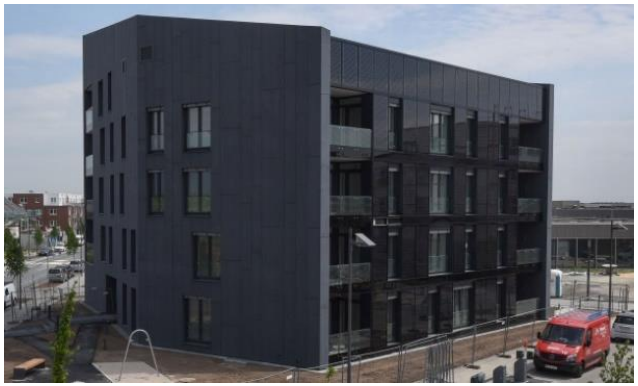
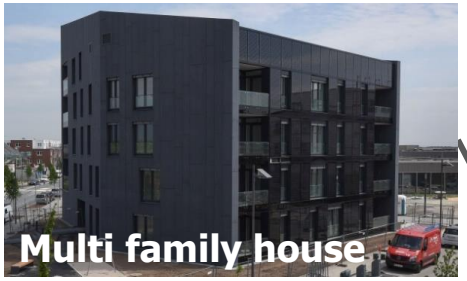



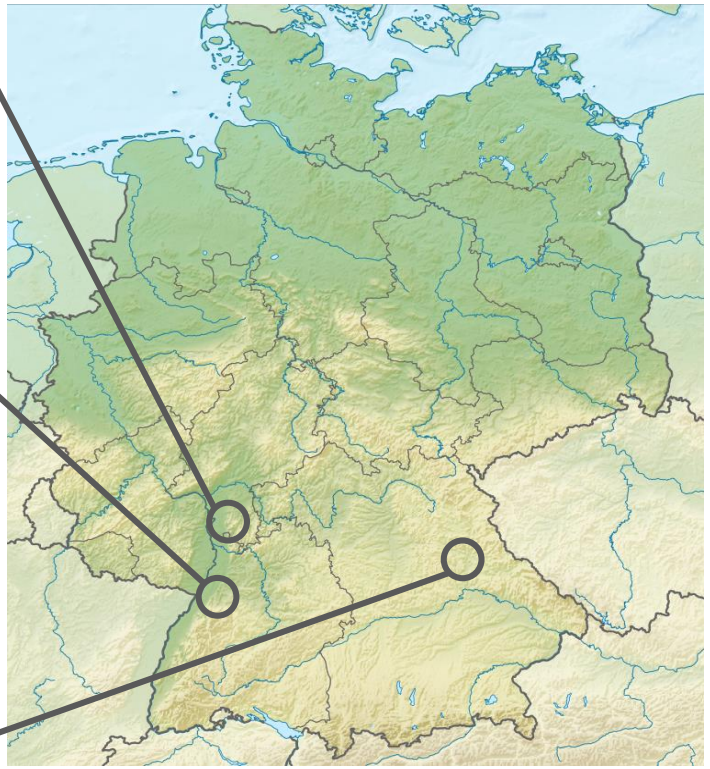

# Monitoring of energy plus buildings with different uses

Dipl.-Ing. Franziska Bockelmann

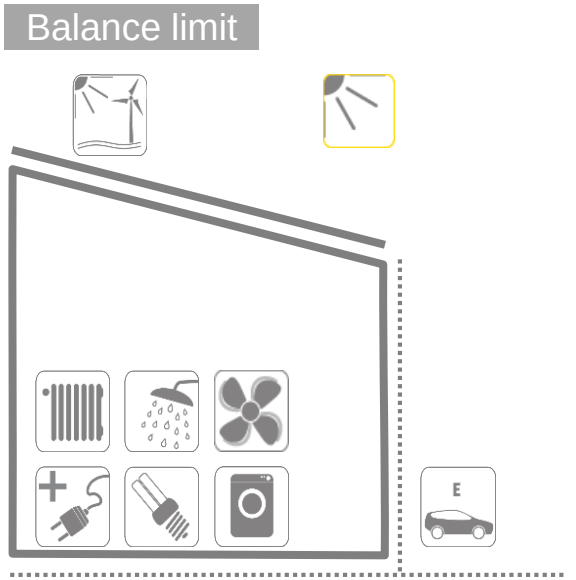
# Location of buildings





# Definitions




## Load cover factor (self-consumption)

$$LCF = \frac{\text{PV direct consumption}}{\text{Total consumption}}$$

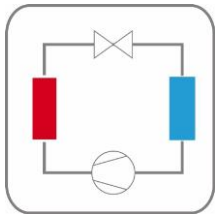
## Supply cover factor (self-generation)

$$SCF = \frac{\text{PV direct consumption}}{\text{PV yield}}$$

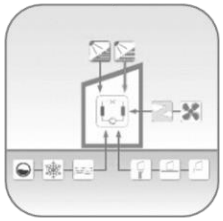
# Single family house Berghalde (2010)


4 Persons
2 floors
NGA 260 m²

15 $kW_p$ roof
Roof slope 17º to the south

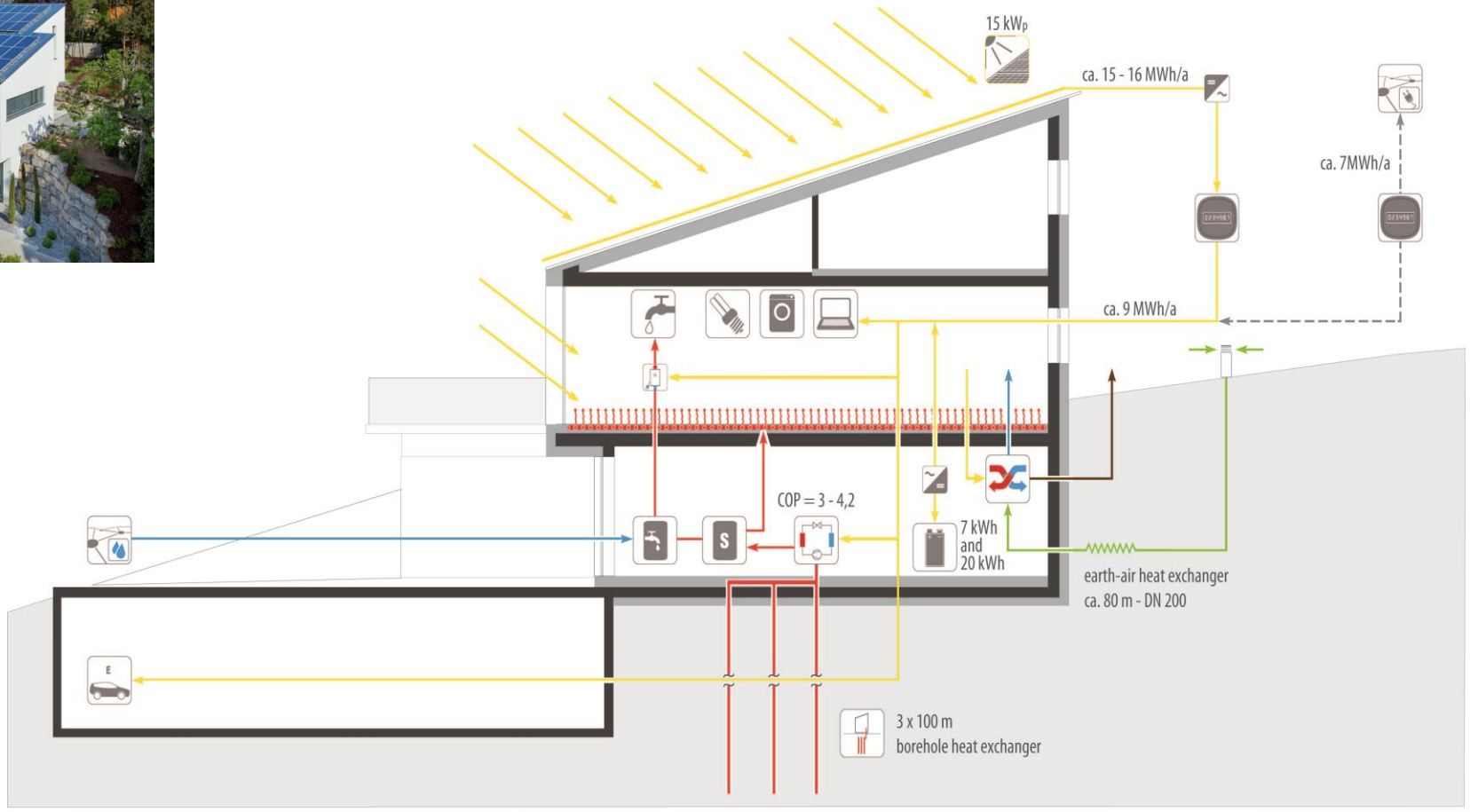


10 $kW_{th}$

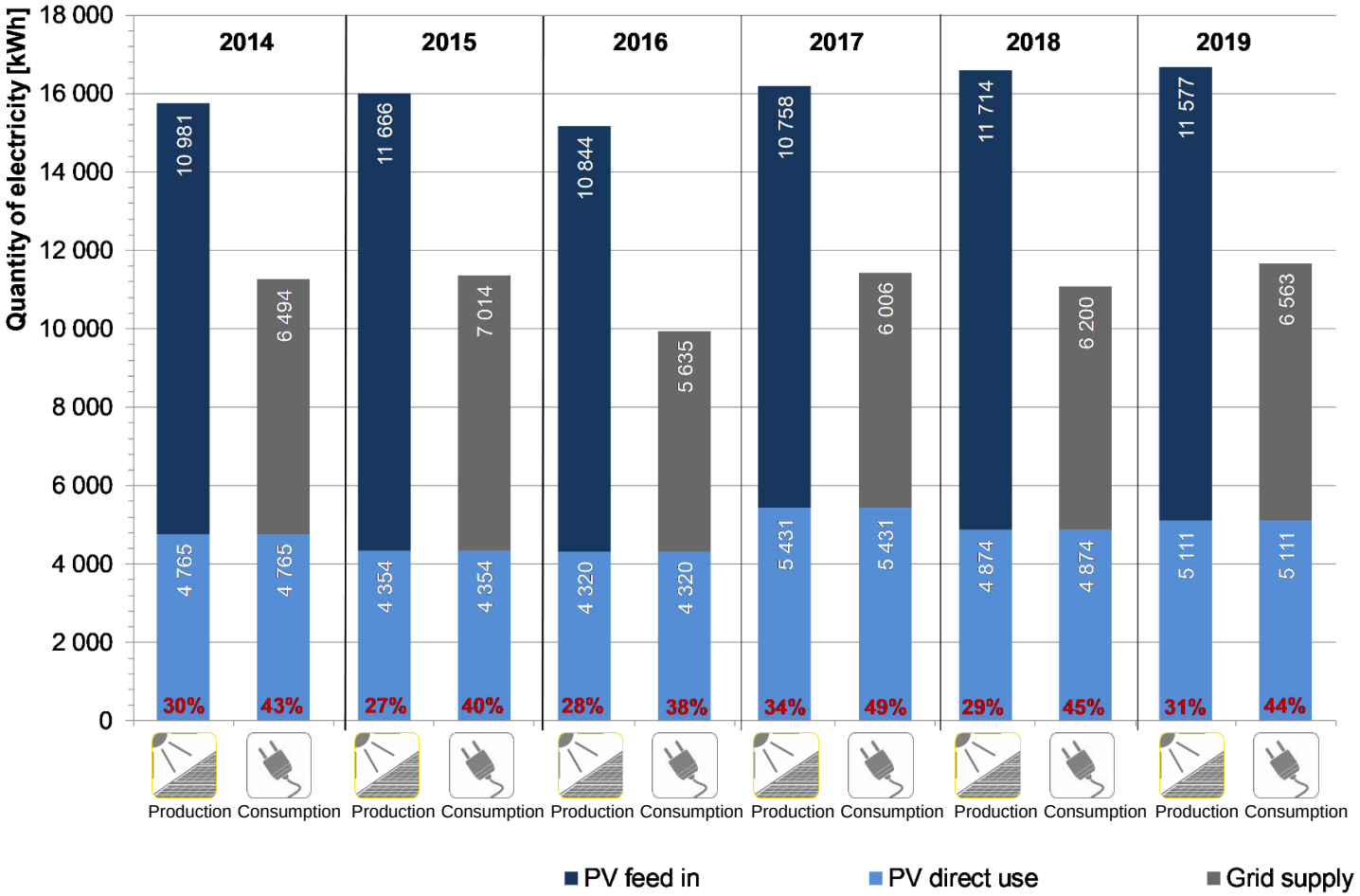


Borehole heat exchanger (3 x 100 m)

# Single family house Berghalde

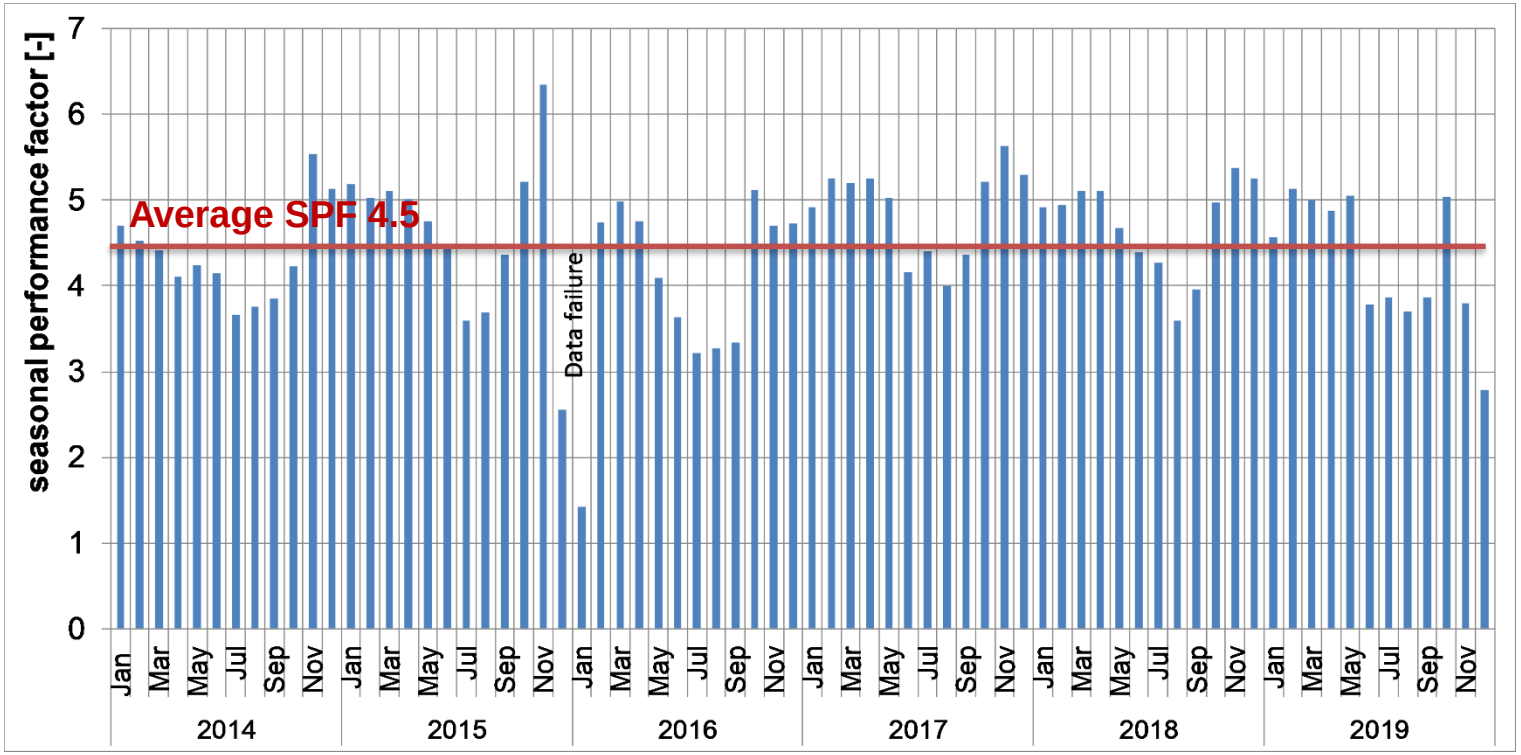


# Annual balance of total energy



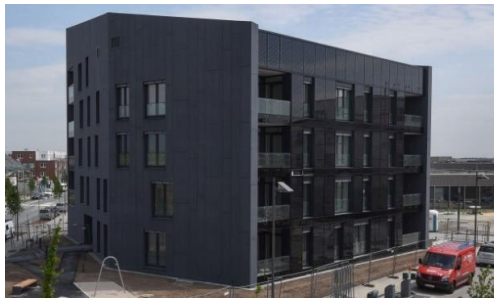

- Solar PV yield
  ~ 1070 kWh/kWp
- SCF ~ 33 %
- LCF ~ 41 %
- Heat consumption
  Room 43.3 kWh/(m²a)
  DHW 6.0 kWh/(m²a)
- Electr. household 19.1 kWh/(m²a)

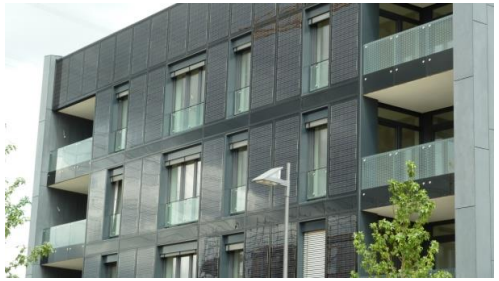
# Seasonal Performance Faktor




- Annual SPF between 4.7 and 5.1
- Average SPF over monitoring period 4.5
- During summer months: heat pump only for hot water, runs with short operating times and on a relatively high temperature level; SPF under 4.0

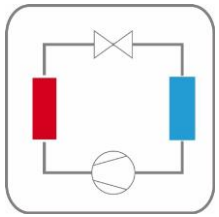
# Multi family house Riedberg (2015)



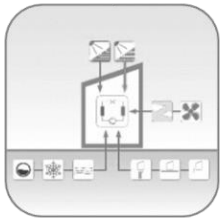



17 apartments
4 floors
NGA 2.417 m²

15 kWp façade
84 kWp roof
Roof slope 10º to the south

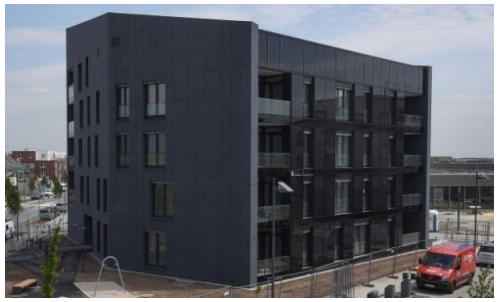


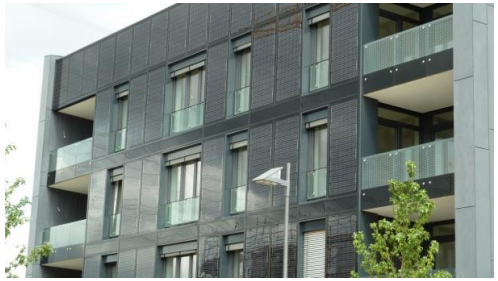
50 $kW_{th}$

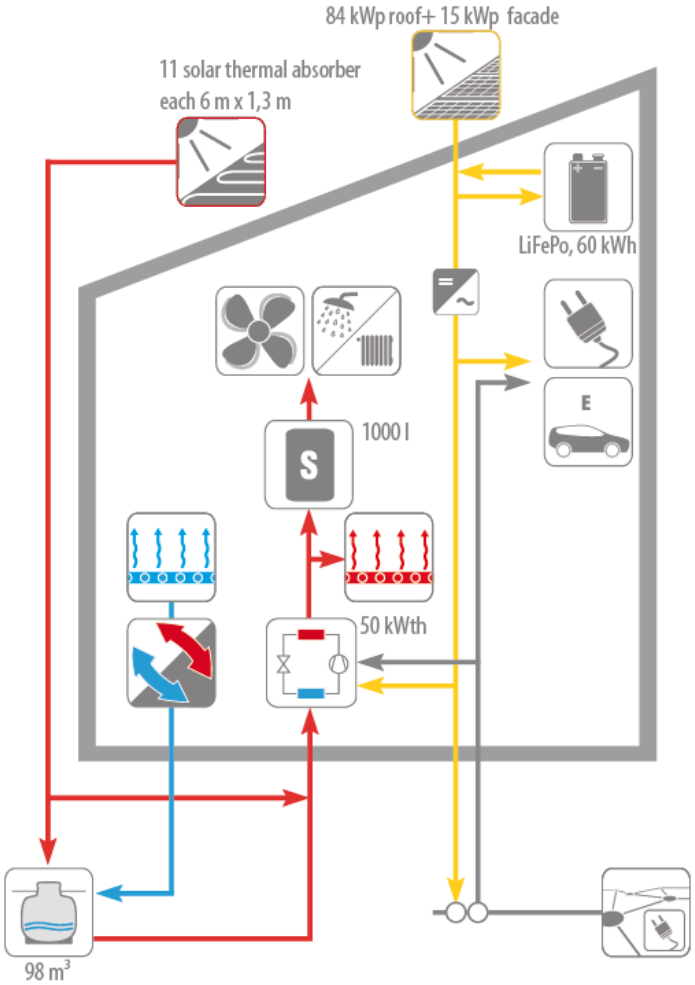


Ice storage (98 m³) and solar absorber (85 m²)

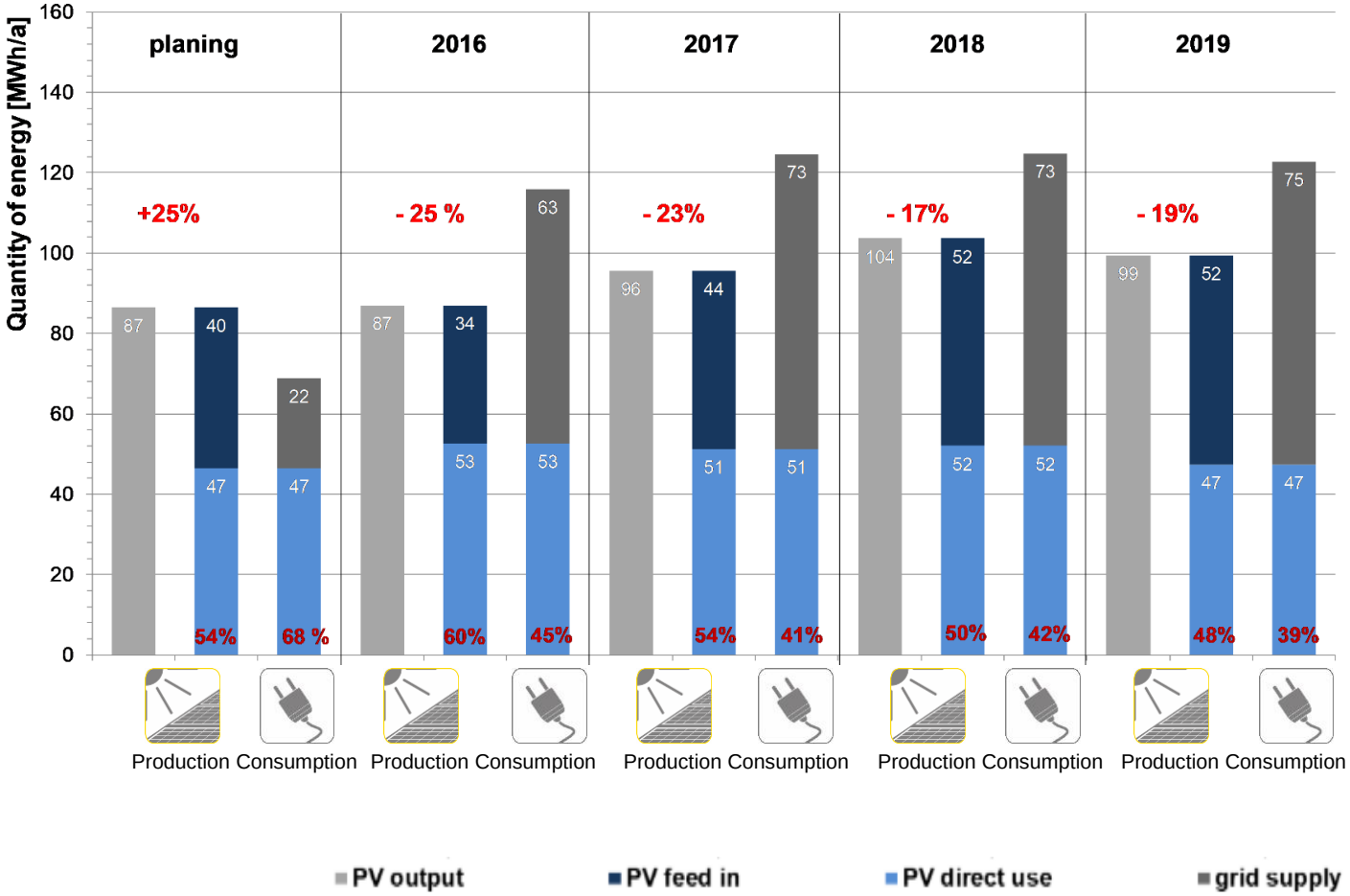
# Multi family house Riedberg (2015)







# Annual balance of total energy



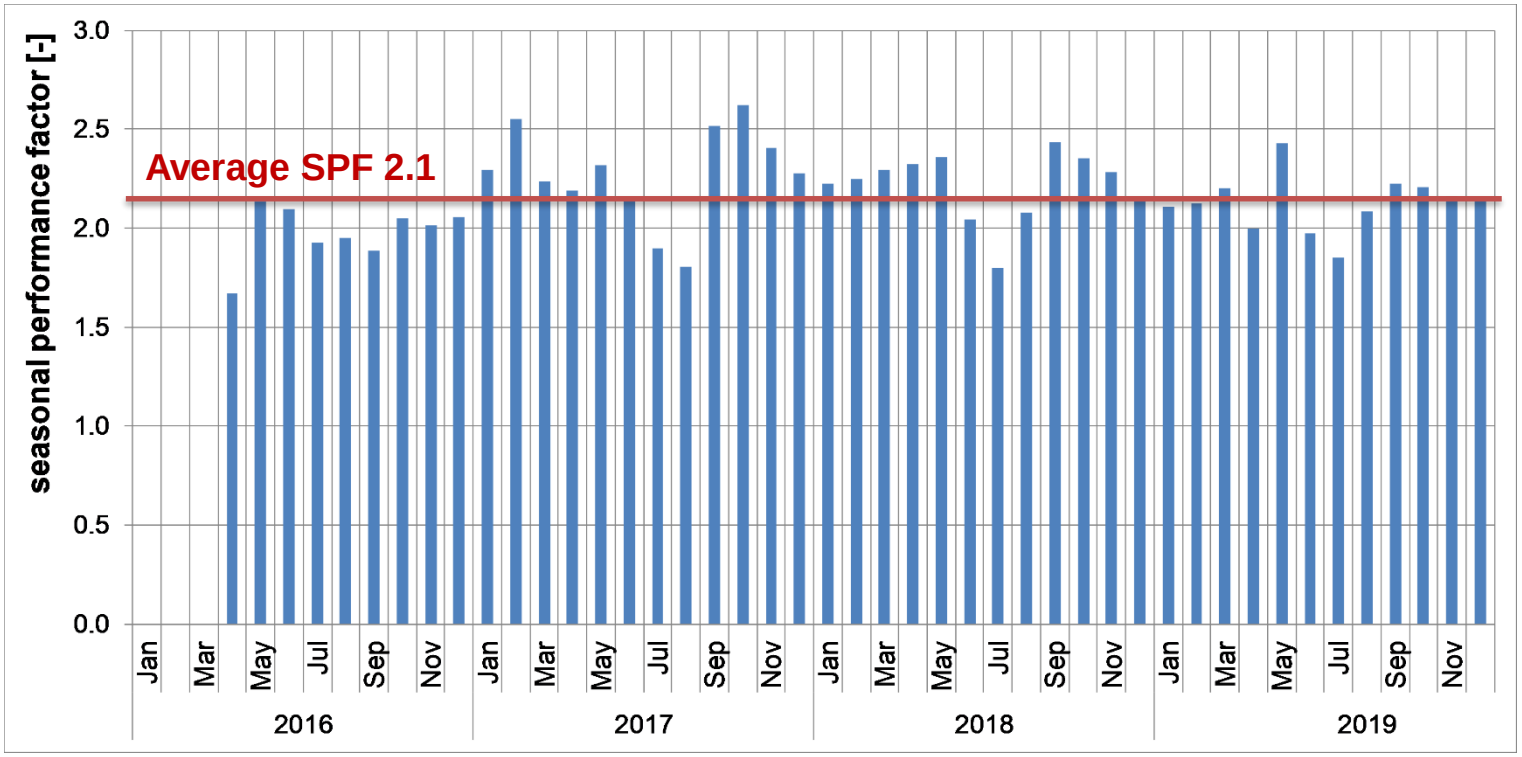

- Solar PV yield
  ~ 975 kWh/kWp

- SCF ~ 53 %
- LCF ~ 42 %

- Heat consumption
  Room 43.7 kWh/(m²a)
  DHW 20.6 kWh/(m²a)

- Electr. household 32.4 kWh/(m²a)

# Seasonal Performance Faktor

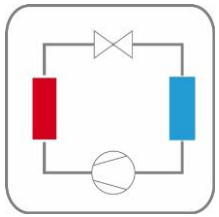



- Annual SPF between 2.0 and 2.3
- Average SPF over monitoring period 2.1
- low SPF because of excessively high return temperatures

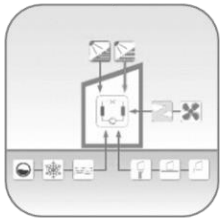
# School WGG (2015)

1.400 students
4 floors
NFA 11.500 m² (school) and 2.900 m² (gym)

216 kWp roof school
75 kWp roof gym
Roof slope 8º to the west and east;
Roof slope 28º to the south

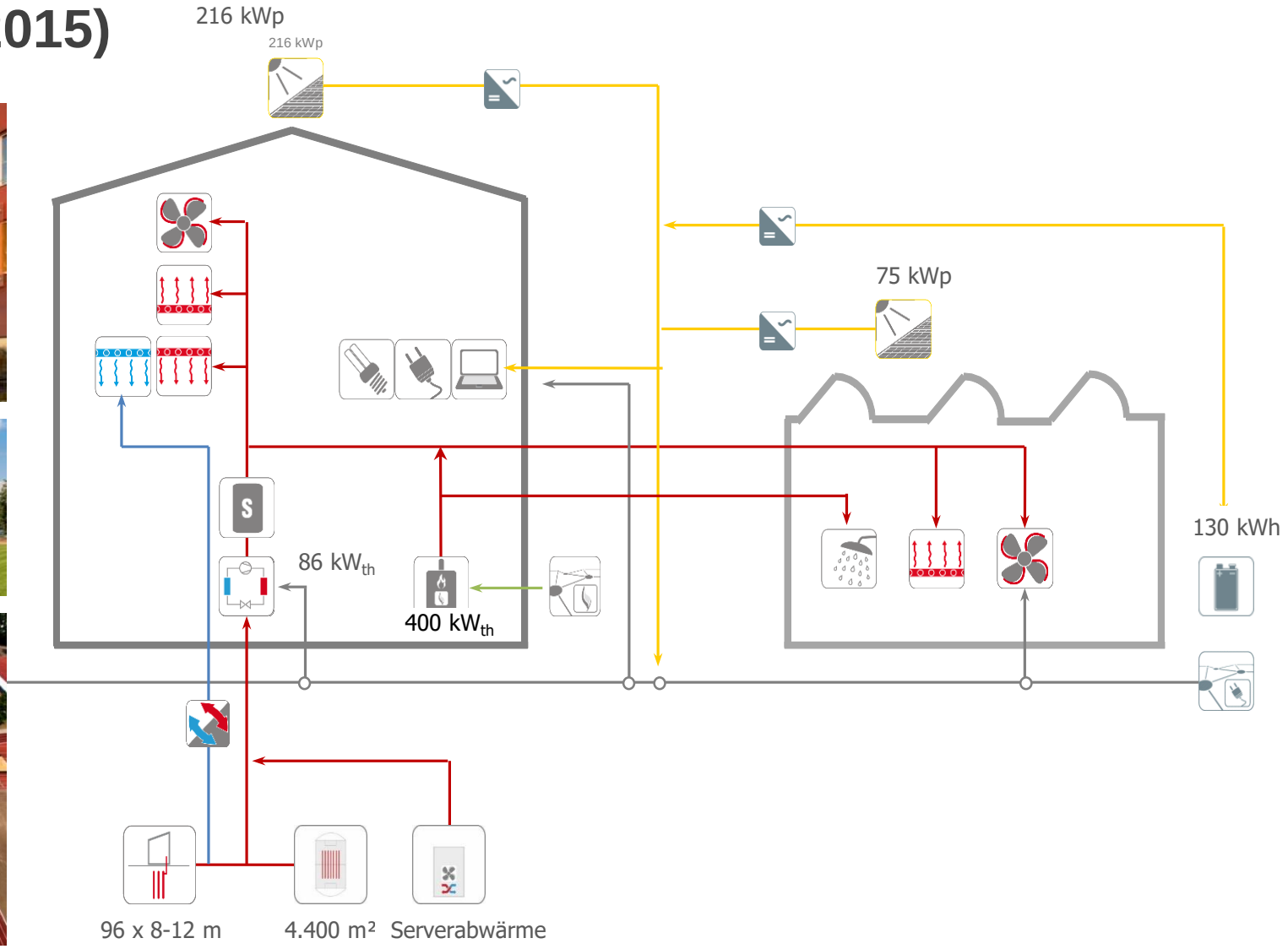


86 $kW_{th}$



Energy piles (96 x 8 -12 m) and agrothermal field (4.400 m²)

# School WGG (2015)

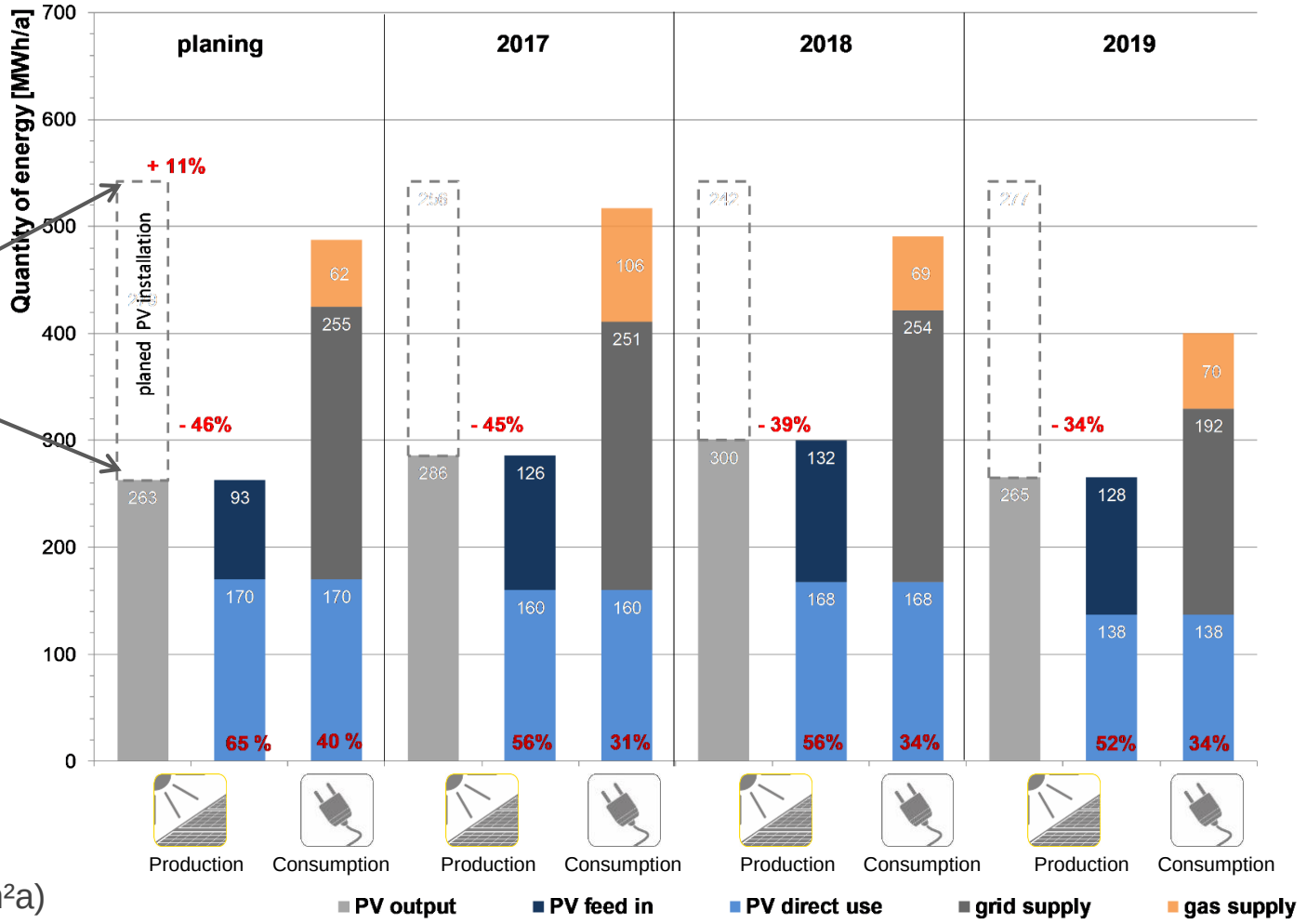


# Annual balance of total energy

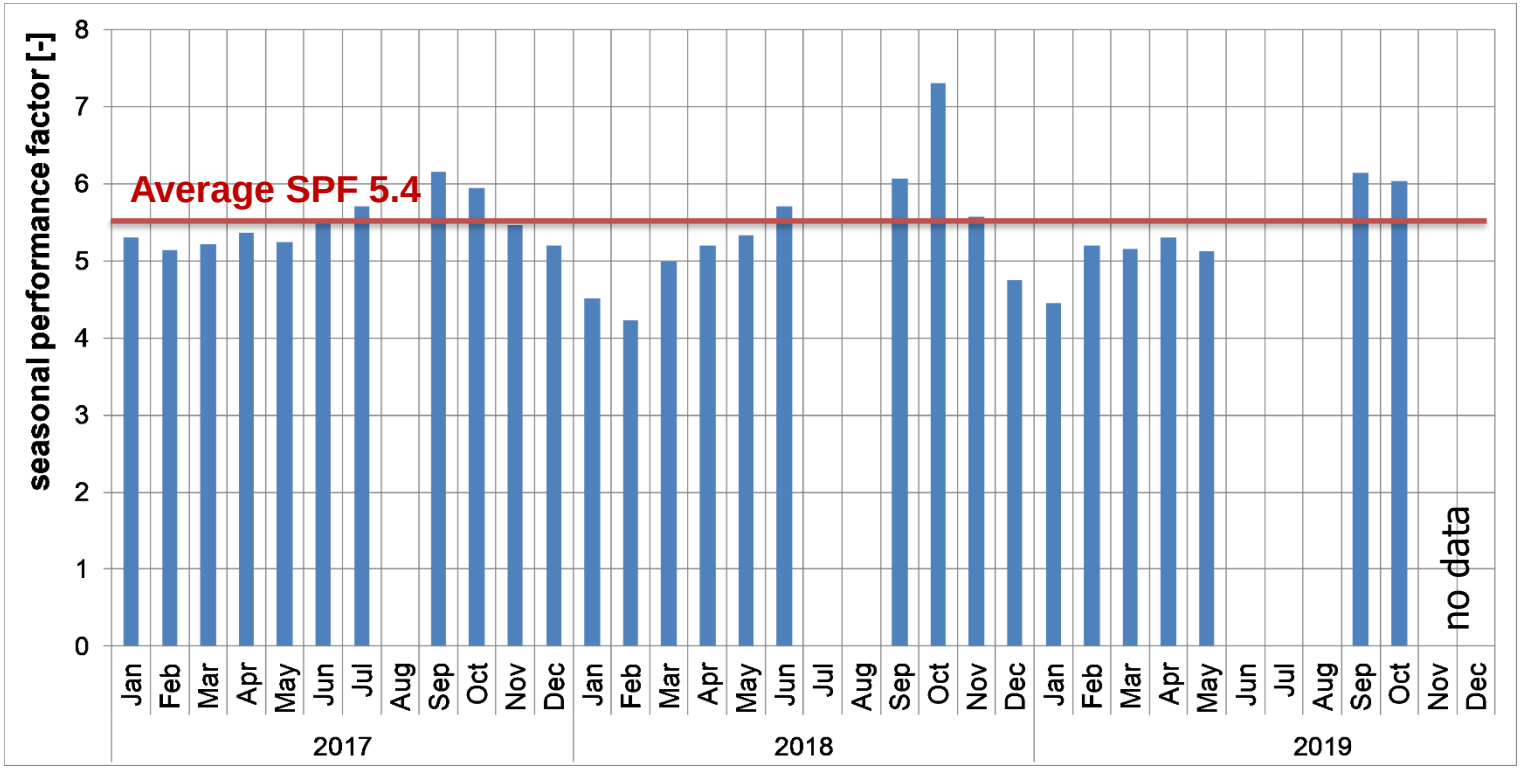
Planned PV-installation 600 kWp

Implemented PV-installation 290 kWp

- Solar PV yield
  ~ 945 kWh/kWp
- SCF ~ 59 %
- LCF ~ 47 %
- Heat consumption
  Room 18.5 kWh/(m²a)
  DHW 1.7 kWh/(m²a)
- Electr. household 24.0 kWh/(m²a)

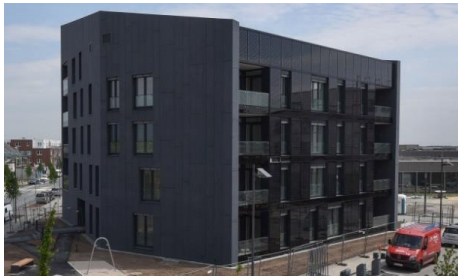


# Seasonal Performance Faktor




- Both HP together - annual SPF between 4.7 and 5.2
- Average monthly SPF over monitoring period 5.4
- No SPF is recorded in the summer months - heat pumps are not in operation

# Final and primary energy as well as $CO_2$-emission



FE

FE - 6 to - 4 MWh/a

FE 20 to 30 MWh/a

FE 135 to 231 MWh/a

PE

PE - 22 to - 17 MWh/a

PE - 13 to 18 MWh/a

PE 100 to 215 MWh/a

$CO_2$

- 240 trees
(- 3 to - 2 t/a)

+ 1200 trees
(11 to 15 t/a)

+ 7200 trees
(80 to 90 t/a)

Estimation (EnEV) – PE: a primary energy factor of 2.8 is applied to the electricity feed-in and a primary energy factor of 1.8 to the electricity purchase; gas 1.1
$CO_2$(UBA 2019 und IWU 2019): electricity 0.468 kg/kWh; gas 0.246 kg/kWh; tree binds 12.5 kgCO2 per year

# Monitoring results - Optimization

- Single family house

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

- Multi family house
  - Plus energy balance has not been reached due to an increased consumption of heating energy as well as increased distribution losses compared to the planning.
  - SPF values below 2.7 due to excessively high return temperatures and problems with the heat transfer at the solar absorbers.
  - System optimization: an additional buffer tank as a hydraulic diverter; adjusting the setpoint for switching between the solar absorbers and ice storage; electric instantaneous water heaters.

# Monitoring results - Optimization

- School

  Plus energy balance could not be reached – planned PV size was not fully implemented

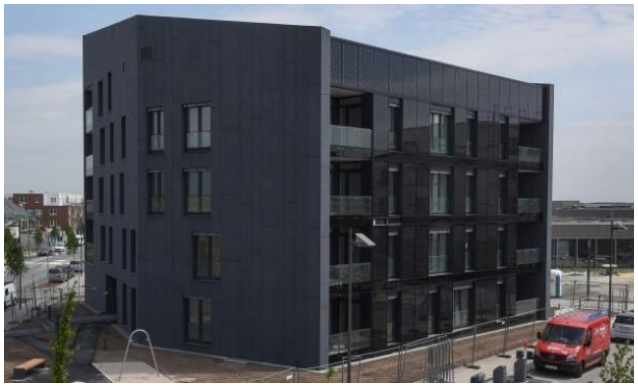
  Optimizations (among others):

  - Room comfort:
    adaption to the actual room utilisation and presence of the pupils for the following parts: release of the adiabatic cooling; supply air temperatures; switchover between summer/winter operation and the control of the night ventilation.
  - Hydraulic system
    error and deficiencies - reduction of the mass flow of the concrete core activation; settings and adjustments of the mass flow of the heating circuit; missing shut-off valve; incorrectly operating volume flow controllers
  - Geothermal energy
    adjustments to the control strategies of both sources: year-round operation of both sources (parallel operation) replaced by an adjustment via a priority distribution (activation / deactivation of one source).

# Conclusion and outlook

Quelle: https://de.dreamstime.com/

- nZEB = part of the energy transformation = plays a key role
  - Total energy balance: electricity + heat
  - PV + heat pump + NT systems
- up to 40 % renewable coverage (LCF) in single and multi-family houses realizable; up to 50 % renewable coverage in schools
- high performance of the heat pump operation
- in larger buildings a nZE balance remains a challenge, which requires an optimized building envelope and system technology as well as integrated renewable production
- Crucial : planned implementation and correct operation of the system technology!


# Thanks for your interest.

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