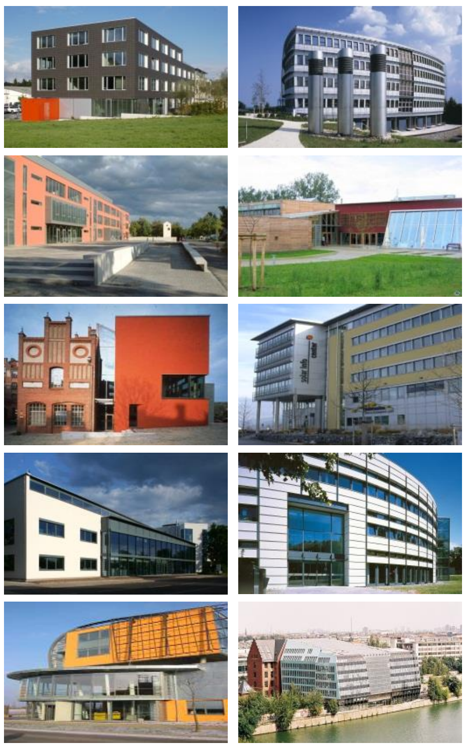
# COOLING CONCEPTS FOR LOW-ENERGY BUILDINGS USING ENVIRONMENTAL ENERGY: THERMAL COMFORT AND ENERGY EFFICIENCY



**Simon Winiger**

Fraunhofer-Institute for Solar Energy Systems ISE

SHC Task 47 Seminar

Sydney, April 5th 2013

www.ise.fraunhofer.de



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# The Fraunhofer ISE

- **Freiburg**: Fraunhofer Institute for Solar Energy Systems
- **Largest solar energy research institute** in Europe, non-profit organization
- **Applied research**
- **Staff**: 1,200
- **Revenue**: 69 Mio. Euros*
- **Income from industry**: 53% of total revenue*
- Income from national and international funding bodies




*2011

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# Areas of Business at Fraunhofer ISE

- Energy Efficient Buildings
- Applied Optics and Functional Surfaces
- Solar Thermal Technology
- Silicon Photovoltaics
- Photovoltaic Modules and Systems
- Alternative Photovoltaic Technologies
- Renewable Power Supply
- Hydrogen Technology

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# Business Area: Energy Efficient Buildings

- Façades and Windows
- Building Concepts, Analysis and Operation
- Heat Storage for Heating and Cooling
- Energy-Efficient and Solar Cooling
- Energy Supply Systems for Buildings
- Lighting Technology
- Building-Integrated PV

# Our Cities Worldwide
## Challenges






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# Vision for Tomorrow
## Smart and Energy Efficient




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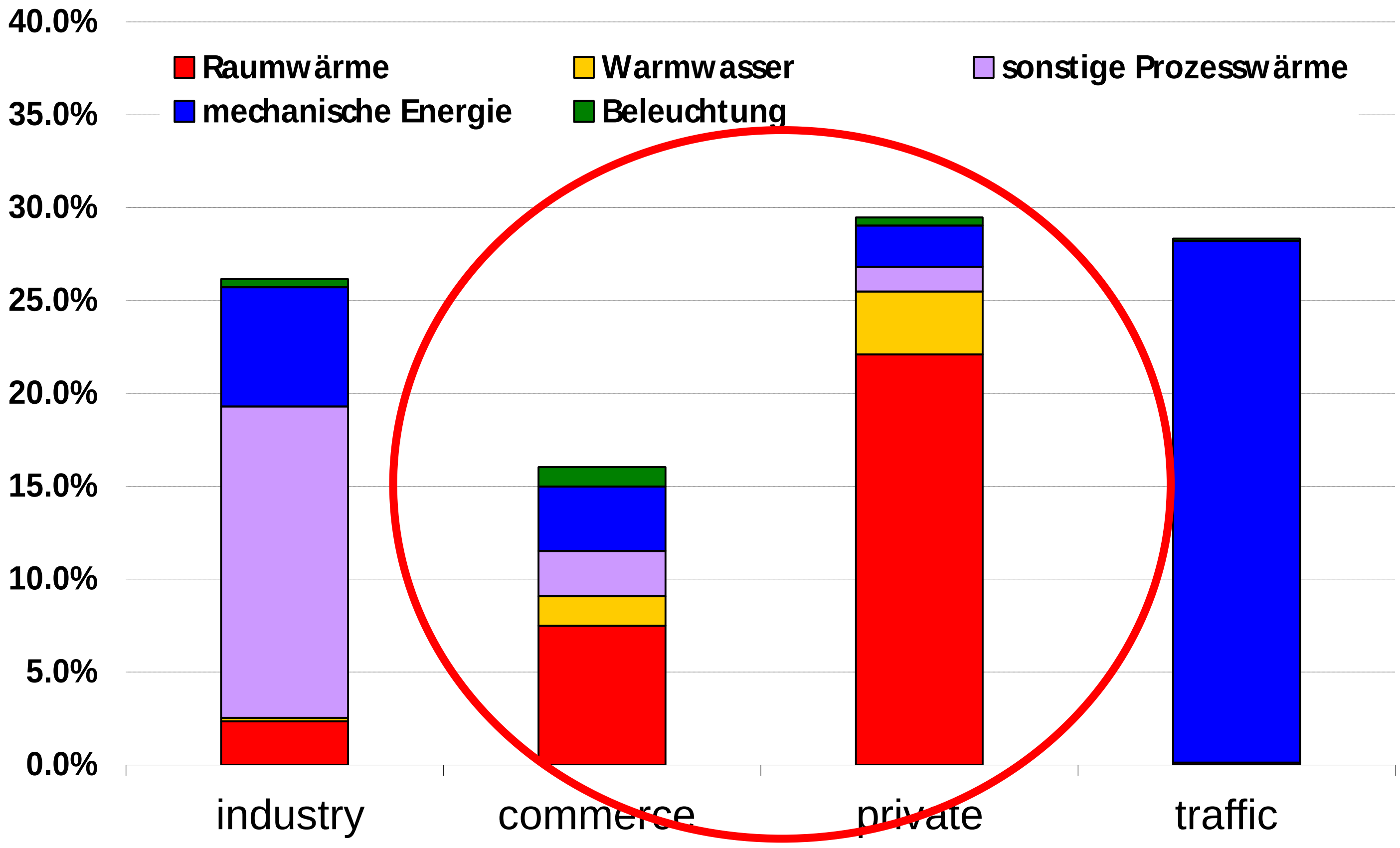
# Buildings and Energy

## Final Energy Use, Germany 2005

- Buildings contribute 42 % to total consumption
- Buildings

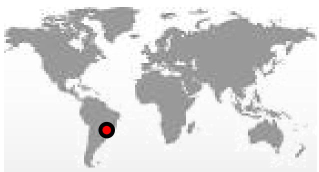
→ 75 % for heating

→ 12 % for hot water




Source: Arbeitsgemeinschaft Energiebilanzen, Verband der Elektrizitätswirtschaft - Projektgruppe Nutzenergiebilanzen

# Buildings and Cities around the world

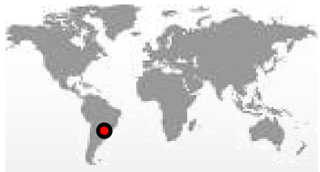



***Edifício Santa Catarina***

São Paulo – Brazil

2005-2007

30.767 m²




***Ventura Towers***

Rio de Janeiro – Brazil

2006-2010

172.000 m²


***Deutsche Bank Twin Towers***

Frankfurt am Main – Germany

1979-1984

60.000 m²


***Shanghai World Financial Center***

Shanghai –China

2003-2008

377.300 m²

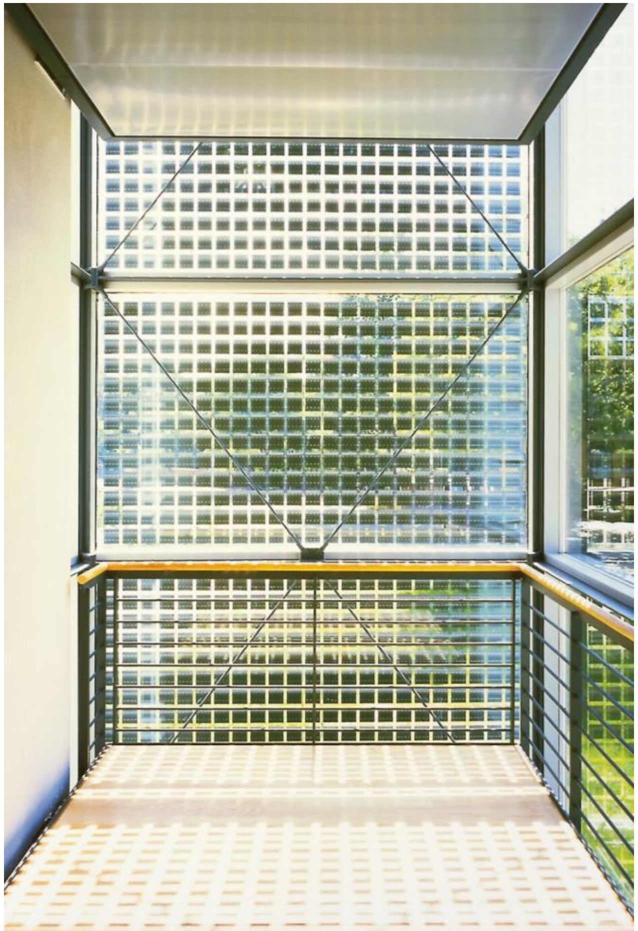

***Hearst Tower***

New York - USA

2003-2006

80.000 m²

# Agenda – Intelligent Buildings. Lean Concepts.



- **Buildings and Climate**
  Learn From Traditional Buildings.
- **Hybrid Ventilation Concepts**
  Reduce the Loads.
- **Water-Driven TABS**
  Reduce the Final Energy Use.
- **Thermal Comfort**
  User Acceptance.





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# Buildings and Climate
## Climate Conscious Design

**Approach:**

- Analysis of Location
- Definition of Goals
- Building Physics
- Efficient HVAC

→ lean building concept

Quelle : www





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# Holistic approach to energy efficient buildings

## Building Envelope: Passive Technologies

Reduction of energy demand

- Building envelope
- Shading
- Ventilation

# Holistic approach to energy efficient buildings

## Use of Environmental Heat Sinks/Sources

Reduction of energy demand
- Building envelope
- Shading
- Ventilation

Use of heat sources/ sinks in the environment
- Ground
- Air
- Building thermal mass



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# Holistic approach to energy efficient buildings

## Energy Efficient HVAC

Reduction of energy demand
- Building envelope
- Shading
- Ventilation

Use of heat sources/ sinks in the environment
- Ground
- Air
- Building thermal mass

Efficient conversion (minimize exergy losses)
- Combined heat, (cooling), power
- Minimize parasitic consumption





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# Holistic approach to energy efficient buildings

## Renewable Power Supply

**Reduction of energy demand**
- Building envelope
- Shading
- Ventilation

**Use of heat sources/ sinks in the environment**
- Ground
- Air (T, x)
- Building thermal mass

**(Fractional) covering of remaining demand using onsite renewable energies**
- Solar thermal
- PV
- (Biomass)

**Efficient conversion (minimize exergy losses)**
- Combined heat, (cooling), power
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# Holistic approach to energy efficient buildings

Reduction of energy demand
- Building envelope
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- Ground
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# EnBau:Monitor
## 90 low-energy commercial and factory buildings











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# Environmental Energy

## Surface-near Geothermal Energy and Ambient Air

| GEOTHERMAL ENERGY | | | AMBIENT AIR | |
| --- | --- | --- | --- | --- |
| surface-near ground | ground water | surface water | nat. / mech. ventilation | cooling tower |
|  |  |  |  |  |
| | | | natural and hybrid ventilation | dry / wet cooling towers |




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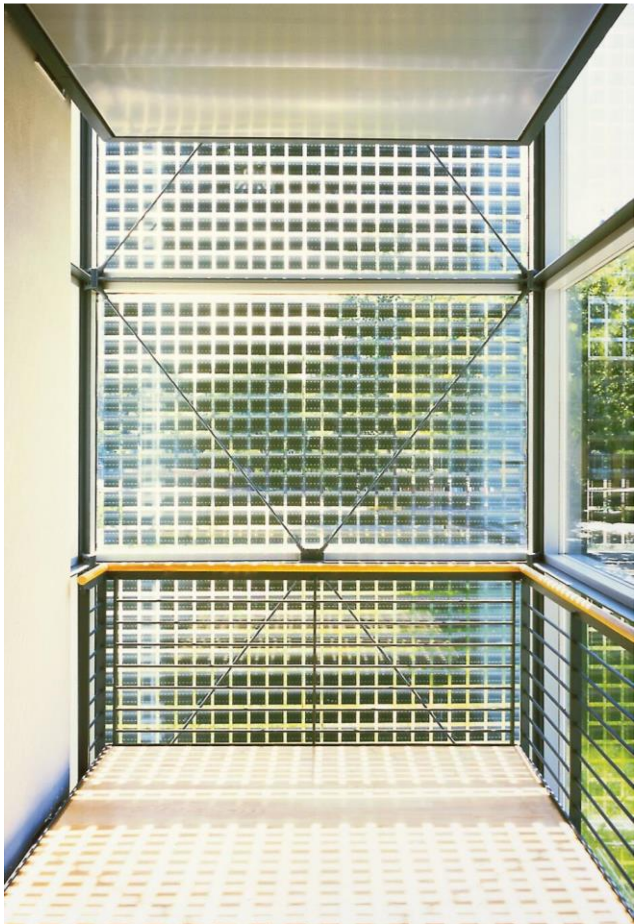
# Intelligent Buildings. Lean Concepts.



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# Passive Cooling and Indoor Climate
## Hybrid Ventilation Concept

building before retrofit, 1970s

building after retrofit

daytime: natural ventilation, mechanical ventilation

nighttime: nighttime ventilation concept in summer, ventilation slats





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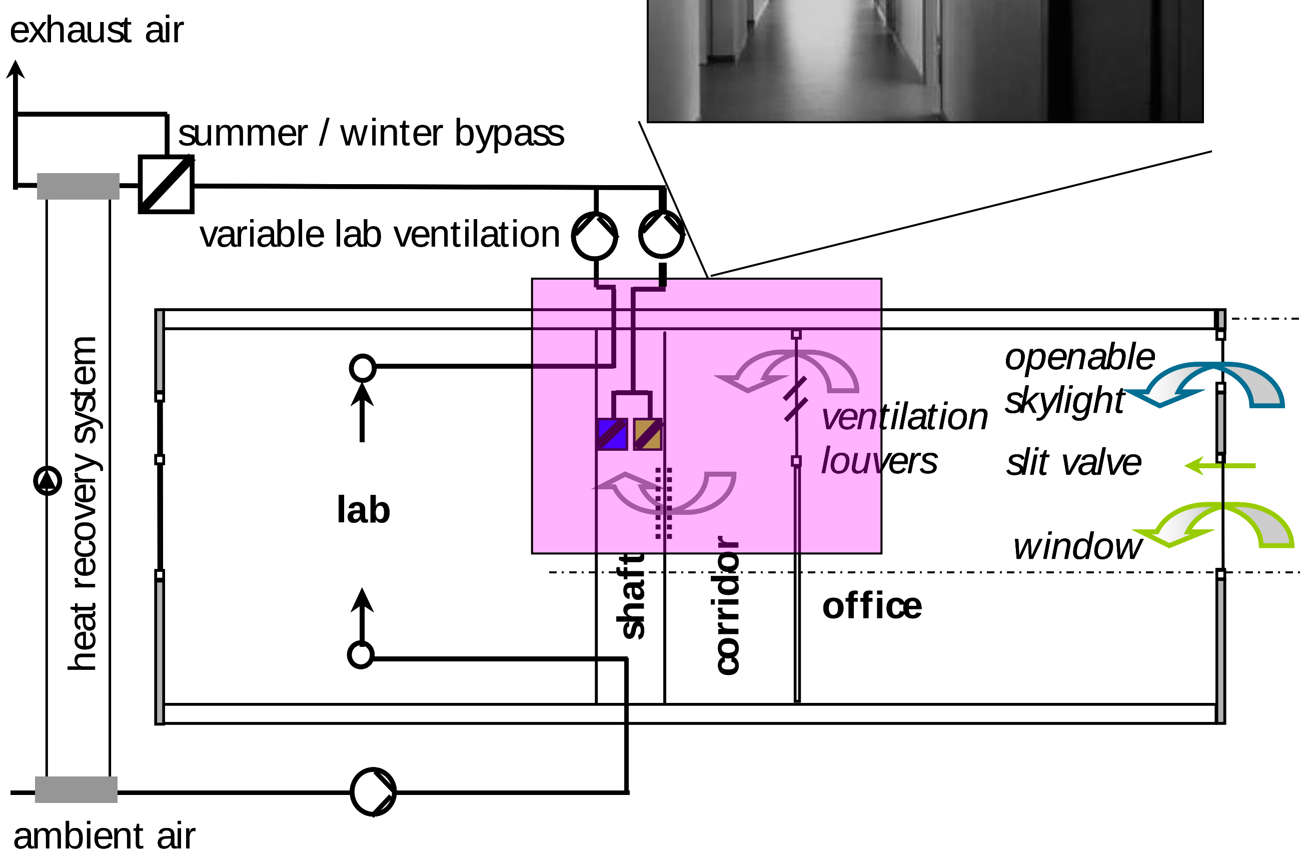
# Hybrid Ventilation
## Fraunhofer ISE





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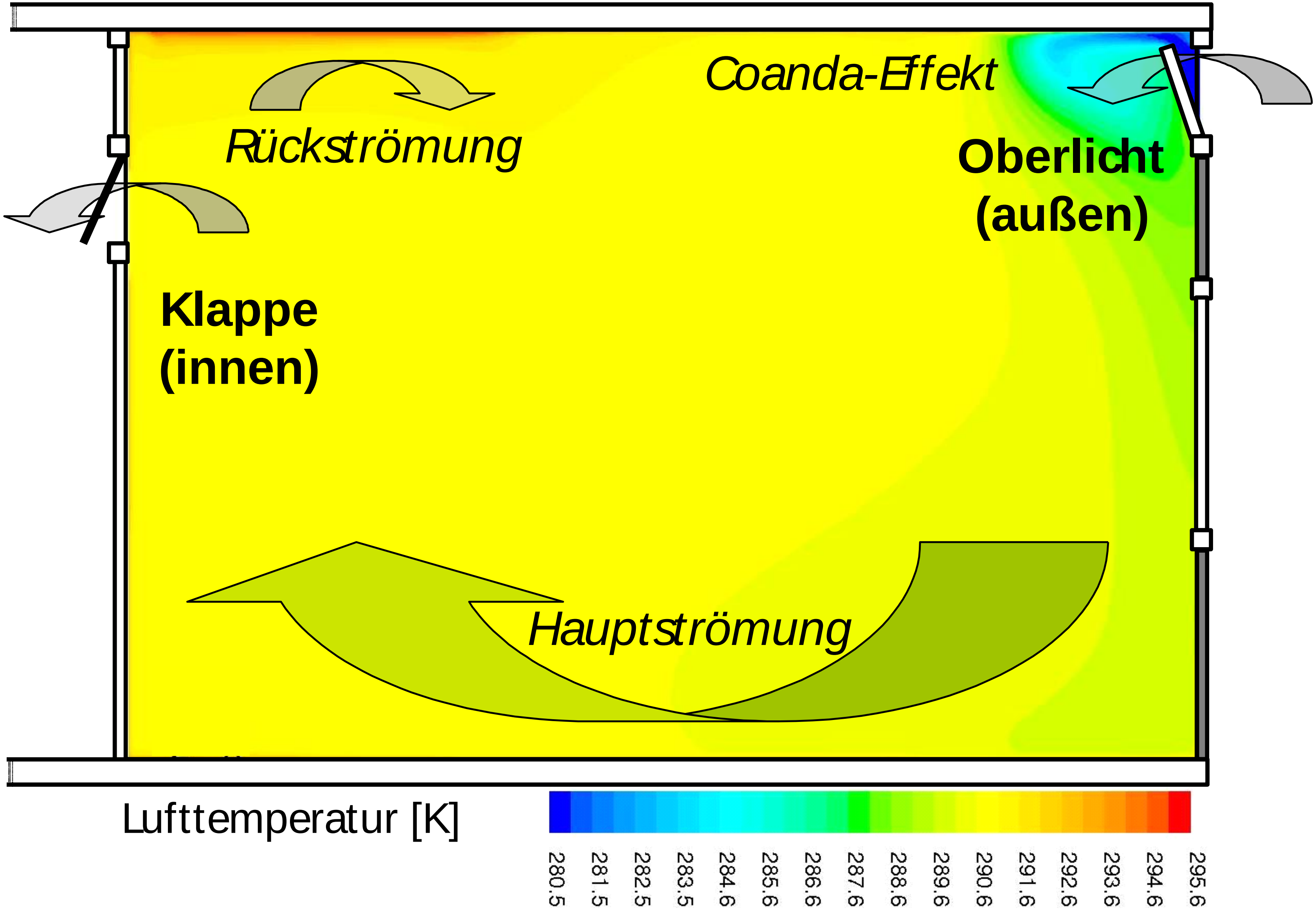
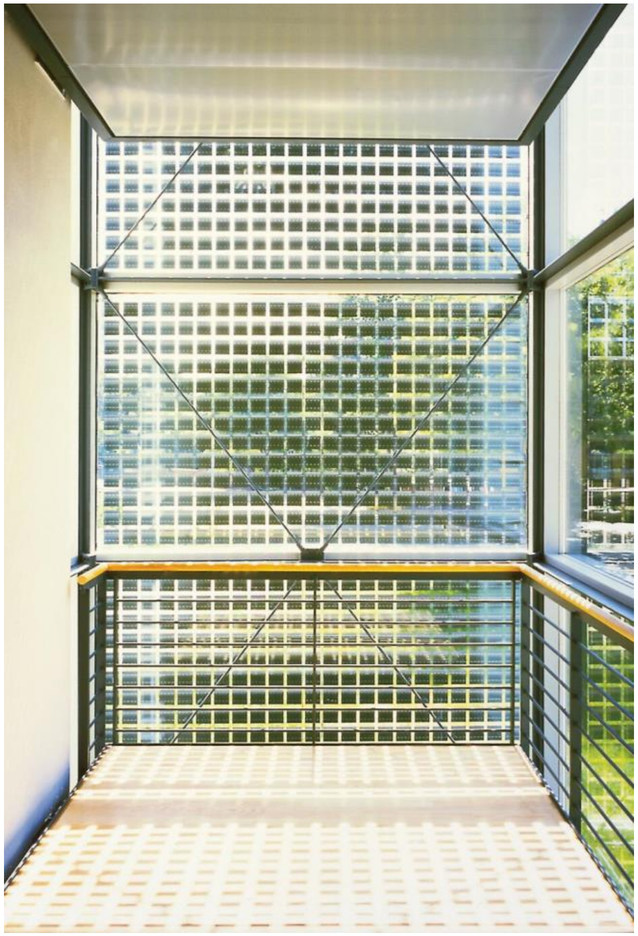

Coanda-Effekt
Rückströmung
Oberlicht
(außen)
Klappe
(innen)
Hauptströmung
Lufttemperatur [K]
280.5
281.5
282.5
283.5
284.6
285.6
286.6
287.6
288.6
289.6
290.6
291.6
292.6
293.6
294.6
295.6

# Conclusion
## Hybrid Ventilation

- **hybrid ventilation concept**
  is a cornerstone in energy efficient buildings.
- **monitoring of user behaviour**
  shows that passively cooled buildings work well.
- **statistical simulation**
  shows that user behaviour is predictable.
- **design guidebooks**
  describe the way how to design and operate
  low-energy buildings with passive cooling

# Intelligent Buildings. Lean Concepts.



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# Environmental Energy

## Surface-near Geothermal Energy and Ambient Air

**GEOTHERMAL ENERGY**

**surface-near ground**

ground up to 120 m

**ground water**

10 to 25 m

open-loop

Restricted use

**surface water**

collection of rainwater in underground tanks

**AMBIENT AIR**

**nat. / mech. ventilation**

natural and hybrid ventilation

**cooling tower**

dry / wet cooling towers

# Potential of Environmental Heat Sources and Sinks

## ground temperature

**COOLING**

supply 12-20°C

deltaT 2-6 K

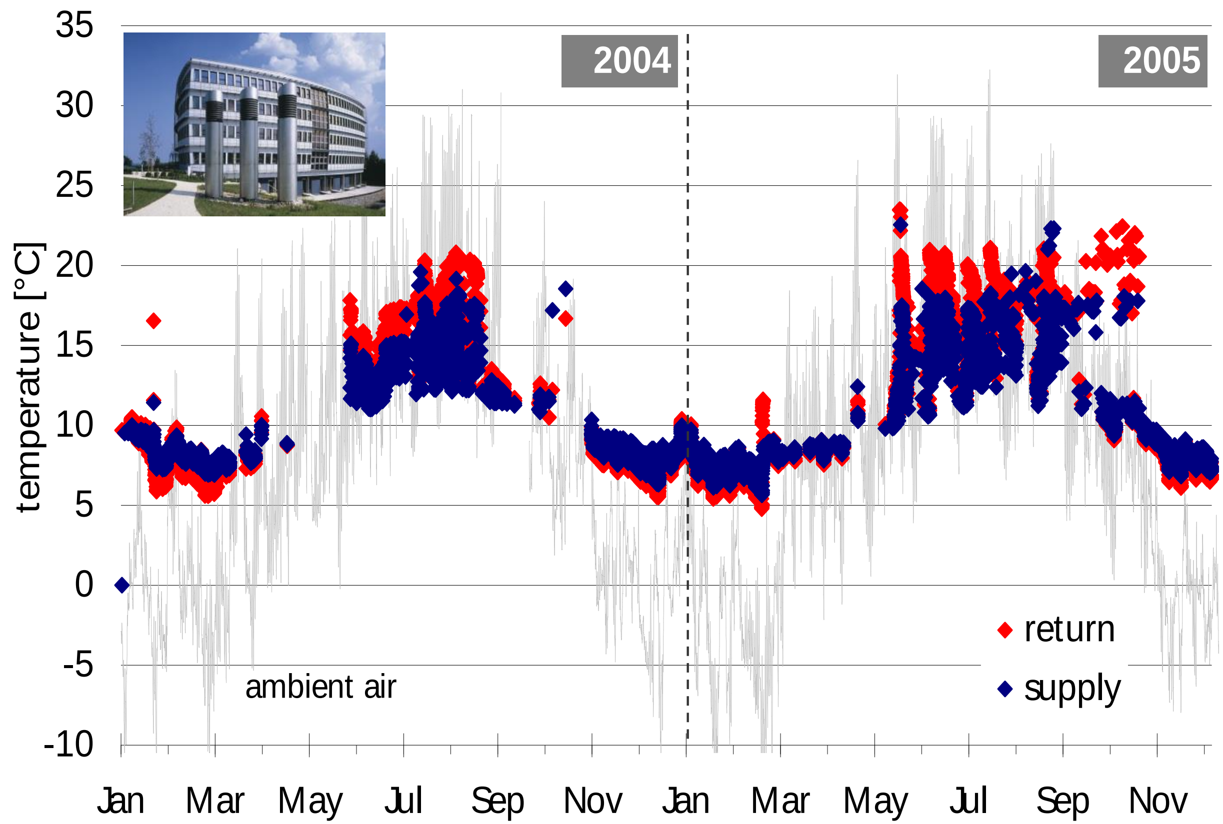
10-40 $W/m_{BHEX}$

**HEATING**

supply 6-14°C

deltaT 2-3 K

8-35 $W/m_{BHEX}$

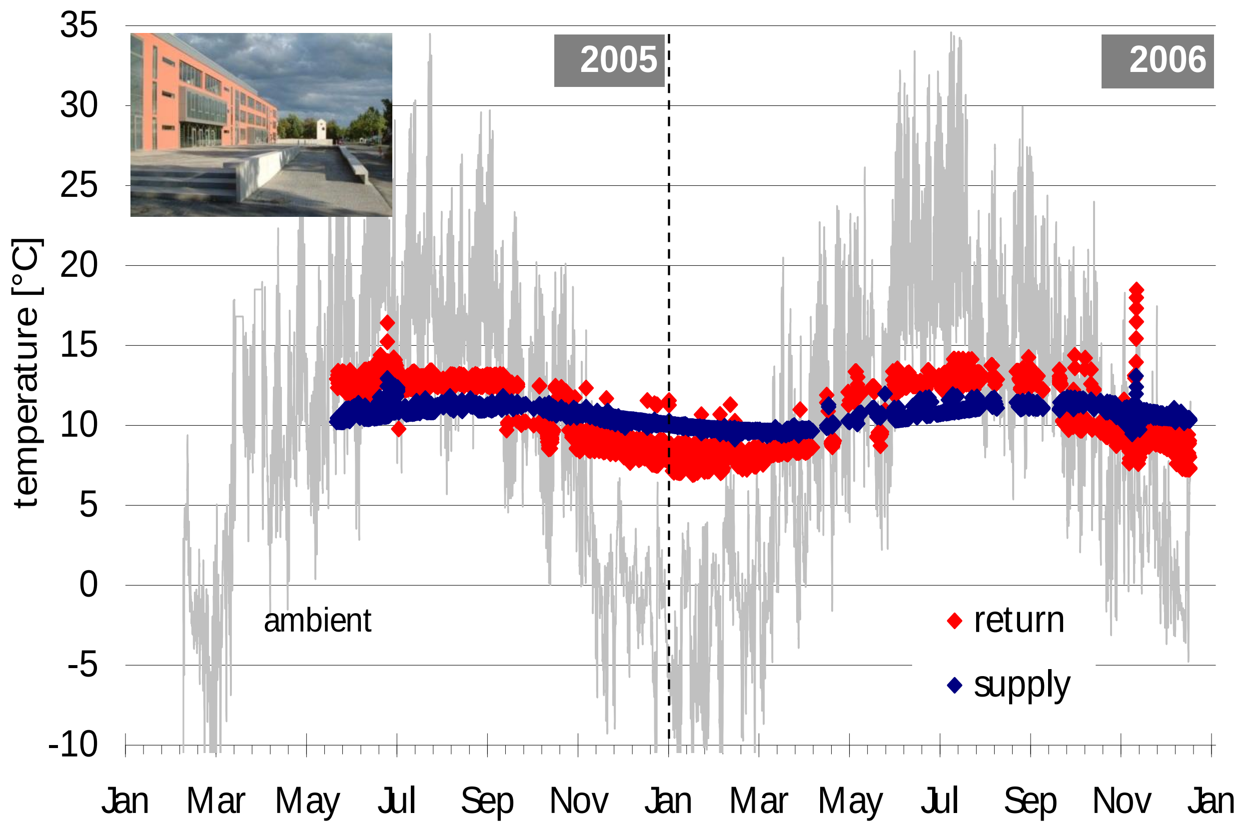


# Potential of Environmental Heat Sources and Sinks
groundwater temperature

**COOLING / HEATING**

supply 9 -12°C

deltaT 2 - 6 K





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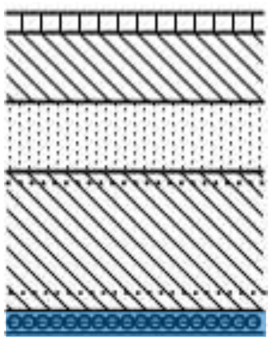
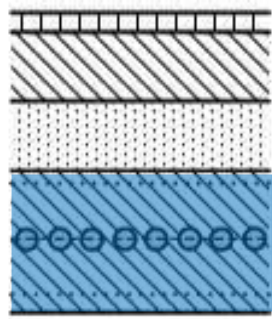
# Water-based Cooling Concepts

## Thermo-Active Building Systems (TABS)

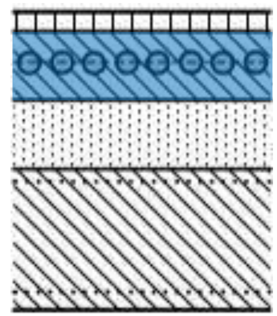
**SURFACE-NEAR CONDITIONING**



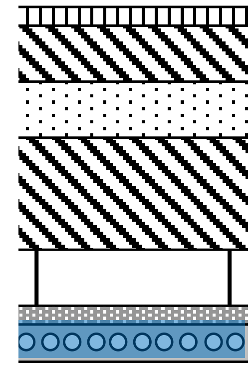
**CONCRETE CORE CONDITIONING**



**FLOOR CONDITIONING**



**CEILING SUSPENDED PANELS**



# Thermo-Active Building Systems

## Concrete Core Conditioning Systems





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# Cooling Panels
## Suspended Systems

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





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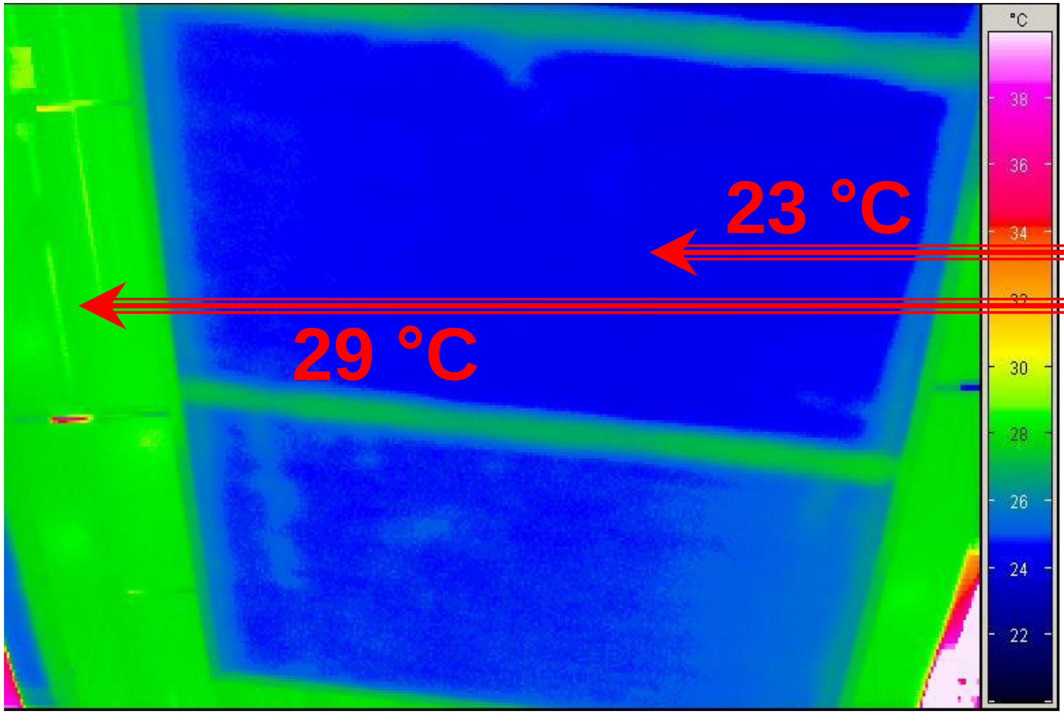
# Cooling Panels
## Suspended Systems




Cooling panels with phase change materials





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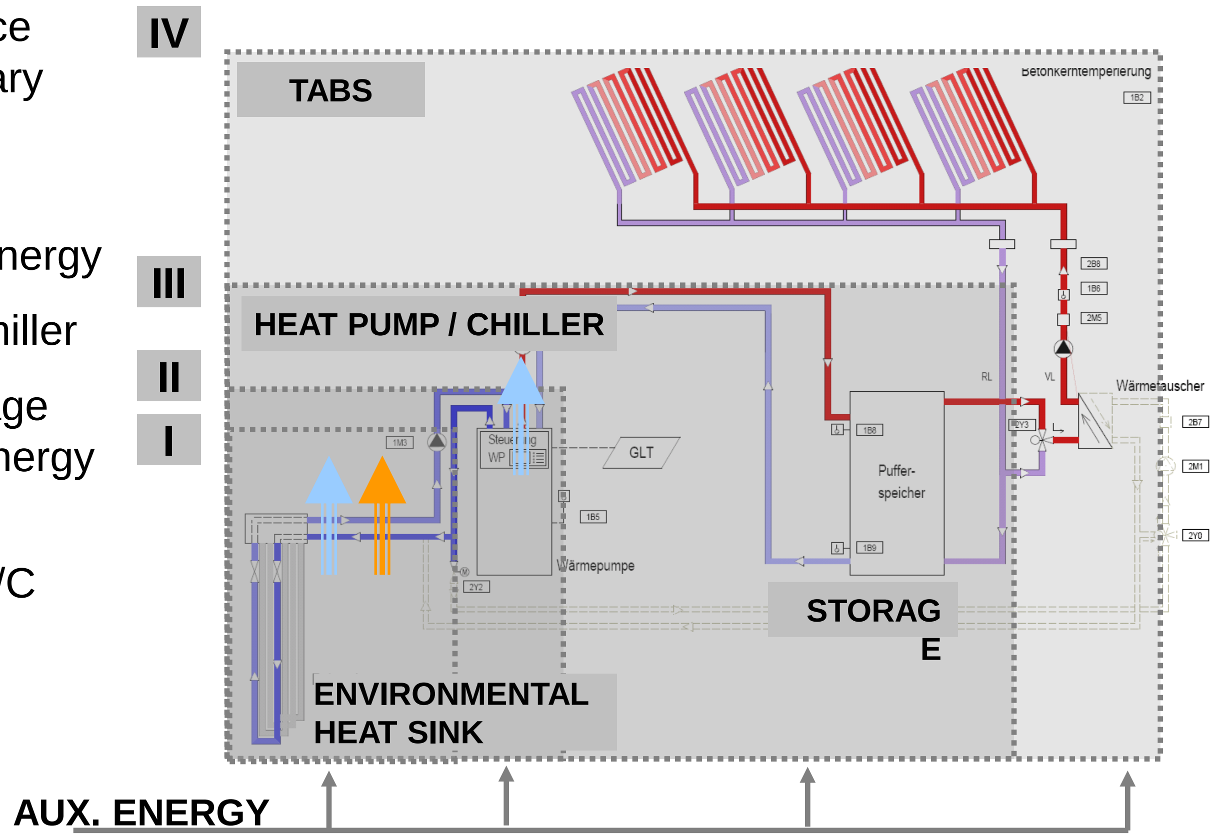
# Methodology of Evaluation

## Balance Boundaries I to IV


- definition of 4 balance boundaries for primary energy analysis
  - I: supply of environmental energy
  - II: heat pump /chiller
  - III: thermal storage and main H/C energy distribution
  - IV: delivery of H/C
- analysis of energy efficiency




$$SPF\ (I-IV) = \frac{Q_{H,C,HP}}{E_{aux}}$$





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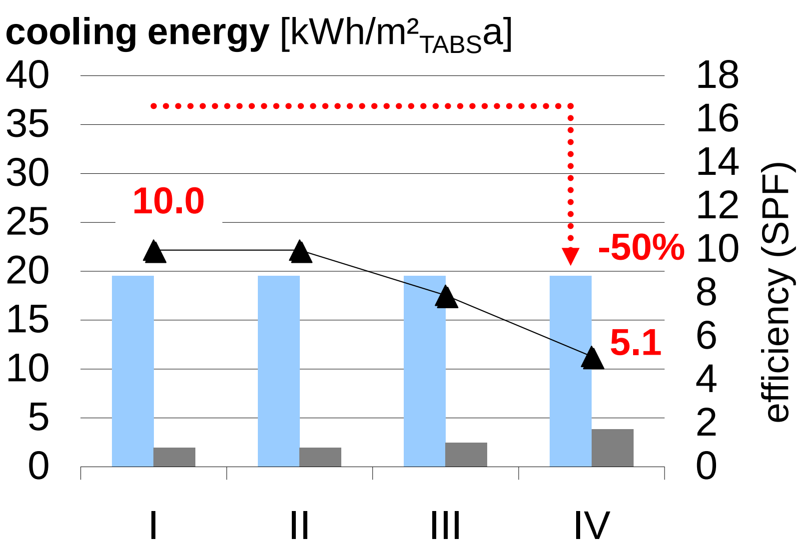
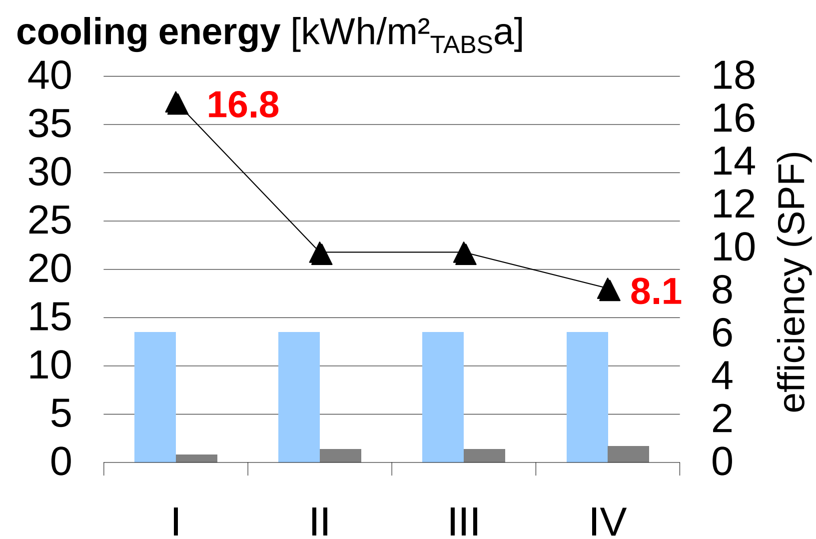
# Impact of Auxiliary Energy
## Cooling Systems

- considerable auxiliary energy use for distribution and delivery
- reduction of energy efficiency **I → IV** of appr. 50 %





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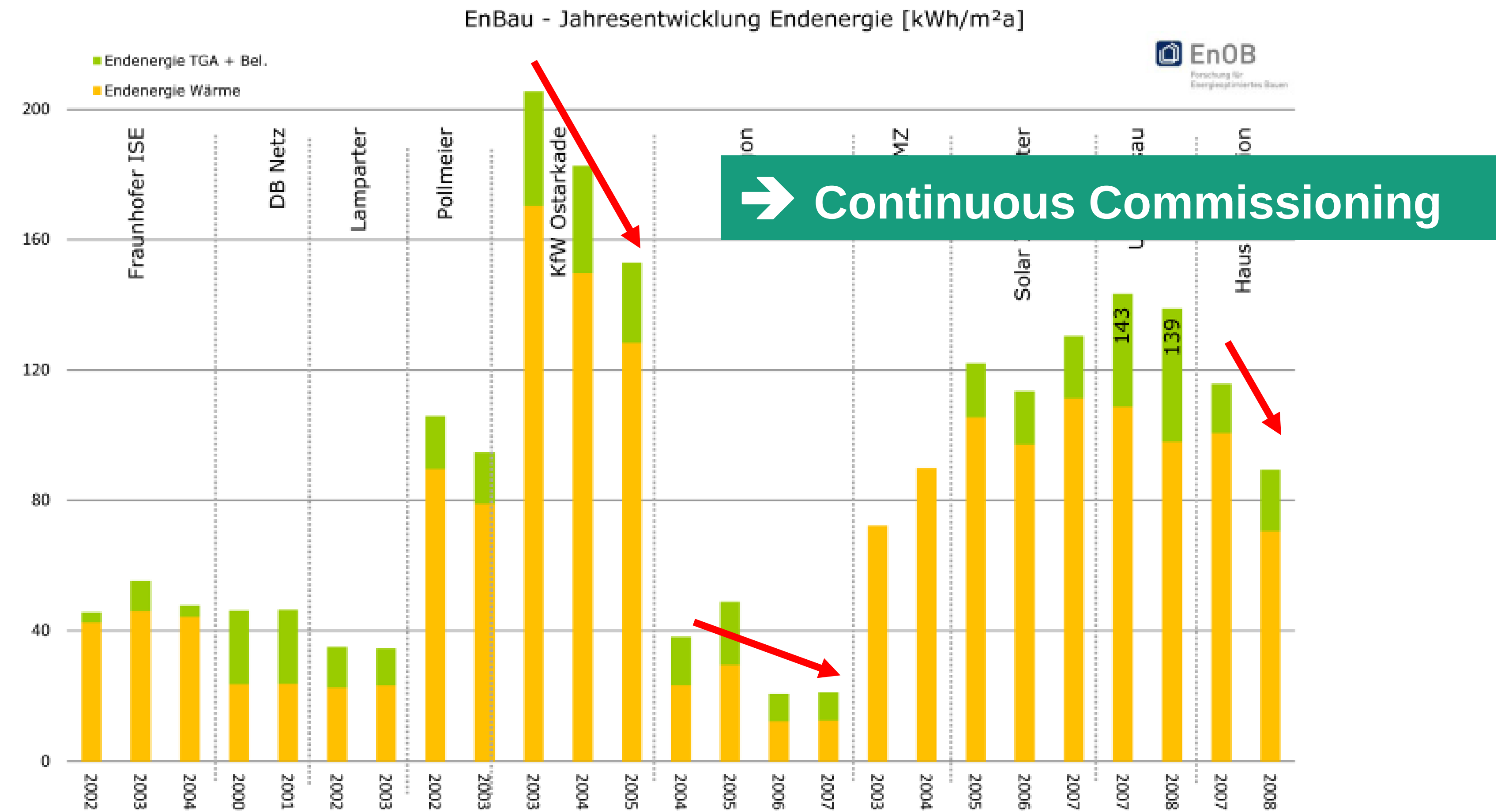
# Monitoring and Optimization of Performance

## Energy Efficient Buildings




Quelle: Bergische Universität Wuppertal, O. Hans

# Conclusion
## low-energy cooling

- **convincing examples**
  for energy efficient (heating and) cooling concepts employing ambient heat sinks and soruces.
- **effcient HVAC components**
  for high energy performance.
- **low temperature differences**
  and high specific mass flow rates need a well-designed low-pressure hydronic system.
- **overall energy performance**
  monitoring campaigns show seasonal performance factors up to 6 $kWh_{th}/kWh_{el}$ for the whole building system, incl. auxilliary energy.



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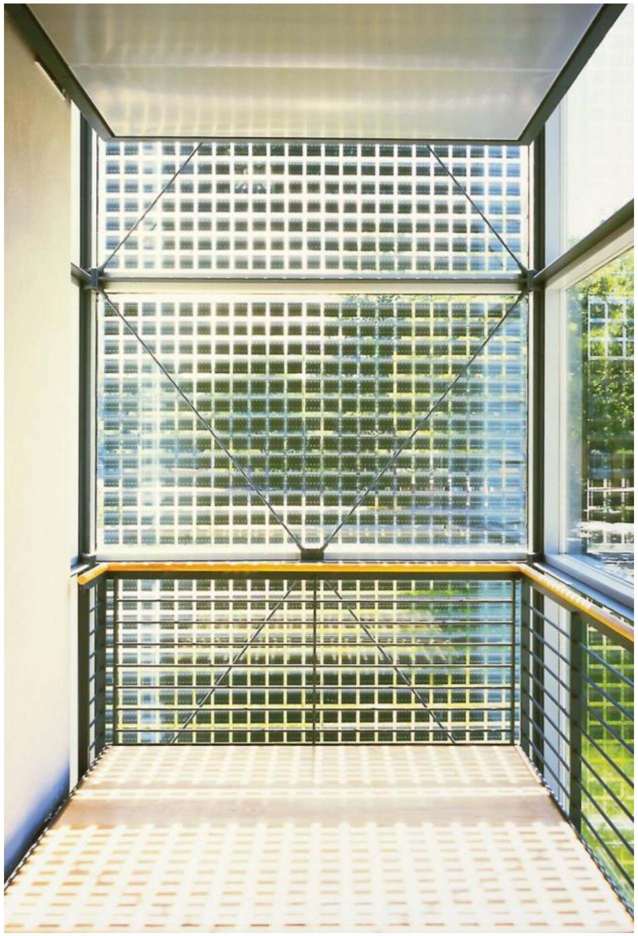
# Intelligent Buildings. Lean Concepts.



- **Buildings and Climate**
  Learn From Traditional Buildings.
- ***keep it simple***
  Understand the Principals.
- **Hybrid Ventilation Concepts**
  Reduce the Loads.
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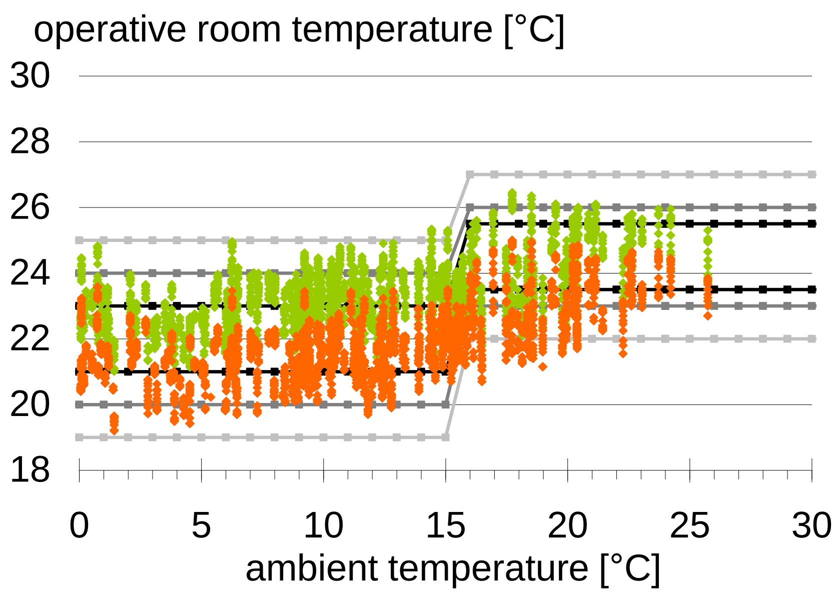
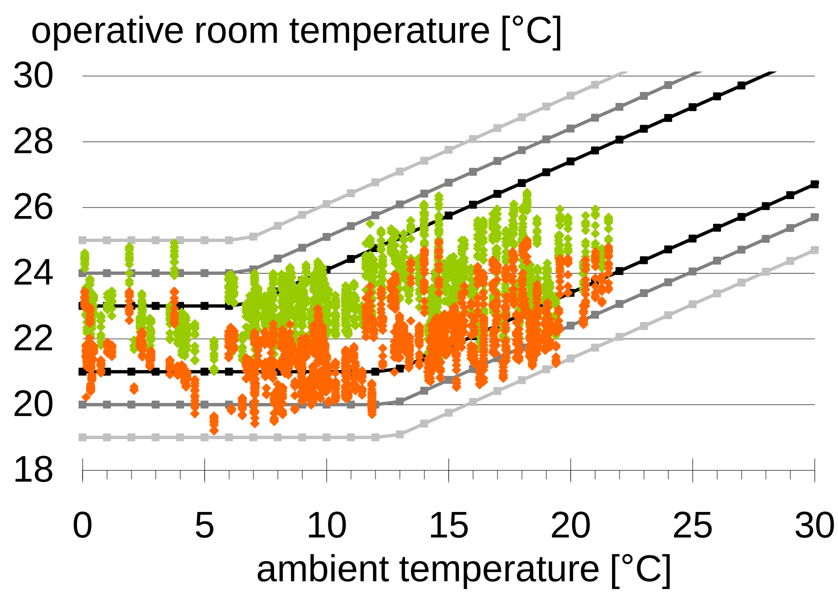
  Reduce the Final Energy Use.
- **Thermal Comfort**
  User Acceptance.

# Comfort according to EN 15251
## Two comfort models

**Static model (PMV)**




**Adaptive model**







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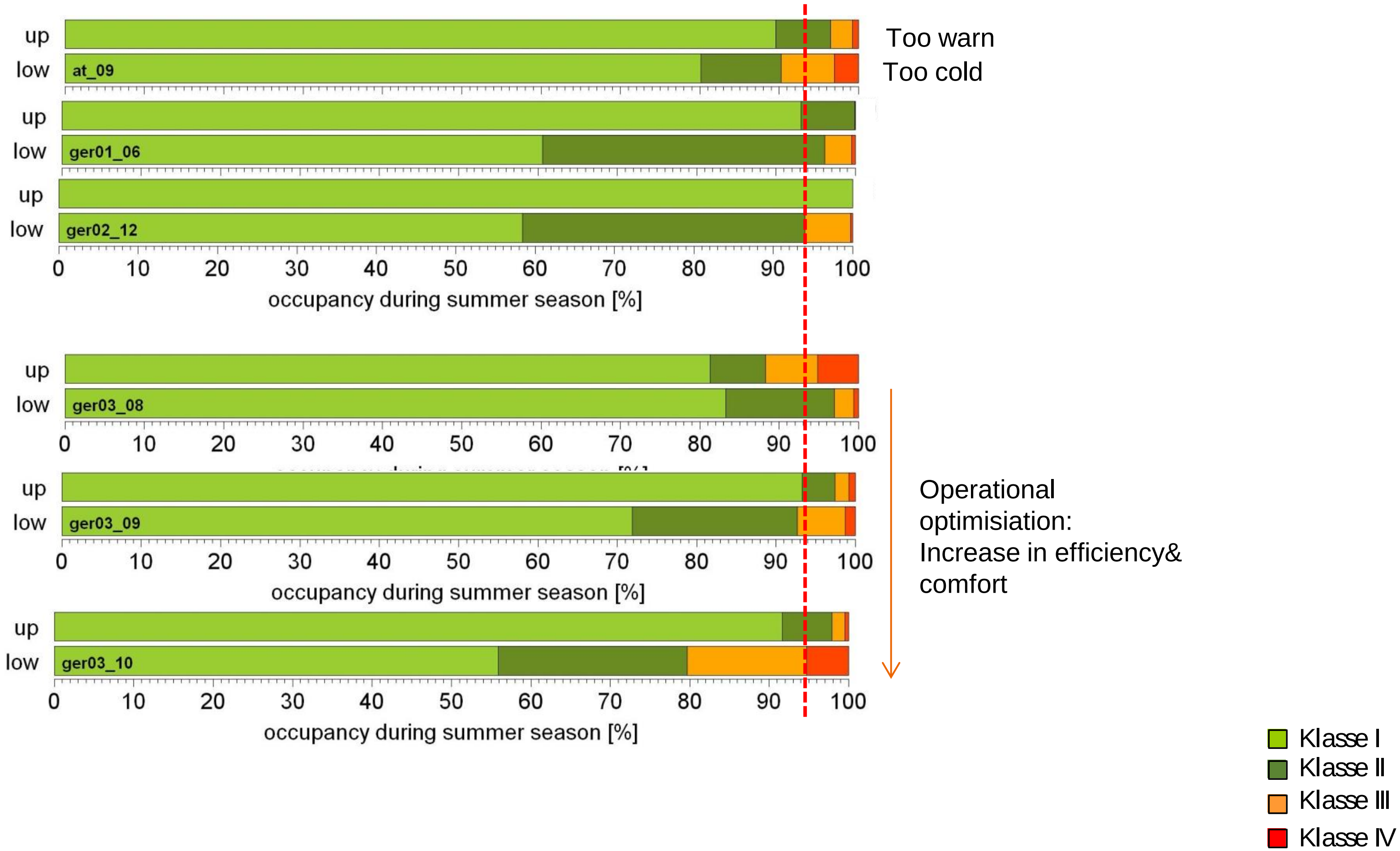
# Comfort according to EN 15251

## Comfort evaluation for summer period





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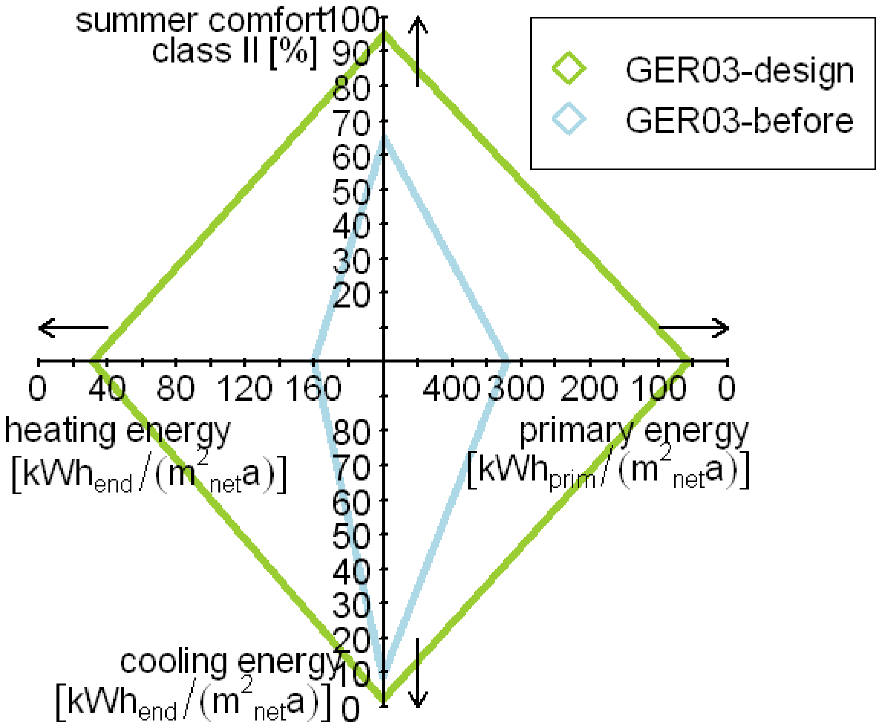
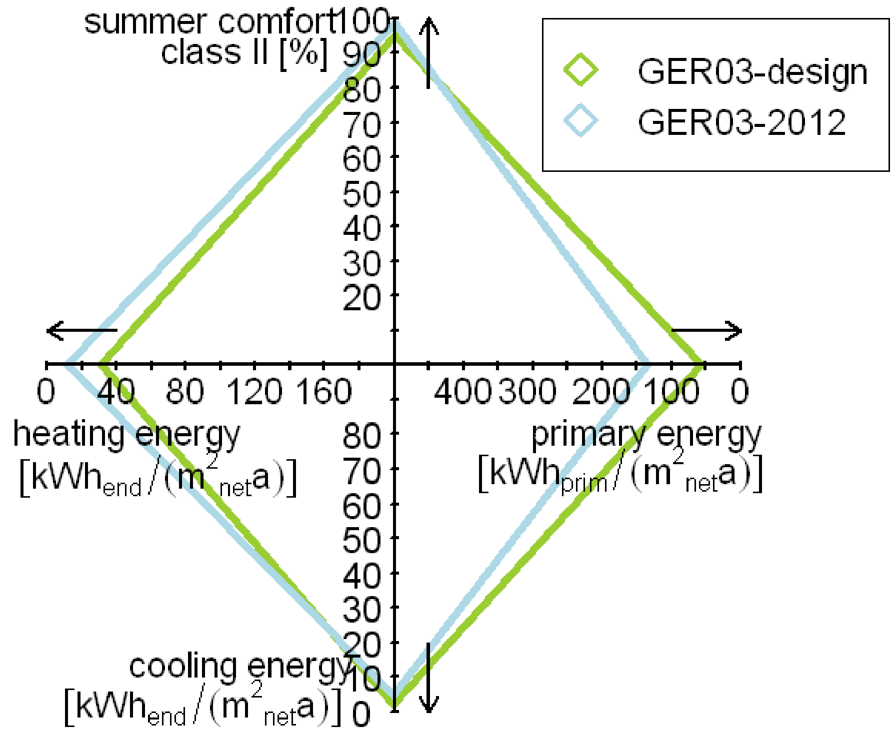
# Holistic Approach of total building's performance

## BEFORE Retrofitting



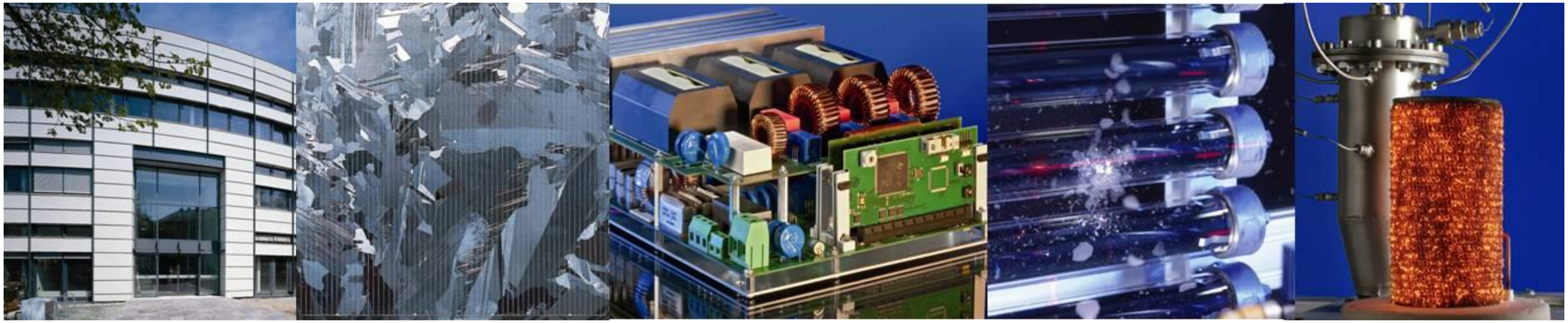

## AFTER



# Conclusion
## Thermal Comfort

- **passive, air-driven cooling**
  provides good thermal comfort according to the adaptive approach.
- **low-energy, water-driven cooling**
  provides good thermal comfort according to the static approach.
- **user / building-interaction**
  people and buildings are rather a statistical than a deterministic system.
- **user behaviour**
  give users the possibility to adapt to the building and to control the building.

# Thank you for your attention



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