SUCCESSFUL RETROFIT OF NON-RESIDENTIAL BUILDINGS: HEATING AND COOLING CONCEPTS

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SHC

IEA SHC Task 47

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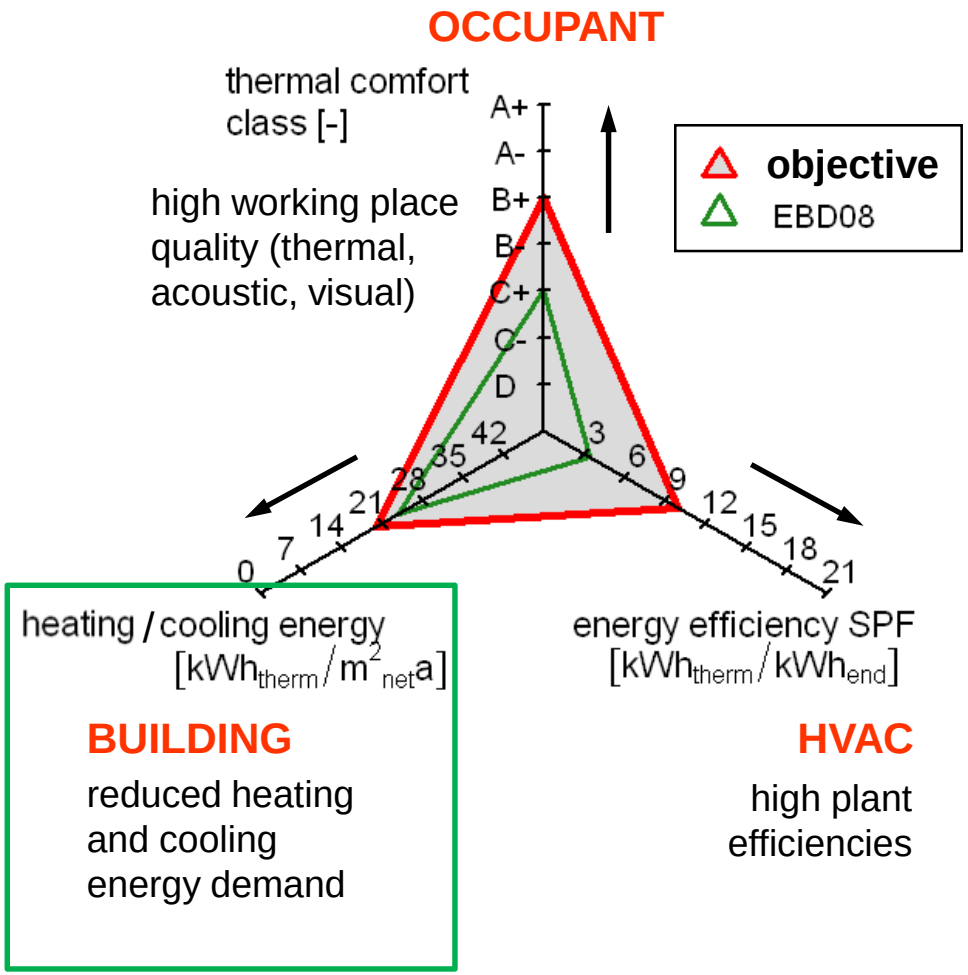
Holistic Evaluation of Concepts

Energy Use – Energy Efficiency – Thermal Comfort



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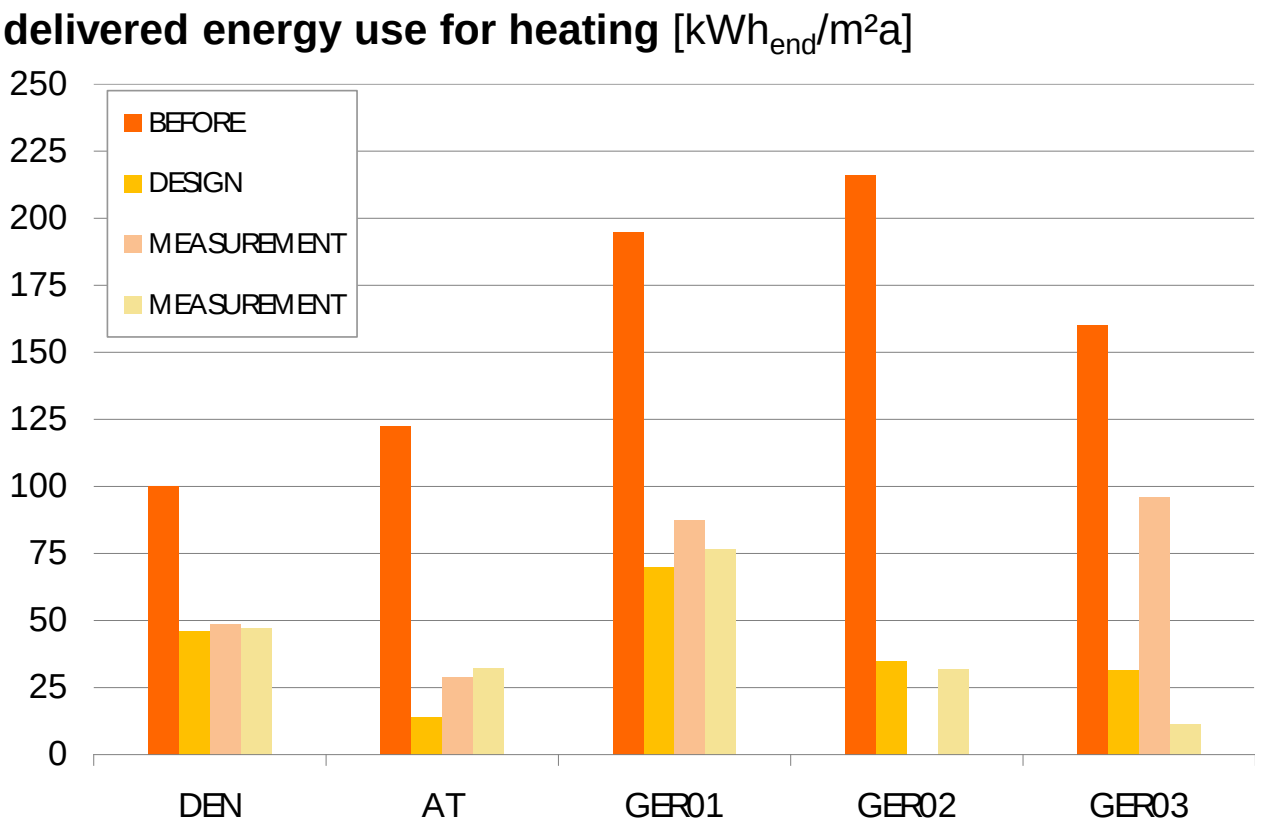
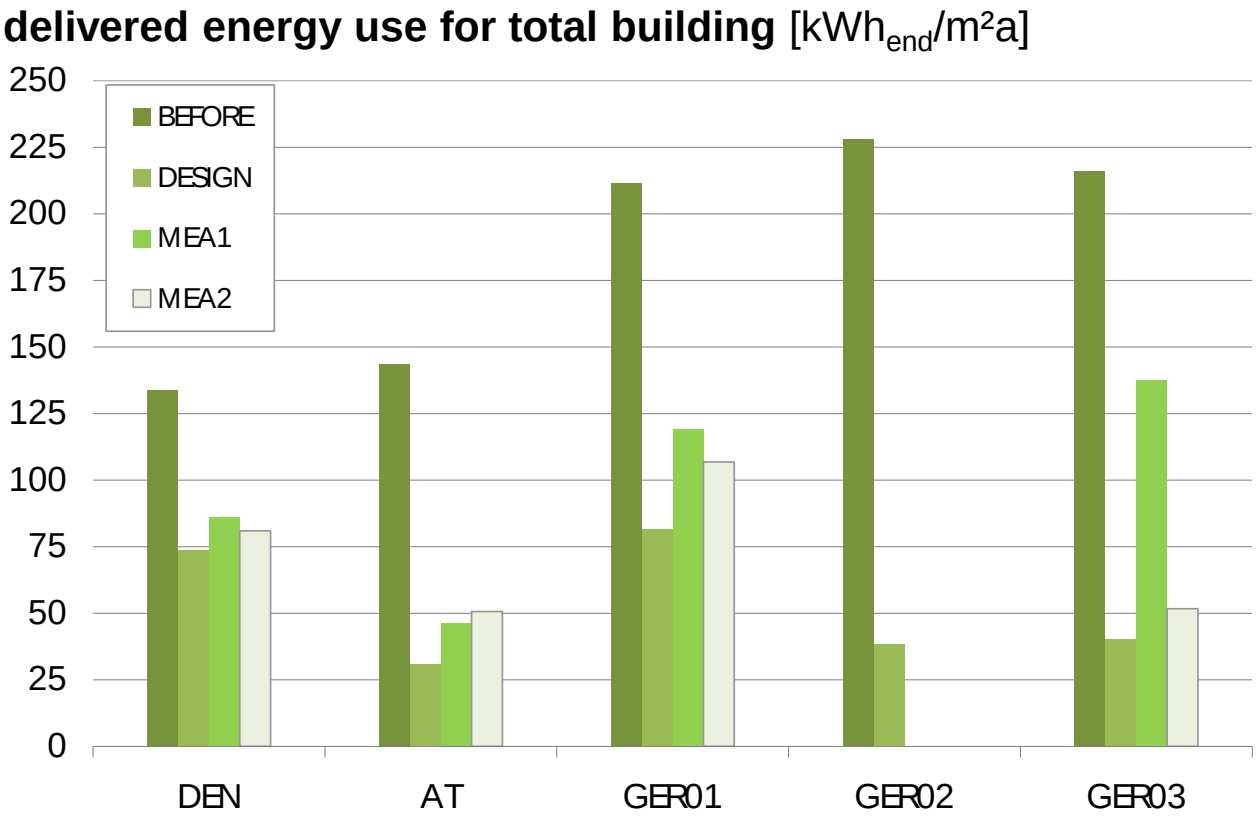
Cross-Comparison
Delivered energy use: heating

- Delivered energy use for heating between 100 and 210 kWh_{end}/m^2a
- Ambitious design values
- Significant reduction of energy use by 50 to 80%
- Operation analysis and optimization fosters further reduction



Cross-Comparison
Delivered energy use: total building*

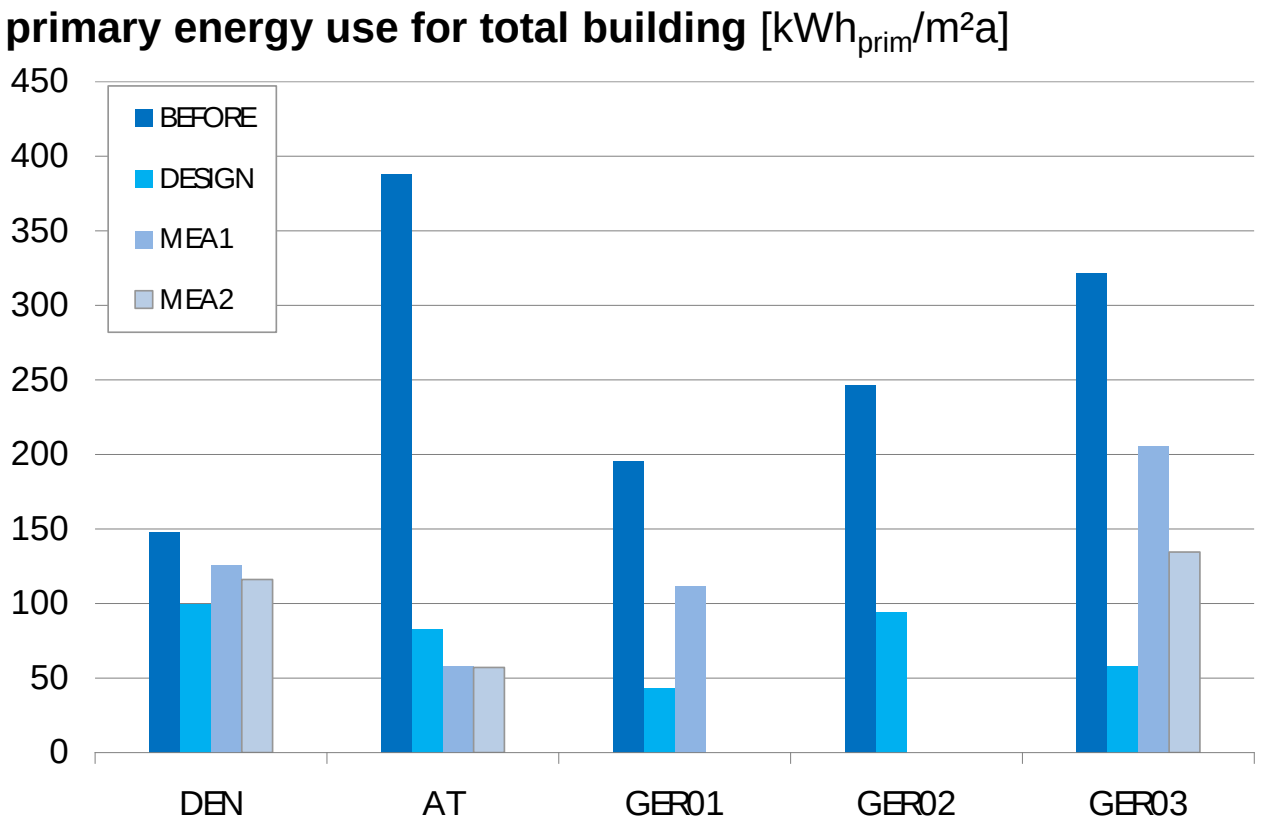
- Energy use for heating, cooling, ventilation and lighting
- Delivered energy use between 125 and 230 kWh_{end}/m^2a
- Again: Operation analysis and optimization fosters further reduction



* Heating, cooling, ventilation and lighting. No energy use for appliances.

Cross-Comparison

Primary energy use: total building*



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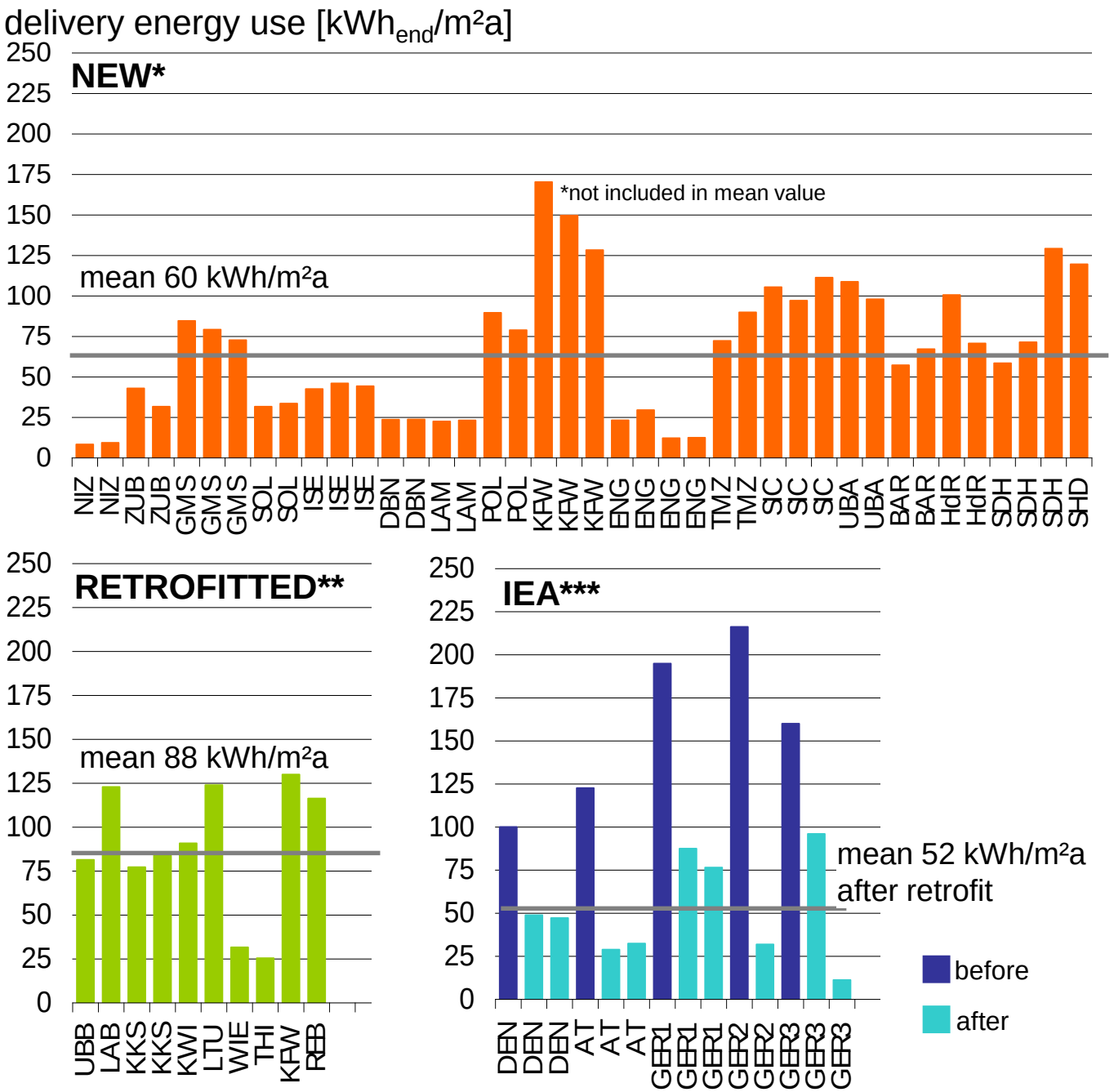
Cross-Comparison Germany

Delivered energy use for heating

- cross-comparison of buildings
- IEA buildings reach very ambitious aims according to heating end energy use



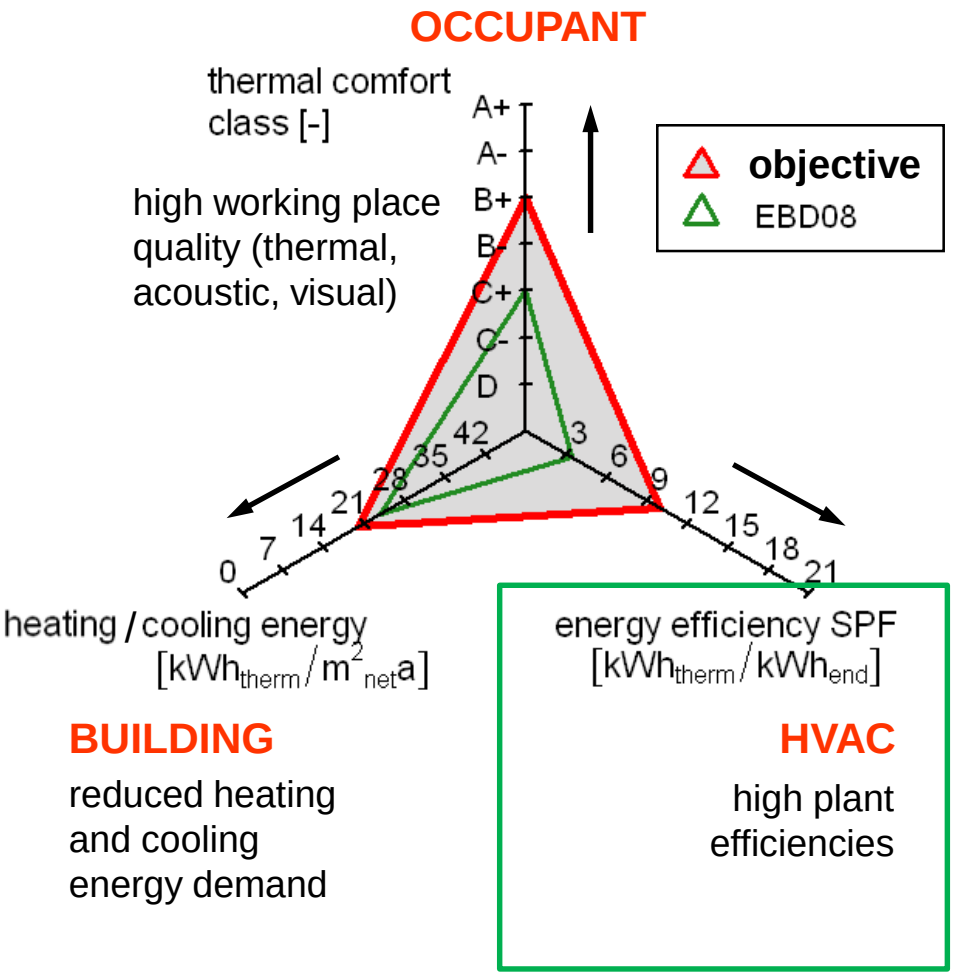
* Monitored new non-residential building within the German program EnoB (www.enob.info)

** Monitored retrofitted non-residential buildings within ther German program EnoB (www.enob.info)

*** Monitored retrofitted non-residential buildings within IES-SHC Task 47.

Holistic Evaluation of Concepts

Energy Use – Energy Efficiency – Thermal Comfort



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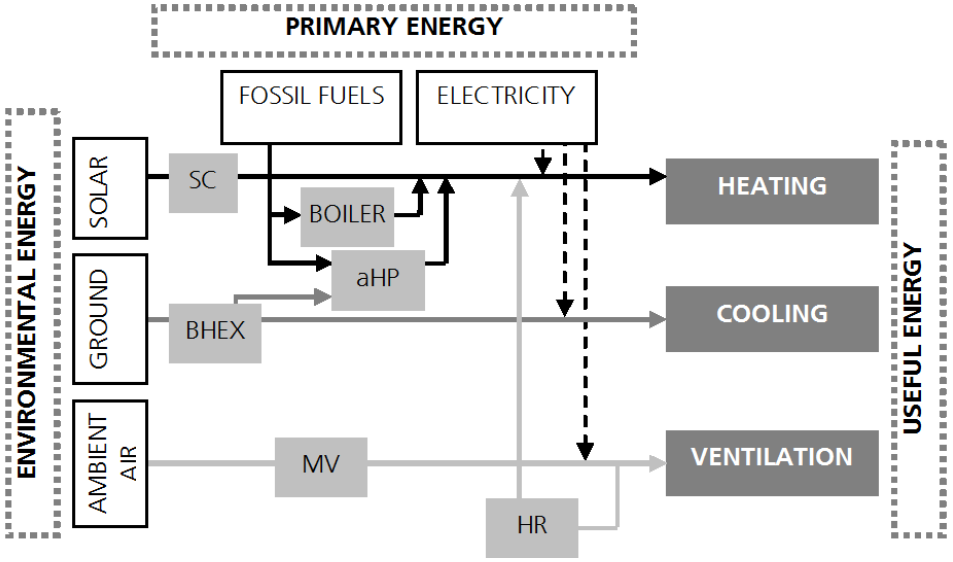
Heating Concept

Ground-coupled thermal heat pumps

Before

- 2 gas boiler, 250 and 283 kW_{therm}
- High temperature heating with radiators
- Natural ventilation

After



- 2 ground-coupled thermal heat pumps each 35 kW_{therm} and 2 gas boilers (2x80 kW_{therm})
- Hybrid ventilation with heat recovery
- Low temperature heating with radiators

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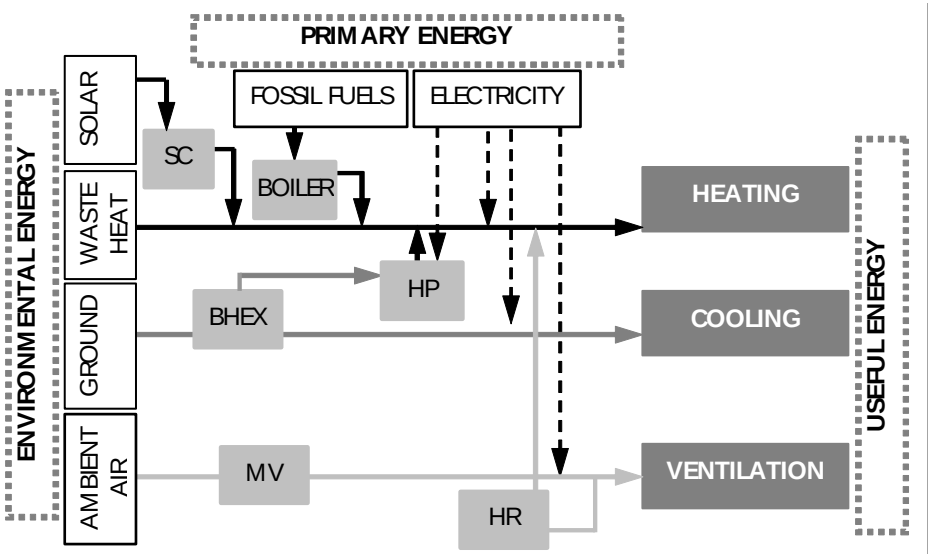
Heating Concept

Ground-coupled electrical heat pumps

Before

- Gas boiler 280 kW_{therm}
- High temperature heating with radiators
- Natural ventilation

After



- Electrical heat pump 33 kW_{therm}, use of waste heat from printing workshop, old gas boiler as backup
- Hybrid ventilation with heat recovery
- Low temperature heating with radiators and convectors

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Operation Performance of Heat Pumps

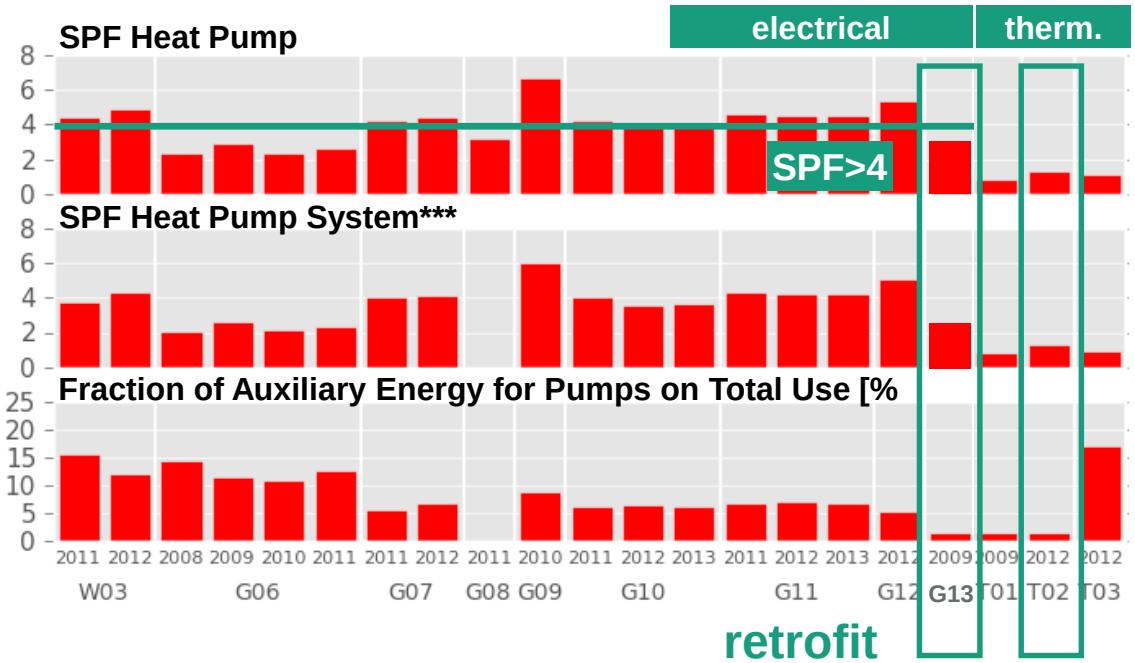
Cross-Comparison: analysis of efficiency*

- **Cross-Comparison**
  - Electrical: 2.4 – 6.6
  - Thermal: 1.1 – 1.3
  - No significant difference between monovalent and bivalent systems
- **Retrofitted Projects:**
  - Electrical: 2.9
  - Thermal: 1.3
  - Higher supply temperature in retrofit projects influences SPF_{el}

*Seasonal performance factors (SPF) presented are relation of thermal energy delivered by heat pump to end energy input to the heat pump (electricity or gas)

**SPF according to VDI 4650, 2 (related to delivered energy, thermal and electrical use)

***Consideration of compressor and pumps in primary circuit



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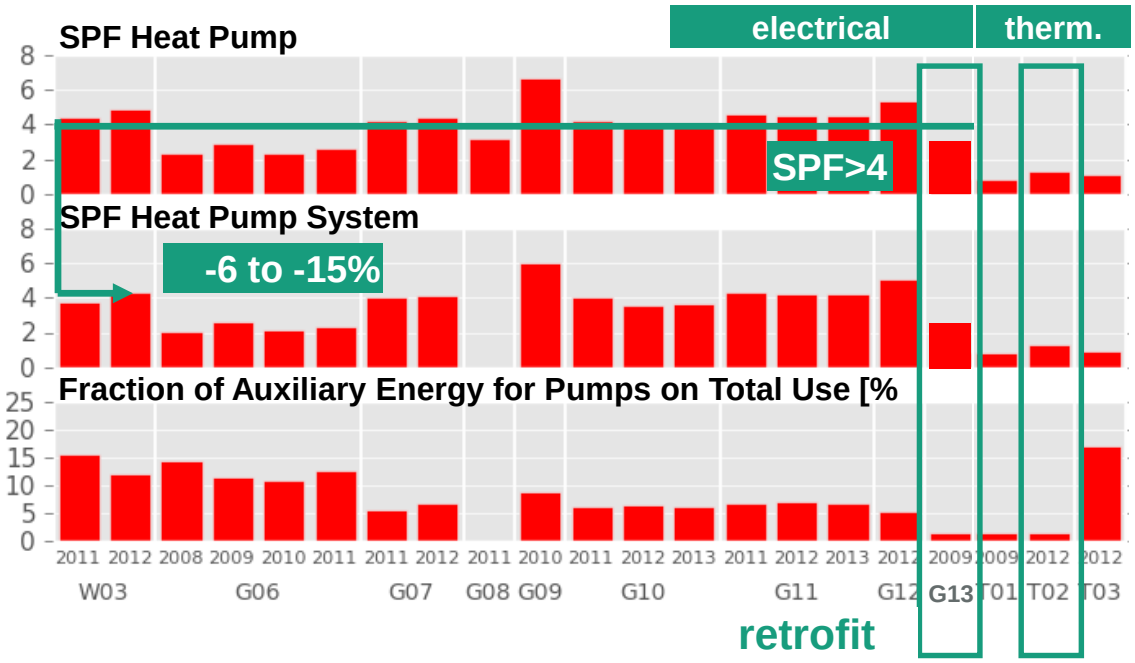
Operation Performance of Heat Pump Systems

Cross-Comparison: analysis of efficiency*

- **Cross-Comparison**
  - Significant electrical energy use for pumps in primary circuit (5 to 20%)
  - Reduction of SPF by 6 to 15 %
- **Retrofitted Projects:**
  - Well designed systems with a comparatively low auxiliary energy use for pumps in primary circuit



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Cooling Concepts

Use of Environmental Heat Sinks for Direct Cooling

GEOTHERMAL ENERGY

surface-near ground

ground water

surface water

AMBIENT AIR

nat. / mech. ventilation

natural and hybrid ventilation

cooling tower

dry / wet cooling towers

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Cooling Concepts
Night Ventilation: Example I

before retrofit, 1970s

after retrofit

- **Daytime**: hybrid ventilation (natural and mechanical)
- **Nighttime**: mechanical ventilation > 2 ACH, ventilation slats

Cooling Concepts
Night Ventilation: Example II

after retrofit

- **Daytime**: hybrid ventilation (natural and mechanical)
- **Nighttime**: mechanical ventilation > 2 - 3 ACH

Cooling Concepts
Night Ventilation: Example II

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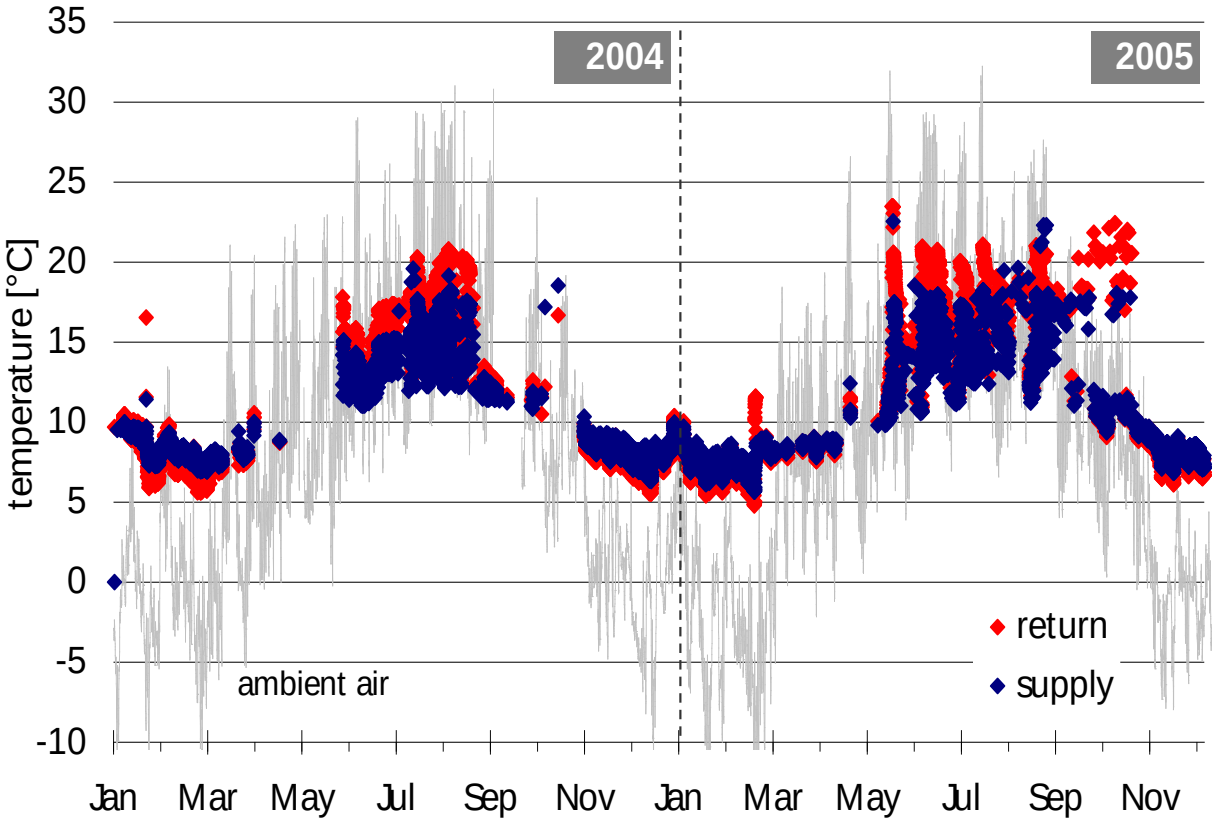
Use of Environmental Heat Sinks for Direct Cooling

Ground Temperatures

- **Summer period:**
  - Supply temperature 12-18°C
  - Temperature difference 1 to 4 Kelvin
  - Cooling power 10 – 40 W/m_{BHEX}



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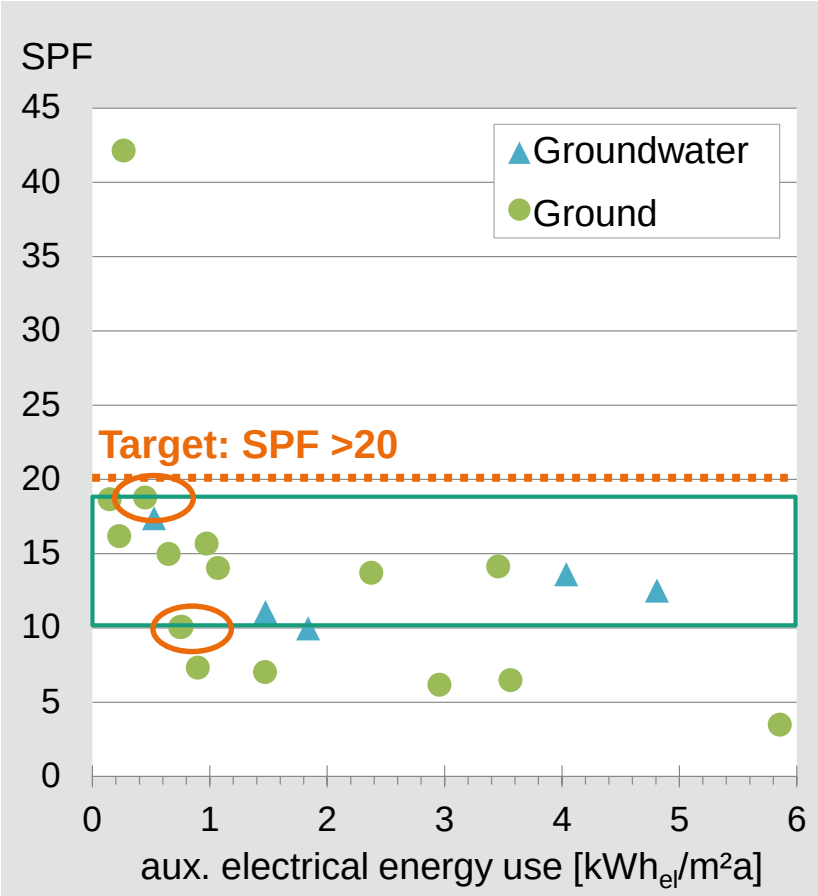
Use of Environmental Heat Sinks for Direct Cooling
Analyses of Efficiency

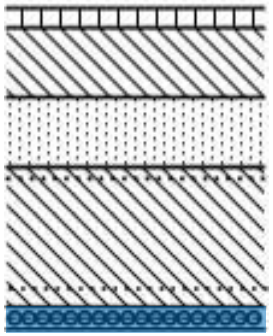
- **Cross-Comparison**
  - Direct cooling via bore-hole heat exchangers or groundwater
  - Efficiency between SPF 10 and 20
  - All systems studied reveal potential for further optimization
  - → Temperature difference in primary circuit often smaller 2 Kelvin
  - → High auxiliary energy use of primary pump due to high pressure drops within hydraulic system and oversized pumps
- **Retrofitted Projects:**
  - Good performance: SPF 10 and 19



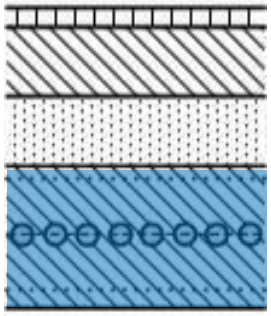
LowEx Cooling Systems

Cooling with high water supply temperatures

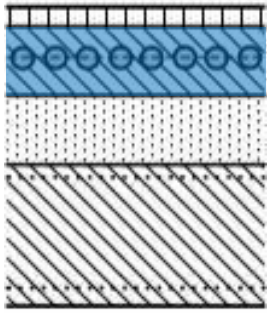
SURFACE-NEAR CONDITIONING



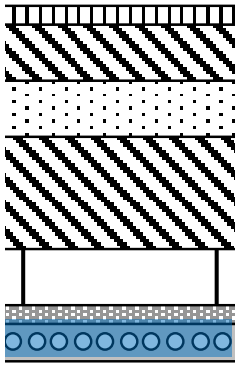
CONCRETE CORE CONDITIONING



FLOOR CONDITIONING



CEILING SUSPENDED PANELS



retrofit

retrofit

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LowEx Cooling Systems

Radiant Cooling by Suspended Panels

KfW-Bank Frankfurt/Main · Arch. RKW, Düsseldorf

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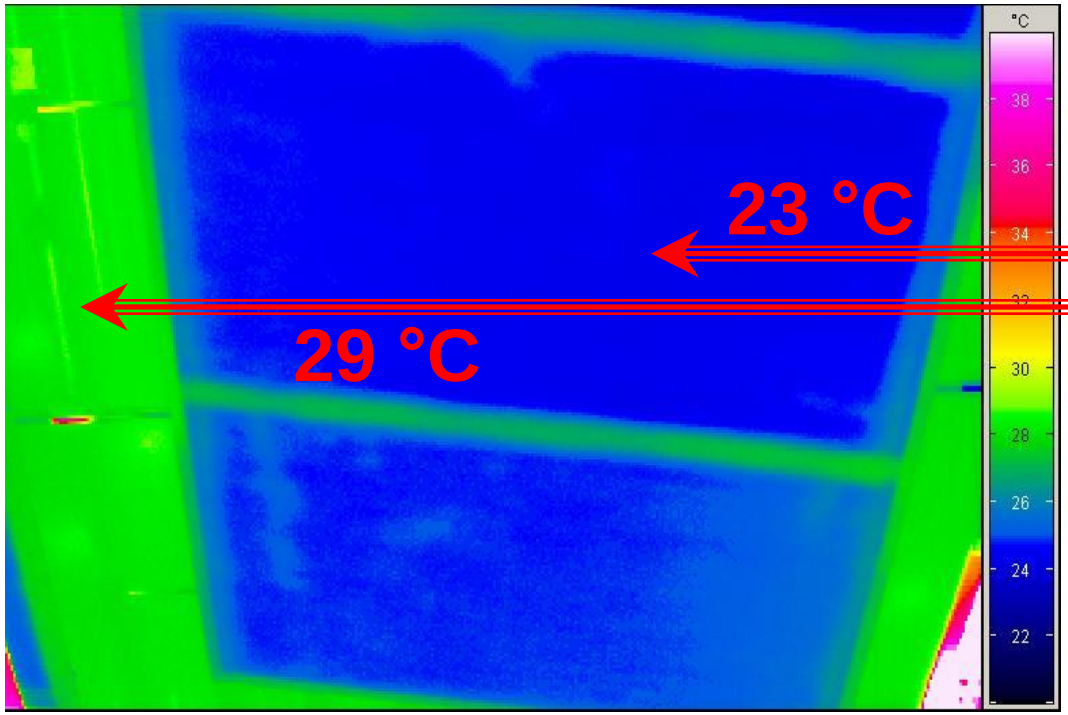
LowEx Cooling Systems

Radiant Cooling by Suspended Panels



Cooling panels with phase change materials

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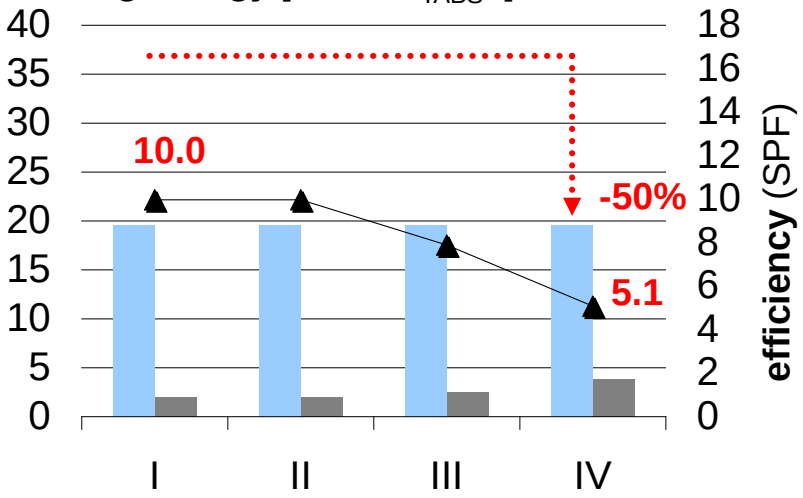
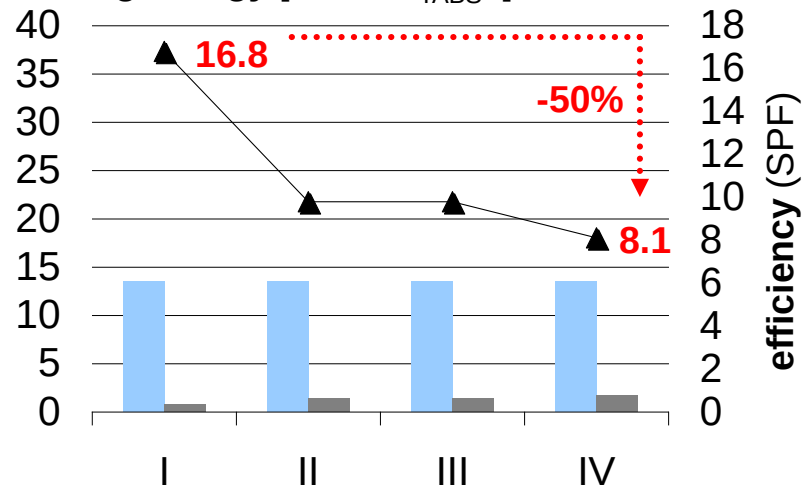
Cooling Concepts

Impact on efficiency by auxiliary energy use of pumps

- Considerable auxiliary energy use for distribution and delivery
- Reduction of energy efficiency: approximately 50 %





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Holistic Evaluation of Concepts

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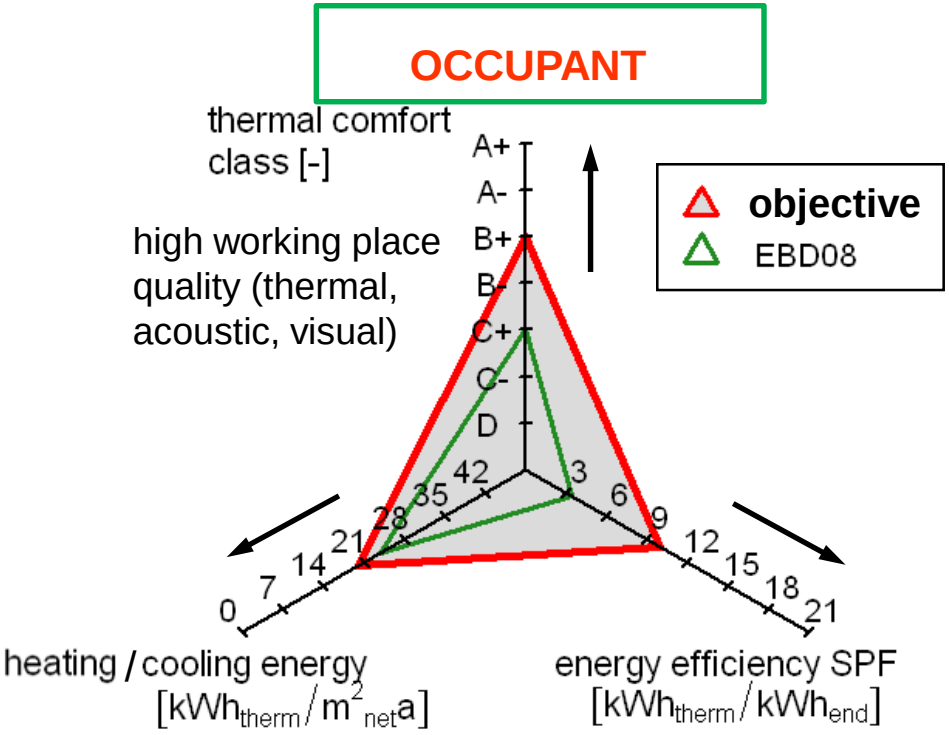

BUILDING

reduced heating and cooling energy demand

HVAC

high plant efficiencies

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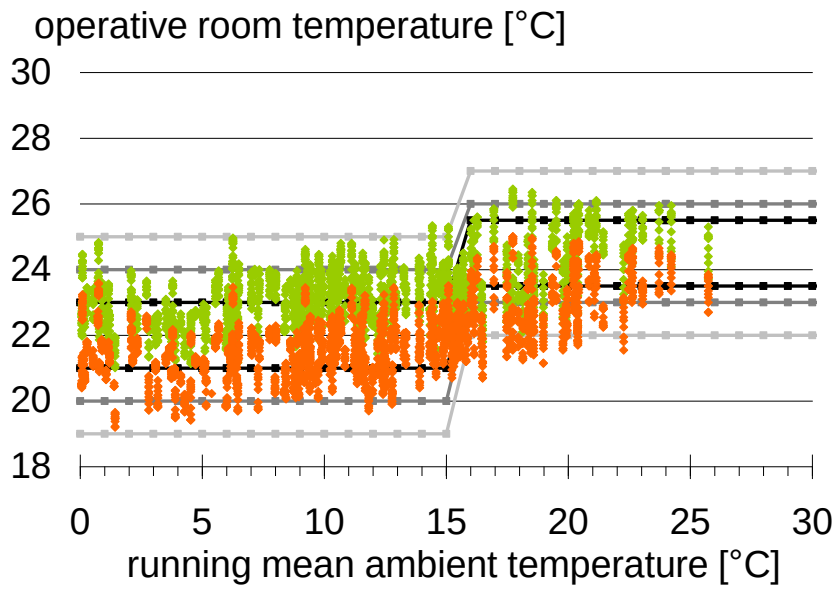
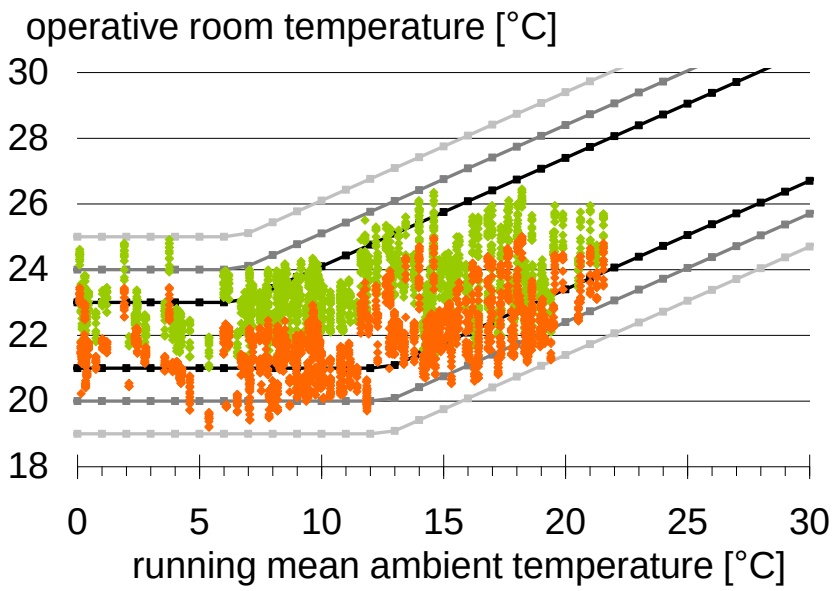
Thermal Comfort according to DIN EN 15251

2 Thermal Comfort Models

Static model (PMV)



Adaptive model



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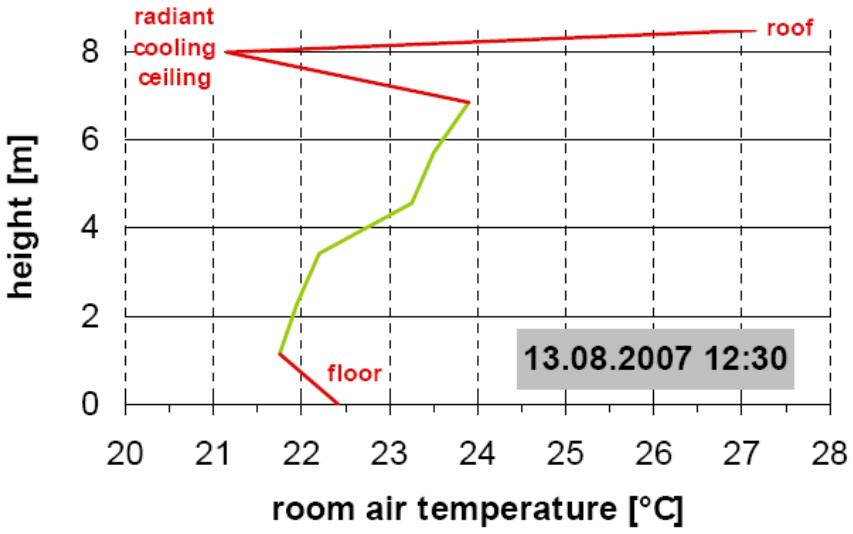
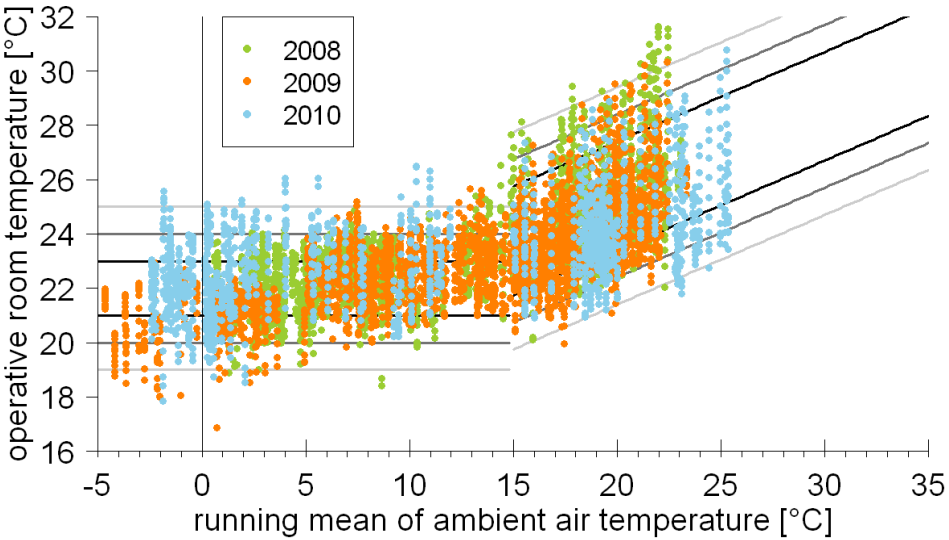
Thermal Comfort according to DIN EN 15251

Conditions in Summer

Local Comfort Evaluation



Global Comfort Evaluation



- Higher supply water temperature of 18°C

  → surface temperature 21°C
- Low vertical temperature differences

- Thermal comfort class II achieved according to adaptive model
- High influence of occupants

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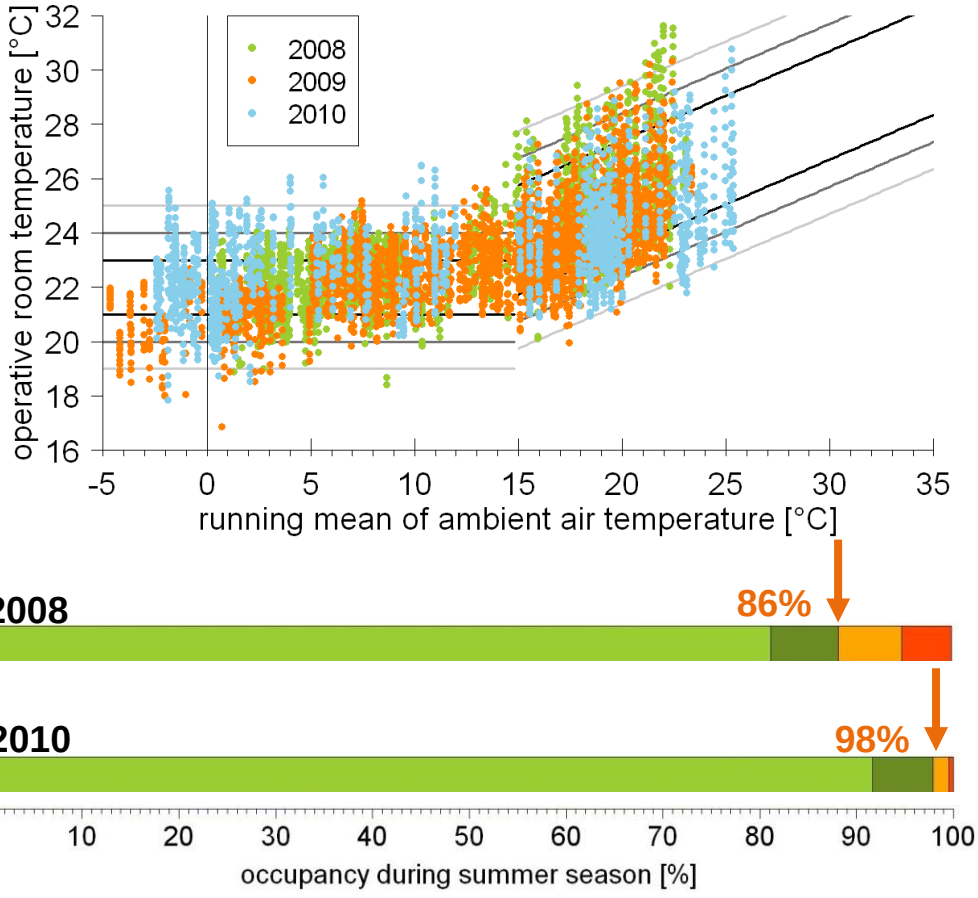
Thermal Comfort according to DIN EN 15251

Continuous Monitoring and Optimization

- Continuous monitoring of HVAC, building and interior room conditions
- Performance of cooling system and thermal comfort could be improved

Global Comfort Evaluation



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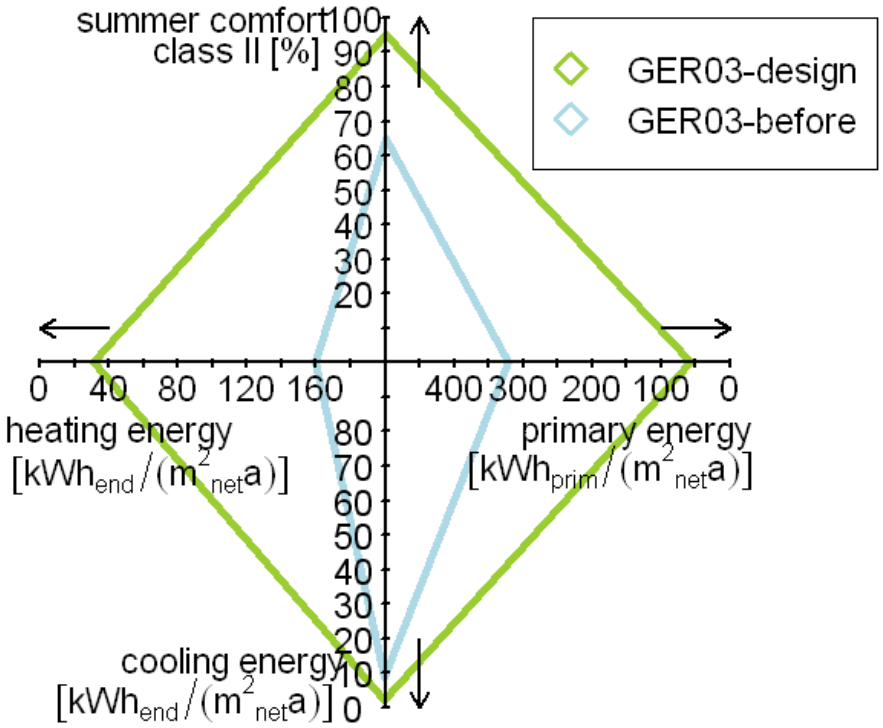
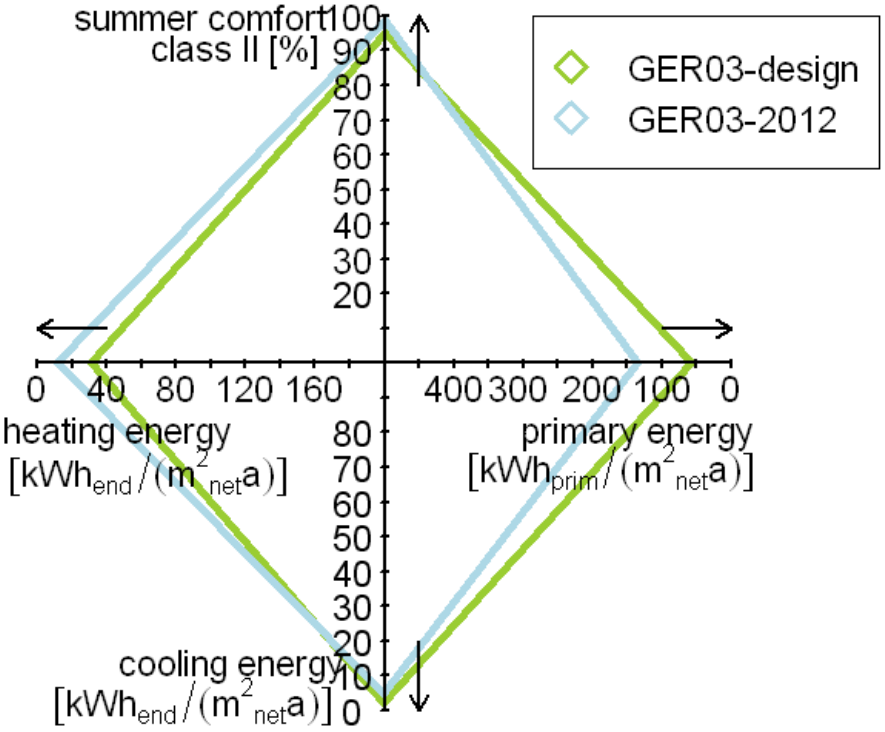
Holistic Approach of total building's performance

Before and after the retrofit

BEFORE Retrofit



AFTER Retrofit



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Summary and Conclusions

- **Building**
  - Use of hybrid ventilation concepts and solar shading
  - Mechanical ventilation systems with heat recovery, if possible
  - Reduction of (specific) heating and cooling loads in order to use LowEx heating and cooling systems in combination with environmental heat sources and sinks
- **HVAC**
  - Primary energy consumption using ground-coupled (reversible) heat pumps is lower than conventional systems with gas boilers and compression chillers
  - Use of waste heat is possible when radiant heating systems are applied
  - Directly cooling using environmental heat sinks is very energy-efficient
  - Auxiliary energy use for pumps and fans needs to be considered

Thank you very much for your attention!

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