Ostschweizer Fachhochschule

Examples of buildings with innovative heat pump integration

Université de Genève,
Séminaire Energie-environnement, 13.03.2025

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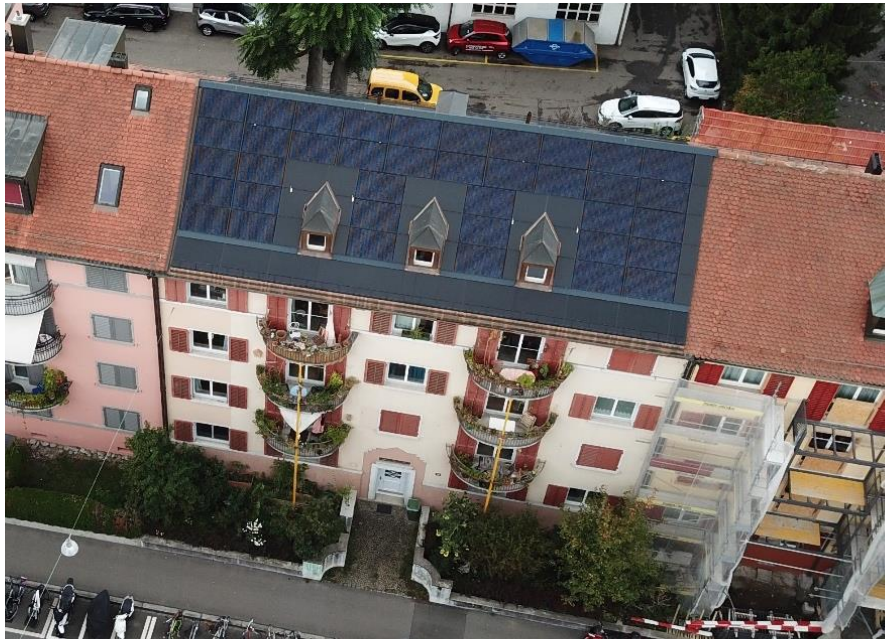
INSTITUT FÜR SOLARTECHNIK

Agenda

Presentation of two innovative heat pump systems where SPF was involved in planning and/or monitoring

Air source HP for an old building in the City of Zürich



New office building in Chur with foundation slab and PVT as HP-sources

Roof-integrated air-to-water heat pump with hybrid PV system in a downtown house

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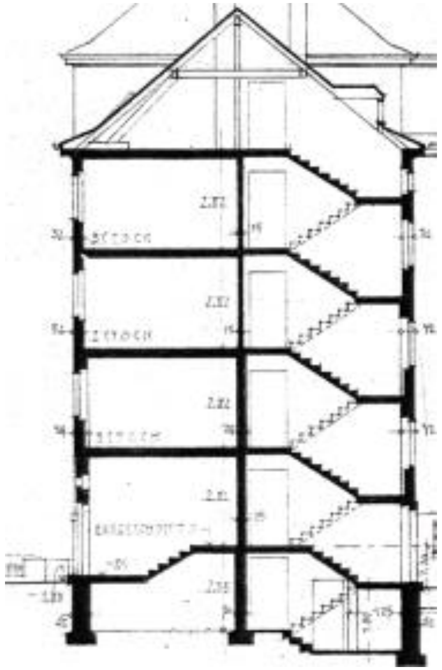
Initial Situation

- Owner: Cooperative of self-managed houses - WOGENO
- 100-year-old, 8 appartments
- Heating system: Gas boiler
- Good condition, thermally renovated
- Annual consumption: 82 kWh/m2
- Flow temperature 49°C at -8°C
- Geothermal probes for HP prohibited
- Standard LW-WP Space/noise problem



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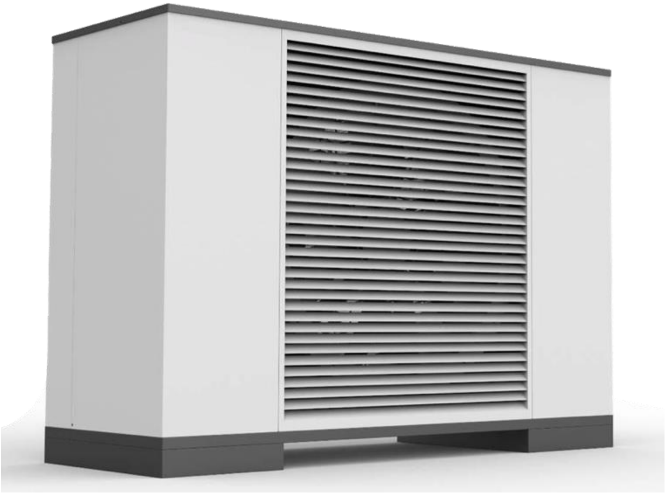
Motivation + goal setting

- WOGENO owns a number of similar city properties
- Energy future without CO2-emissions
- Modern system with high efficiency
- Compact design without compromising on comfort
- If possible, continue to use existing components
- No wasted space
- No noise emission to neighbors

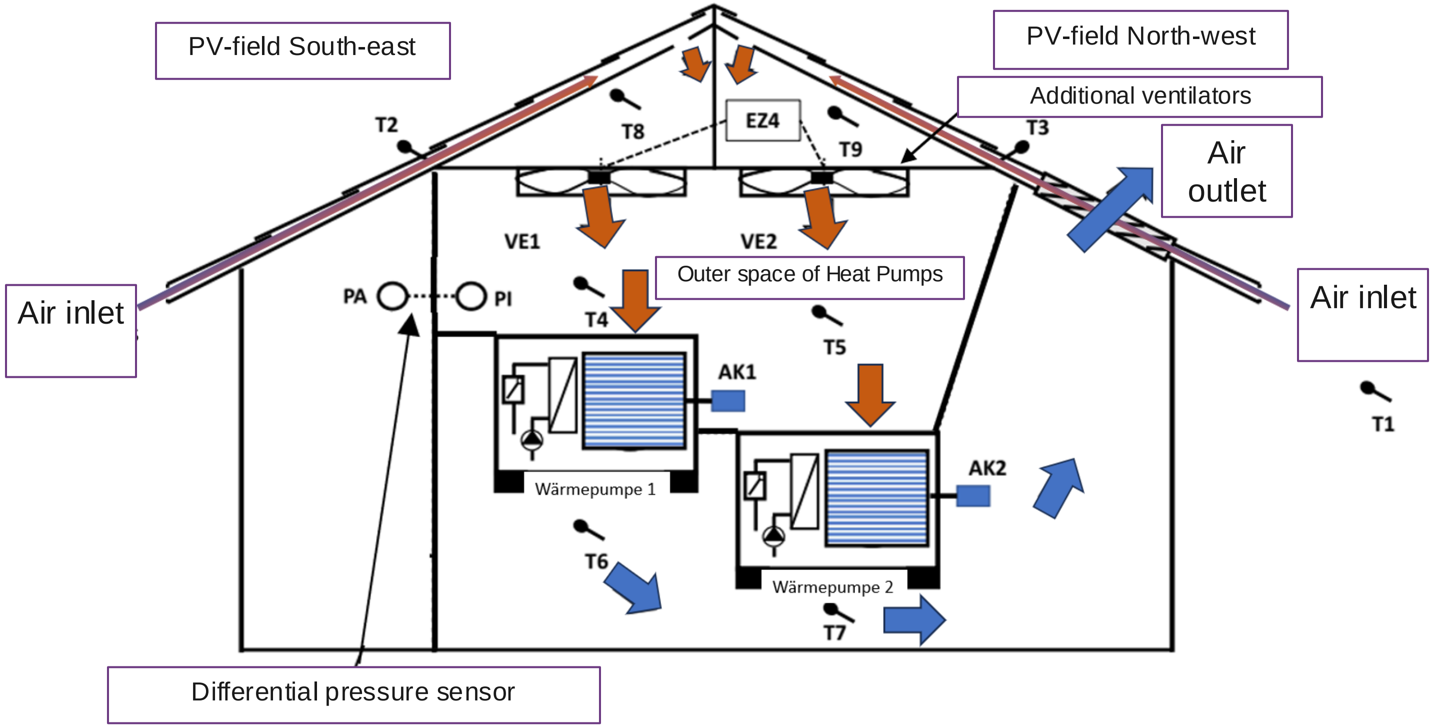
Wogeno houses locations in Zurich

Solution: System concept for heat and electricity supply

- Air-source HP cascade with 2 M-Tec WPLK618
- SOLTOP energy roof 24 kW-peak, fully integrated as an air collector onsite PVT-system
- South-east + North-west roofs each with duct and fan
- Integration of the system into the roof and attic

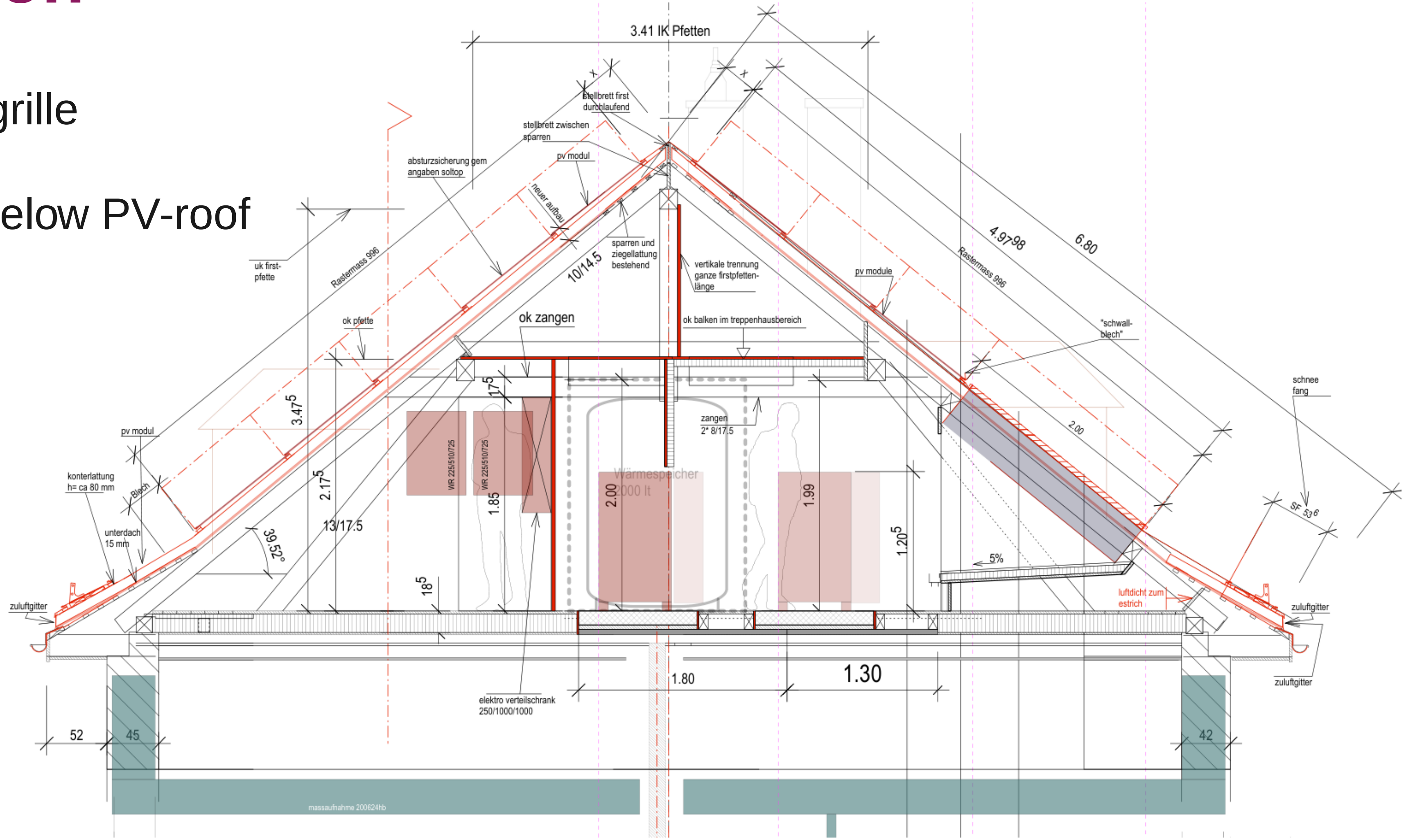


System concept: details of the air flow



Roof construction

- Fresh air inlet with inlet grille
  - Highest pressure drop
  - Good air distribution below PV-roof



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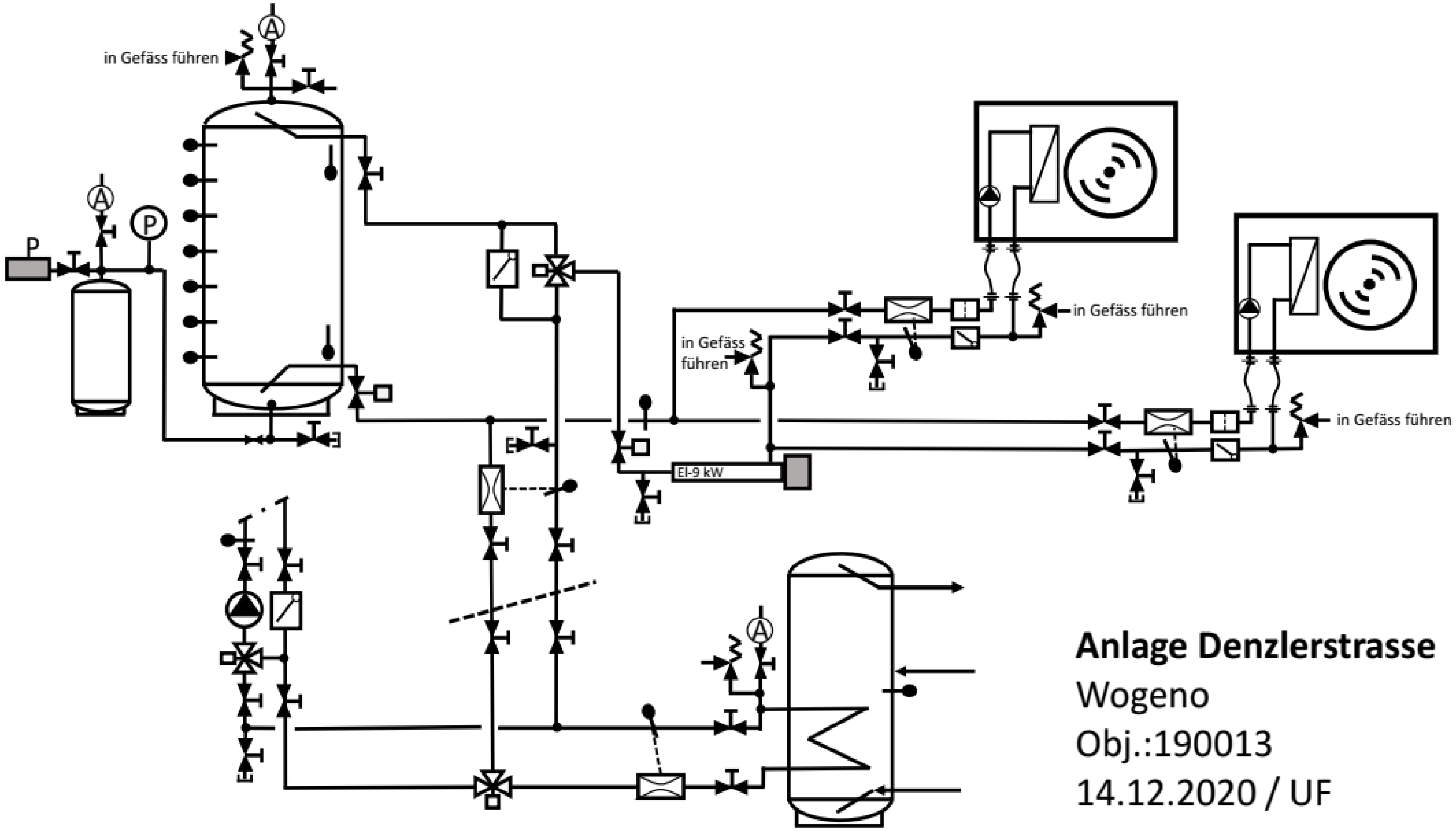
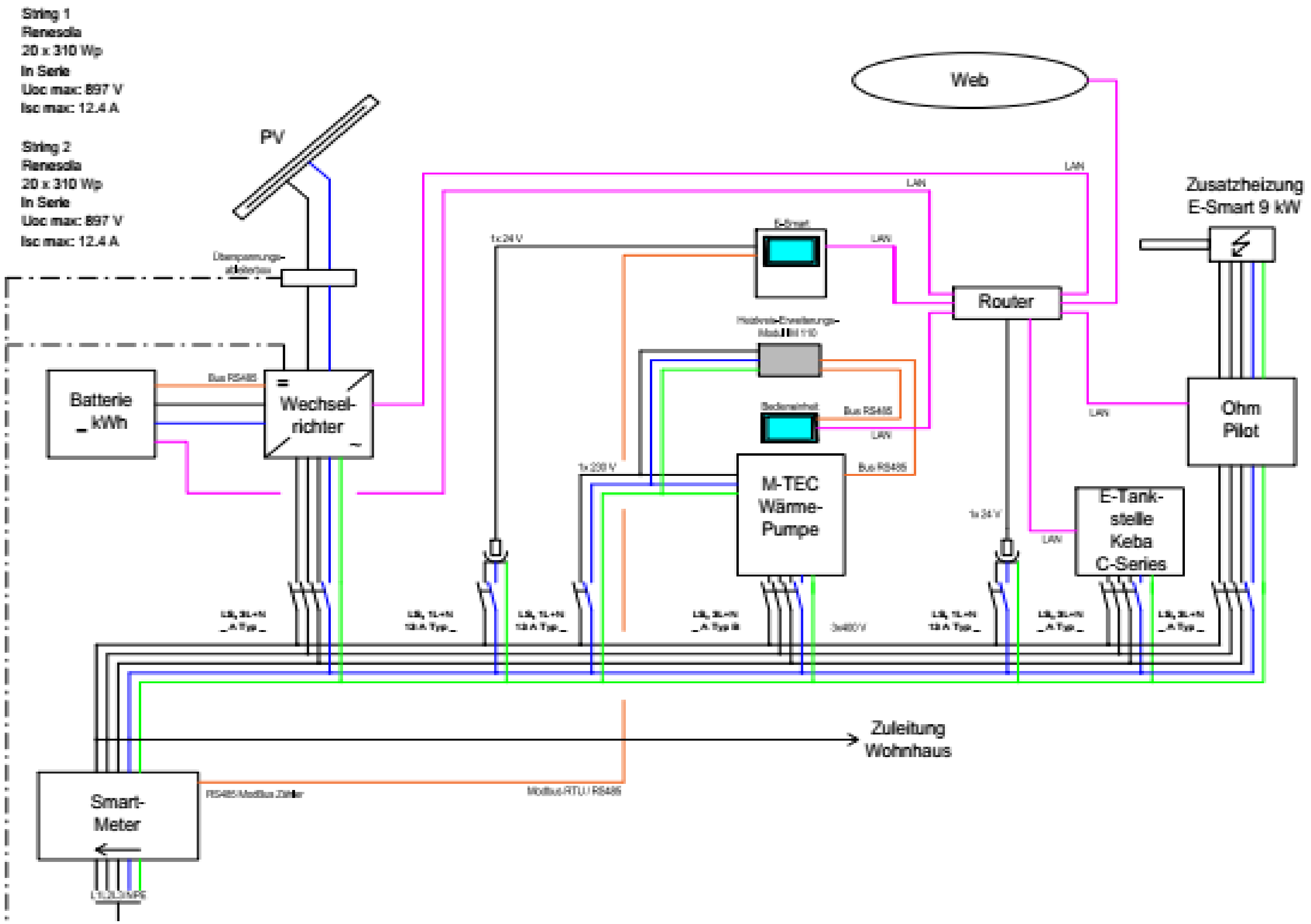
Heating System

- 2000 l storage tank for PCM
- Old 500 l boiler, 6 m^2 register
- Heating rod, 9 kW
- New boiler from December 2023



Electrical diagram

- All components connected via LAN
- Communication via Modbus TCP
- Combination of EMS (E-Smart) and control system
- New electric house connection with ZEV (RCP, consommation propre)
- Battery: 14 kWh



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Realization (Fall 2020, total duration 2 months)

Attic after demolition of the chimneys

Concrete foundation for HP

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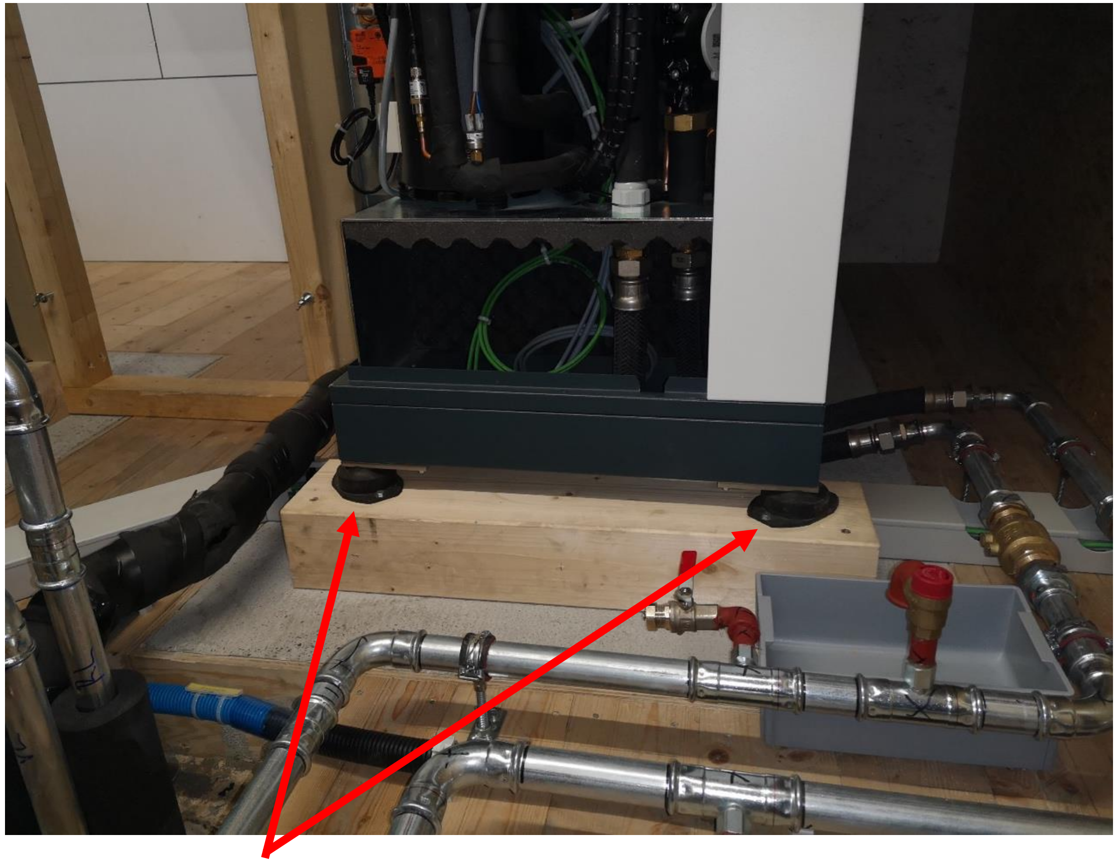
Inserting the heat pump

Installation of storage tank and heat pumps

Insert storage tank



Vibration damper for the HP

Air inlet and outlet for the heat pumps

Air intake grille above the rain gutter in the solar roof

Air outlet niche for both HPs

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Winter operation

- No restrictions for intake and discharge openings during snowfall

Air intake grille above the rain gutter in the solar roof

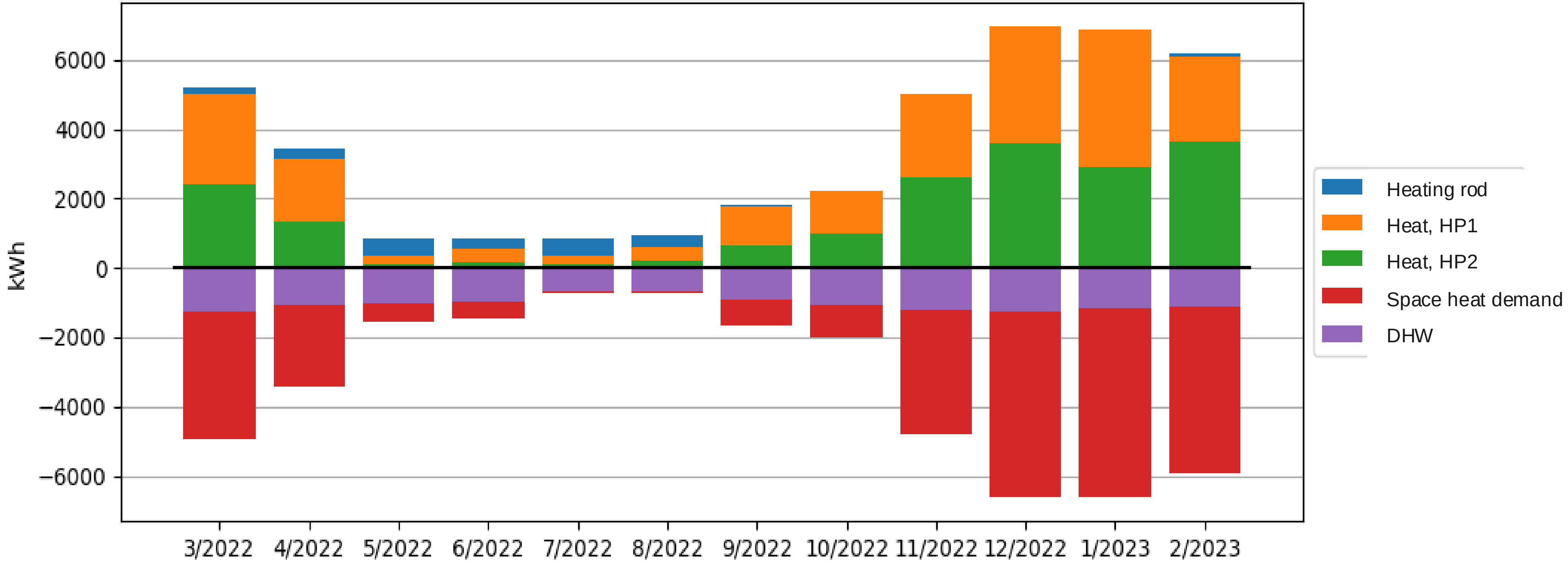
Air outlet opening of both HPs

Energy parameters of the energy supply

Parameter	
Space heating + hot water	28 MWh/a + 12 MWh/a
Energy index for SH & DHW	59 kWh/m a^2
Electricity consumption (without cooking)	20 MWh/a
PV yield	21 MWh/a
SPF (seasonal performance factor)	3.86

- Old building with moderate thermal insulation, only one façade insulated
- High SPF against the background of high radiator flow temperatures (T-flow 49 °C @ -8 °C T-outside air)

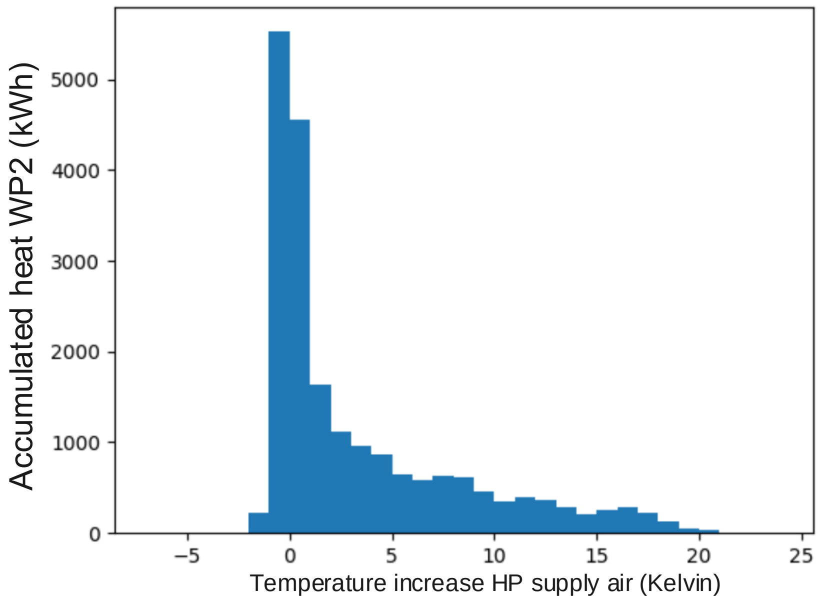
Heat supply and heat demand



Effect of air heating on the efficiency of the heat pump

- **Seasonal Performance Factor (year)**:
  - Preheating increases the SPF by approx. 0.38
  - from SPF 3.52 to SPF 3.86
- **No relevant contribution of summer period**:
  - Only little heat demand
  - Outside air already warm (15 - 30 °C)
  - Further warming by 7 to 10 K

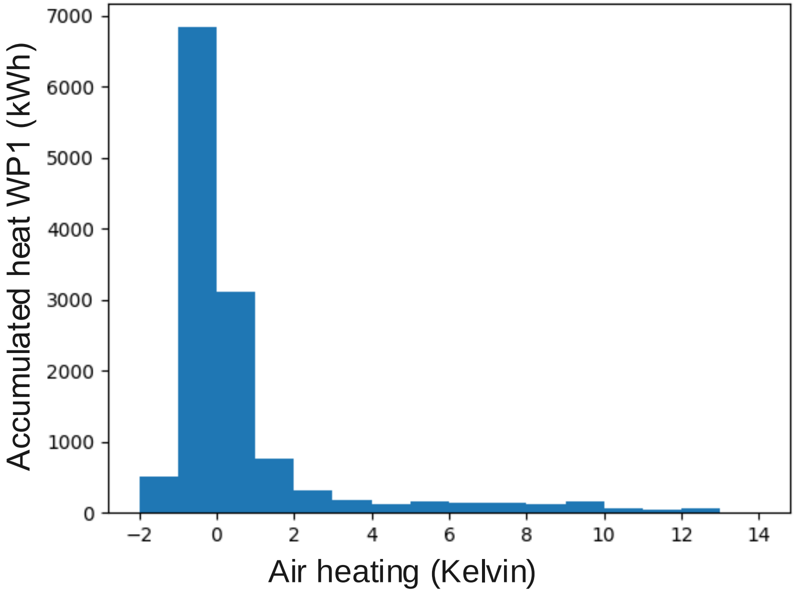
Annual values: heat supplied by WP2 versus deltaT of air heating



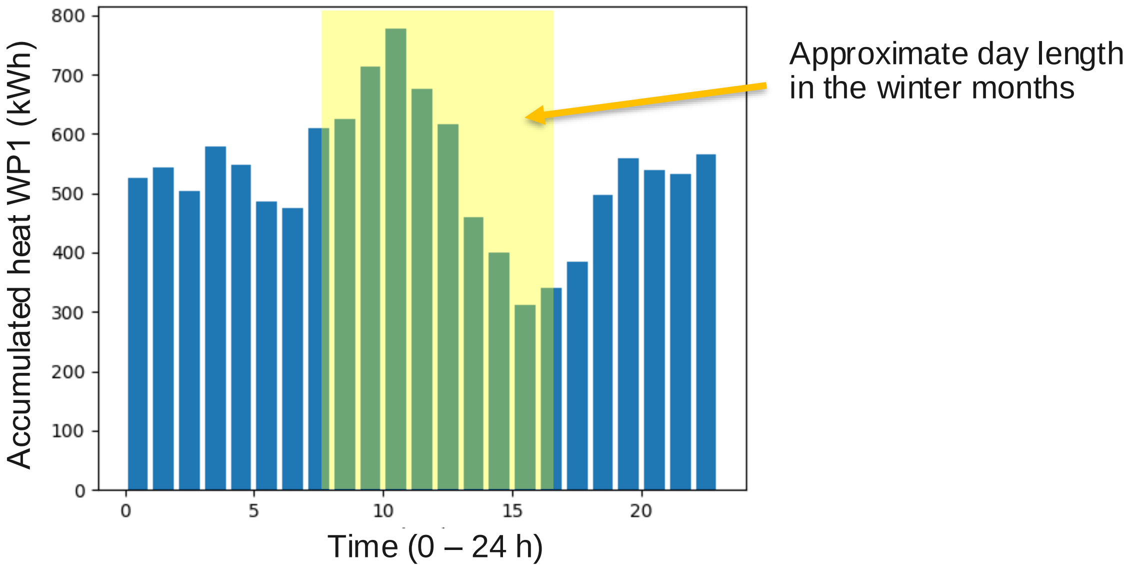
Effect of air heating on the efficiency of the heat pump

- Effect of preheating in **winter (here: Nov. - Feb.)** less than expected
- Shifting the heat pump running times to hours of sunshine would be good (would require thermal storage capacity, which is not available in this building)

Winter: heat supplied by WP1 versus deltaT of air heating



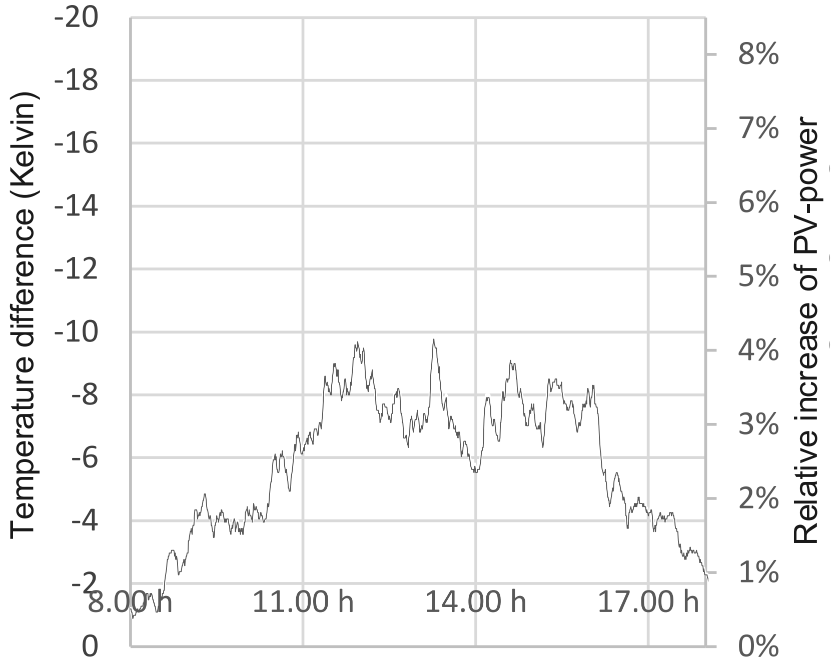
Winter: heat supplied per time of day



Effect of ventilation on the efficiency of the PV system

- Test on three very similar summer days with variation of the **fan output: 0 %, 40 %, 100 %**
- **0 %**: no cooling («reference PV system»)
- **100 %**: PV additional yield lower than power consumption of the fans
- **40 %**:
  - Increase in PV daily yield from 110.0 kWh to 112.4 kWh
  - Additional yield minus electricity for fans: +1.5%
- Result: only a small increase in PV yield in summer due to the cooling of the PV modules

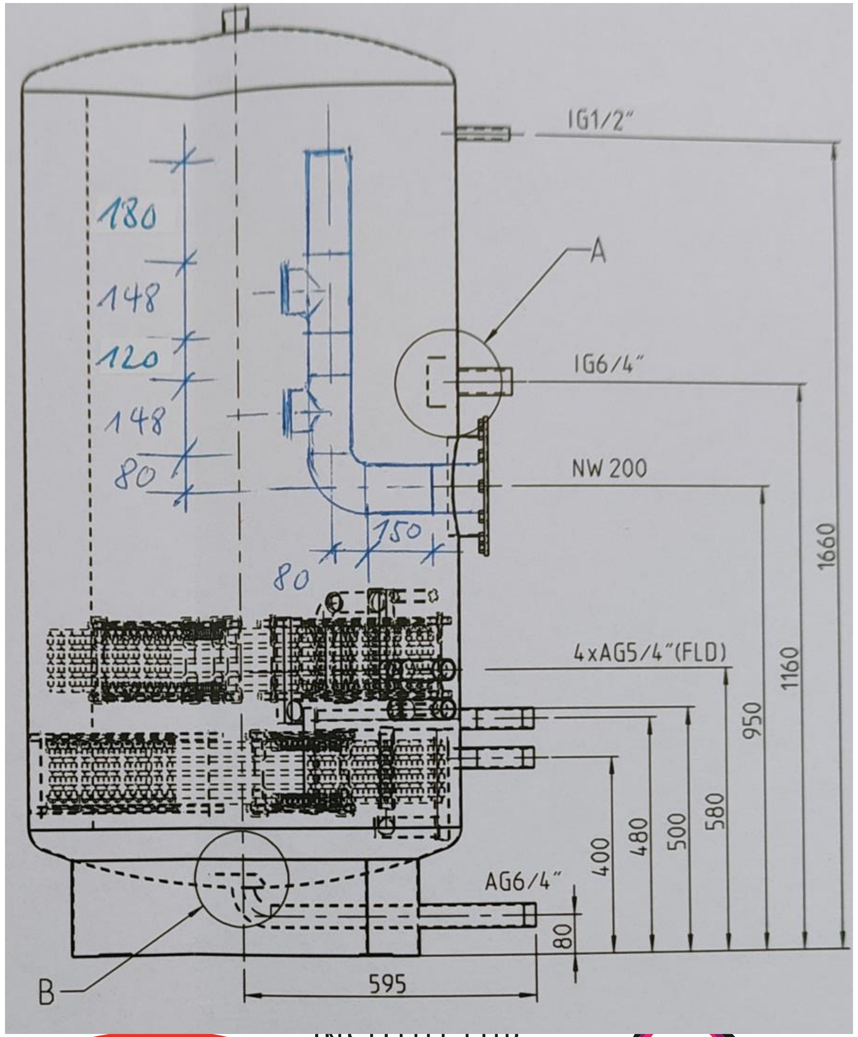
PV module cooling resp.
PV efficiency increase
at 40 % fan power



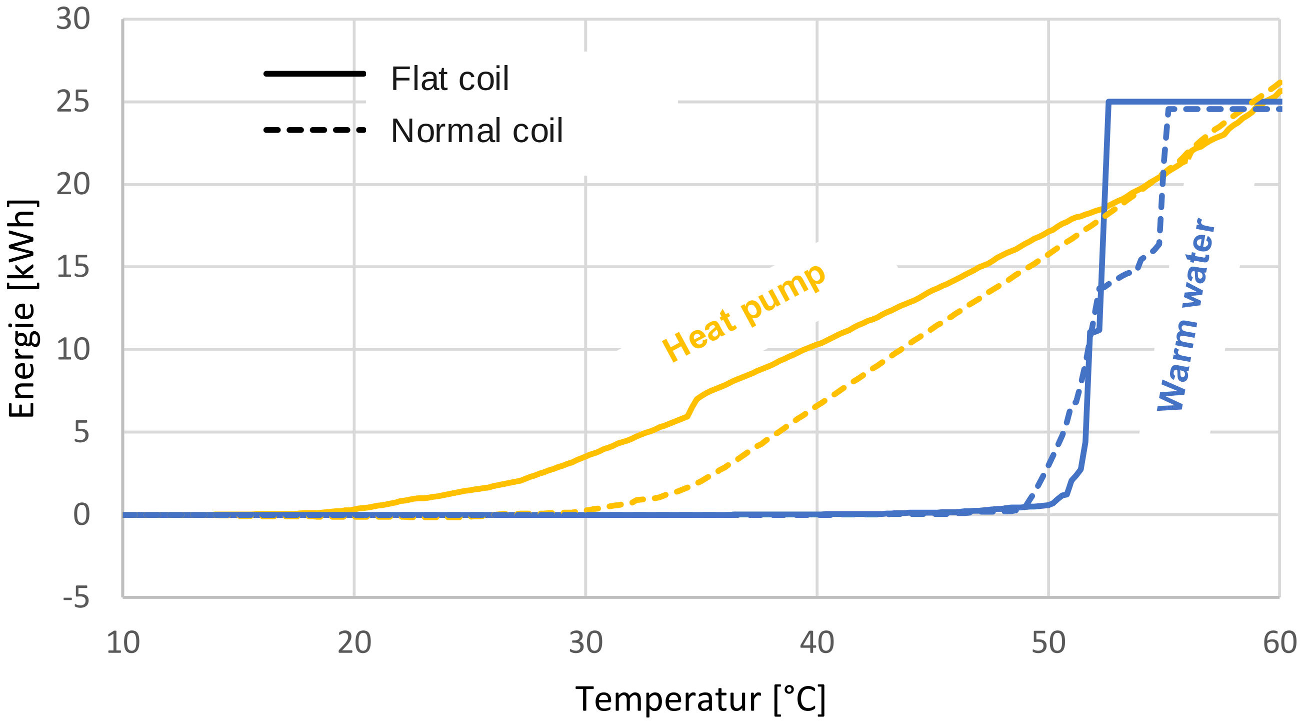
Boiler replacement Goal 1: fewer charging cycles!

OLD:
- Enamel boiler 500 litres
- Tubular heat exchanger 6 m^2

New:
- Stainless steel boiler 800 l
- Flat coil heat exchanger 8.5 m^2
- Circulation-return layer lance



Boiler replacement Goal 2: higher COP!



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Estimation of economic efficiency

8 apartments, ERA 690 m^2 , Heat demand$_{SH,DHW}$ 59 kWh/a, part of a 100-year-old perimeter block development

Variant		Investment costs	Amortization (gas price 20 Rp./kWh incl. maintenance)
Like implemented (PVT roof and roof-integrated air-to-water heat pump)		355’000 Fr.	without subsidies: 29 years with subsidies: 17 years
Minimum variant (only roof-integrated air-to-water HP)		133’000 Fr.	16 years (without subsidies)

Evaluation and outlook

- Heat pump:
  - Successful demonstration of the roof integration of two air-to-water heat pumps (noise / "all-weather operation")
  - Supplement to "classic" HP-concepts – particularly interesting in an urban context
- Building:
  - 100-year-old building now on net zero energy with (very) good operation, JAZ 3.86
  - Further potential: floor heating (reduced T_{flow} , thermal mass) or fan convectors (reduce T_{flow})
- PVT roof:
  - Benefits <u>in the presented building</u> are low (heating of the HP supply air / cooling of the PV)
- Soltop Energie AG is examining the market launch of a roof-integrated heat pump box (without PVT)

Thermally acitvated foundation slab and hybrid (PVT) solar system for a new office building

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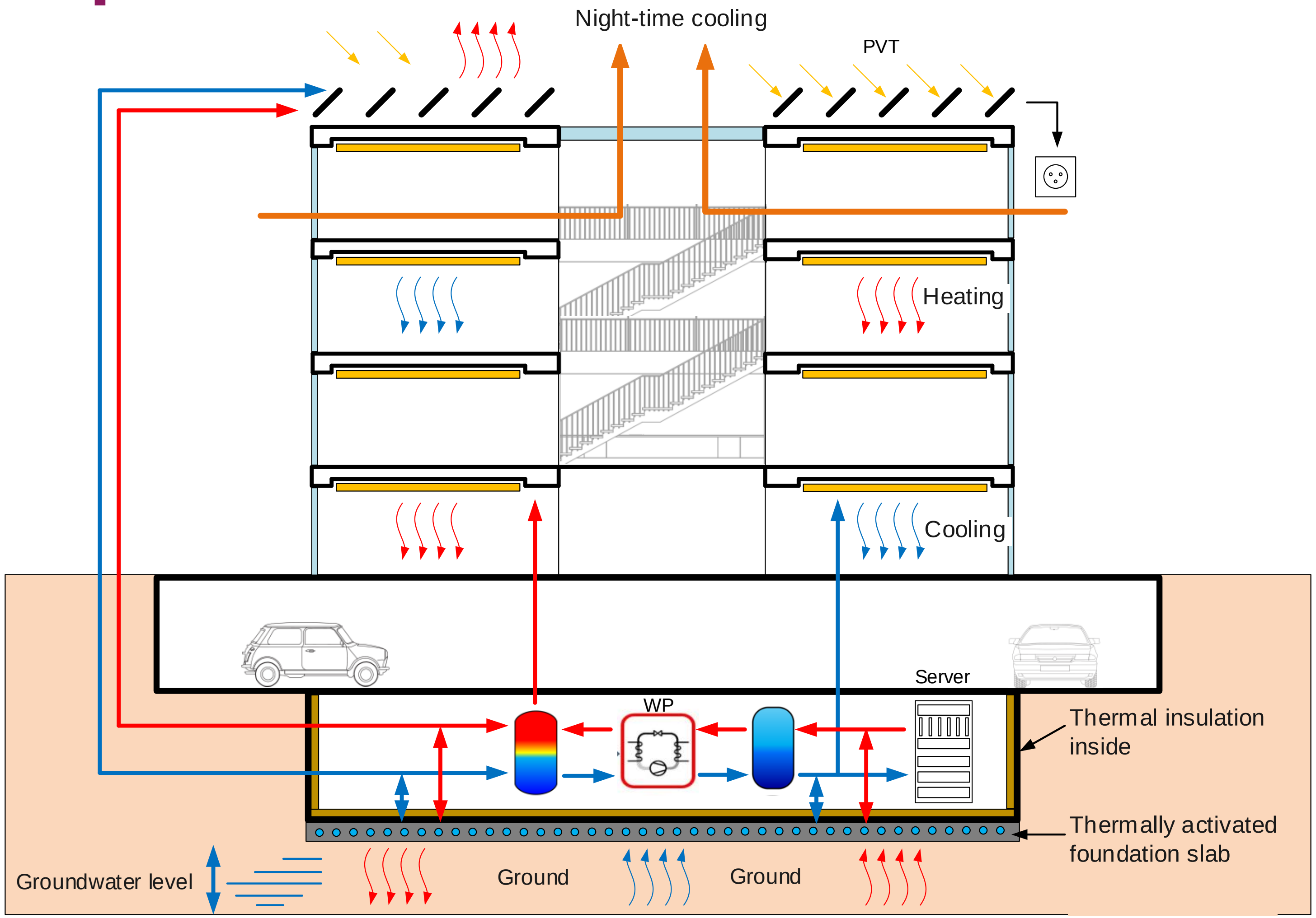
vassella
erneuerbare
energie
rinnovabili

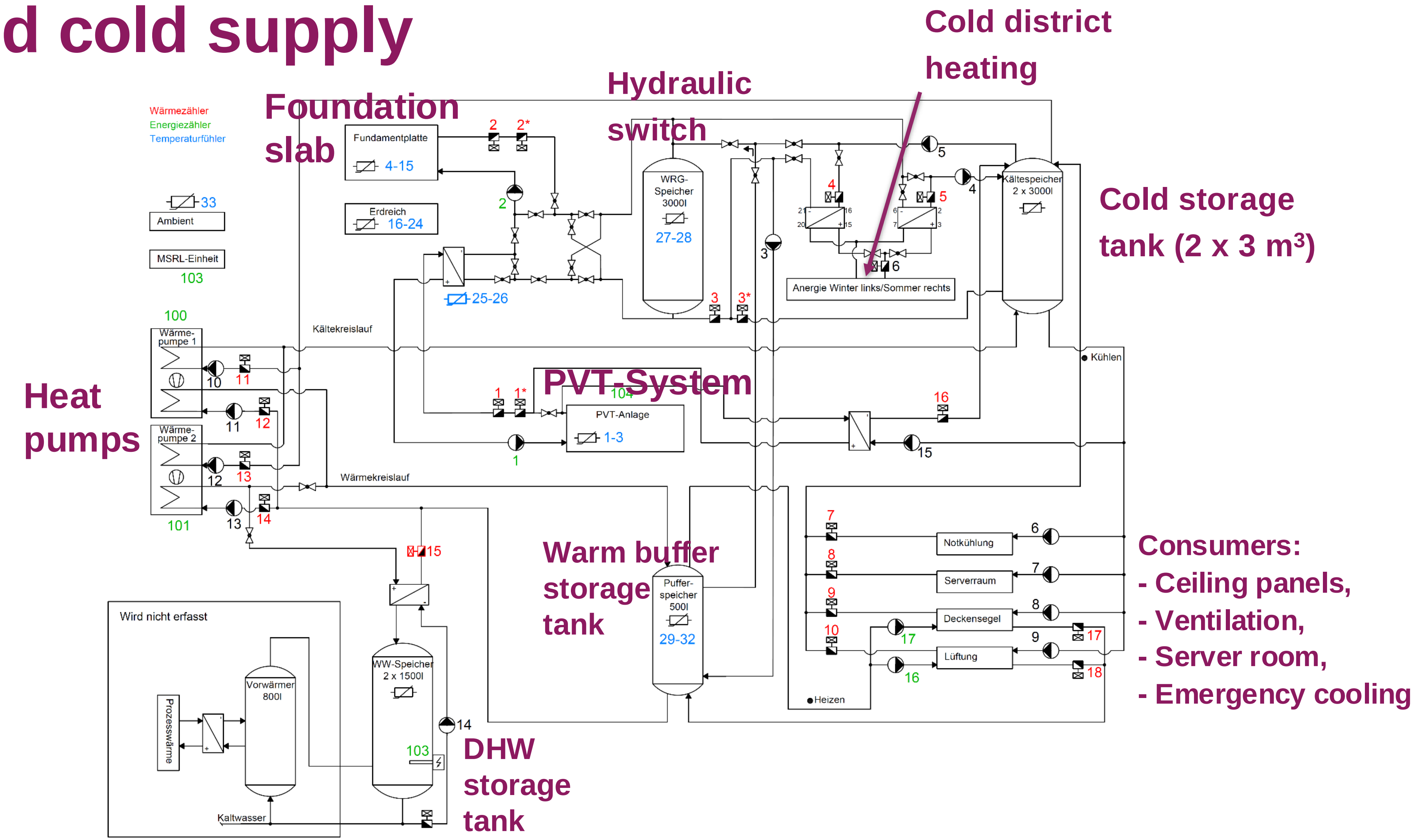
Introduction

- **Motivation**
  - 6000 m² new building with exemplary character
  - Achieving the highest possible level of self-sufficiency for electricity and heat
  - Owner‘s mission: implementation of projects with pioneering, innovative technologies
- **Questions to be answered (foundation slab / HP-system)**
  - Can an office building of this type cover its own heating and cooling requirements with PVT and a thermally active foundation slab?
  - How should the foundation slab be optimally managed?
  - Can the necessary cooling capacity be provided with a PVT system?

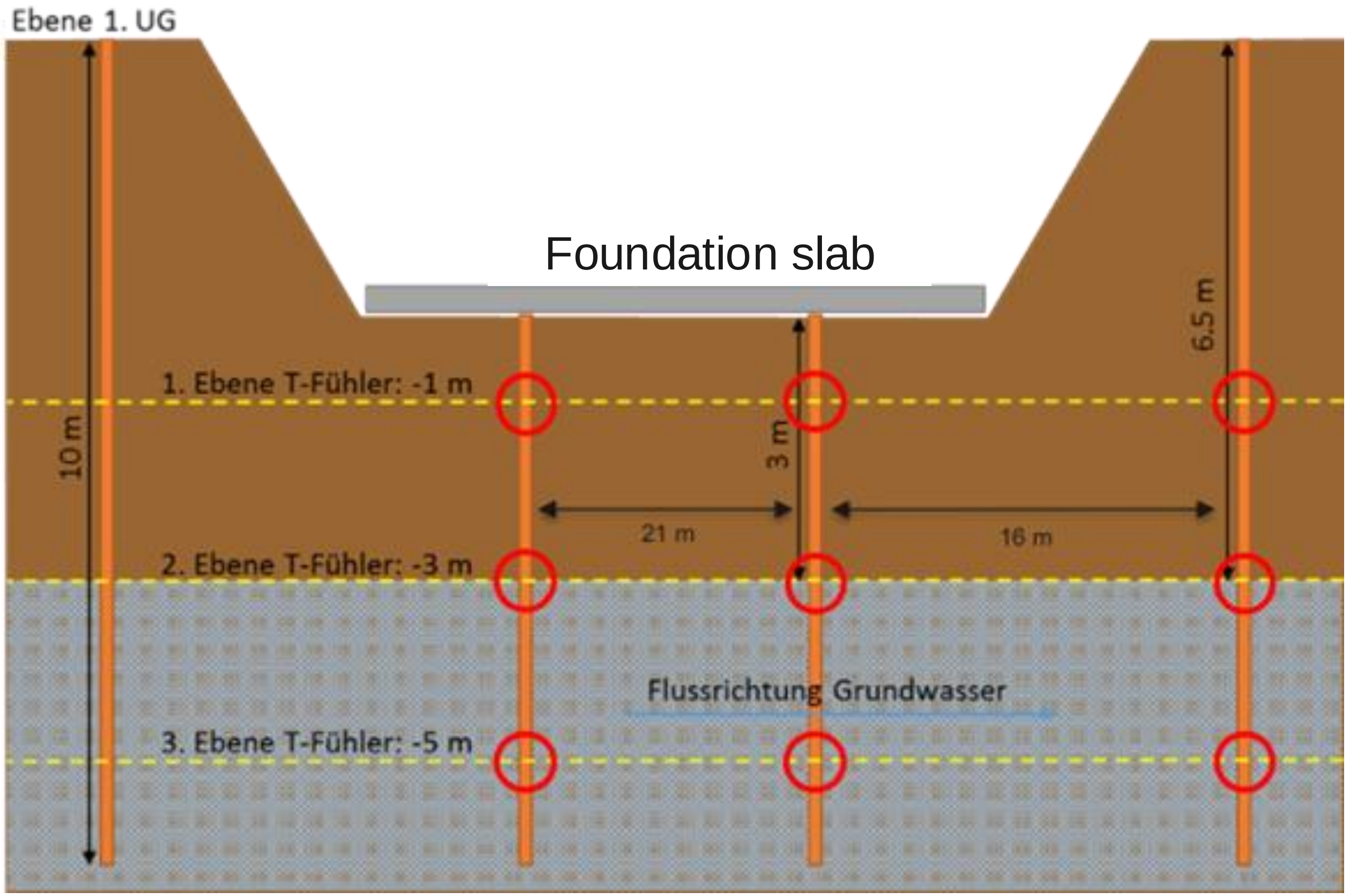
System description



Heat and cold supply



Cross-section of ground with temperature sensors



Dry ground up to approx. 3 m below slab

Ground water influence assumed

Excavation

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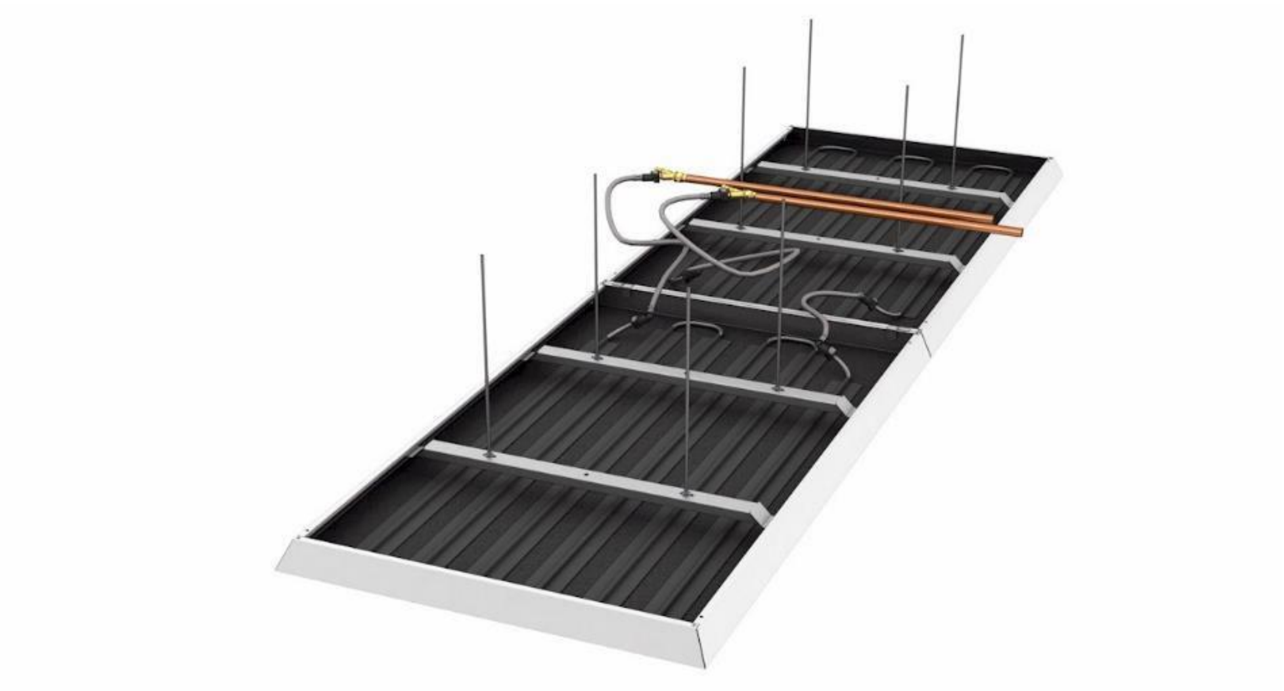
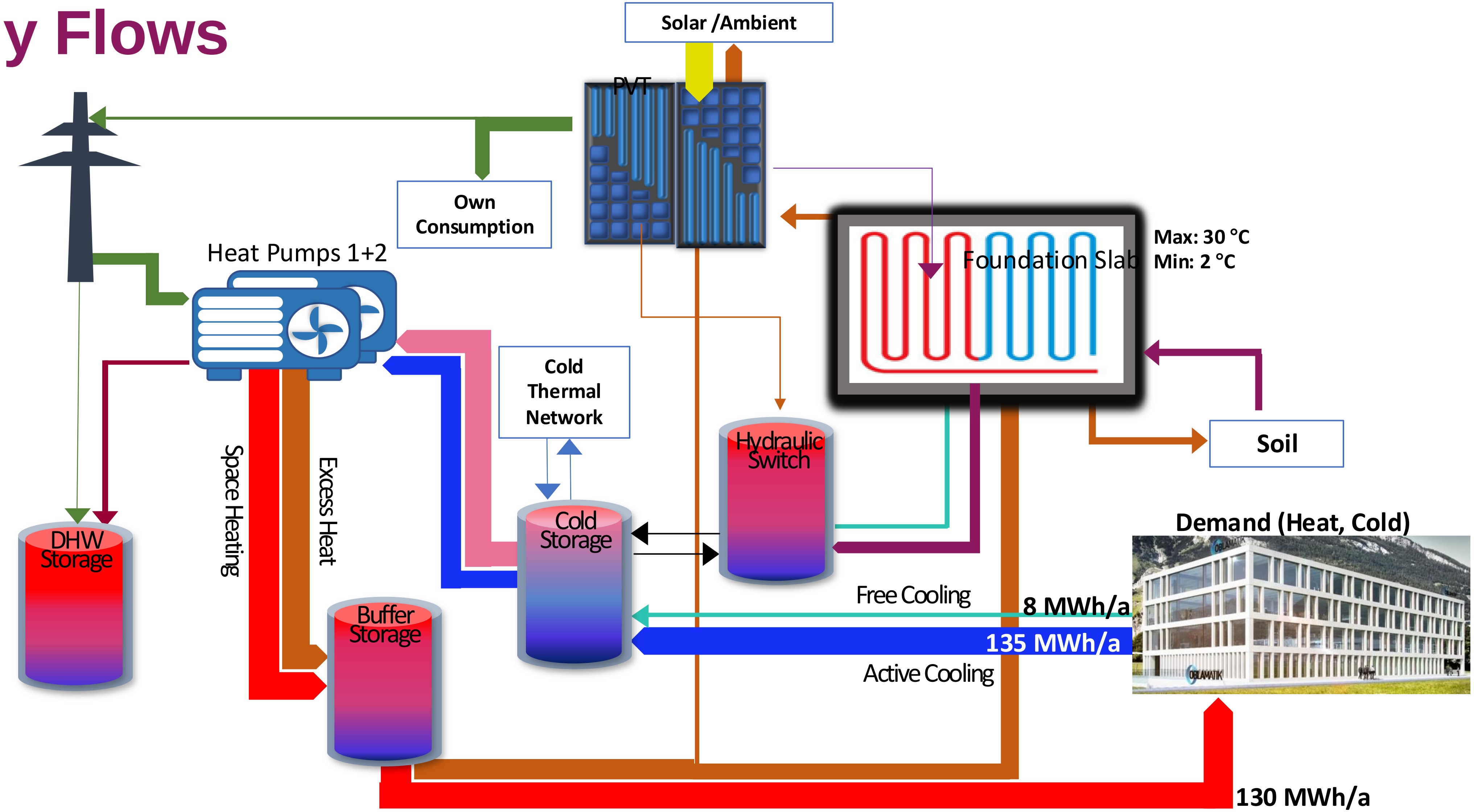
Laying of piping in the foundation slab

PVT system on the flat roof

Ceiling panels for heating and cooling



Energy Flows

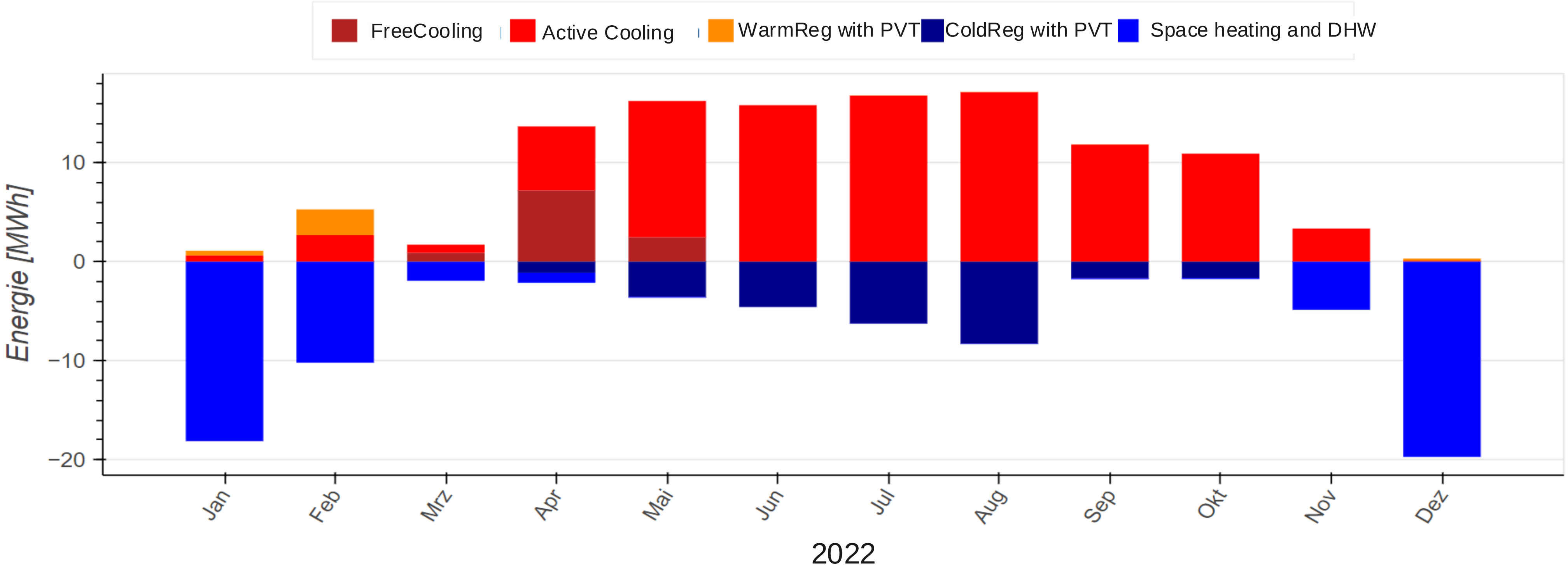


Key indicators of the system

- **Demands**: Cooling 143 MWh/a, Space Heating 130 MWh/a
- **Heat pump efficiencies**:
  - Space heating: 5.8
  - Cooling: 4.8
  - Domestic hot water: 3.5
- **Autarky** from Cold Thermal Network: 99 % (nearly not needed…)

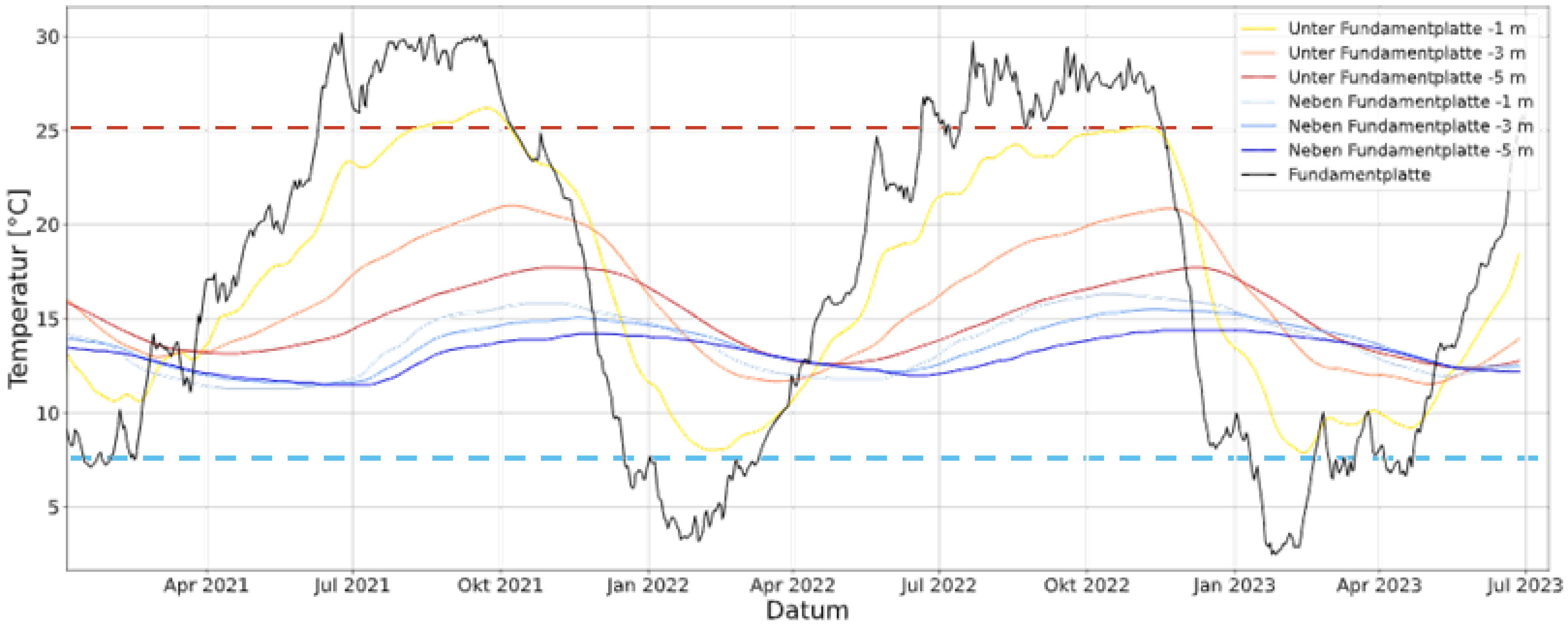
Foundation slab

- Heat input: 104 MWh/a
- Heat output: 86 MWh/a
- Max. cooling capacity: 153 kW
- Max. heat output: 120 kW



Foundation slab: need for “sophisticated” control logic

- From October to March (winter): Cooling down of foundation slab only if its temperature is > 25 °C
- From March to July: regeneration with PVT heat only if foundation slab temp. < 7 °C



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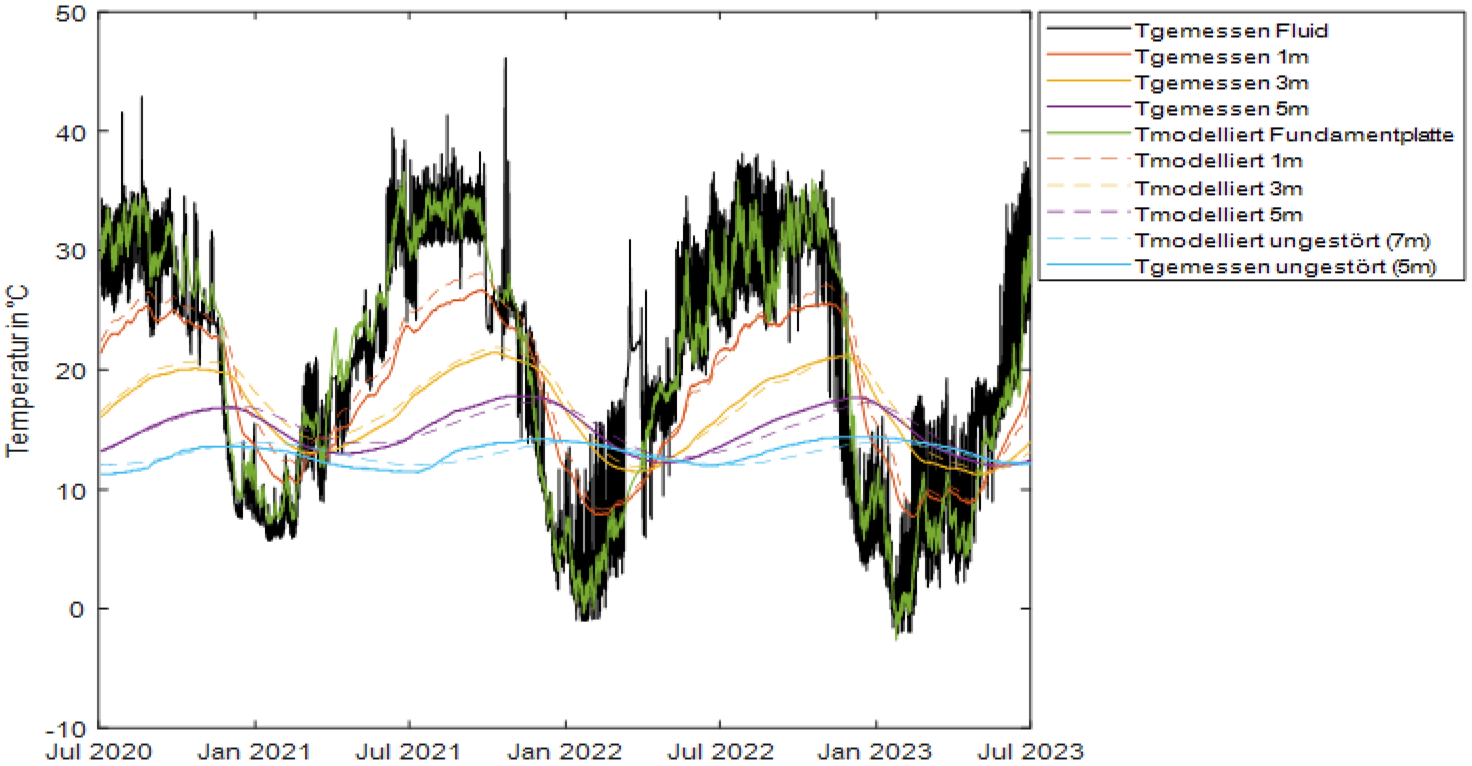
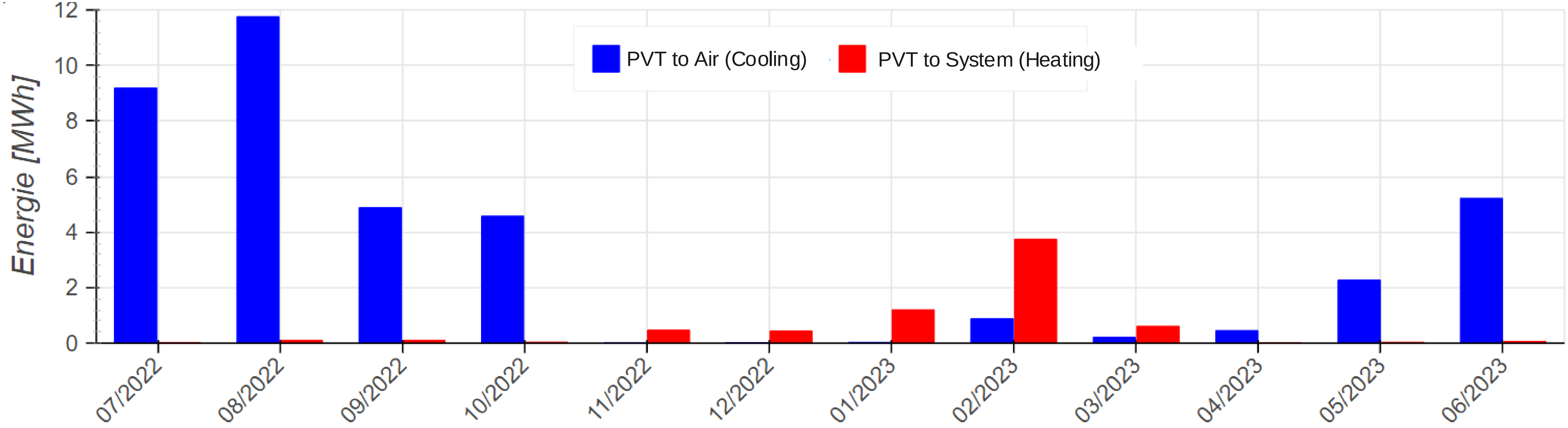
Foundation slab + ground: validated model

- Matlab model on temperatures in the foundation slab and in the soil
- No impact on groundwater and vice versa



PVT system (384 m²)

- Specific cooling yield: 127 kWh/m²
- Specific heat yield: 14 kWh/m² (only!)
- Max. Cooling capacity: 80 kW
- Max. Heating output: 60 kW
- normal PV yields



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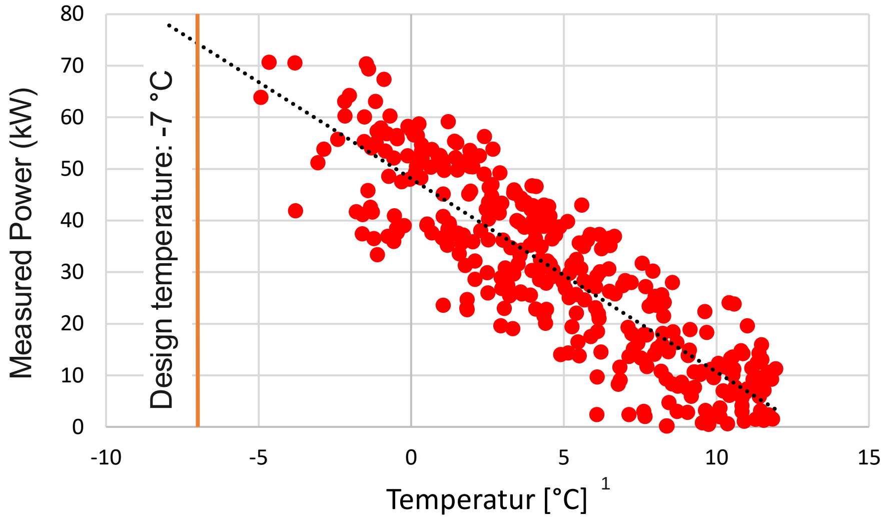
Heat pump sizing

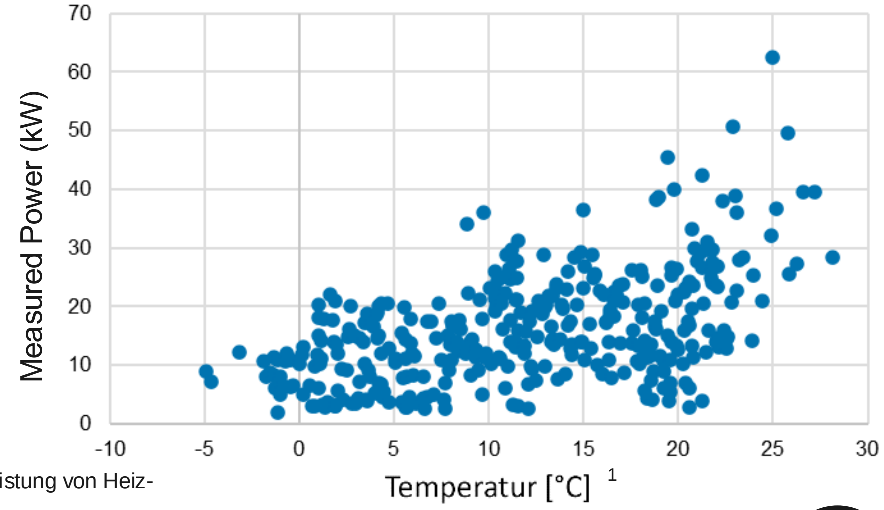
- Planed heating/cooling capacity
  360 kW / 252 kW

- Installed heating/cooling capacity:
  160 kW / 90 kW

- Measurements:
  - Required heat output 75 kW
  - Required cooling capacity approx. 45 kW

- Consequences of oversizing
  - Frequent starts (up to 15 times per day)
  - Reduced service life of the compressor





[1]according to: I. Bosshard, M. Troxler, A. Guliyeva, K. Klevitz, M. Haller, et al. OptiPower - Untersuchung der optimalen Auslegung der Leistung von Heiz- und Kühlsystemen für Wohn- und Verwaltungsgebäude, SPF Institut für Solartechnik, Swiss Federal Office of Energy SFOE; 2023.

Cost comparison (estimations)

Costs in CHF		PVT system with thermoactive slab	PV system with recooler + thermoactive slab	PV system with A/W-HP	PV system + geothermal probes
CAPEX	Heat pumps	80'000	80'000	246'000	80'000
	Thermoactive slab	220000	220000	0	0
	Probe field	0	0	0	500'000
	PV/PVT system	285'000	100'000	100'000	100'000
	Recooler	0	40'000	0	0
	Subtotal for installation costs	**585'000**	**440'000**	**346'000**	**680'000**
OPEX (20 Years)	Electricity HP and circulation pumps	360'000	375'000	461'000	375'000
	Maintenance system (0.5% CAPEX)	58'500	44'000	34'600	68'000
	PV electricity	-420'000	-420'000	-420'000	-420'000
	Subtotal operating costs	**-1'500**	**-1'000**	**75'600**	**23'000**
	Total costs	**583'500**	**439'000**	**421'600**	**703'000**
Yearly costs	**T = 20 a, i = 6%**	**50'900**	**38'300**	**36'700**	**61'300**

Conclusions

- Heat pump
  - System efficiency very good (overall $SPF_{heat\&cold}$ 5.0)
  - Thanks to dynamic simulation (IDA-ICE), the capacity calculated according to SIA could be significantly reduced
  - Still tendency to on-off-operation of the HPs
    - critical for efficiency and lifetime…
    - In case of replacement: several HP with unequal capacities?
  - HP-system is 5 K better than a conventional air-water heat pump solution, i.e. more efficient

Conclusions

- Foundation slab
  - Works well, after optimization practically independent of the cold thermal network
  - Positive overall heat balance (more heat input)
  - The minimum temperature was lowered by adding glycol □ better usage of the slab
  - No groundwater influence □ confirmed by numerical model
- PVT
  - In present building: unused heat potential
  - As a consequence of very low heat extraction: normal PV yields
  - Rather low use as a direct heat source in the winter months
- Complete system
  - The system is well regulated and works according to the requirements.
  - The system is complex and change can affect the balance of the overall system

HP-solution for an old building in the City of Zürich

Project Report (in German language):
Download-Link

New office building in Chur with foundation slab and PVT as HP-sources

Project Report (in German language):
Download-Link