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

Dr.-Ing. Doreen Kalz

Fraunhofer-Institute for Solar Energy Systems ISE

Symposium IEA SHC Task 47

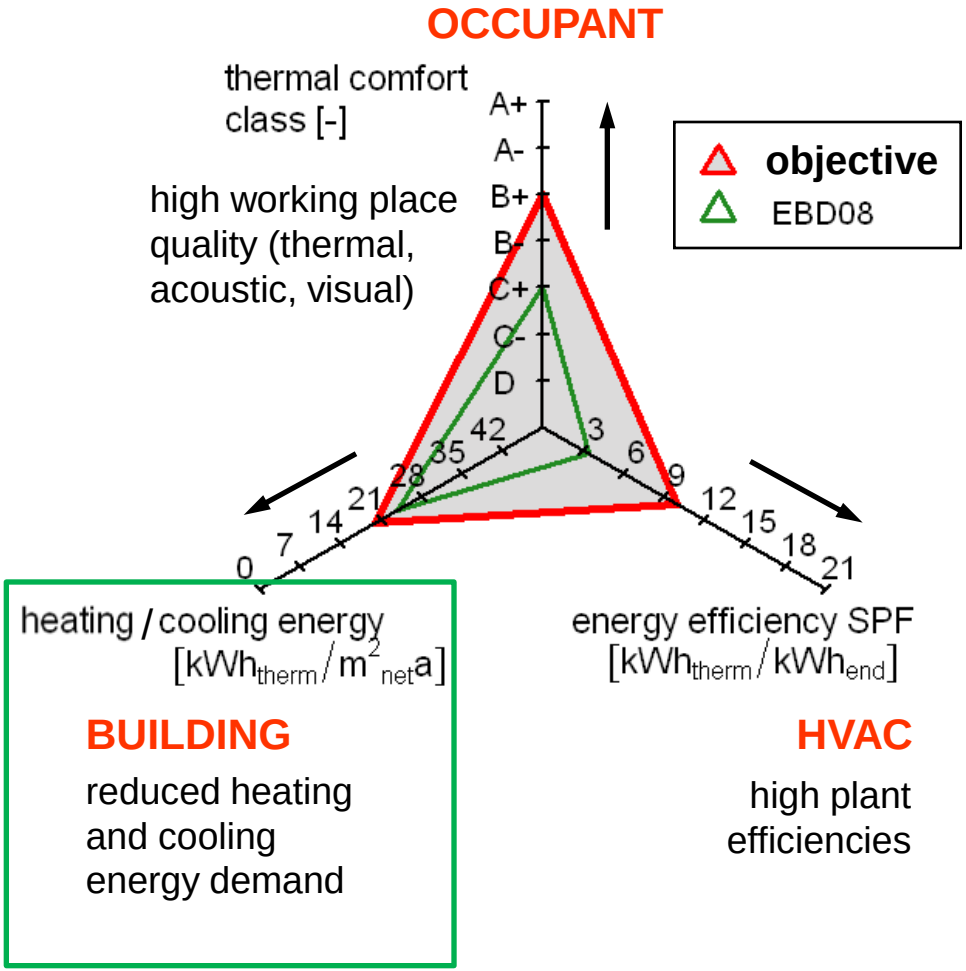
Frankfurt, 3. April 2014

www.ise.fraunhofer.de

Fraunhofer ISE

Holistic Evaluation of Concepts

Energy Use – Energy Efficiency – Thermal Comfort

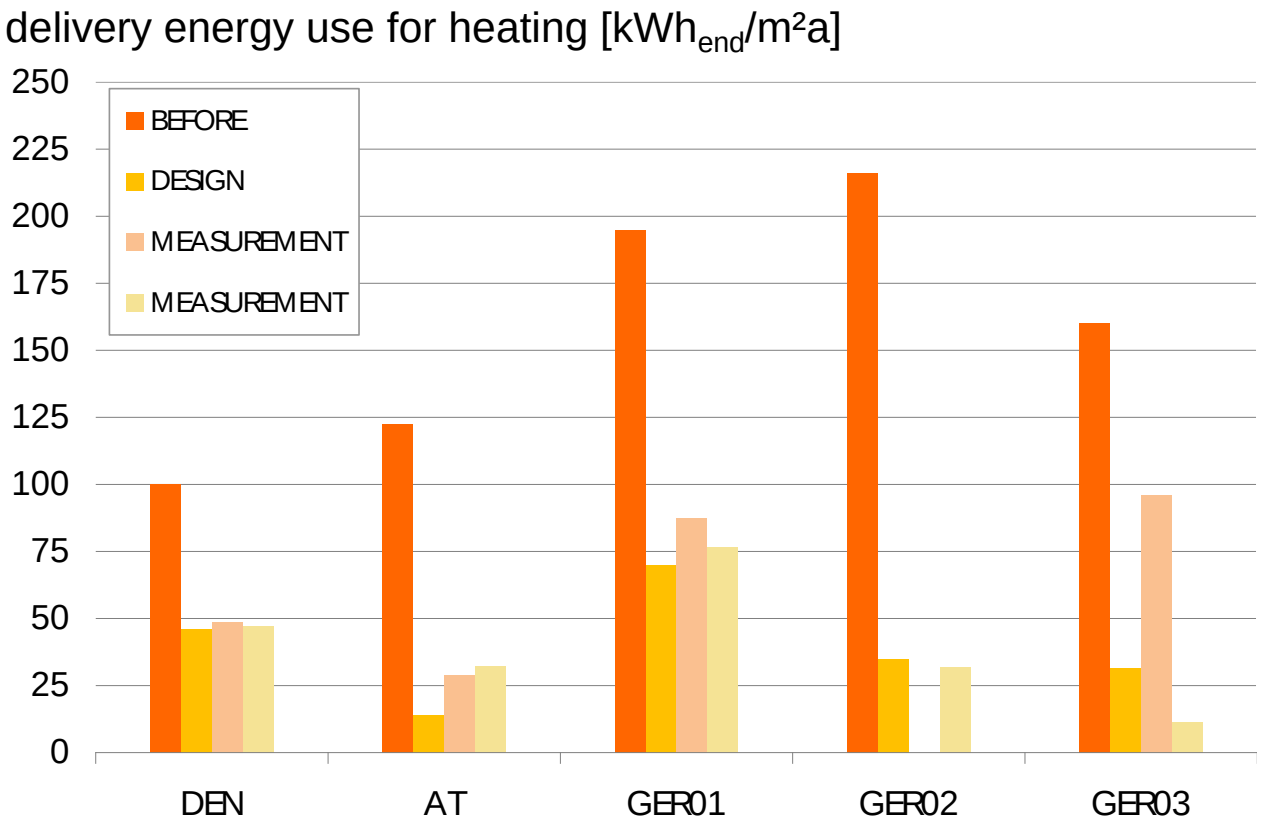


SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

EnOB Forschung für Energieoptimiertes Bauen

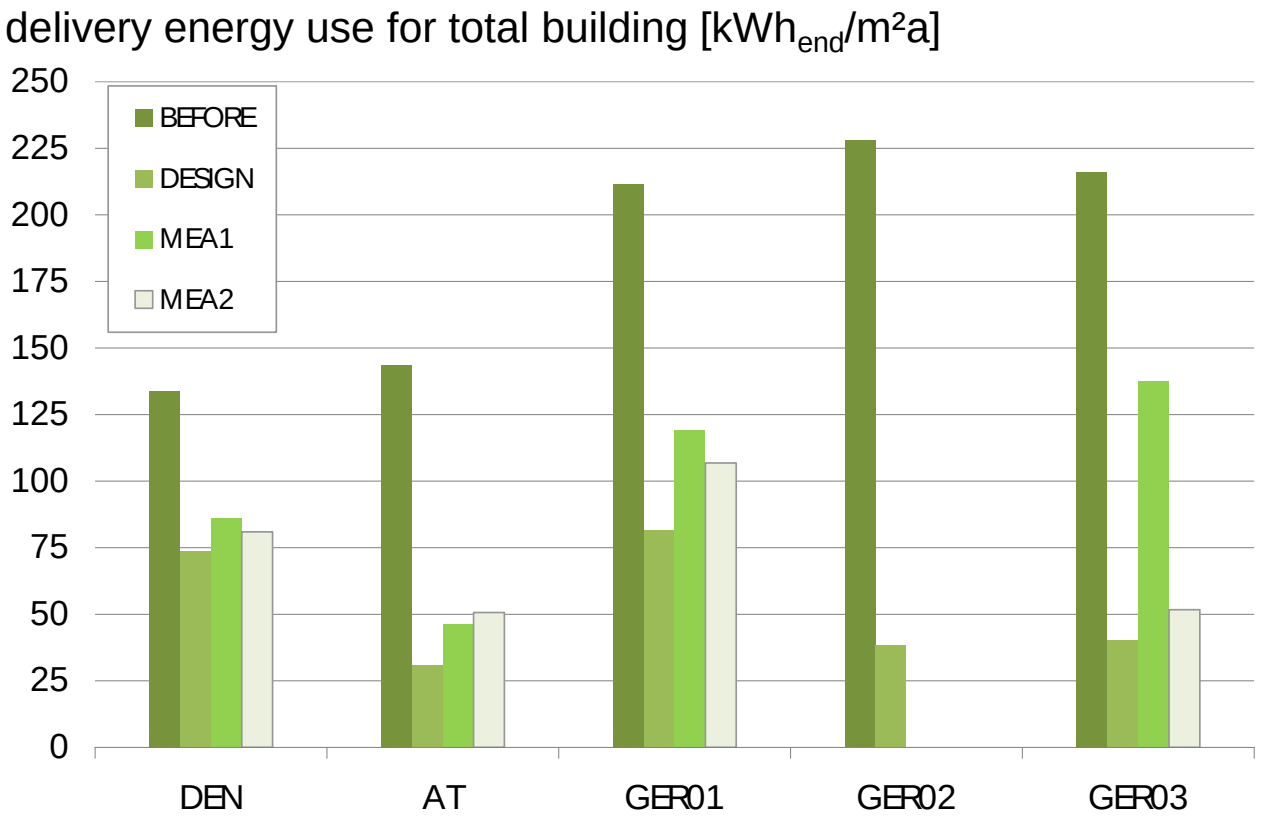
Fraunhofer ISE

Cross-Comparison
Delivered energy use: heating



Cross-Comparison

Delivered energy use: total building



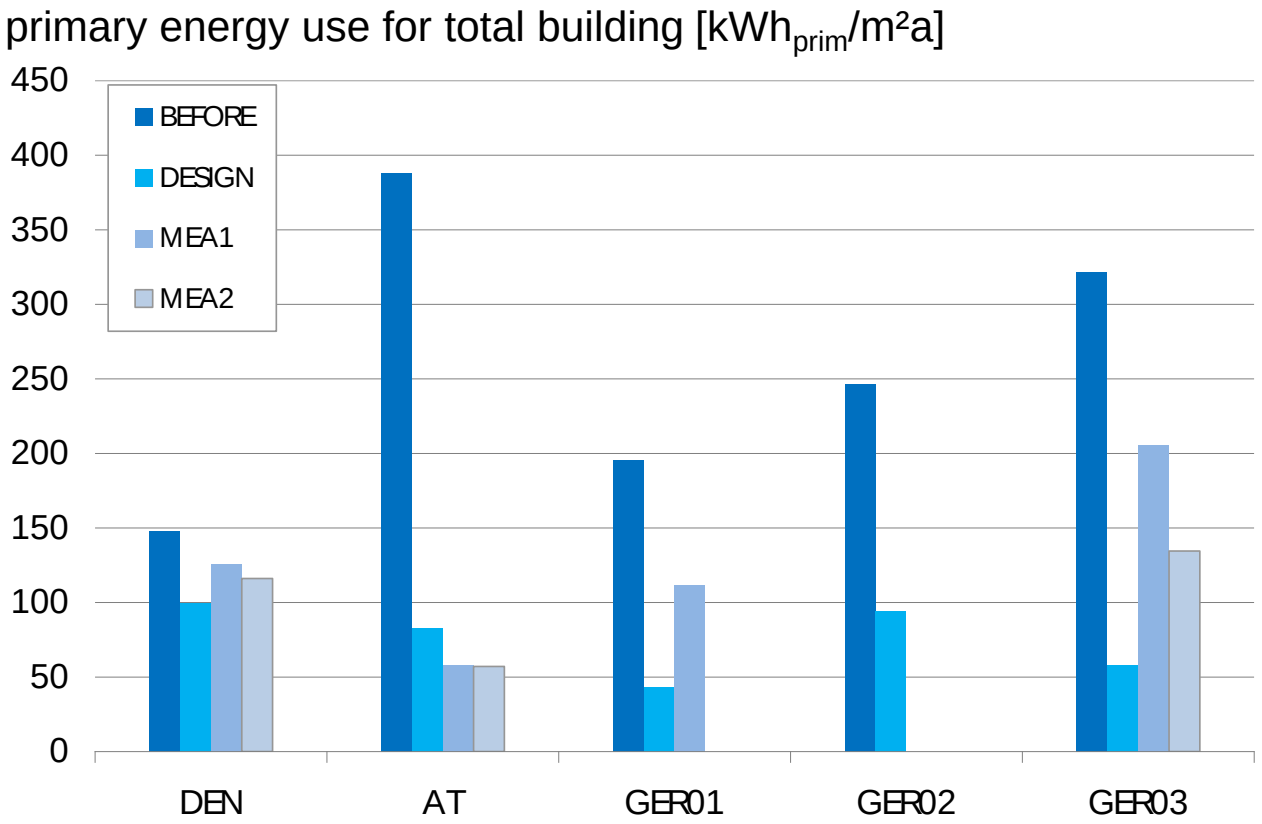
SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

EnOB
Forschung für Energieoptimiertes Bauen

Fraunhofer ISE

Cross-Comparison

Primary energy use: total building



SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

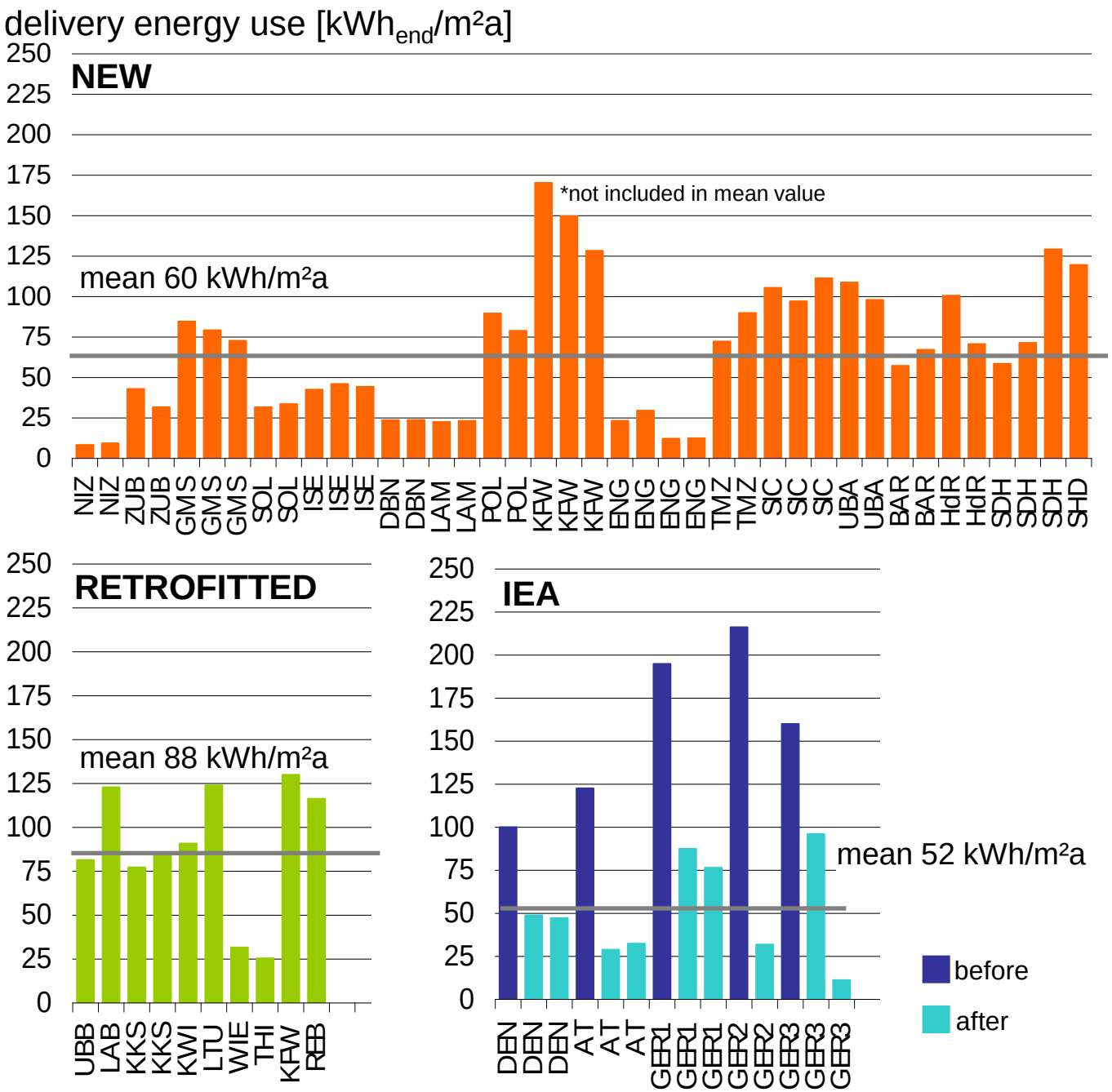
EnOB
Forschung für Energieoptimiertes Bauen

Fraunhofer ISE

Cross-Comparison Germany

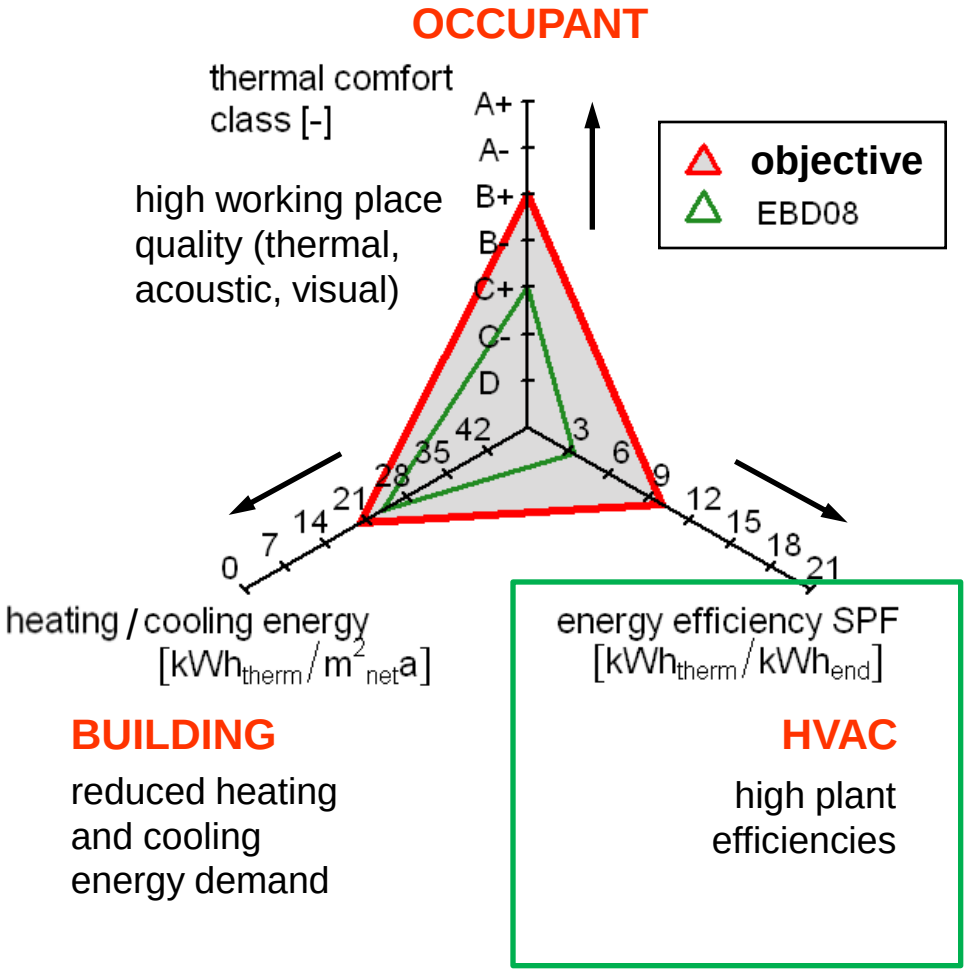
End energy use for heating

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



Holistic Evaluation of Concepts

Energy Use – Energy Efficiency – Thermal Comfort



SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

EnOB Forschung für Energieoptimiertes Bauen

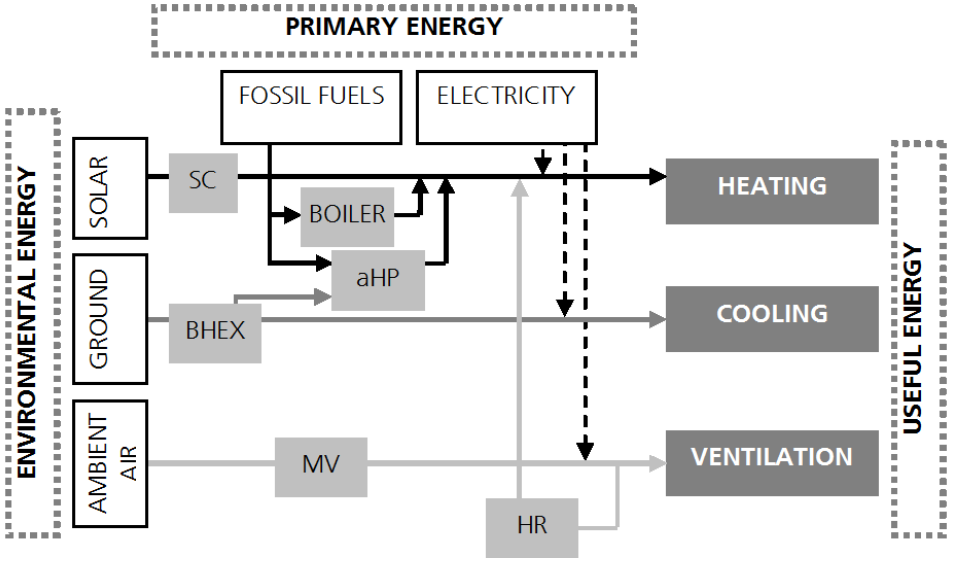
Fraunhofer ISE

Heating Concepts
Ground-coupled thermal heat pumps

Before

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

After



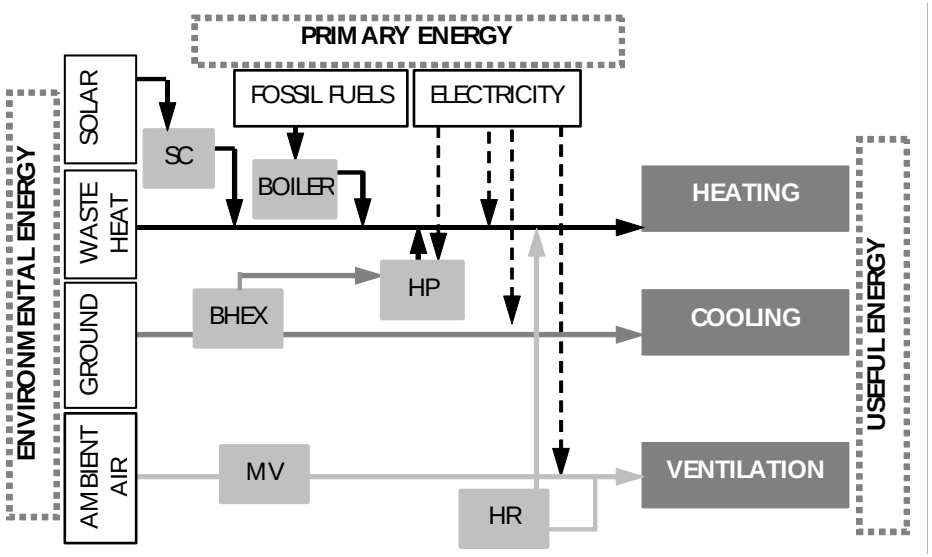
- 2 ground-coupled thermal heat pumps each 35 kW_{therm} and 2 gas boilers (2x80 kW_{therm})
- Hybrid ventilation with heat recovery
- Low temperature heating with radiators

Heating Concepts
Ground-coupled electrical heat pumps

Before

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

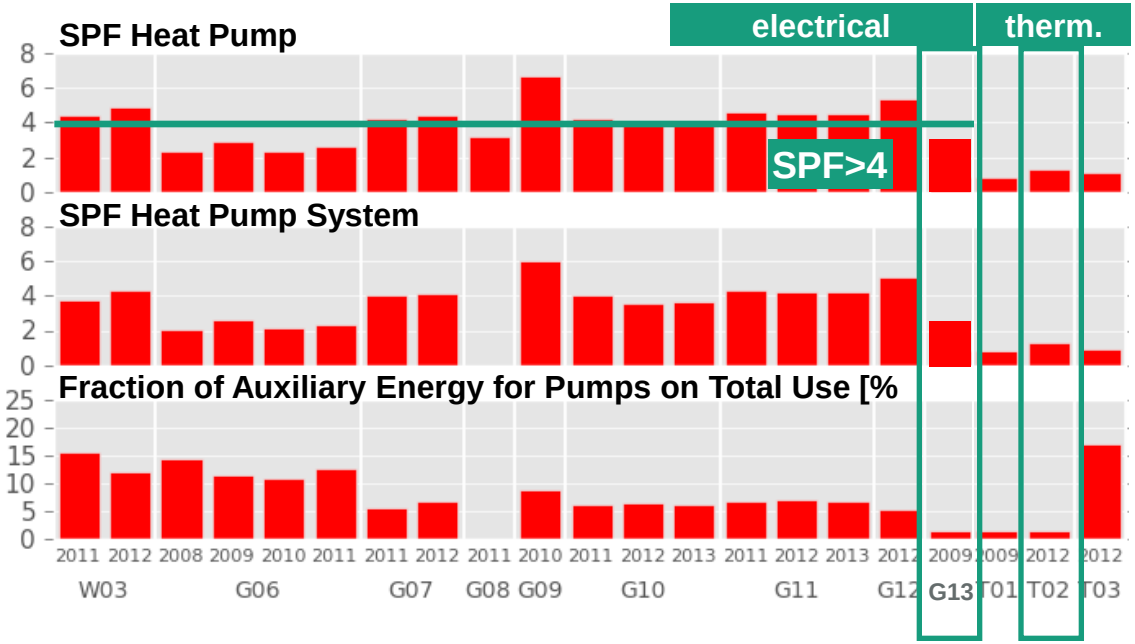
After



- 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

Operation Performance of Heat Pumps
Cross-Comparison: analysis of efficiency

- **Cross-Comparison**
  - Electrical: 2.4 – 6.6
  - Thermal: 0.8 – 1.3*
  - No significant difference between monovalent and bivalent systems
- **Retrofitted Projects:**
  - Electrical: 2.9
  - Thermal: 1.3
  - Higher supply temperature influence SPF_{el}



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

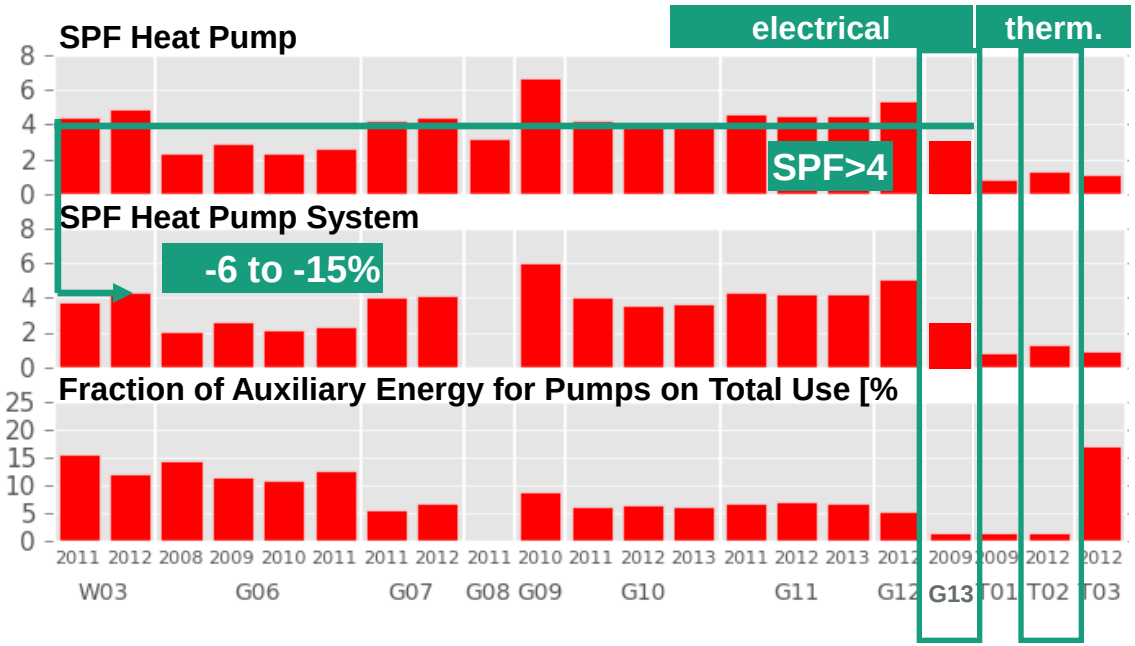
SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

EnOB Forschung für Energieoptimiertes Bauen

Fraunhofer ISE

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



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

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

EnOB Forschung für Energieoptimiertes Bauen

Fraunhofer ISE

Use of Environmental Heat Sink

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

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

EnOB Forschung für Energieoptimiertes Bauen

Fraunhofer ISE

Environmental Heat Sink Air

Night ventilation concept

before retrofit, 1970s

after retrofit

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

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

EnOB Forschung für Energieoptimiertes Bauen

Fraunhofer ISE

Environmental Heat Sink Air

Night ventilation concept

after retrofit

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

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

EnOB Forschung für Energieoptimiertes Bauen

Fraunhofer ISE

Environmental Heat Sink Air

Night ventilation concept

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

EnOB
Forschung für
Energieoptimiertes Bauen

Fraunhofer
ISE


sto
Tel. 07821 / 95070
hewe-lahr.de

Use of Environmental Heat Sink

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

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

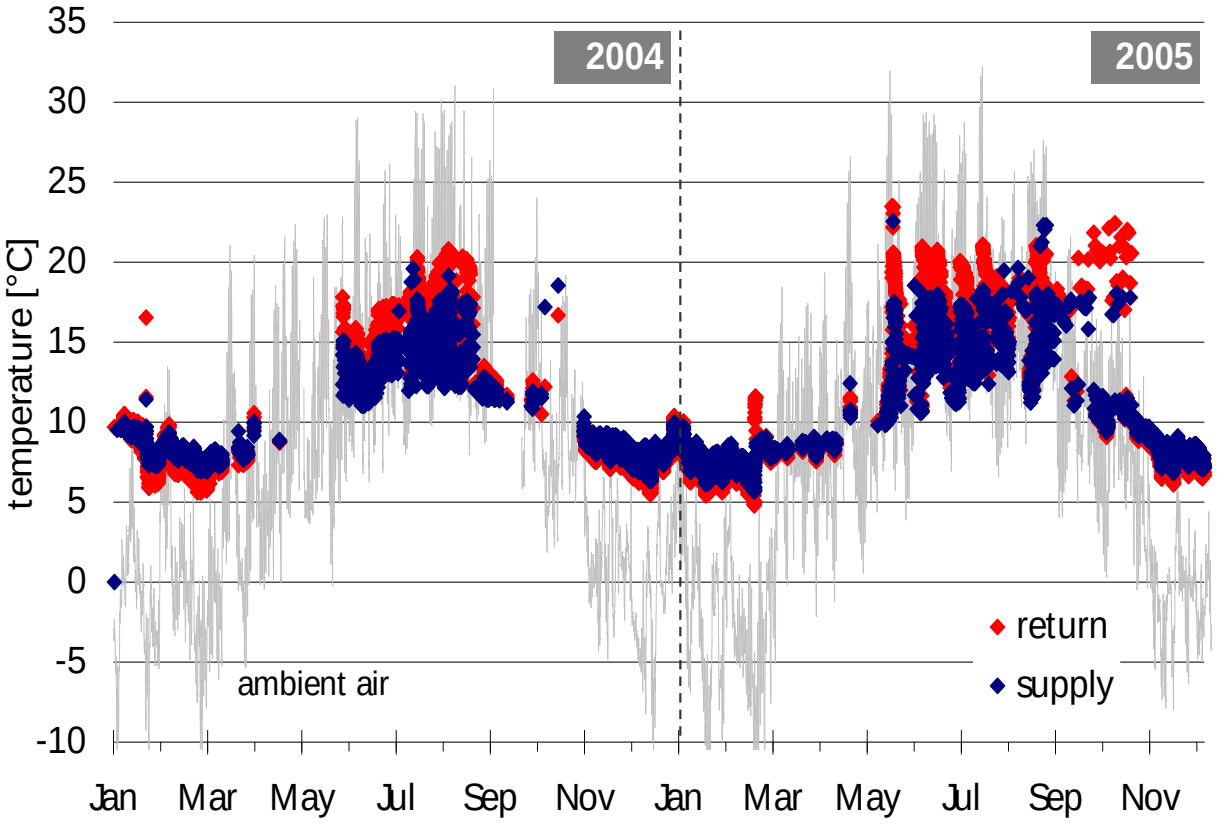
EnOB Forschung für Energieoptimiertes Bauen

Fraunhofer ISE

Use of Environmental Heat Sink

Ground temperatures

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



SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

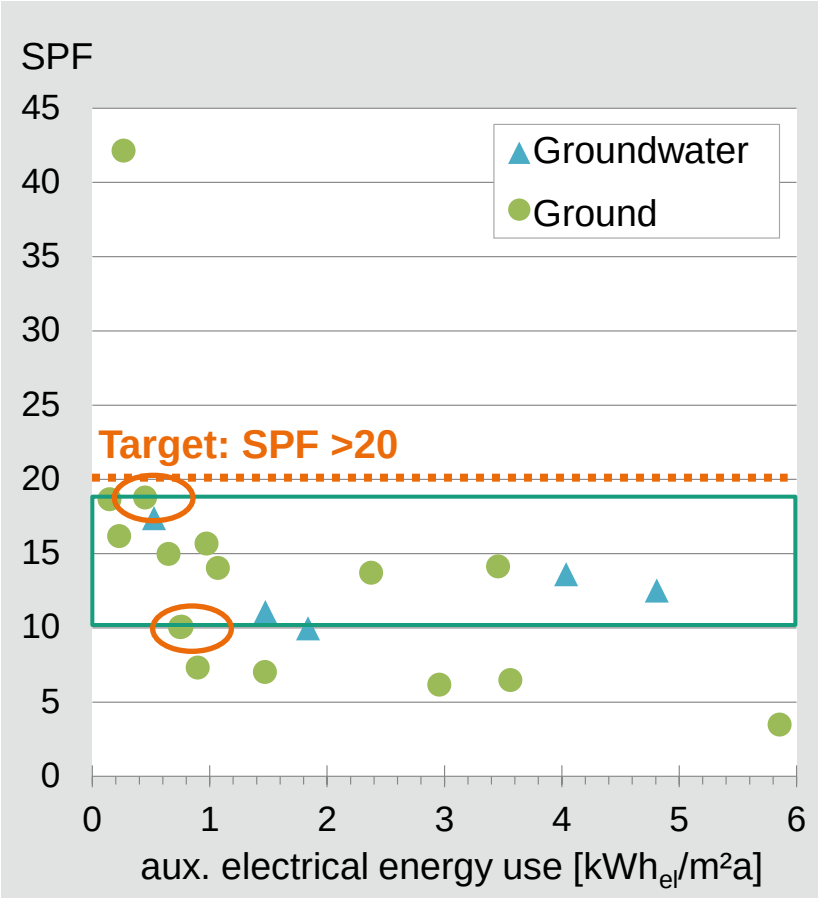
EnOB Forschung für Energieoptimiertes Bauen

Fraunhofer ISE

Use of Environmental Heat Sink

Direct cooling: analysis 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



SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

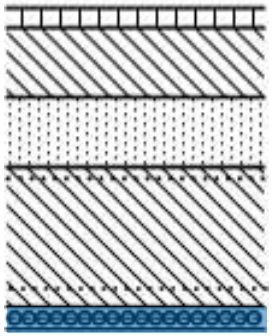
EnOB
Forschung für Energieoptimiertes Bauen

Fraunhofer ISE

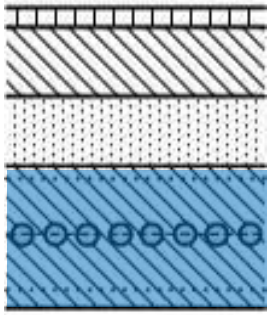
LowEx Cooling Systems

Cooling with high supply water temperatures

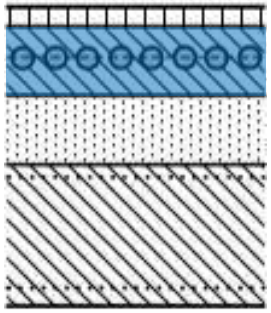
SURFACE-NEAR CONDITIONING



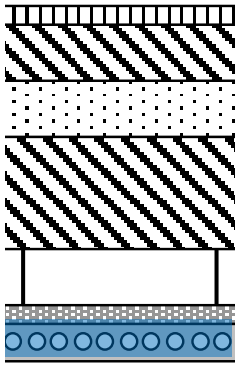
CONCRETE CORE CONDITIONING



FLOOR CONDITIONING



CEILING SUSPENDED PANELS



retrofit

retrofit

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

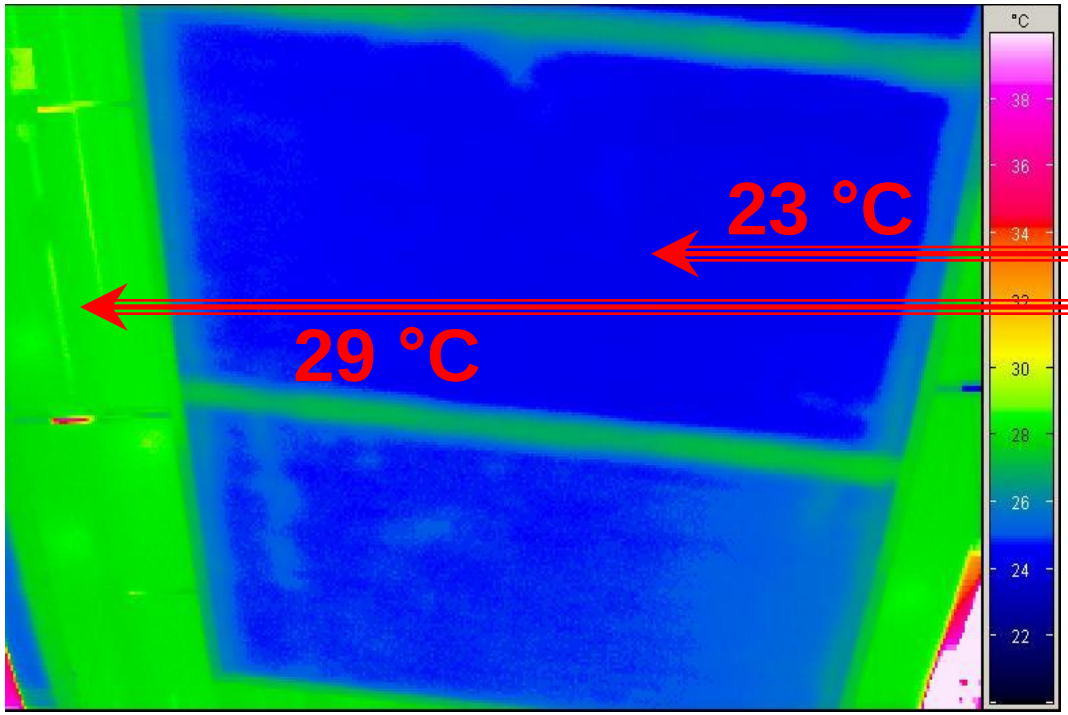
EnOB Forschung für Energieoptimiertes Bauen

Fraunhofer ISE

Radiant Cooling

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

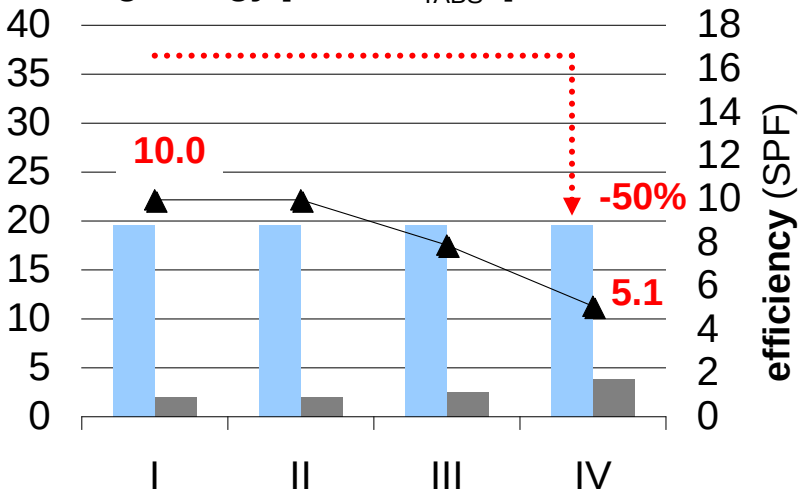
Radiant Cooling
Suspended Panels

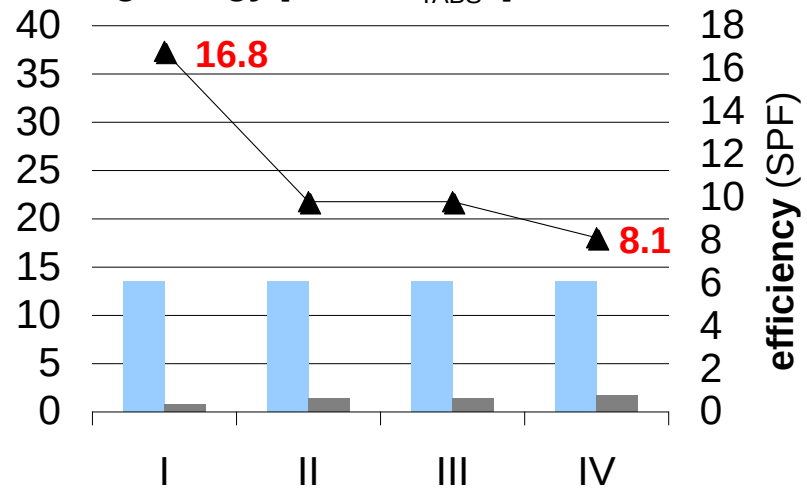


Cooling panels with phase change materials

Cooling System
Impact on auxiliary energy use for pumps

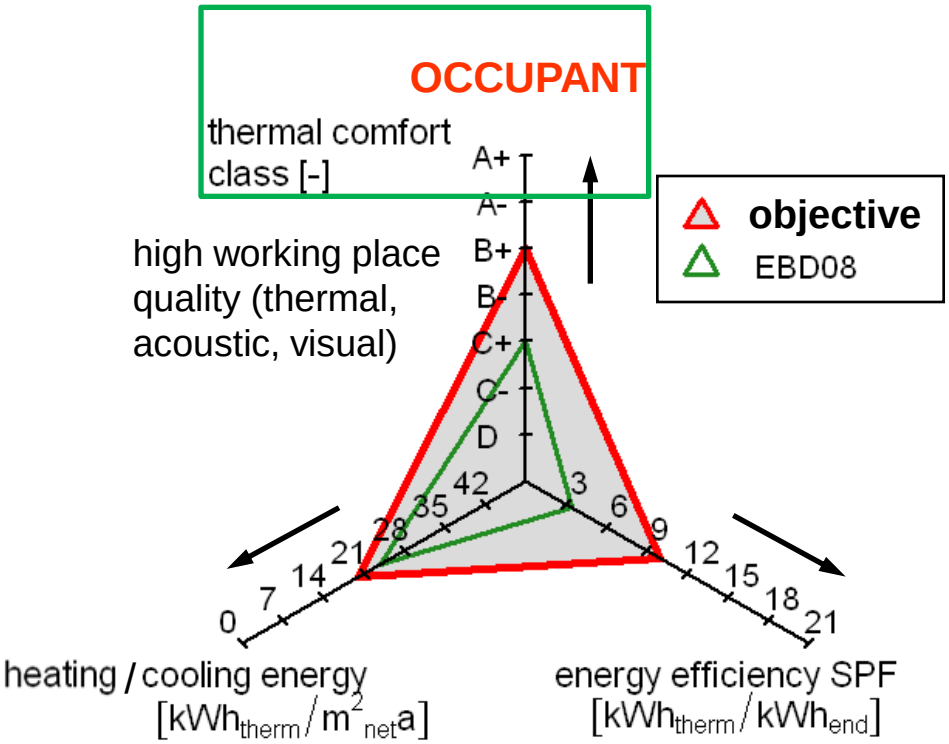
- considerable auxiliary energy use for distribution and delivery
- reduction of energy efficiency: approximately 50 %





Holistic Evaluation of Concepts

Energy Use – Energy Efficiency – Thermal Comfort



BUILDING

reduced heating and cooling energy demand

HVAC

high plant efficiencies

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

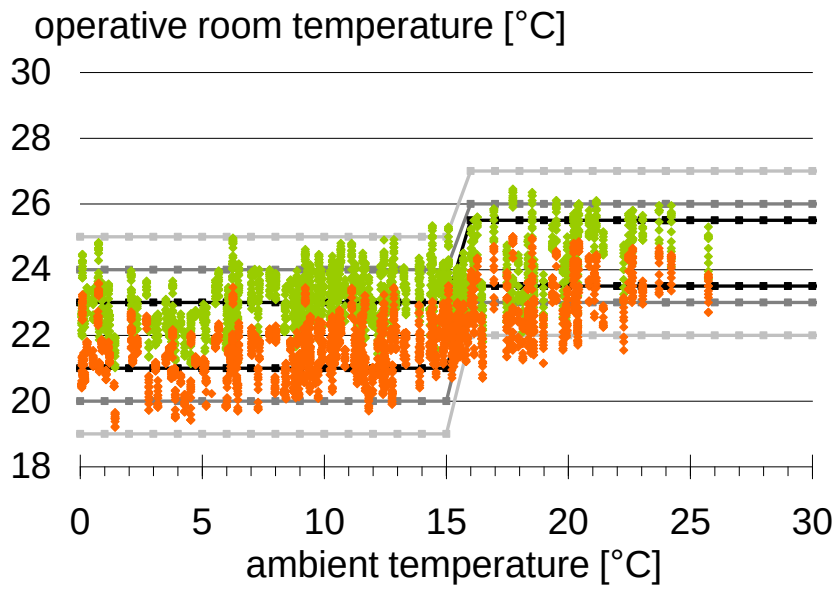
EnOB Forschung für Energieoptimiertes Bauen

Fraunhofer ISE

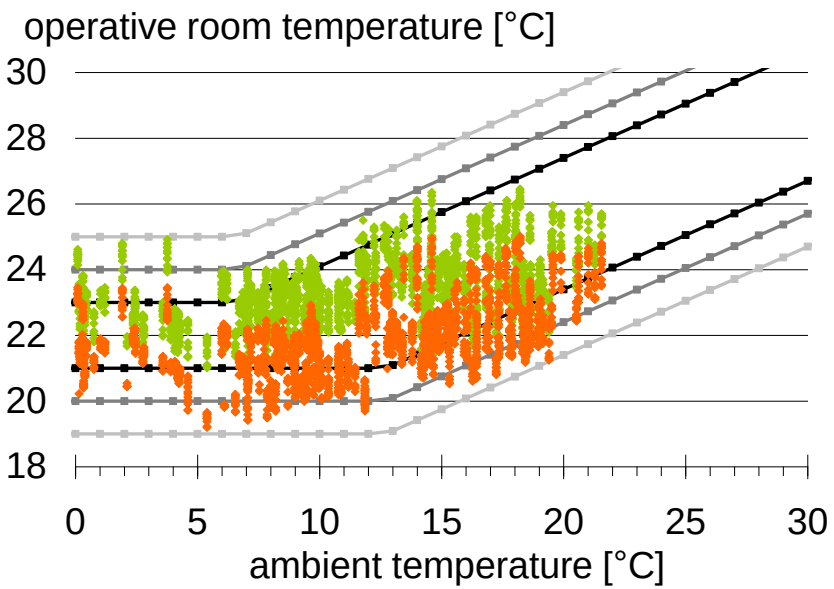
Thermal Comfort according to DIN EN 15251

2 Comfort models

Static model (PMV)



Adaptive model



SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

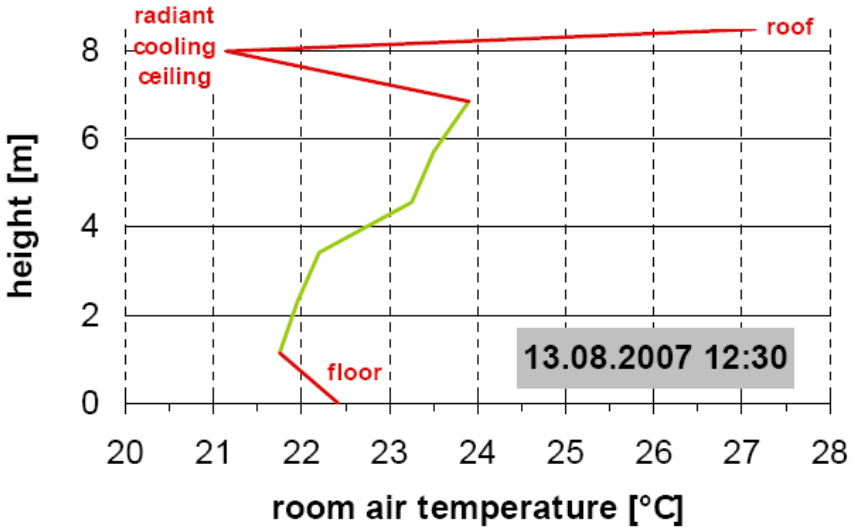
EnOB
Forschung für Energieoptimiertes Bauen

Fraunhofer ISE

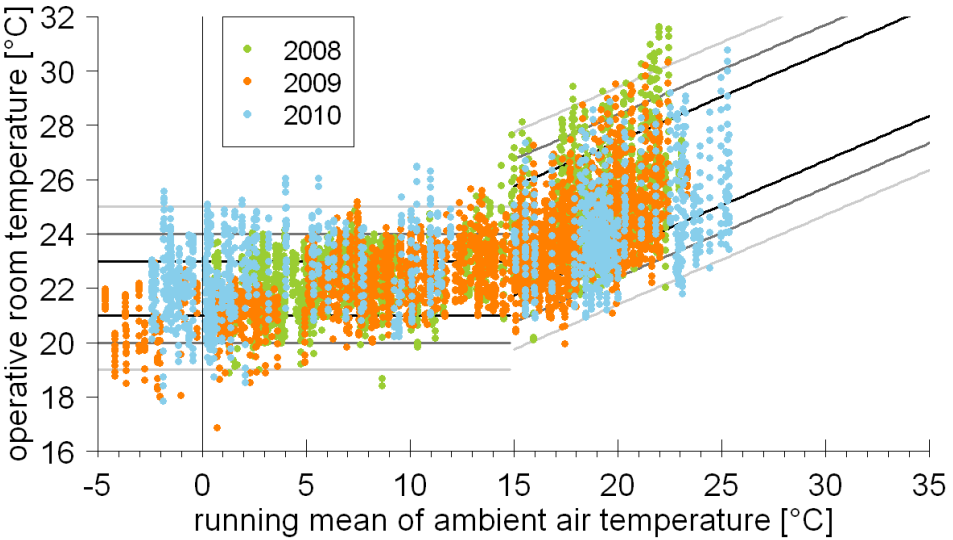
Thermal Comfort according to DIN EN 15251

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

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

EnOB Forschung für Energieoptimiertes Bauen

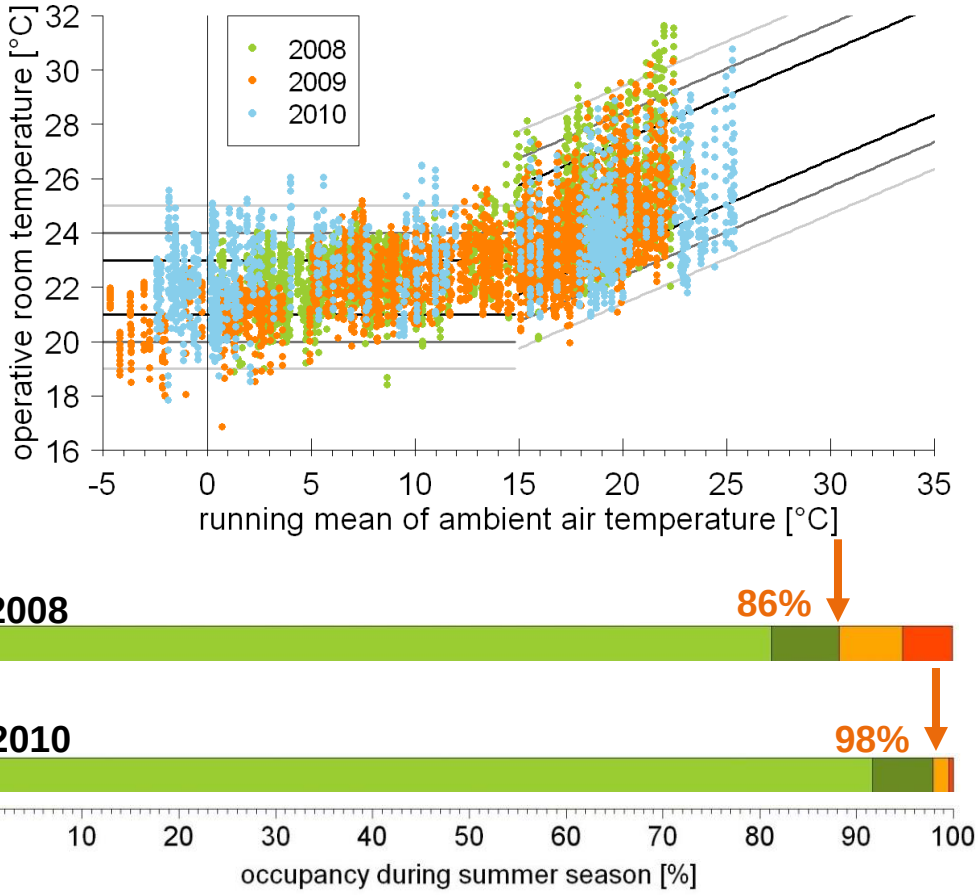
Fraunhofer ISE

Thermal Comfort according to DIN EN 15251

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



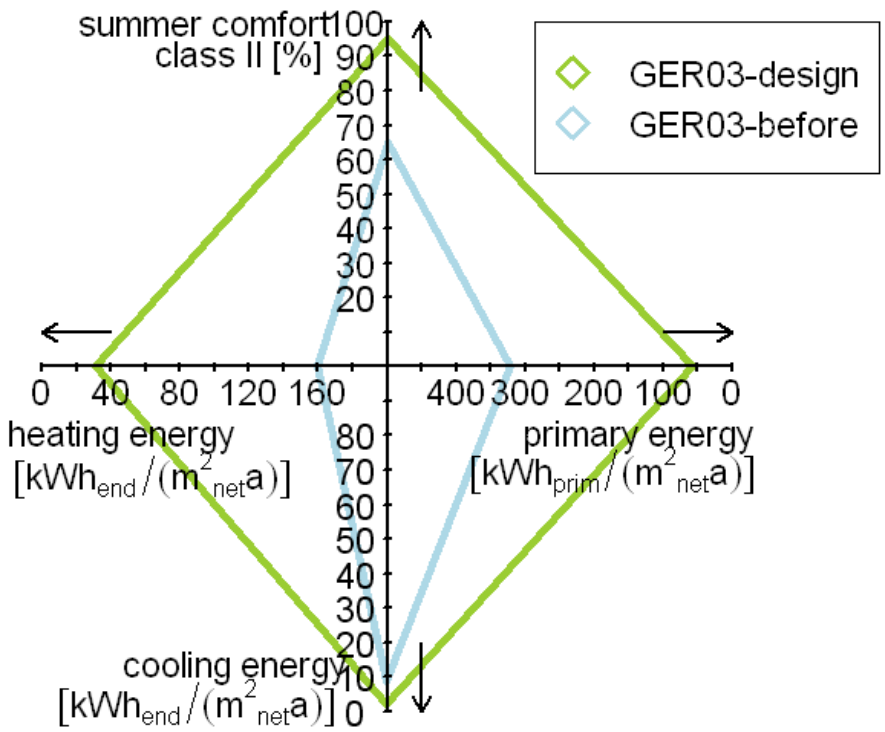
SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

EnOB Forschung für Energieoptimiertes Bauen

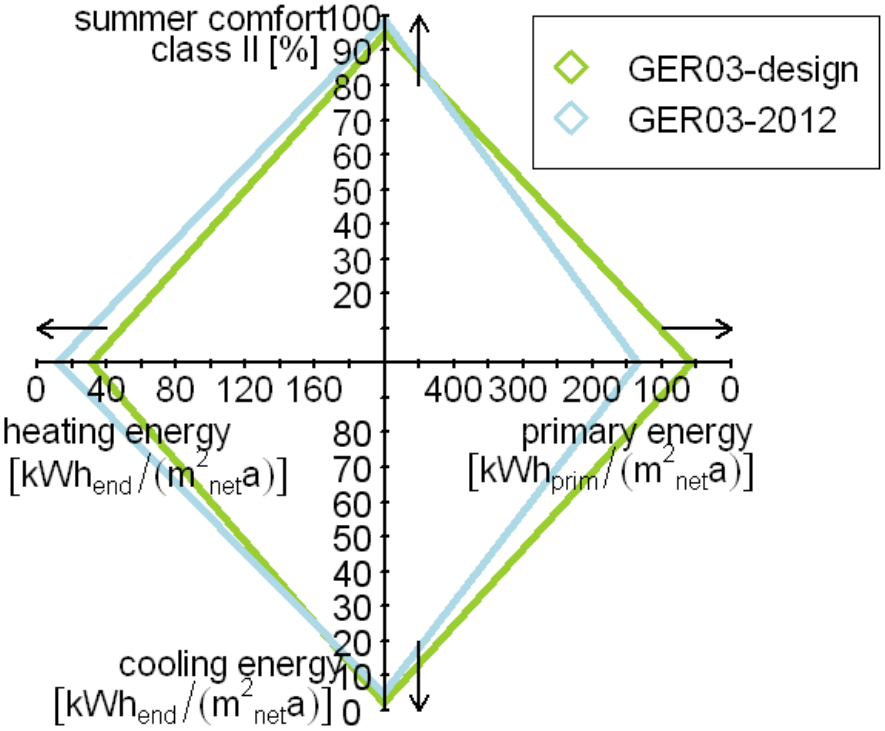
Fraunhofer ISE

Holistic Approach of total building's performance

BEFORE Retrofit



AFTER Retrofit



Summary and Conclusion

- **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!

Fraunhofer-Institute for Solar Energy Systems ISE

Dr.-Ing. Doreen Kalz

www.ise.fraunhofer.de

doreen.kalz@ise.fraunhofer.de

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

EnOB Forschung für Energieoptimiertes Bauen

Fraunhofer ISE