IEA HPT Annex 49





Long-term monitoring and smart heat pumps for nZEB

Franziska Bockelmann

Christina Betzold

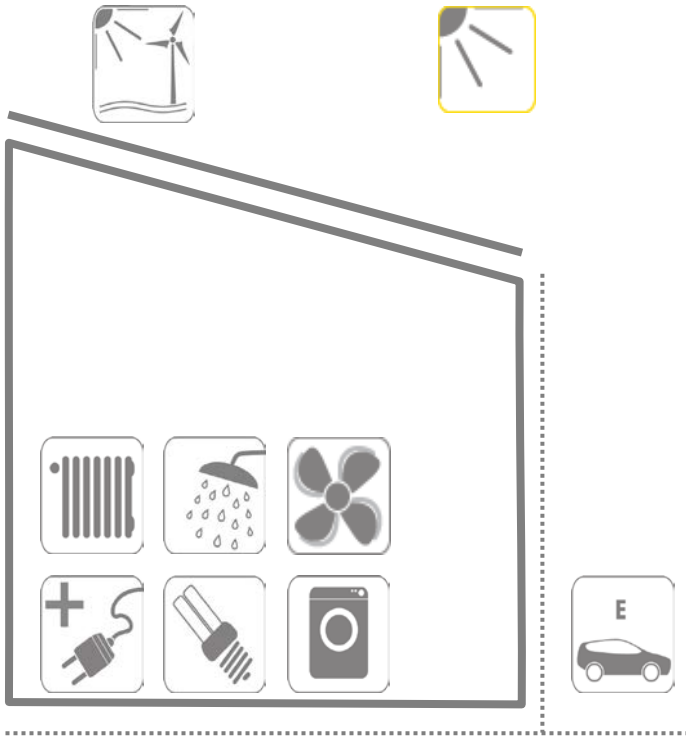
Berghalde



1. Monitoring results
2. Optimization: increase of self – supply
   - Implementation building
   - Systemsimulation
3. Outlook and conclusion

Characteristics of the energyplus standard

Balance limit



Requirements

- heating / cooling
- domestic hot water
- ventilation
- auxiliary energy
- lighting
- appliance
- renewable energy
- e-mobility

FED < 0

PED < 0

FED: Final energy demand

PED: Primary energy demand

- **Annual balance of primary energy and final energy ≤ 0**
- **Direct self energy use > 30 %**

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single family house
(4 Persons)

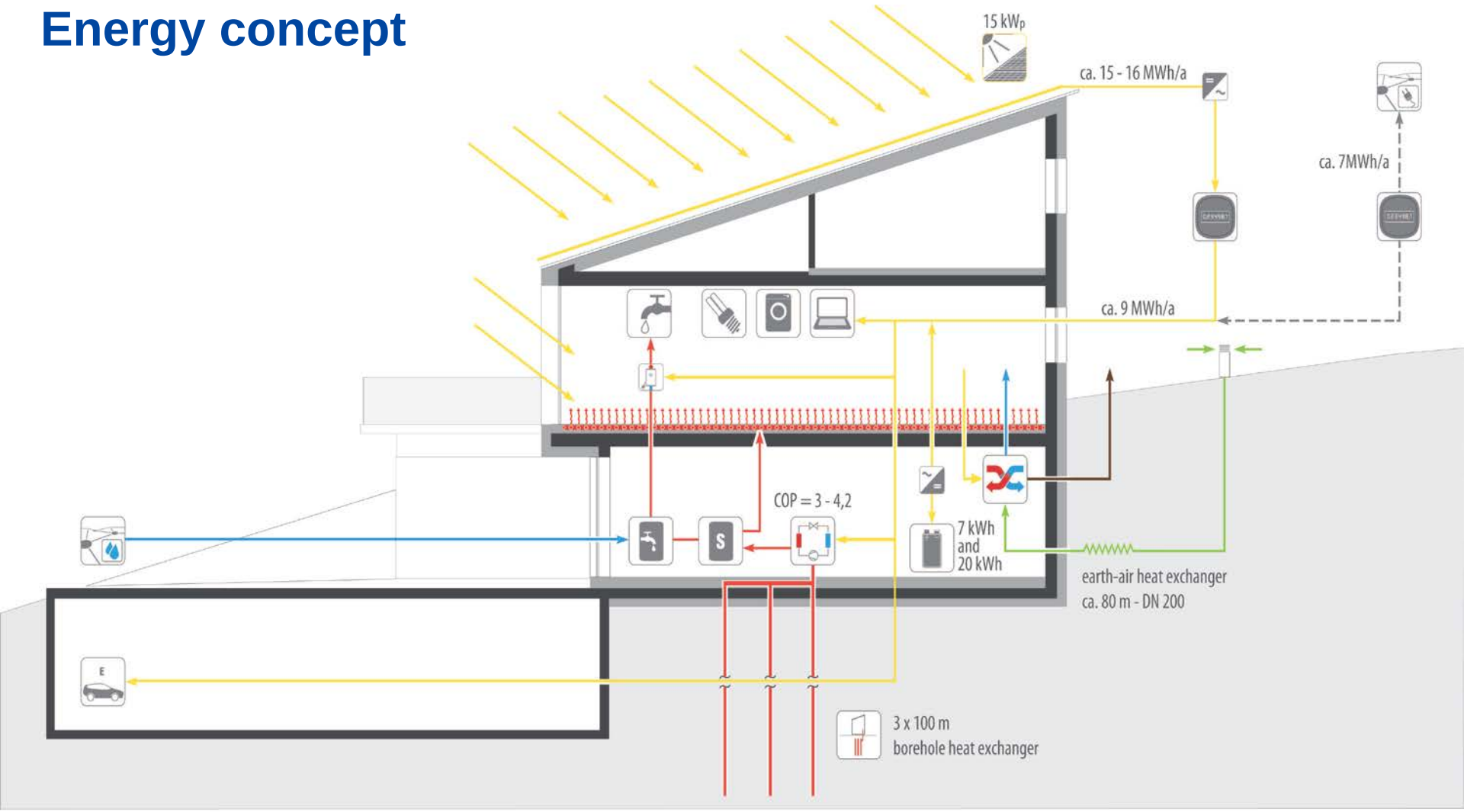
near Stuttgart

build 2010

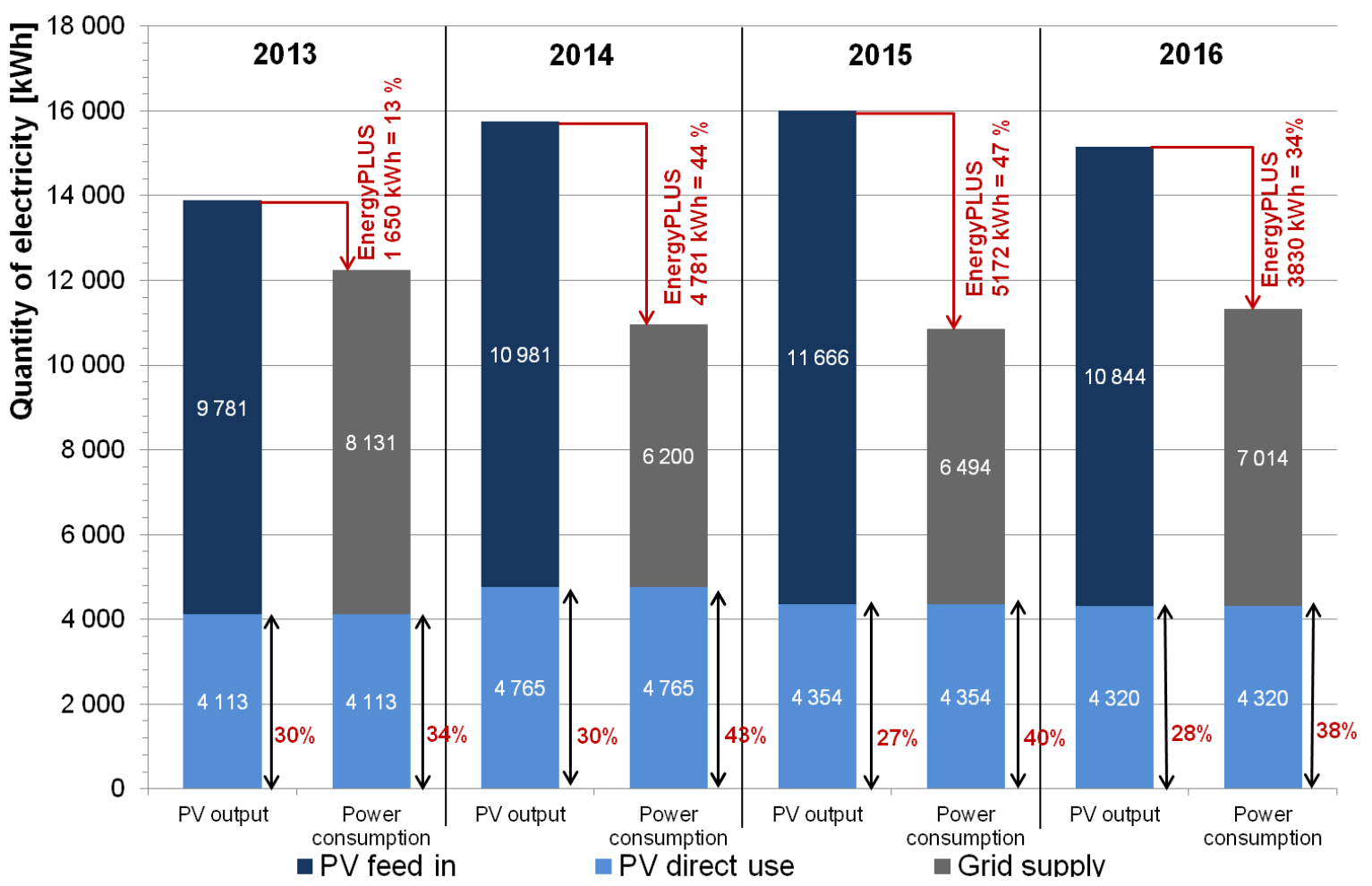
260 m² floor area

high energy efficiency
- orientation
- shape of building
- high quality air-tight envelope

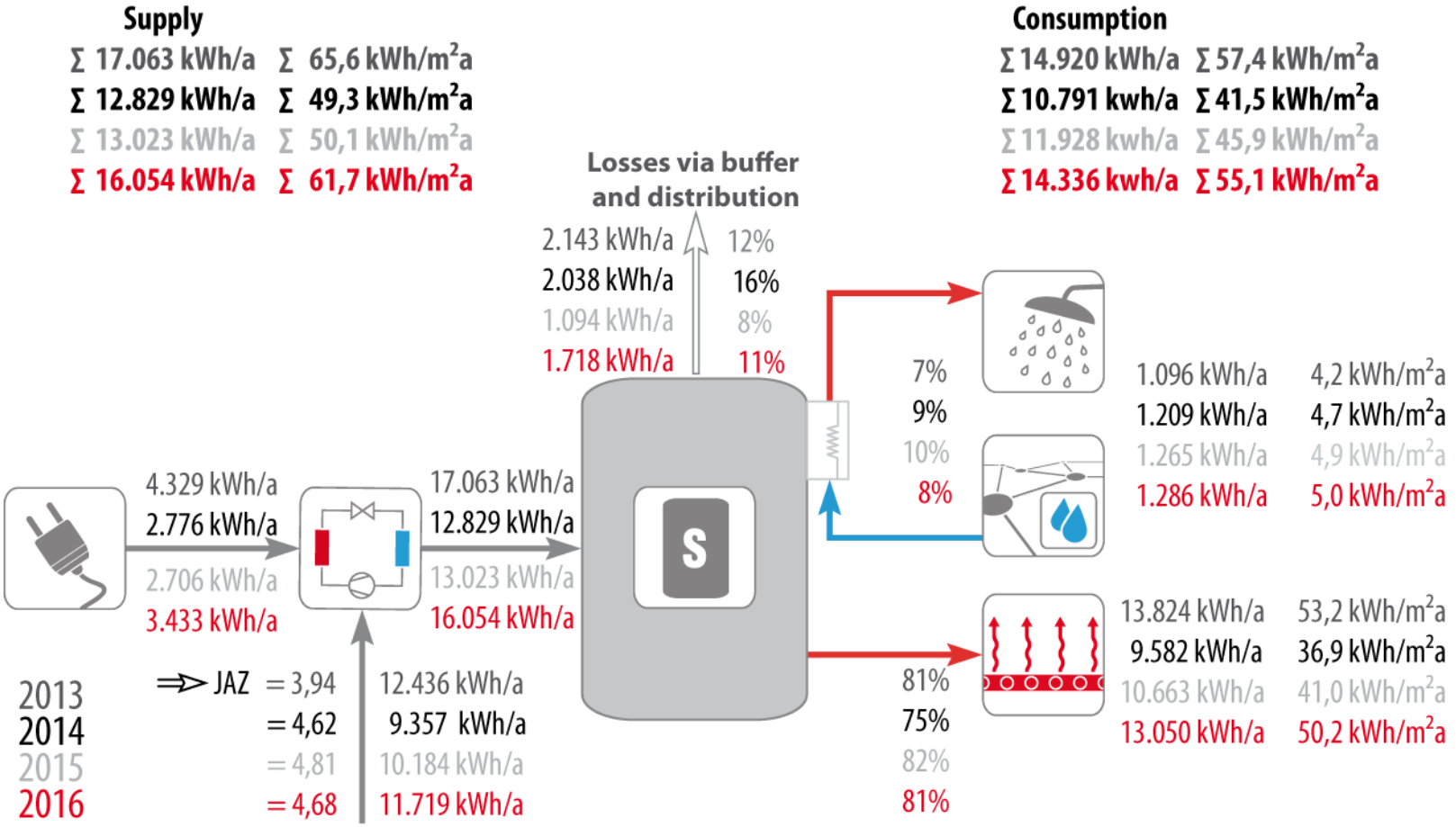
Energy concept



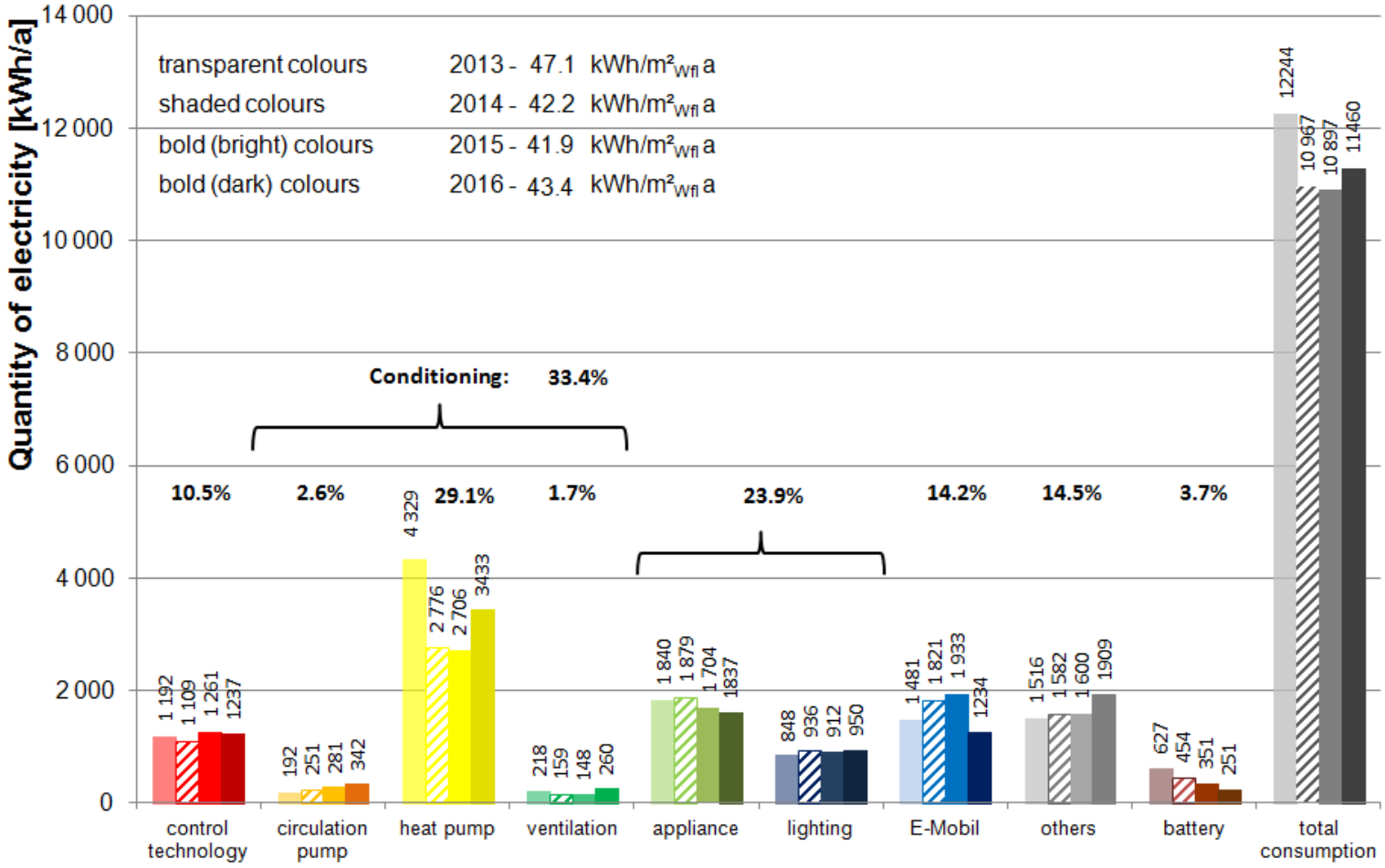
Annual balance of total electricity



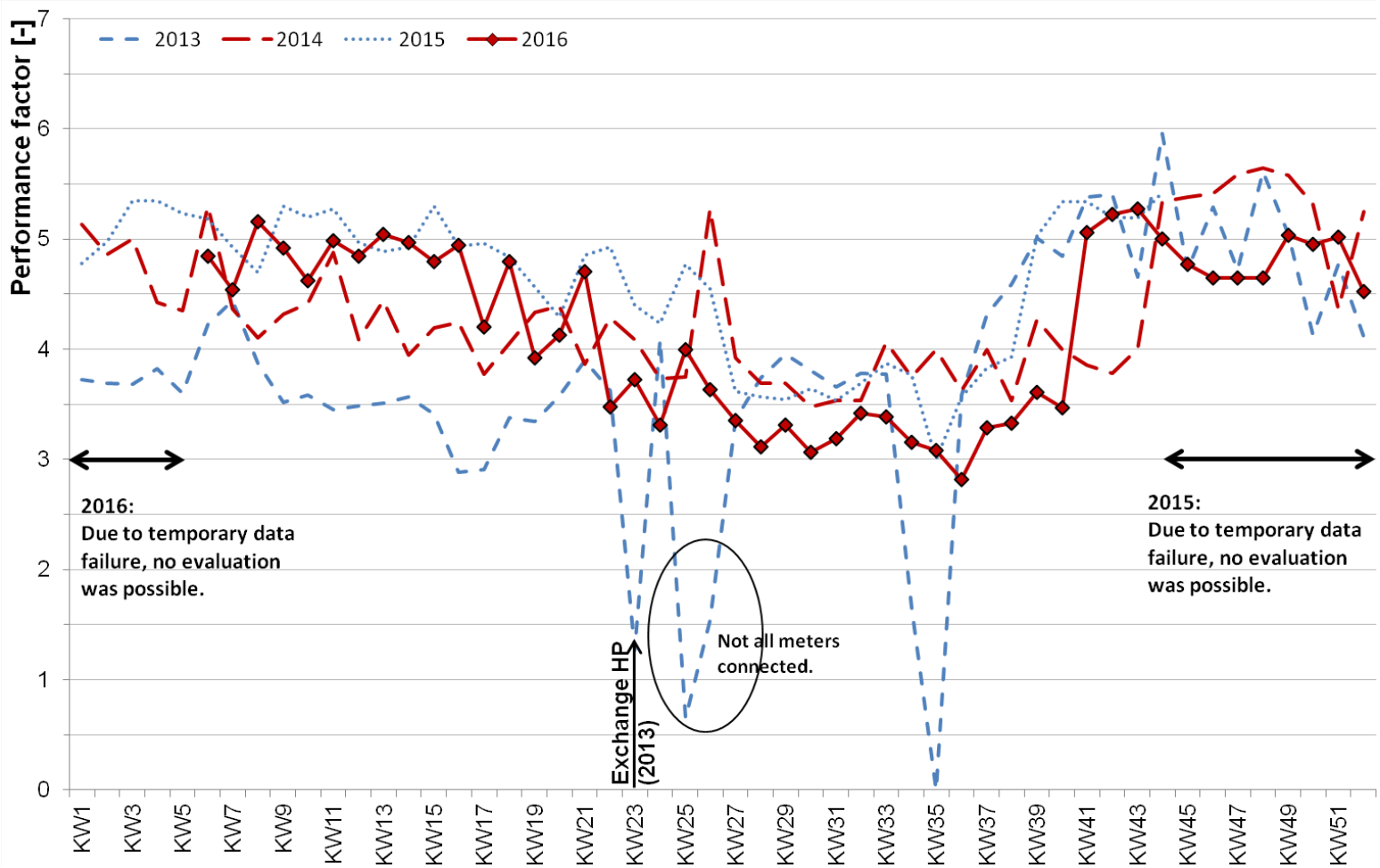
Annual thermal energy balance



Annual electrical energy consumption



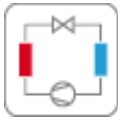
weekly performance factor heat pump



Optimization – increase of self - supply













- Operation of all electricity-intensive appliances and units (heat pump) at the time when power output from the PV is available
- Use of all available thermal storage (floor heating and buffer)
- Targeted operation of the heat pump
- Implementing enhanced control strategies to increase the running time of the heat pump.
  - Increasing the temperature in the buffer → increase the storage capacity
  - Increase the reference value of surface and supply temperature of the floor heating → increase the operation time of the heat pump
- Implementing of battery

User comfort is not be limited by the proposed measures!

Systemsimulation

Simulation combination	Basis									
buffer expansion							S+	S+	S+	
PV-control strategy										
battery (7 kWh or 27 kWh)			7	7		7		7	27	
night temperature set back										
total power consumption	11.227 kWh	- 2,4 %	0 %	- 2,4 %	+ 1,3%	+ 1,3%	+ 4,5%	+ 4,5%	+ 4,5%	
direct use of PV-output	27 %	28 %	31 %	31 %	34 %	37 %	38 %	41 %	48 %	
fraction on power consumption	34 %	36 %	37 %	39 %	42 %	45%	45 %	48 %	54 %	
grid power	7.420 kWh	- 5,4%	- 4,6%	- 9,9%	- 11,2%	- 15,5%	- 13,3%	- 17,0%	- 28,0%	

all storage applications

Conclusion and outlook

- Berghalde: Plus-Energy-standard with a high user satisfaction is completely fulfilled since the beginning of the operation.

- Plus-Energy-Buildings = an important module for our future energy supply with renewable energies

- high PV-power self-supply = forward - looking projects

- key role: PV + heat pump + low-temperature-system

Herzo Base



1. Project Herzo Base
2. Energy concept
3. Control strategy
4. Conclusion and outlook

1. Herzo Base

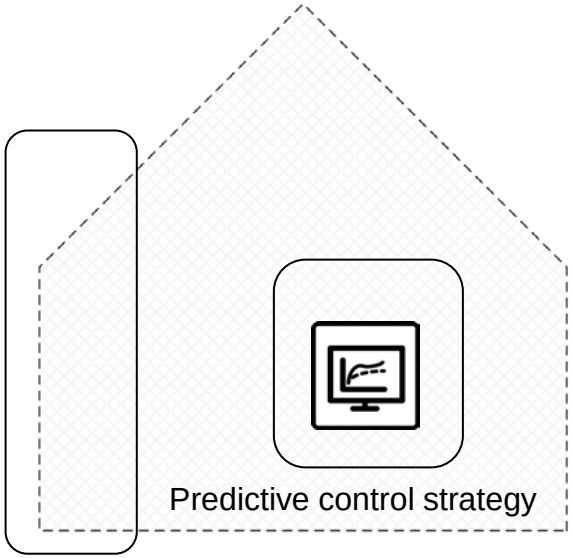
What was the idea?

System integration

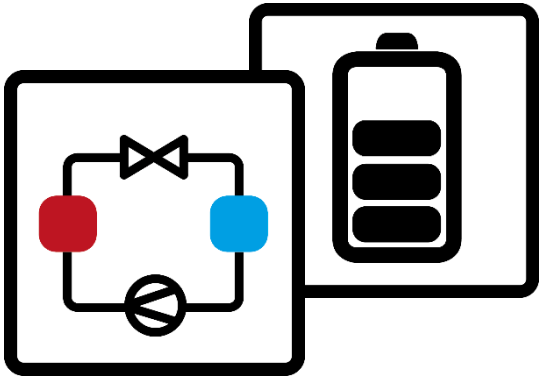
Passive components



Highly heat-insulating building materials



Active components



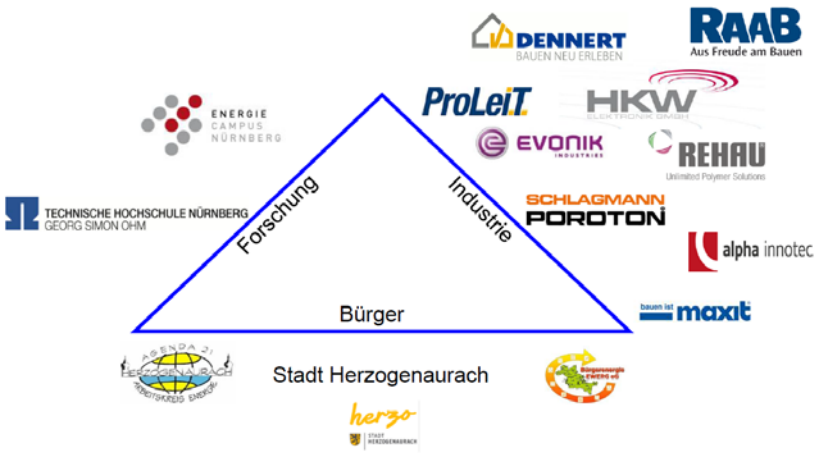
Heat pumps and Battery

- Increasing self-consumption of PV
- Plus Energy Building

1. Herzo Base

Partners and location

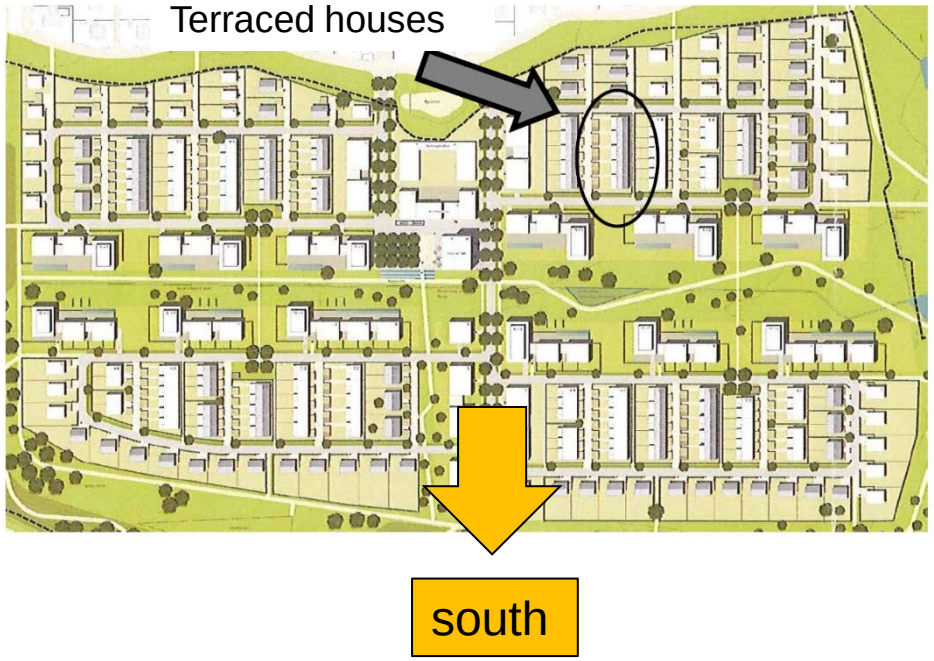
Project partners



- 12 partners
- 3 years

Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag
FK 03ET1364A

District „Herzo Base“



1. Herzo Base

The terraced houses

Figure of terraced houses



Specific values

Heating and cooling power

- max. heat load: 22.7 kW
- max. cool load: 52 kW

Heating and cooling energy

- Heating energy: 8.9 kWh/m²a
- Cooling energy: 25.6 kWh/m²a
- DHW: 16.9 kWh/m²a

PV Production

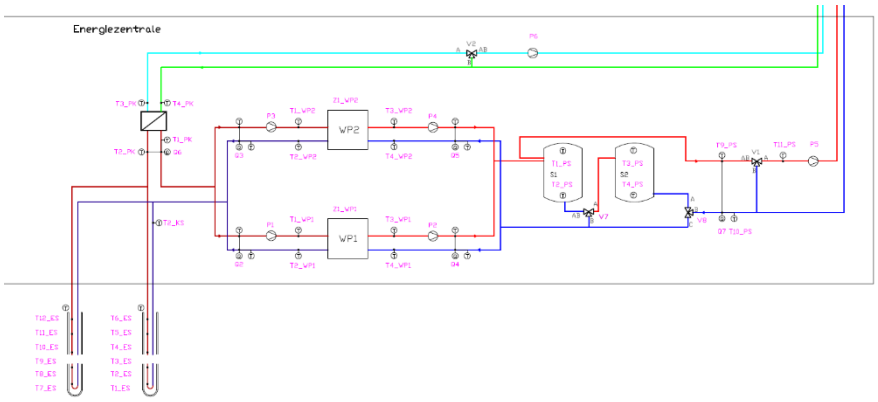
- PV: 66 MWh/a
- Peak: 98 kWp

2. Energy concept

Hydraulic structure

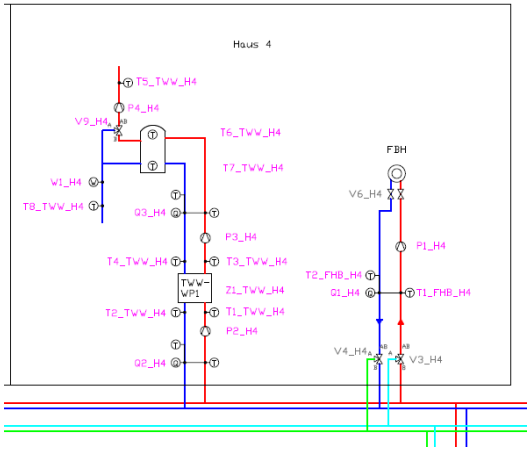
Installation room

- Geothermal source
- 2 modulating HPs
- Storage cascade



DHW

- Thermal source
- 8 DHW-HPs
- 200 liters storage



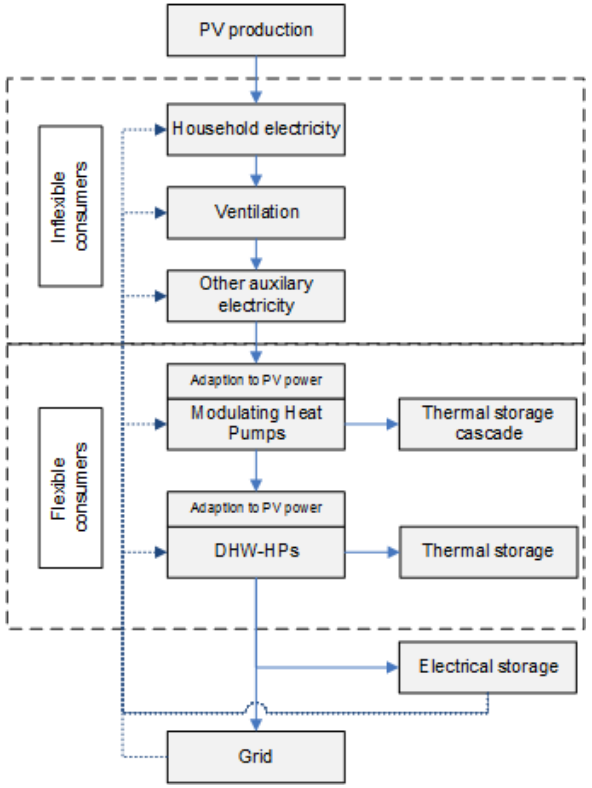
3. Control strategy

PV control

Control method

1. Target
    a. security of supply
    b. Increasing PV self-consumption
2. Method
    a. First: Inflexible consumers consumpt PV
    b. Next: Flexible consumers adapt to PV surplus
    c. Increase thermal storage temperature

Flow Chart of PV control



3. Control strategy

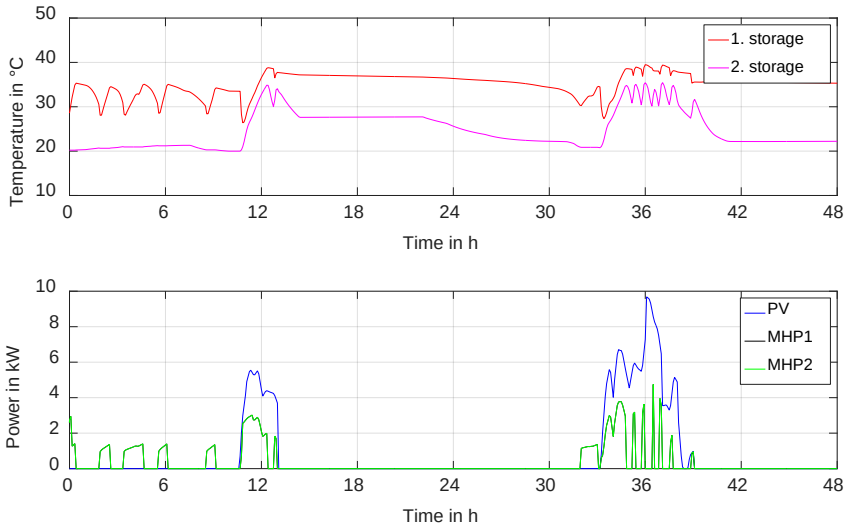
Adaption of modulating HPs to PV power

Operation modes

1. Grid and battery operation
    a. Consumpting as less energy as possible
    b. 40 % Modulation (high COP)

2. PV operation
    a. Using maximal PV power by adapting the speed
    b. Charging storages to maximal capacity

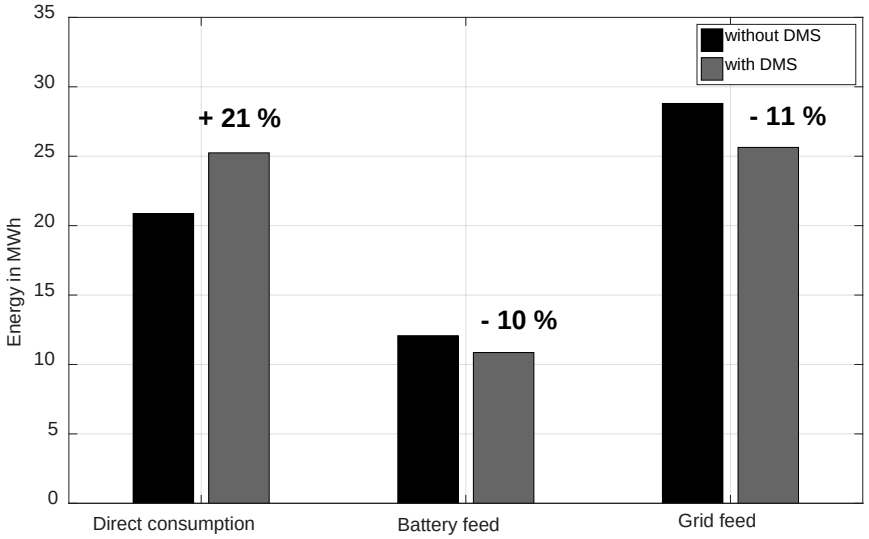
PV adaption



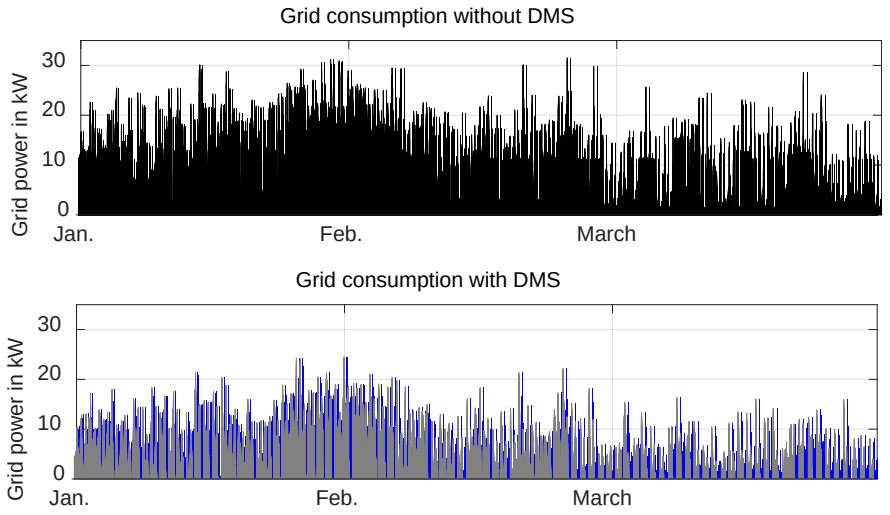
3. Control strategy

PV control

PV self-consumption



Grid consumption



Load peak reduction of 24 %

3. Control strategy

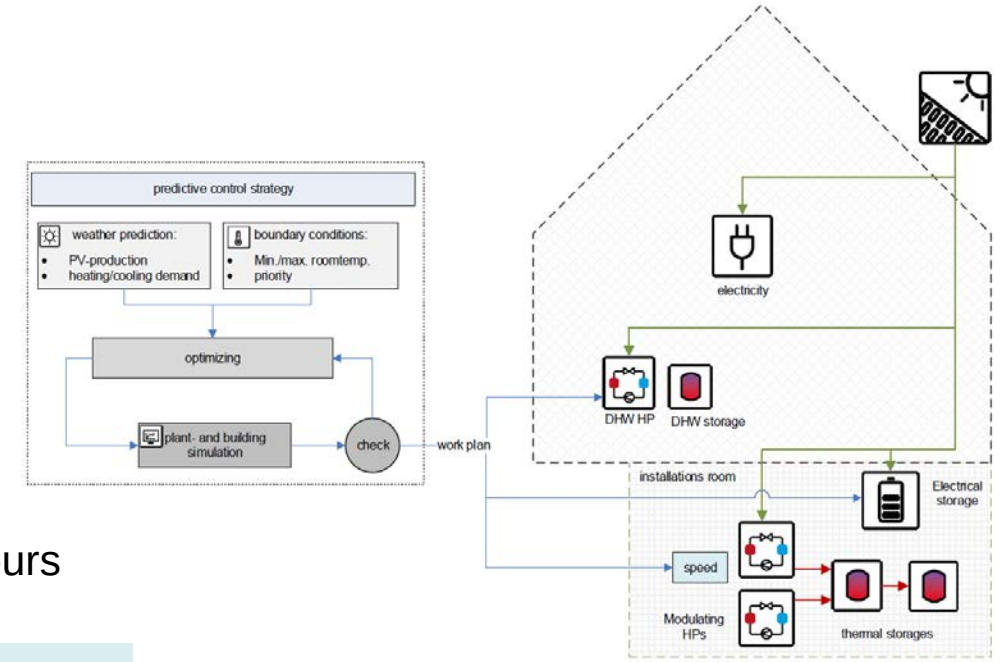
MPC control (ongoing work…)

Prediction control

1. Targets
    a. Cost efficiency
    b. Energy efficiency
    c. Load management
2. Method
    a. MPC model
    b. Weather prediction
    c. Optimal modulation for 24 hours

Monitored by PV control to secure the energy supply

Model structure



4. Conclusion and outlook

Impact of smart heat pumps

Impact of modulating heat pumps on nZEBs:

- Modulating HP increase efficiency
- PV Adaption increase the PV self-consumption

Impact of control strategies for modulating heat pumps on nZEBs:

- *PV controlled strategy increase PV self-consumption*
- *MPC control can find optimum between efficiency and costs*