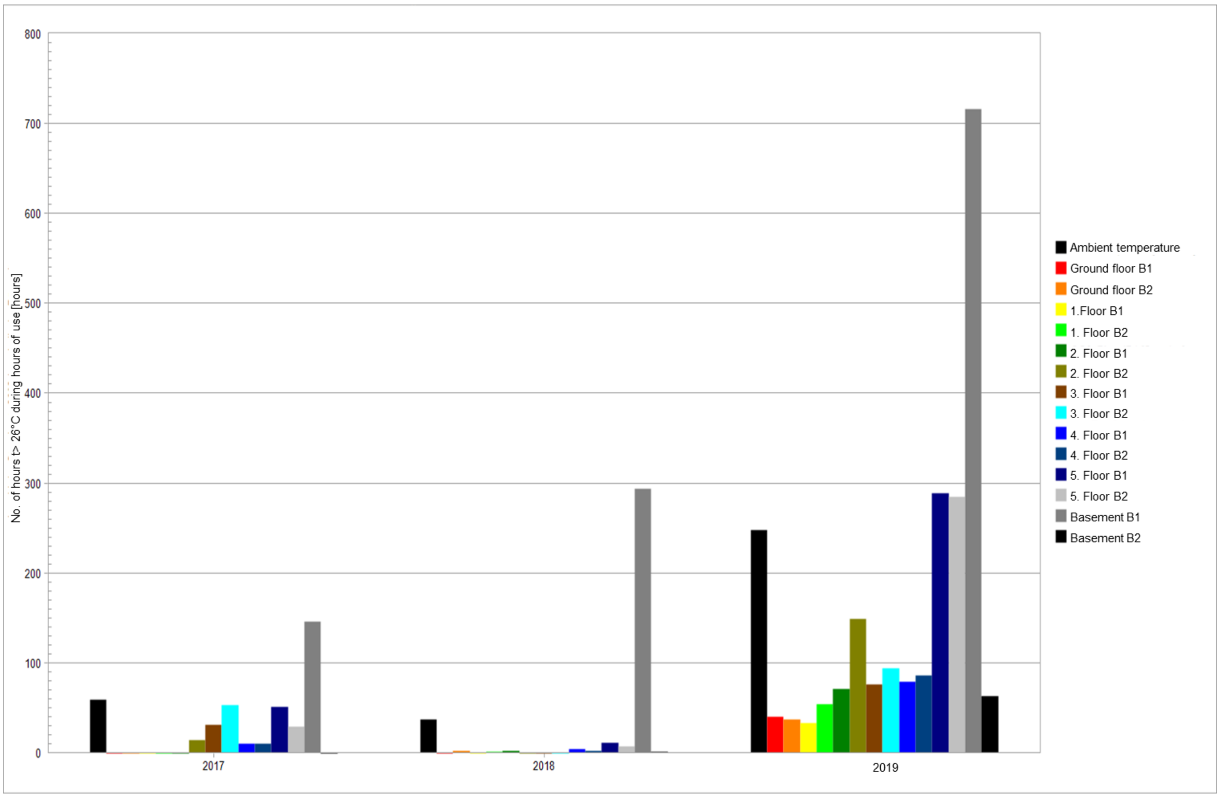

Figure 22: Example: Overheating hours per year and room

TARGET VALUE	COMMENT/ RATING	RECOMMENDATIONS FOR ACTION AND IMPACT
XXX	*xx*	*xx*

Annex 2.2 – Example questionnaire GMon

Short-term questionnaire for spot-monitoring

Building xx

room- no.:	sub.no.

date:______._____._____ / ____:____h

Some questions about yourself

Gender

○ male ○ female ○ diverse

How many hours of your total working time do you spend in this room on an average working day?

○ 1 to 2 hours ○ 3 to 4 hours ○ 5 to 6 hours

About the current indoor climate

1. **I feel the room temperature at the moment as: (If you wish, you can mark the appropriate place between two categories)**

cold cool a bit cool neutral a bit warm warm hot

2. **I would prefer the room temperature:** cooler ○ neither nor ○ warmer ○

3. **At the moment, I feel the humidity to be:**

very dry dry a bit dry neutral a bit humid humid very humid

4. **I feel a draft at my workplace:** yes ○ no ○

bothers me a lot	○	○	○	○	○	○	○	*not at all*

5. **I find the quality of the air in the room to be:**

Very bad	○	○	○	○	○	○	○	*very good*

6. **There are odor nuisances in my workplace:** yes ○ no ○

bothers me a lot	○	○	○	○	○	○	○	*not at all*

7. **How do you rate the illumination of your workplace by daylight?**

Very bad	○	○	○	○	○	○	○	*very good*

8. **How do you rate the sun and glare protection in your office?**

Very bad	○	○	○	○	○	○	○	*very good*

9. **At this time of year, I regulate the room air temperature by:**

	always	*often*	*rare*	*never*	*not possible*
*Setting the **radiator** (thermostat)*	○	○	○	○	○
*Setting the **control panel** (BMS)*	○	○	○	○	○
*Opening the **window***	○	○	○	○	○
*Opening the **office door***	○	○	○	○	○
*Adjustment of the **sun or glare protection***	○	○	○	○	○
*Adaptation of the **clothing***	○	○	○	○	○
***(other)** e.g. setting a fan or an electric fan heater*					
____________________________________	○	○	○	○	○

About your food intake

10. **Please indicate which foods you have eaten in the last 15 minutes.**

Hot drink	○	*Caffeine drink*	○	*Food*	○
Cold drink	○	*Cigarette*	○	*nothing*	○

About your activity level

11. **Which activities did you mainly do in the given time?**

		(inside)			(outside)		
		sitting	standing	walking	walking	running	driving
Act.1	*in the last 10 minutes*	○	○	○	○	○	○
Act.2	*in the previous 10 minutes before **Act. 1***	○	○	○	○	○	○
Act.3	*in the previous 10 minutes before **Act. 2***	○	○	○	○	○	○
Act.4	*in the previous 30 minutes before **Act. 3***	○	○	○	○	○	○

About your clothing

12. **Please describe what clothes you are wearing at the moment.**

Feet

socks	○ *(none)*	○ *thin*	○ *thick*	○ *wool*
shoes	○ *(none)*	○ *light*	○ *street*	○ *winter / boots*

Middle layer

underwear	○ *(none)*	○ *short*	○ *long*	○ *heavy cloth*
T-shirt	○ *(none)*	○ *short sleeves*	○ *long sleeves*	○ *heavy cloth*
Shirt/blouse	○ *(none)*	○ *shoulder free*	○ *short sleeves*	○ *long sleeves*

Outer layer

trousers	○ *(none)*	○ *short*	○ *fitted*	○ *loose falling*
dress	○ *(none)*	○ *short sleeves*	○ *long sleeves*	○ *heavy cloth*
skirt	○ *(none)*	○ *mini skirt*	○ *knee-length*	○ *ankle-length*
pullover	○ *(none)*	○ *short sleeves*	○ *long sleeves*	○ *turtleneck*
jacket	○ *(none)*	○ *light*	○ *heavy*	○ *suit jacket*

13. Overall, I feel that my workplace is:

very uncomfortable ○ ○ ○ ○ ○ ○ ○ *very comfortable*

14. If there is anything else you would like to share about your workplace or this short questionnaire, you can do so here:

- Thank you! -

4 Stakeholder viewpoints

4.1 Questionnaire

A questionnaire for stakeholders was prepared and distributed among the participating countries to investigate what is important to the stakeholders and the obstacles to widespread solar energy buildings.

In total, 310 responses were received from 13 countries. Figure 38 and Figure 39 show the percentage of responses and represented organizations from all the countries.

The questionnaire included general questions on planning, project development, performance, financial, and environmental aspects. Each question ranks in five steps, from very relevant to very irrelevant.

The questions within the different categories are:

4.1.1 Planning aspects

How important do you find the ***need for changes*** in the following planning aspects related to Solar Energy Buildings?

- National legislation and regulation related to renewable energy technologies
- Public awareness/social acceptance
- Urban planning and Zoning regulations
- Environmental impact assessment
- Building and public use permit
- Other planning aspects or potential “showstoppers” in your country? Please specify

4.1.2 Project development aspects

How ***important*** do you find the following aspects related to Solar Energy Buildings?

- Appearance of the Solar Energy Building - esthetical qualities
- Building transition is visible
- Building has a Solar Energy label
- Possibility to follow energy performance of buildings, e.g. via app
- Minimal invasive measures during implementation
- User involvement
- Which point would you put on the top of your list?

4.1.3 Performance aspects

How ***important*** do you find the following aspects related to Solar Energy Buildings?

- Local/national production of components for the building and the solar energy systems
- High degree of self-sufficiency
- Electricity costs (for pumps, heat pump)
- Energy demand reduction in parallel with installation of solar energy systems
- Stable rules on selling energy/electricity (limitations on quantities, selling price, taxation on sale, etc.)
- Which point would you put on the top of your list?

4.1.4 Financial aspects

How ***important*** do you find the following aspects related to Solar Energy Buildings?

- Lifecycle costs (Total Cost of Ownership over the lifetime, TCO)
- Initial costs (Capital Expenditure, CAPEX)
- Operational costs (Operational Expenditure, OPEX)

- Subsidies
- Performance guarantee
- Good financing methods
- Other financial issues? Please specify

4.1.5 Environmental aspects

How ***important*** do you find the following aspects related to Solar Energy Buildings?

- CO_2 emission reduction with respect to operation of the solar energy building
- CO_2 emission reduction considering the embodied energy of the solar energy building
- Use of ecological materials
- Use of recyclable materials
- Other environmental impacts? Please specify
- Which point would you put on the top of your list?

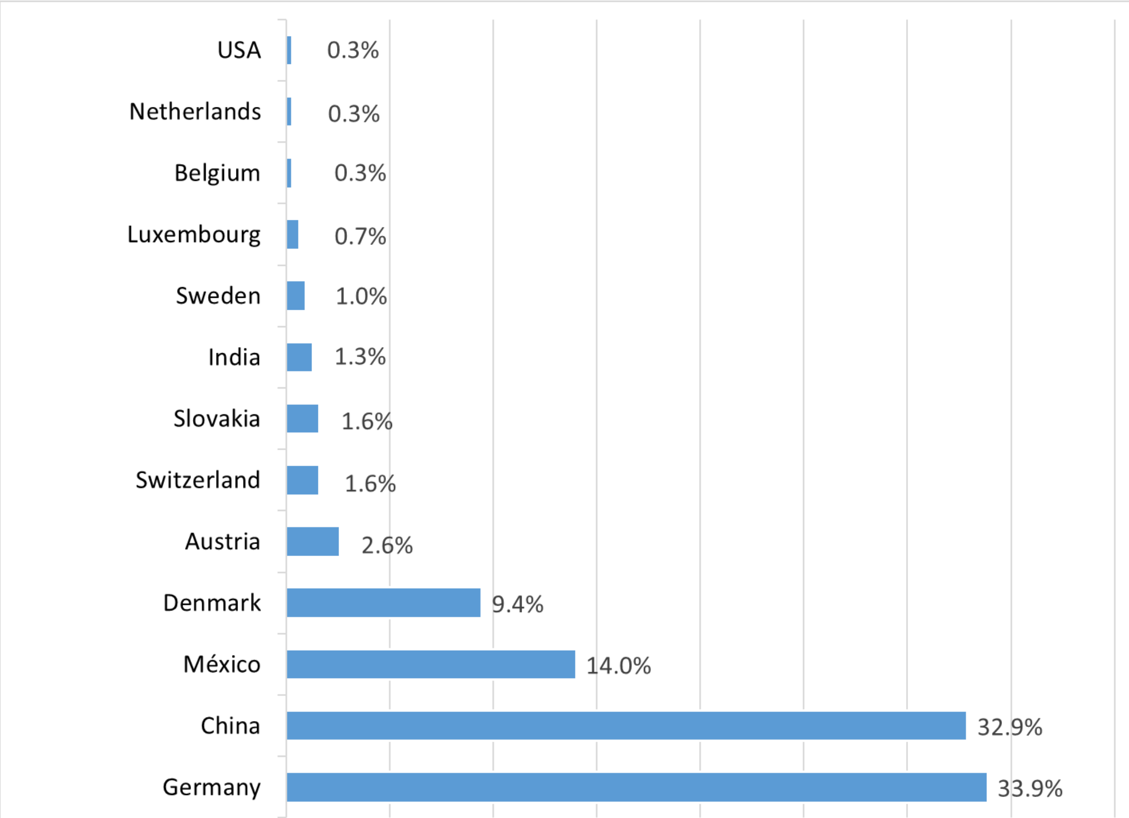

Figure 38: Distribution of answers from all countries.

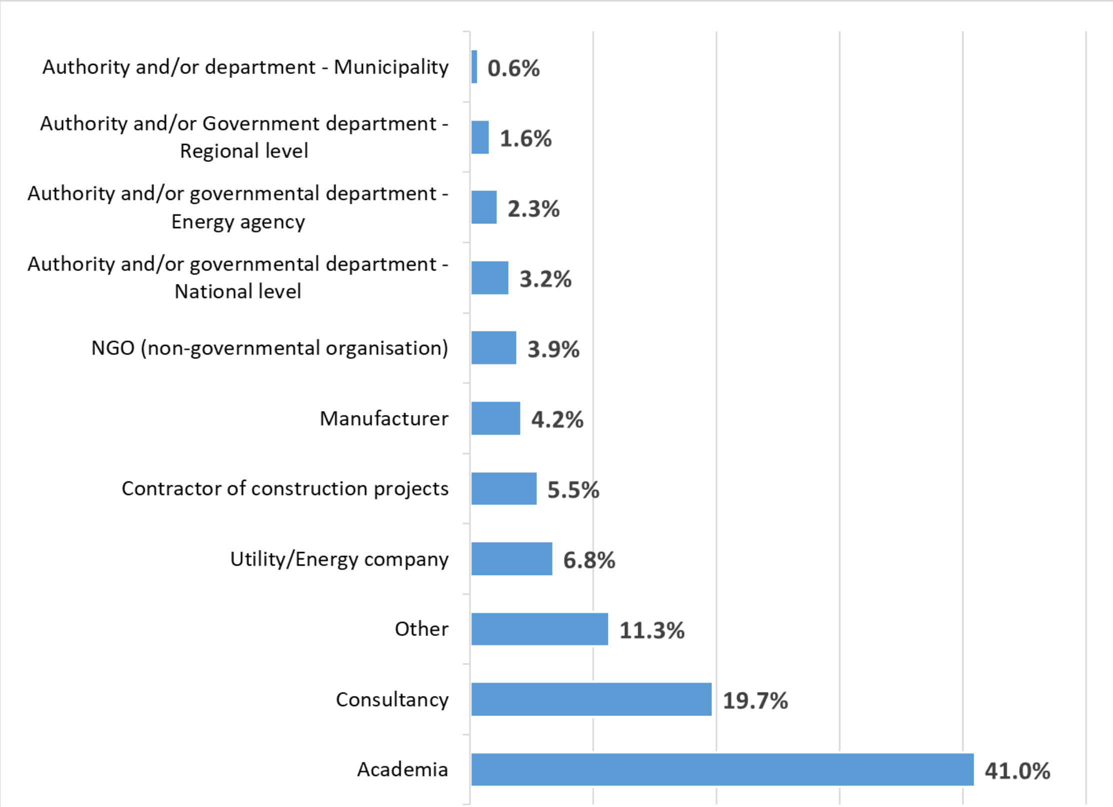

Figure 39: Distribution of organizations from all countries.

4.2 Analysis of questionnaire responses from all countries

Below, the percentage answers to the questions are listed in Table 3 to Table 7. In Table 50, Table 51 and Table 7, an additional column to the right shows the most important aspect.

*Table 3: Responses to planning aspects: How important do you find the **need for changes** in the following planning aspects related to Solar Energy Buildings?*

Planning aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant
National legislation and regulation related to renewable energy technologies	**66.1 %**	22.3 %	5.2 %	2.3 %	4.2 %
Public awareness/social acceptance	**43.9 %**	38.4 %	11 %	3.5 %	3.2 %
Urban planning and Zoning regulations	**41.6 %**	32.9 %	17.1 %	4.5 %	3.9 %
Environmental impact assessment	34.2 %	**38.4 %**	18.7 %	4.8 %	3.9 %
Building and public use permit	**43.9 %**	32.3 %	14.5 %	4.8 %	4.5 %

*Table 4: Responses to project development aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Project development aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant	Aspect on top of the list
Appearance of the Solar Energy Building - esthetical qualities	27.2 %	**33.5 %**	24.8 %	11 %	3.2 %	17.2 %
Building transition is visible	14.8 %	**34.8 %**	29.4 %	16.1 %	4.8 %	6.8 %
Building has a Solar Energy label	19.7 %	**31.6 %**	26.5 %	15.5 %	6.8 %	7.8 %

Possibility to follow energy performance of buildings, e.g. via app	36.8 %	**38.1 %**	15.2 %	7.1 %	6.7 %	**25.6 %**
Minimal invasive measures during implementation	31 %	**34.5 %**	23.9 %	8.4 %	2.3 %	17.9 %
User involvement	35.8 %	**38.4 %**	18.4 %	4.5 %	2.9 %	24.7 %

*Table 5: Responses to performance aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Performance aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant	On top of the list
Local/national production of components for the building and the solar energy systems	32.3 %	**40 %**	18.7 %	6.1 %	2.9 %	13.6 %
High degree of self-sufficiency	39.7 %	**40 %**	13.9 %	4.2 %	2.3 %	14 %
Electricity costs (for pumps, heat pump)	**44.2 %**	39 %	12.6 %	1.9 %	2.3 %	16.2 %
Energy demand reduction in parallel with installation of solar energy systems	**53.5 %**	28.7 %	11.9 %	4.5 %	1.3 %	26.6 %
Stable rules on selling energy/electricity (limitations on quantities, selling price, taxation on sale, etc.)	**51.9 %**	31.6 %	10 %	2.6 %	3.9 %	**29.2 %**

*Table 6: Responses to financial aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Financial aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant
Lifecycle costs (Total Cost of Ownership over the lifetime, TCO)	**49.4 %**	36.5 %	10.6 %	1 %	2.6 %
Initial costs (Capital Expenditure, CAPEX)	**42.3 %**	40 %	13.9 %	1.3 %	2.6 %
Operational costs (Operational Expenditure, OPEX)	39.4 %	**44.8 %**	11 %	2.6 %	2.3 %
Subsidies	32.9 %	**36.8 %**	24.5 %	4.2 %	1.6 %
Performance guarantees	34.2 %	**38.7 %**	19.4 %	6.1 %	1.6 %
Good financing method	35.8 %	**39.4 %**	18.4 %	4.8 %	1.6 %

*Table 7: Responses to environmental aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Environmental aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant	On top of the list
CO_2 emission reduction with respect to operation of the solar energy building	**62.6 %**	27.7 %	5.5 %	0.6 %	3.5 %	**44.6 %**
CO_2 emission reduction considering the embodied energy of the solar energy building	**49 %**	37.7 %	9 %	1.3 %	2.9 %	33.8 %
Use of ecological materials	31.9 %	**45.5 %**	15.2 %	4.8 %	2.6 %	8.5 %
Use of recyclable materials	37.7 %	**41.9 %**	12.6 %	4.8 %	2.9 %	11.5 %

From the tables, it is concluded that changes in national legislation and regulations on renewable energy technologies are most needed and that the rules on selling energy are stable. It is also of vital importance that CO_2 emission reductions related to the operation of the buildings are achieved and that the energy demand of the buildings is reduced in parallel with the installation of solar energy systems.

4.3 Analysis of the questionnaire responses from Germany, China, Mexico, and Denmark

Most answers were received from Germany (104), China (101), Mexico (43), and Denmark (29). Therefore, a separate analysis is undertaken for each of the mentioned countries to focus on differences and similarities between the countries.

4.3.1 Analysis of the questionnaire responses from Germany

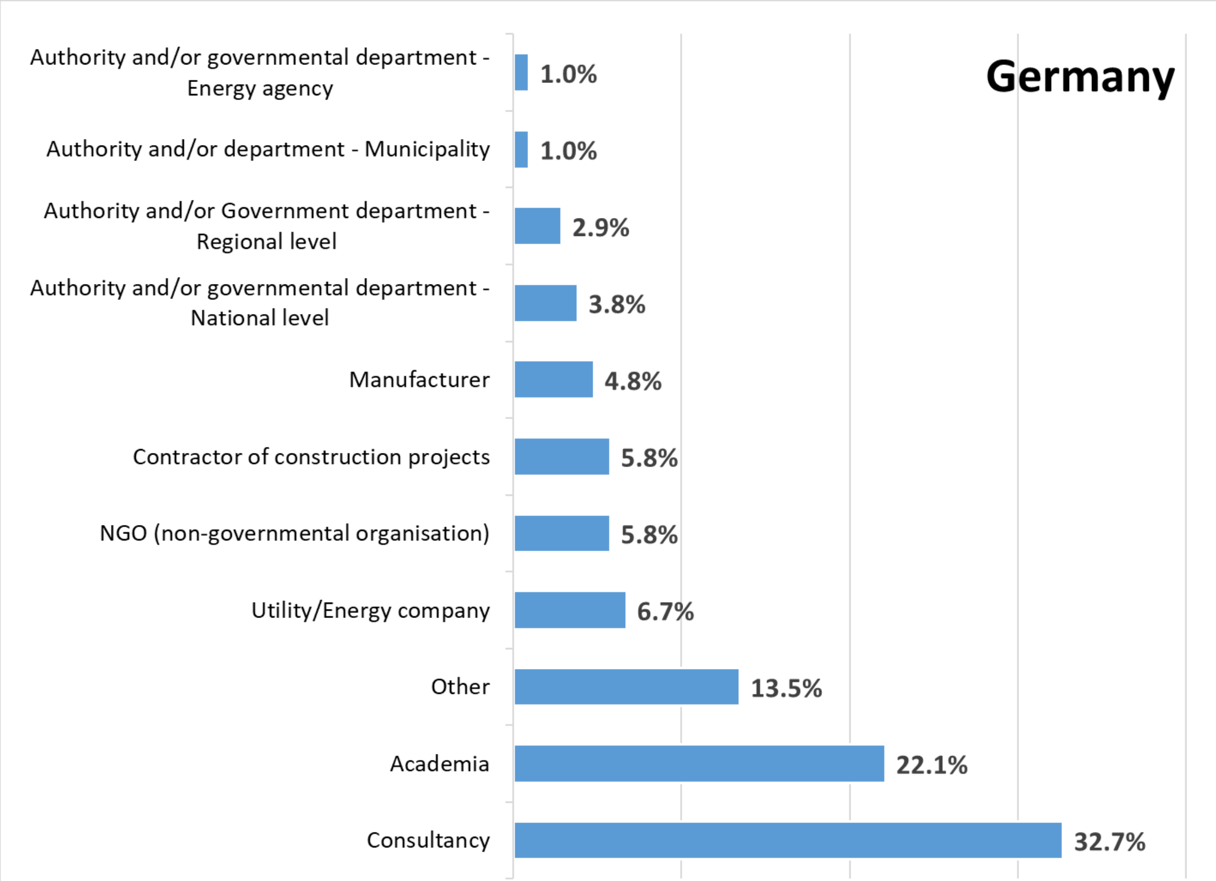

Figure 40: Distribution of organizations from Germany.

*Table 8: Responses to planning aspects: How important do you find the **need for changes** in the following planning aspects related to Solar Energy Buildings?*

Planning aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant
National legislation and regulation related to renewable energy technologies	**66.3 %**	21.2 %	3.8 %	3.8 %	4.8 %
Public awareness/social acceptance	37.5 %	**42.3 %**	13.5 %	4.8 %	1.9 %

Urban planning and Zoning regulations	35.6 %	**36.5 %**	14.4 %	11.5 %	1.9 %
Environmental impact assessment	22.1 %	**48.1 %**	20.2 %	4.8 %	4.8 %
Building and public use permit	**44.2 %**	33.7 %	12.5 %	3.8 %	5.8 %

*Table 9: Responses to project development aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Project development aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant	Aspect on top of the list
Appearance of the Solar Energy Building - esthetical qualities	17.3 %	**33.7 %**	28.8 %	13.5 %	6.7 %	16.3 %
Building transition is visible	3.8 %	**35.6 %**	32.7 %	19.2 %	8.7 %	3.8 %
Building has a Solar Energy label	6.7 %	**30.8 %**	**30.8 %**	22.1 %	9.6 %	5.8 %
Possibility to follow energy performance of buildings, e.g. via app	19.2 %	**43.3 %**	19.2 %	8.7 %	9.6 %	19.2 %
Minimal invasive measures during implementation	16.3 %	**33.7 %**	**33.7 %**	12.5 %	3.8 %	16.3 %
User involvement	35.6 %	**48.1 %**	8.7 %	3.8 %	3.8 %	**38.5 %**

*Table 10: Responses to performance aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Performance aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant	On top of the list
Local/national production of components for the building and the solar energy systems	22.1 %	**48.1 %**	22.1 %	6.7 %	1 %	13.5 %
High degree of self-sufficiency	36.5 %	**42.3 %**	13.5 %	5.8 %	1.9 %	9.6 %
Electricity costs (for pumps, heat pump)	40.4 %	**45.2 %**	11.5 %	0 %	2.9 %	14.4 %
Energy demand reduction in parallel with installation of solar energy systems	**51 %**	32.7 %	8.7 %	6.7 %	1 %	29.8 %
Stable rules on selling energy/electricity (limitations on quantities, selling price, taxation on sale, etc.)	**47.1 %**	40.4 %	4.8 %	1.9 %	5.8 %	**31.7 %**

*Table 11: Responses to financial aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Financial aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant
Lifecycle costs (Total Cost of Ownership over the lifetime, TCO)	**43.3 %**	43.3 %	9.6 %	1 %	2.9 %
Initial costs (Capital Expenditure, CAPEX)	26.9 %	**56.7 %**	13.5 %	0 %	2.9 %
Operational costs (Operational Expenditure, OPEX)	33.7 %	**50 %**	11.5 %	2.9 %	1.9 %
Subsidies	16.3 %	**41.3 %**	39.4 %	2.9 %	0 %
Performance guarantees	28.8 %	**53.8 %**	14.4 %	2.9 %	0 %
Good financing method	26.9 %	**46.2 %**	22.1 %	4.8 %	0 %

Table 12: Responses to environmental aspects: How ***important*** *do you find the following aspects related to Solar Energy Buildings?*

Environmental aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant	On top of the list
CO_2 emission reduction with respect to operation of the solar energy building	**64.4 %**	26 %	3.8 %	0 %	5.8 %	**47.5 %**
CO_2 emission reduction considering the embodied energy of the solar energy building	**40.4 %**	43.3 %	10.6 %	1.9 %	3.8 %	25.7 %
Use of ecological materials	26.9 %	**55.8 %**	12.5 %	1 %	4.8 %	6.9 %
Use of recyclable materials	42.3 %	**46.2 %**	5.8 %	1 %	4.8 %	19.8 %

From the tables, it is clear that for Germany, the need for changes in environmental impact assessments is not as important as it is for other countries. Also, low initial costs for solar energy systems are not as important in Germany as it is in other countries. On the other side, performance guarantees seem to be somewhat more important in Germany than in other countries.

4.3.2 Analysis of the questionnaire responses from China

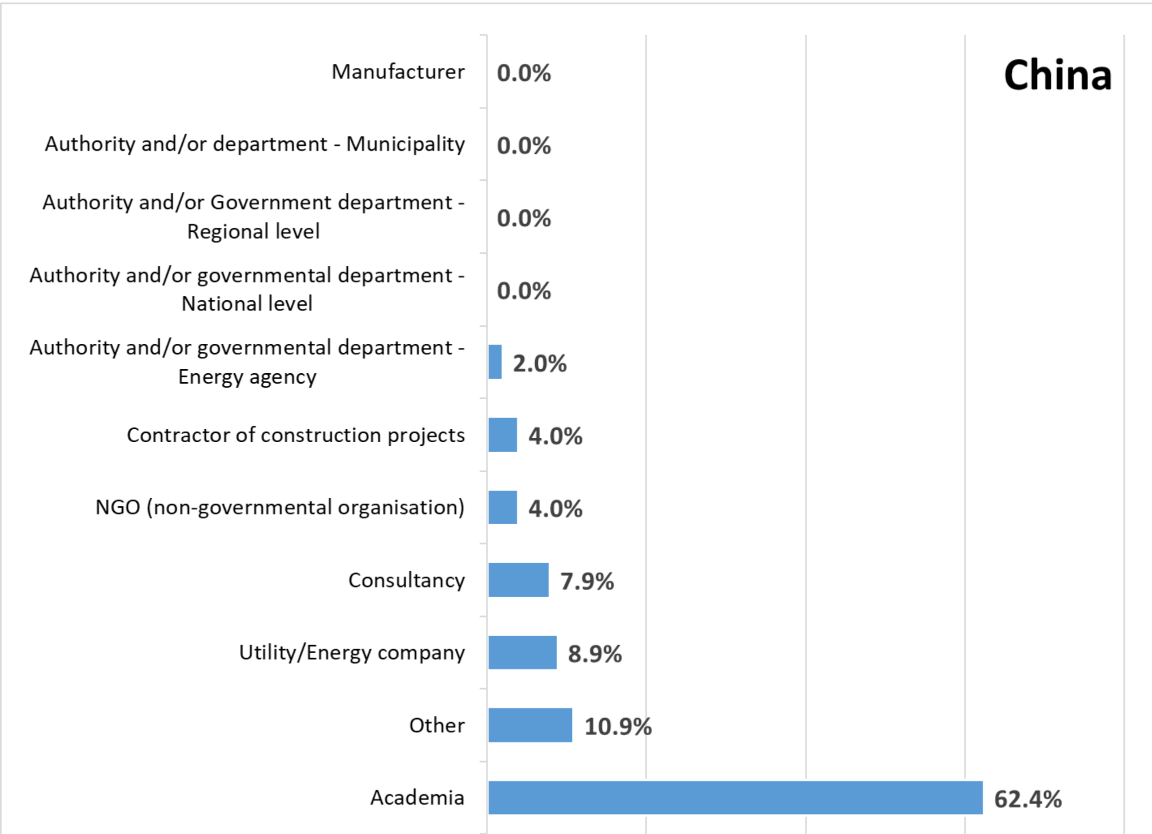

Figure 41: Distribution of organizations from China.

*Table 13: Responses to planning aspects: How important do you find the **need for changes** in the following planning aspects related to Solar Energy Buildings?*

Planning aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant
National legislation and regulation related to renewable energy technologies	**64 %**	27 %	7 %	2 %	0 %
Public awareness/social acceptance	**56 %**	31 %	10 %	3 %	0 %
Urban planning and Zoning regulations	**55 %**	28 %	17 %	0 %	0 %
Environmental impact assessment	**49 %**	32 %	14 %	5 %	0 %
Building and public use permit	35 %	**42 %**	18 %	4 %	1 %

*Table 14: Responses to project development aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Project development aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant	Aspect on top of the list
Appearance of the Solar Energy Building - esthetical qualities	**40 %**	31 %	21 %	7 %	1 %	17 %
Building transition is visible	30 %	**36 %**	24 %	9 %	1 %	9 %
Building has a Solar Energy label	**28 %**	**28 %**	31 %	10 %	3 %	5 %
Possibility to follow energy performance of buildings, e.g. via app	**50 %**	33 %	12 %	4 %	1 %	**36 %**
Minimal invasive measures during implementation	**48 %**	34 %	15 %	3 %	0 %	25 %
User involvement	**33 %**	**33 %**	29 %	4 %	1 %	8 %

*Table 15: Responses to performance aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Performance aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant	On top of the list
Local/national production of components for the building and the solar energy systems	37 %	**40 %**	20 %	2 %	1 %	9 %
High degree of self-sufficiency	**46 %**	36 %	17 %	1 %	0 %	14 %
Electricity costs (for pumps, heat pump)	**56 %**	28 %	13 %	3 %	0 %	25 %
Energy demand reduction in parallel with installation of solar energy systems	**60 %**	27 %	12 %	1 %	0 %	**32 %**
Stable rules on selling energy/electricity (limitations on quantities, selling price, taxation on sale, etc.)	**54 %**	33 %	12 %	1 %	0 %	20 %

*Table 16: Responses to financial aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Financial aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant

Lifecycle costs (Total Cost of Ownership over the lifetime, TCO)	**53 %**	32 %	14 %	1 %	0 %
Initial costs (Capital Expenditure, CAPEX)	**61 %**	25 %	11 %	3 %	0 %
Operational costs (Operational Expenditure, OPEX)	**56 %**	34 %	9 %	1 %	0 %
Subsidies	**52 %**	29 %	12 %	6 %	1 %
Performance guarantees	**32 %**	28 %	27 %	13 %	0 %
Good financing method	**39 %**	37 %	21 %	3 %	0 %

*Table 17: Responses to environmental aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Environmental aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant	On top of the list
CO2 emission reduction with respect to operation of the solar energy building	**64 %**	28 %	6 %	1 %	1 %	34 %
CO2 emission reduction considering the embodied energy of the solar energy building	**62 %**	29 %	7 %	1 %	1 %	**49 %**
Use of ecological materials	37 %	**40 %**	14 %	8 %	1 %	8 %
Use of recyclable materials	35 %	**41 %**	17 %	6 %	1 %	7 %

For China, changes in public awareness/social acceptance, urban planning and zoning regulations, and environmental impact assessments are more needed than in other countries. It is also more important in China than in other countries that the buildings have high esthetical qualities, that the building transition is visible, that it is possible to follow the energy performance of the buildings, and that there are minimal measures during the implementation of the solar energy systems. In China, it is also more important than in other countries to have low initial costs for solar energy systems and low operational costs inclusive of electricity costs for the solar energy systems. Further, high subsidies are considered more important in China than in other countries. Finally, CO_2 emission reductions related to the embodied energy of solar energy buildings are more important in China than in other countries.

4.3.3 Analysis of the questionnaire responses from Mexico

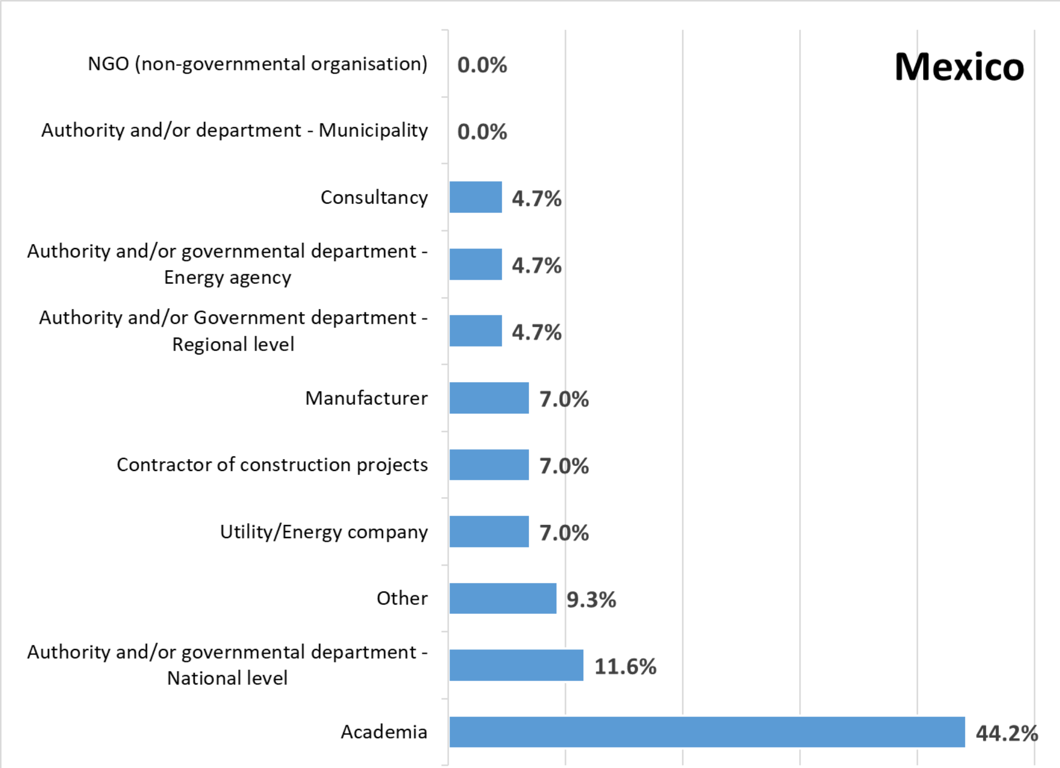

Figure 42: Distribution of organizations from Mexico.

*Table 18: Responses to planning aspects: How important do you find the **need for changes** in the following planning aspects related to Solar Energy Buildings?*

Planning aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant
National legislation and regulation related to renewable energy technologies	**76.7 %**	9.3 %	2.3 %	0 %	11.6 %
Public awareness/social acceptance	**46.5 %**	32.6 %	4.7 %	7 %	9.3 %
Urban planning and Zoning regulations	**44.2 %**	32.6 %	9.3 %	0 %	14 %
Environmental impact assessment	**44.2 %**	32.6 %	14 %	0 %	9.3 %
Building and public use permit	**62.8 %**	18.6 %	7 %	2.3 %	9.3 %

*Table 19: Responses to project development aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Project development aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant	Aspect on top of the list
Appearance of the Solar Energy Building - esthetical qualities	4.7 %	**41.9 %**	37.2 %	16.3 %	0 %	2.4 %
Building transition is visible	11.6 %	**41.9 %**	27.9 %	16.3 %	2.3 %	7.1 %
Building has a Solar Energy label	**41.9 %**	39.5 %	7 %	4.7 %	7 %	21.4 %
Possibility to follow energy performance of buildings, e.g. via app	**51.2 %**	39.5 %	2.3 %	0 %	7 %	23.8 %
Minimal invasive measures during implementation	23.3 %	**46.5 %**	18.6 %	9.3 %	2.3 %	9.5 %
User involvement	**48.8 %**	34.9 %	11.6 %	2.3 %	2.3 %	**35.7 %**

*Table 20: Responses to performance aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Performance aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant	On top of the list
Local/national production of components for the building and the solar energy systems	**58.1 %**	25.6 %	2.3 %	7 %	7 %	**36.6 %**
High degree of self-sufficiency	41.9 %	**44.2 %**	7 %	2.3 %	4.7 %	14.6 %
Electricity costs (for pumps, heat pump)	39.5 %	**44.2 %**	9.3 %	2.3 %	4.7 %	2.4 %
Energy demand reduction in parallel with installation of solar energy systems	**65.1 %**	23.3 %	4.7 %	2.3 %	4.7 %	22 %
Stable rules on selling energy/electricity (limitations on quantities, selling price, taxation on sale, etc.)	**65.1 %**	18.6 %	9.3 %	2.3 %	4.7 %	24.4 %

*Table 21: Responses to financial aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Financial aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant
Lifecycle costs (Total Cost of Ownership over the lifetime, TCO)	**51.2 %**	39.5 %	2.3 %	2.3 %	4.7 %
Initial costs (Capital Expenditure, CAPEX)	**46.5 %**	34.9 %	11.6 %	2.3 %	4.7 %
Operational costs (Operational Expenditure, OPEX)	39.5 %	**41.9 %**	9.3 %	4.7 %	4.7 %
Subsidies	30.2 %	**44.2 %**	16.3 %	2.3 %	7 %
Performance guarantees	**44.2 %**	39.5 %	9.3 %	0 %	7 %
Good financing method	**60.5 %**	23.3 %	7 %	2.3 %	7 %

*Table 22: Responses to environmental aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Environmental aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant	On top of the list
CO2 emission reduction with respect to operation of the solar energy building	**65.1 %**	25.6 %	2.3 %	0 %	7 %	**50 %**
CO2 emission reduction considering the embodied energy of the solar energy building	**67.4 %**	23.3 %	2.3 %	0 %	7 %	38.1 %
Use of ecological materials	**41.9 %**	37.2 %	14 %	2.3 %	4.7 %	7.1 %
Use of recyclable materials	**37.2 %**	**37.2 %**	11.6 %	9.3 %	4.7 %	4.8 %

For Mexico, changes in national legislation and regulations on renewable energy technologies and changes in building and public use permits are more needed than in other countries. It is also more important to have stable rules on selling energy in Mexico than in other countries. Further, it is more important in Mexico to mark buildings with a solar energy label, to be able to follow the energy performance of the buildings and to increase user involvement than in other countries. Finally, it is more important in Mexico than in other countries to rely on local production of components and systems, to reduce the energy demand of the buildings in parallel to with installation of solar energy systems, to reduce CO_2 emissions related to the embodied energy of the solar energy buildings and to have good financing methods.

4.3.4 Analysis of the questionnaire responses from Denmark

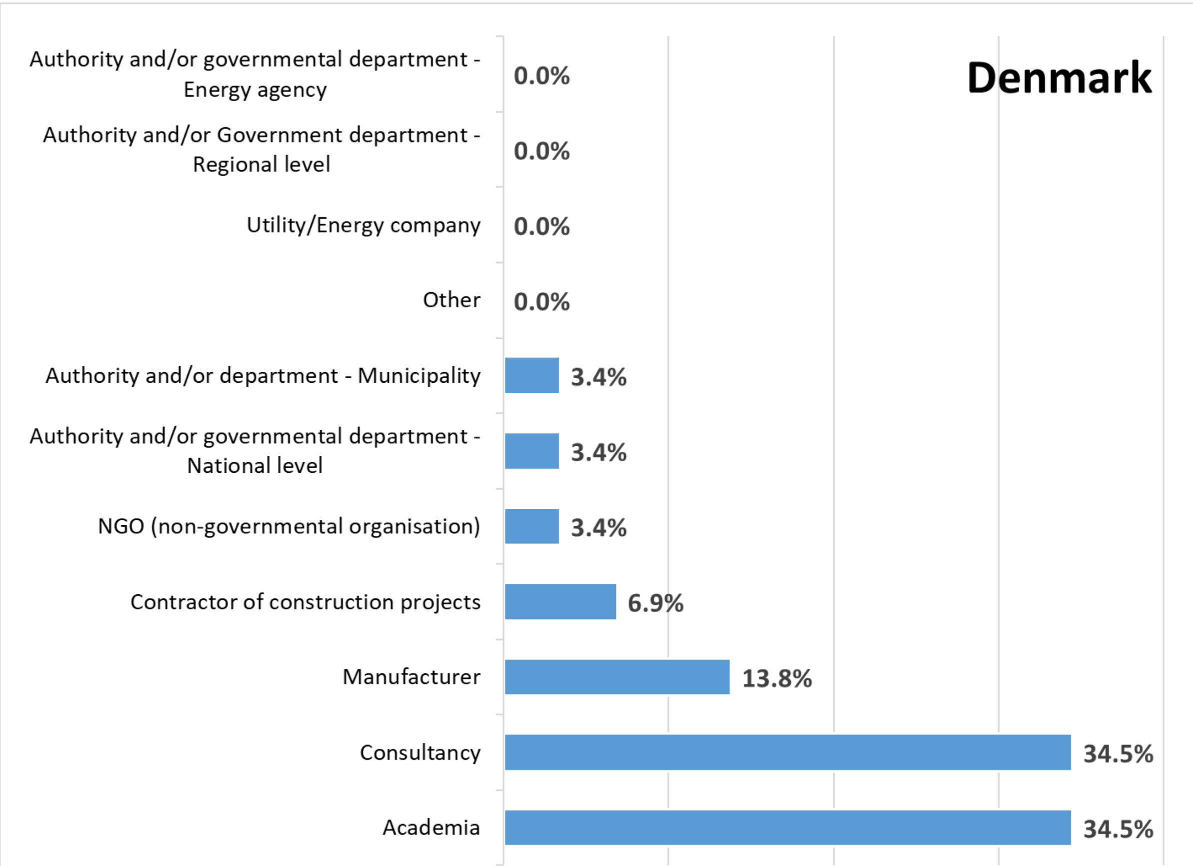

Figure 43: Distribution of organizations from Denmark.

*Table 23: Responses to planning aspects: How important do you find the **need for changes** in the following planning aspects related to Solar Energy Buildings?*

Planning aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant
National legislation and regulation related to renewable energy technologies	**58.6 %**	17.2 %	10.3 %	3.4 %	10.3 %
Public awareness/social acceptance	27.6 %	**44.8 %**	17.2 %	0 %	10.3 %
Urban planning and Zoning regulations	27.6 %	**31 %**	24.1 %	6.9 %	10.3 %
Environmental impact assessment	24.1 %	**37.9 %**	17.2 %	13.8 %	6.9 %
Building and public use permit	**44.8 %**	17.2 %	20.7 %	6.9 %	10.3 %

*Table 24: Responses to project development aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Project development aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant	Aspect on top of the list
Appearance of the Solar Energy Building - esthetical qualities	**37.9 %**	34.5%	17.2 %	6.9 %	3.4 %	39.3 %
Building transition is visible	10.3 %	20.7 %	**31 %**	24.1 %	13.8 %	3.6 %
Building has a Solar Energy label	10.3 %	24.1 %	**31 %**	24.1 %	10.3 %	7.1 %
Possibility to follow energy performance of buildings, e.g. via app	31 %	**41.4 %**	13.8 %	10.3 %	3.4 %	**25 %**
Minimal invasive measures during implementation	**41.4 %**	17.2 %	27.6 %	10.3 %	3.4 %	10.7 %
User involvement	20.7 %	**37.9 %**	24.1 %	10.3 %	6.9 %	14.3 %

*Table 25: Responses to performance aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Performance aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant	On top of the list
Local/national production of components for the building and the solar energy systems	20.7 %	**34.5 %**	20.7 %	10.3 %	13.8 %	0 %
High degree of self-sufficiency	27.6 %	**34.5 %**	13.8 %	13.8 %	10.3 %	20.7 %
Electricity costs (for pumps, heat pump)	**31 %**	**31 %**	24.1 %	6.9 %	6.9 %	10.3 %
Energy demand reduction in parallel with installation of solar energy systems	**44.8 %**	20.7 %	20.7 %	10.3 %	3.4 %	13.8 %
Stable rules on selling energy/electricity (limitations on quantities, selling price, taxation on sale, etc.)	**58.6 %**	17.2 %	13.8 %	0 %	10.3 %	**55.2 %**

*Table 26: Responses to financial aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Financial aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant

Lifecycle costs (Total Cost of Ownership over the lifetime, TCO)	**48.3 %**	31 %	13.8 %	0 %	6.9 %
Initial costs (Capital Expenditure, CAPEX)	31 %	**44.8 %**	17.2 %	0 %	6.9 %
Operational costs (Operational Expenditure, OPEX)	20.7 %	**48.3 %**	20.7 %	3.4 %	6.9 %
Subsidies	27.6 %	**44.8 %**	17.2 %	6.9 %	3.4 %
Performance guarantees	**41.4 %**	31 %	20.7 %	0 %	6.9 %
Good financing method	31 %	**37.9 %**	20.7 %	6.9 %	3.4 %

*Table 27: Responses to environmental aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Environmental aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant	On top of the list
CO2 emission reduction with respect to operation of the solar energy building	**51.7 %**	31 %	10.3 %	3.4 %	3.4 %	**58.6 %**
CO2 emission reduction considering the embodied energy of the solar energy building	24.1 %	**55.2 %**	13.8 %	3.4 %	3.4 %	17.2 %
Use of ecological materials	20.7 %	**48.3 %**	13.8 %	13.8 %	3.4 %	10.3 %
Use of recyclable materials	37.9 %	**41.4 %**	10.3 %	6.9 %	3.4 %	13.8 %

For Denmark, the esthetical qualities of the buildings are somewhat more important than in other countries. On the other side, in Denmark minimal invasive measures during implementation of the solar energy systems are more important than in other countries. Also, the initial costs and the electricity costs for the operation of the solar energy systems are not as important in Denmark as they are in other countries. Finally, reductions of CO_2 emissions seem less important in Denmark compared to other countries.

4.4 Analysis of the questionnaire responses from consultants and academics in all countries

Most of the questionnaire responses come from consultants and academics. Therefore, the focus of this section is on the differences and similarities between these two groups.

4.4.1 Analysis of the questionnaire responses from consultants

*Table 28: Responses to planning aspects: How important do you find the **need for changes** in the following planning aspects related to Solar Energy Buildings?*

Planning aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant
National legislation and regulation related to renewable energy technologies	**68.9 %**	19.7 %	4.9 %	1.6 %	4.9 %
Public awareness/social acceptance	41 %	**39.3 %**	14.8 %	3.3 %	1.6 %
Urban planning and Zoning regulations	36.1 %	**29.5 %**	24.6 %	9.8 %	0 %
Environmental impact assessment	27.9 %	**41 %**	23 %	4.9 %	3.3 %
Building and public use permit	**44.3 %**	27.9 %	18 %	4.9 %	4.9 %

*Table 29: Responses to project development aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Project development aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant	Aspect on top of the list
Appearance of the Solar Energy Building - esthetical qualities	26.2 %	**39.3 %**	19.7 %	8.2 %	6.6 %	16.4 %
Building transition is visible	6.6 %	**39.3 %**	31.1 %	19.7 %	3.3 %	4.9 %
Building has a Solar Energy label	19.7 %	**24.6 %**	**26.2 %**	21.3 %	8.2 %	8.2 %
Possibility to follow energy performance of buildings, e.g. via app	34.4 %	**31.1 %**	19.7 %	8.2 %	6.6 %	27.9 %
Minimal invasive measures during implementation	23 %	**29.5 %**	**34.4 %**	8.2 %	3.8 %	16.4 %
User involvement	36.1 %	**47.5 %**	9.8 %	4.9 %	1.6 %	**26.2 %**

*Table 30: Responses to performance aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Performance aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant	On top of the list
Local/national production of components for the building and the solar energy systems	26.2 %	**44.3 %**	19.7 %	6.6 %	3.3 %	8.2 %
High degree of self-sufficiency	**39.3 %**	**39.3 %**	11.5 %	6.6 %	3.3 %	6.6 %
Electricity costs (for pumps, heat pump)	**45.9 %**	36.1 %	16.4 %	1.6 %	0 %	16.4 %
Energy demand reduction in parallel with installation of solar energy systems	**55.7 %**	32.8 %	8.2 %	3.3 %	0 %	32.8 %
Stable rules on selling energy/electricity (limitations on quantities, selling price, taxation on sale, etc.)	**45.9 %**	41 %	8.2 %	1.6 %	3.3 %	**36.1 %**

*Table 31: Responses to financial aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Financial aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant
Lifecycle costs (Total Cost of Ownership over the lifetime, TCO)	**52.5 %**	31.1 %	13.1 %	0 %	3.3 %
Initial costs (Capital Expenditure, CAPEX)	39.3 %	**42.6 %**	14.8 %	0 %	3.3 %
Operational costs (Operational Expenditure, OPEX)	34.4 %	**49.2 %**	11.5 %	1.6 %	3.3 %
Subsidies	21.3 %	**44.3 %**	29.5 %	4.9 %	0 %
Performance guarantees	32.8 %	**42.6 %**	21.3 %	3.3 %	0 %
Good financing method	31.1 %	**41 %**	24.6 %	3.3 %	0 %

*Table 32: Responses to environmental aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Environmental aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant	On top of the list
CO_2 emission reduction with respect to operation of the solar energy building	**70.5 %**	24.6 %	1.6 %	0 %	3.3 %	**52.5 %**
CO_2 emission reduction considering the embodied energy of the solar energy building	**42.6 %**	47.5 %	6.6 %	1.6 %	1.6 %	28.8 %
Use of ecological materials	26.2 %	**55.7 %**	14.8 %	0 %	3.3 %	6.8 %
Use of recyclable materials	39.3 %	**50.8 %**	4.9 %	1.6 %	3.3 %	11.9 %

4.4.2 Analysis of the questionnaire responses from academics

*Table 33: Responses to planning aspects: How important do you find the **need for changes** in the following planning aspects related to Solar Energy Buildings?*

Planning aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant
National legislation and regulation related to renewable energy technologies	**65.9 %**	25.4 %	4.8 %	2.4 %	1.6 %
Public awareness/social acceptance	**45.2 %**	41.3 %	8.7 %	3.2 %	1.6 %
Urban planning and Zoning regulations	**48.4 %**	34.1 %	13.5 %	0.8 %	3.2 %
Environmental impact assessment	36.5 %	**42.9 %**	14.3 %	4 %	2.4 %
Building and public use permit	**45.2 %**	38.9 %	10.3 %	3.2 %	2.4 %

*Table 34: Responses to project development aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Project development aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant	Aspect on top of the list
Appearance of the Solar Energy Building - esthetical qualities	31 %	**38.1 %**	20.6 %	9.5 %	0.8 %	17.6 %
Building transition is visible	18.3 %	**38.9 %**	25.4 %	15.1 %	2.4 %	8 %
Building has a Solar Energy label	22.2 %	**39.7 %**	25.4 %	10.3 %	2.4 %	6.4 %
Possibility to follow energy performance of buildings, e.g. via app	**40.5 %**	**40.5 %**	11.9 %	4.8 %	2.4 %	28 %
Minimal invasive measures during implementation	37.3 %	**40.5 %**	16.7 %	5.6 %	0 %	18.4 %
User involvement	34.9 %	**38.9 %**	21.4 %	3.2 %	1.6 %	**21.6 %**

*Table 35: Responses to performance aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Performance aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant	On top of the list

Local/national production of components for the building and the solar energy systems	31.7 %	**42.1 %**	19 %	6.3 %	0.8 %	15.2 %
High degree of self-sufficiency	38.1 %	**43.7 %**	15.1 %	2.4 %	0.8 %	16 %
Electricity costs (for pumps, heat pump)	**48.4 %**	39.7 %	10.3 %	0.8 %	0.8 %	17.6 %
Energy demand reduction in parallel with installation of solar energy systems	**54 %**	27 %	15.1 %	3.2 %	0.8 %	**27.2 %**
Stable rules on selling energy/electricity (limitations on quantities, selling price, taxation on sale, etc.)	**54.8 %**	30.2 %	11.9 %	1.6 %	1.6 %	23.2 %

*Table 36: Responses to financial aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Financial aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant
Lifecycle costs (Total Cost of Ownership over the lifetime, TCO)	**47.6 %**	40.5 %	10.3 %	1.6 %	0 %
Initial costs (Capital Expenditure, CAPEX)	**47.6 %**	35.7 %	14.3 %	2.4 %	0 %
Operational costs (Operational Expenditure, OPEX)	45.2 %	**46 %**	7.9 %	0.8 %	0 %
Subsidies	35.7 %	**41.3 %**	19 %	3.2 %	0.8 %
Performance guarantees	**38.9 %**	34.9 %	17.5 %	8.7 %	0 %
Good financing method	35.7 %	**43.7 %**	15.1 %	4.8 %	0.8 %

*Table 37: Responses to environmental aspects: How **important** do you find the following aspects related to Solar Energy Buildings?*

Environmental aspects	Very relevant	Somewhat relevant	Neutral	Somewhat irrelevant	Very irrelevant	On top of the list
CO2 emission reduction with respect to operation of the solar energy building	**63.5 %**	29.4 %	5.6 %	0.8 %	0.8 %	**49.2 %**
CO2 emission reduction considering the embodied energy of the solar energy building	**55.6 %**	33.3 %	8.7 %	1.6 %	0.8 %	32.8 %
Use of ecological materials	38.1 %	**42.9 %**	15.1 %	3.2 %	0.8 %	10.7 %
Use of recyclable materials	35.7 %	**42.9 %**	15.1 %	4.8 %	1.6 %	7.4 %

From the tables, it is elucidated that the viewpoints of academics and consultants are not significantly different.