

# Performance Analysis of Energy Efficient Buildings

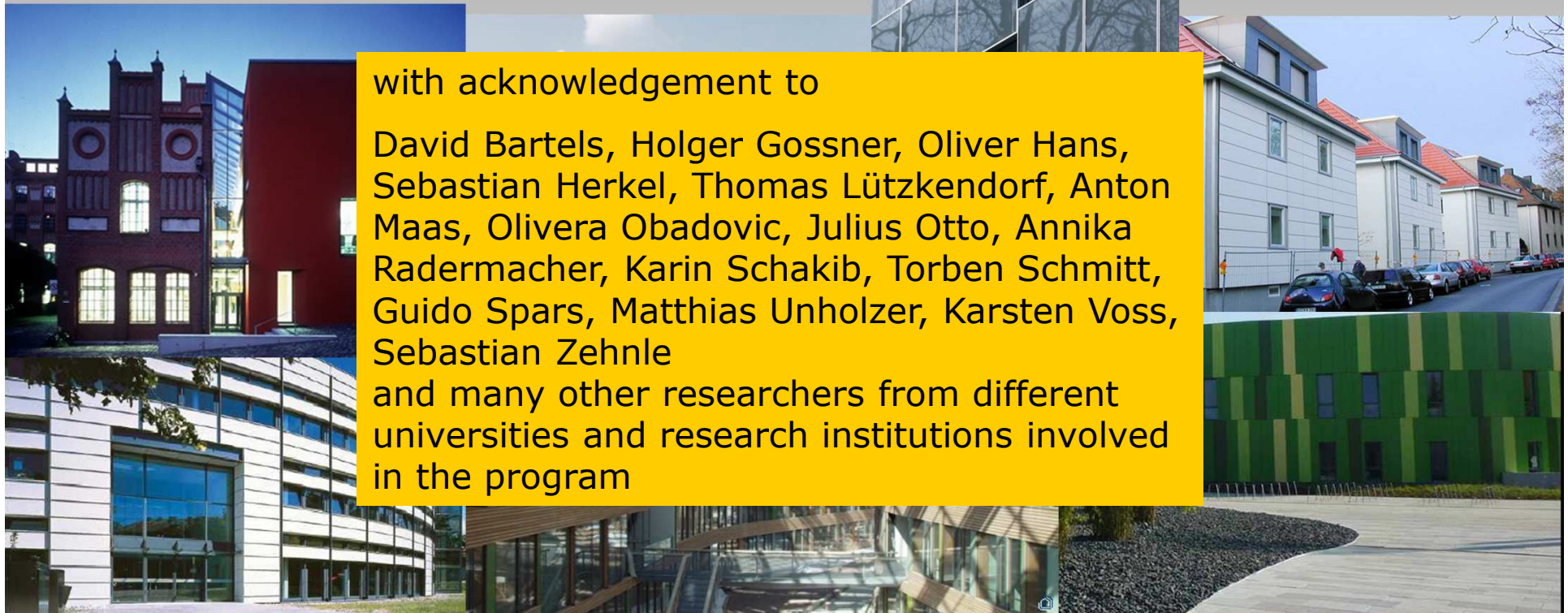
## Results and Experiences from the German Research and Demonstration Program EnOB

Andreas Wagner, Karlsruhe Institute of Technology, Germany

with acknowledgement to

David Bartels, Holger Gossner, Oliver Hans, Sebastian Herkel, Thomas Lützkendorf, Anton Maas, Olivera Obadovic, Julius Otto, Annika Radermacher, Karin Schakib, Torben Schmitt, Guido Spars, Matthias Unholzer, Karsten Voss, Sebastian Zehnle

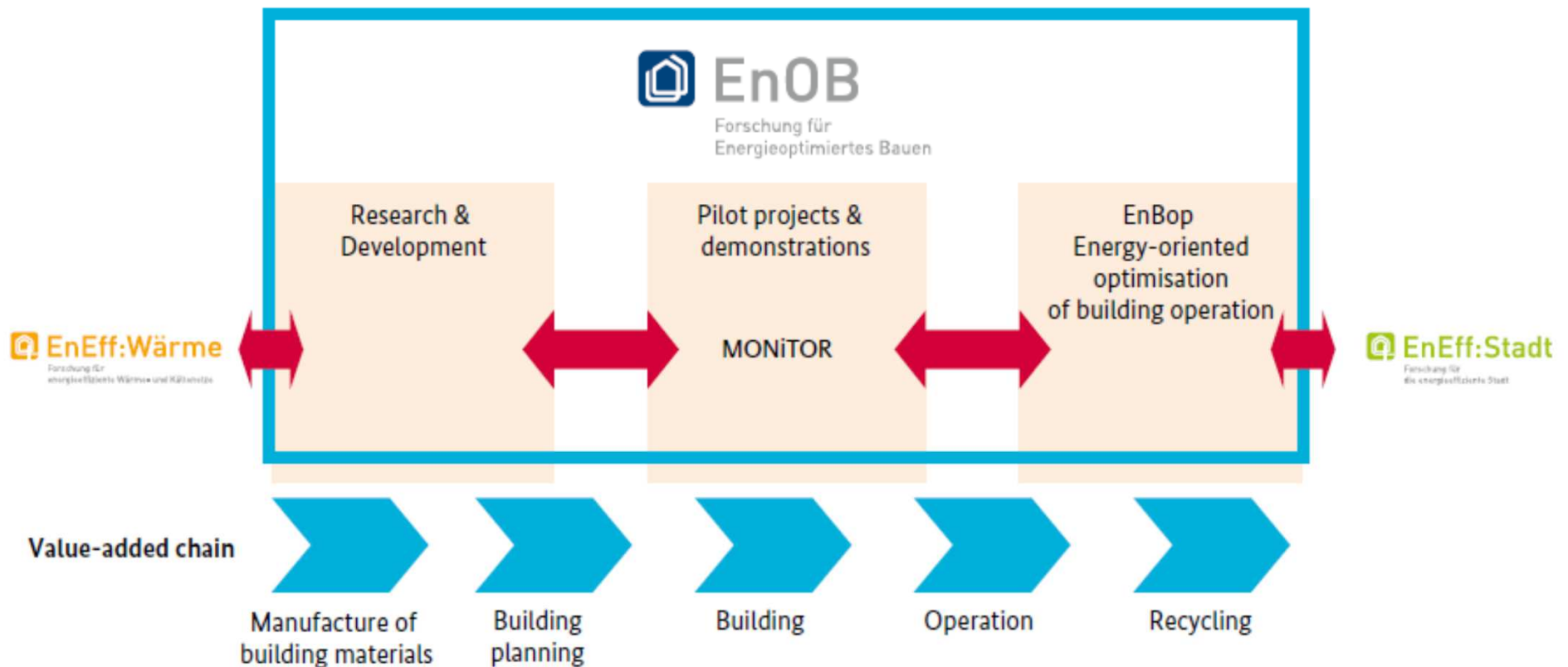
and many other researchers from different universities and research institutions involved in the program



# Content

- The German research program EnOB
- Energy performance of the funded demonstration buildings
- Approaches for economic analysis
- Occupant satisfaction at workplaces
- Review on applied technologies
- Conclusions and outlook

# Structure of the research program EnOB



## Criteria for funding in the demonstration program

- Ambitious **target values** for total primary energy consumption
- Application of new building technologies
- High quality in terms of architecture and urban design, integrated design process
- 2-year monitoring and performance analysis

→ „Light towers“ for multiplication

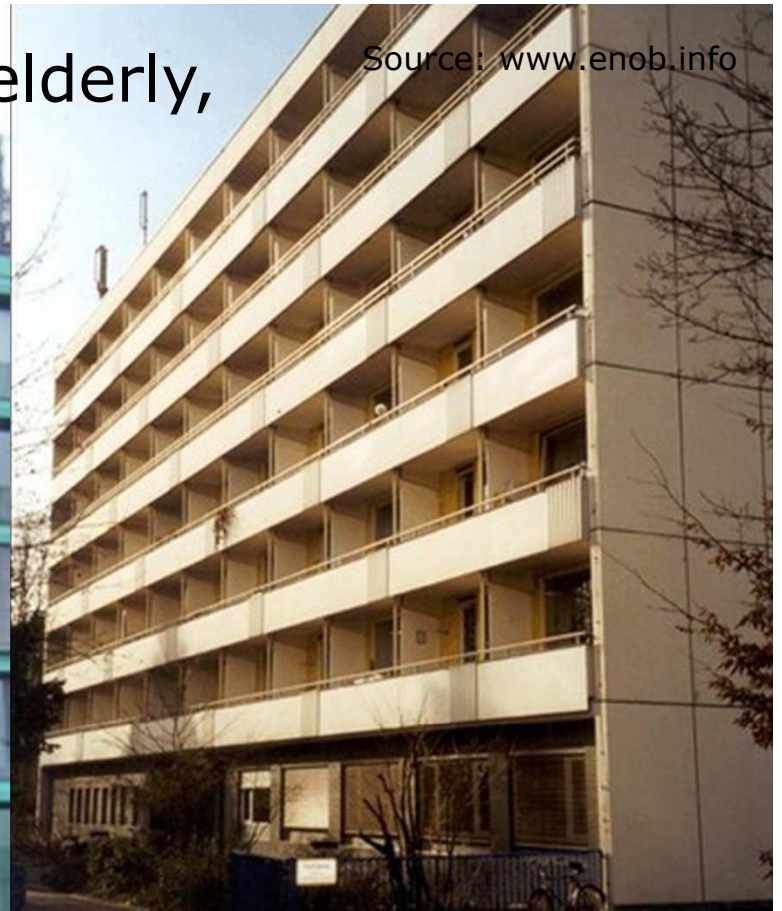
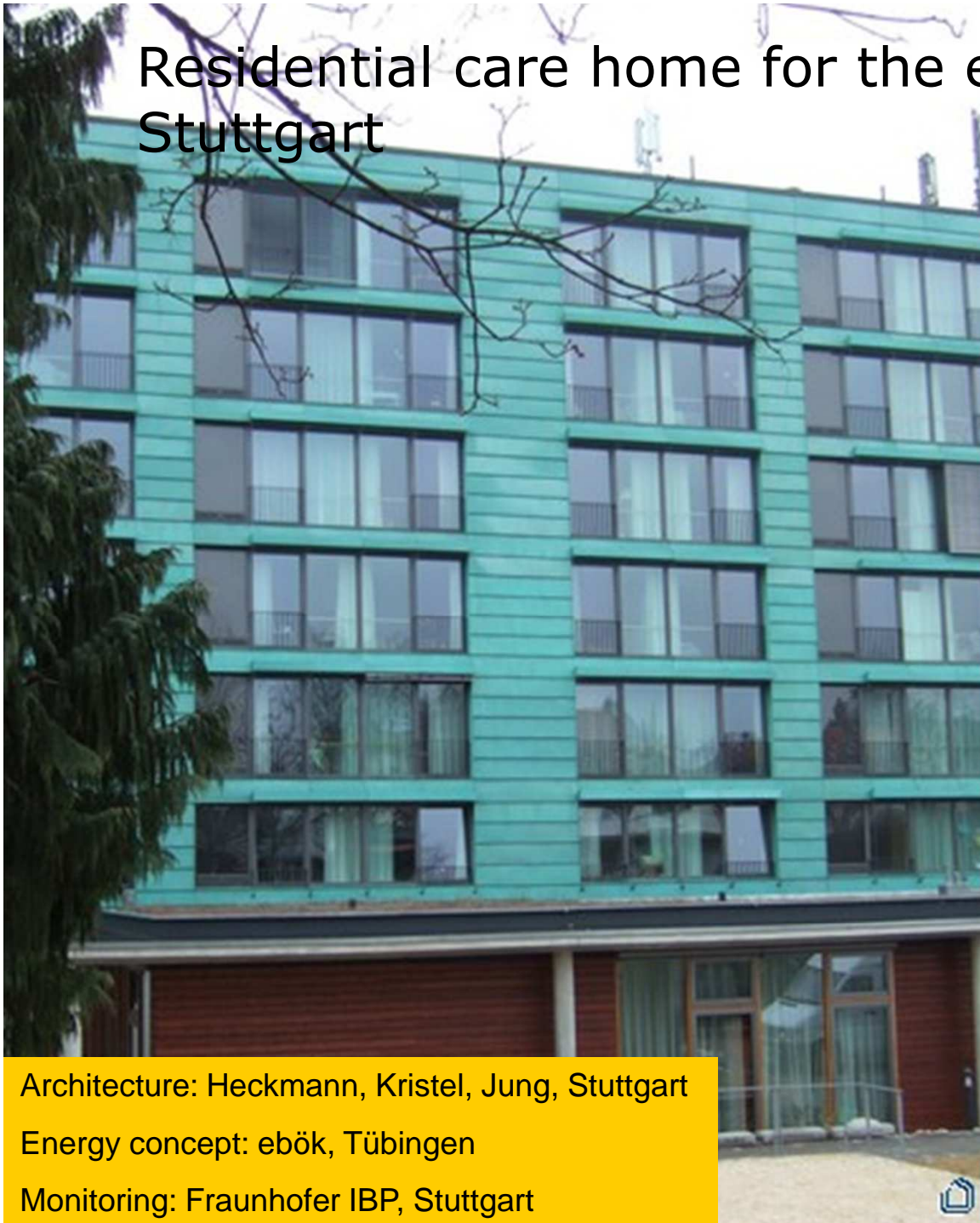
→ in-situ results on building performance





# Residential care home for the elderly, Stuttgart

Source: [www.enob.info](http://www.enob.info)



Architecture: Heckmann, Kristel, Jung, Stuttgart

Energy concept: ebök, Tübingen

Monitoring: Fraunhofer IBP, Stuttgart

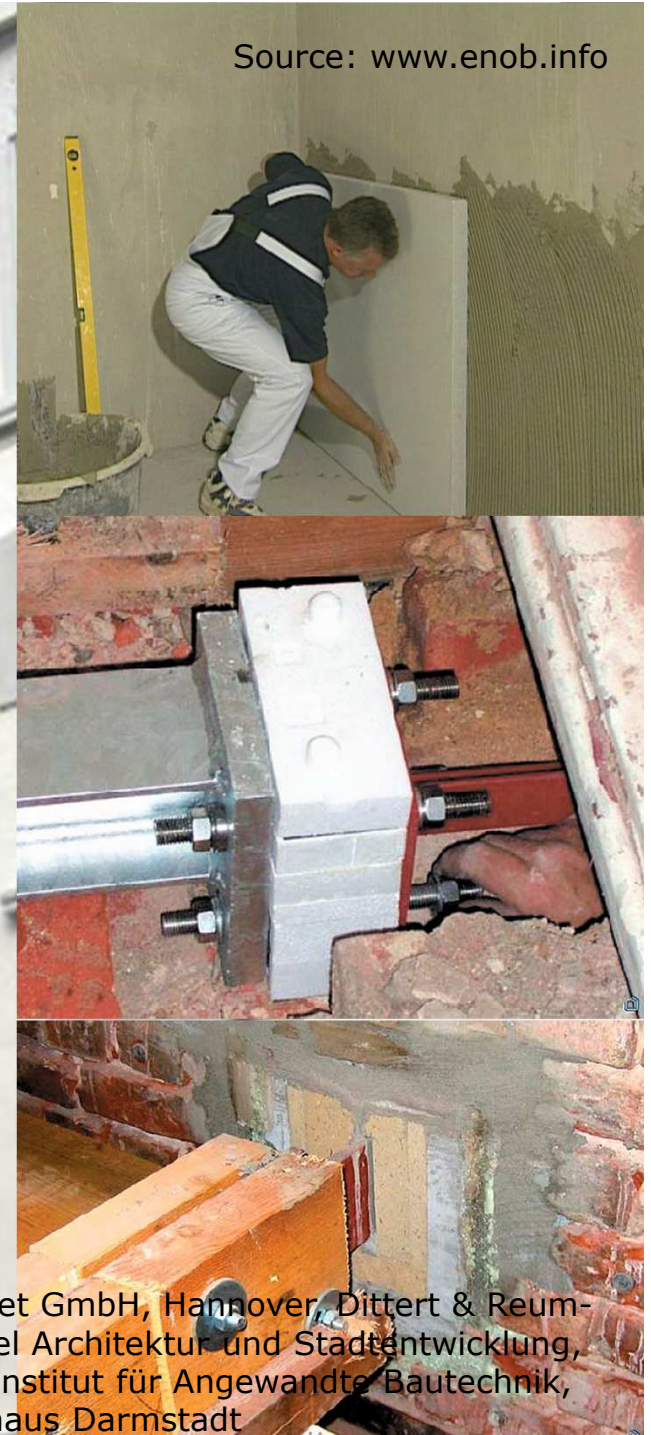
© Fraunhofer IBP



# Historical building „Kleine Freiheit“, Hamburg

Architecture: Dittert & Reumschüssel, Hamburg  
Energy concept: innovaTec Energiesysteme, Ahnatal  
Monitoring: Fraunhofer IBP

Source: [www.enob.info](http://www.enob.info)

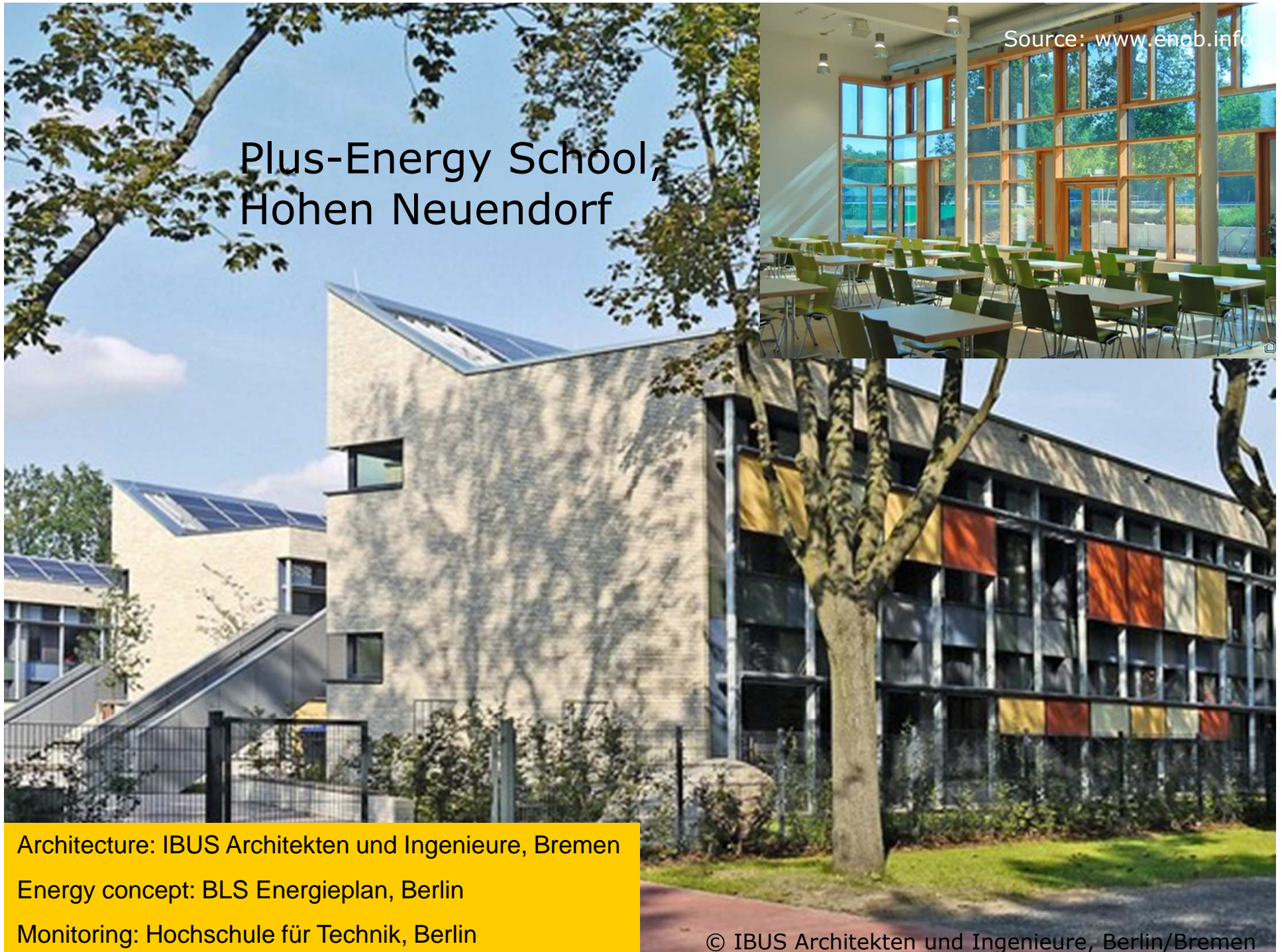


© Target GmbH, Hannover, Dittert & Reumschüssel Architektur und Stadtentwicklung, TUHH Institut für Angewandte Bautechnik, Passivhaus Darmstadt



# Plus-Energy School, Hohen Neuendorf

Source: [www.enob.info](http://www.enob.info)



Architecture: IBUS Architekten und Ingenieure, Bremen

Energy concept: BLS Energieplan, Berlin

Monitoring: Hochschule für Technik, Berlin

© IBUS Architekten und Ingenieure, Berlin/Bremen



# ENERGON office building, Ulm

Source: [www.enob.info](http://www.enob.info)



Architecture: oehler faigle archkom solar architektur, Bretten

Energy concept: ebök Ingenieurbüro, Tübingen

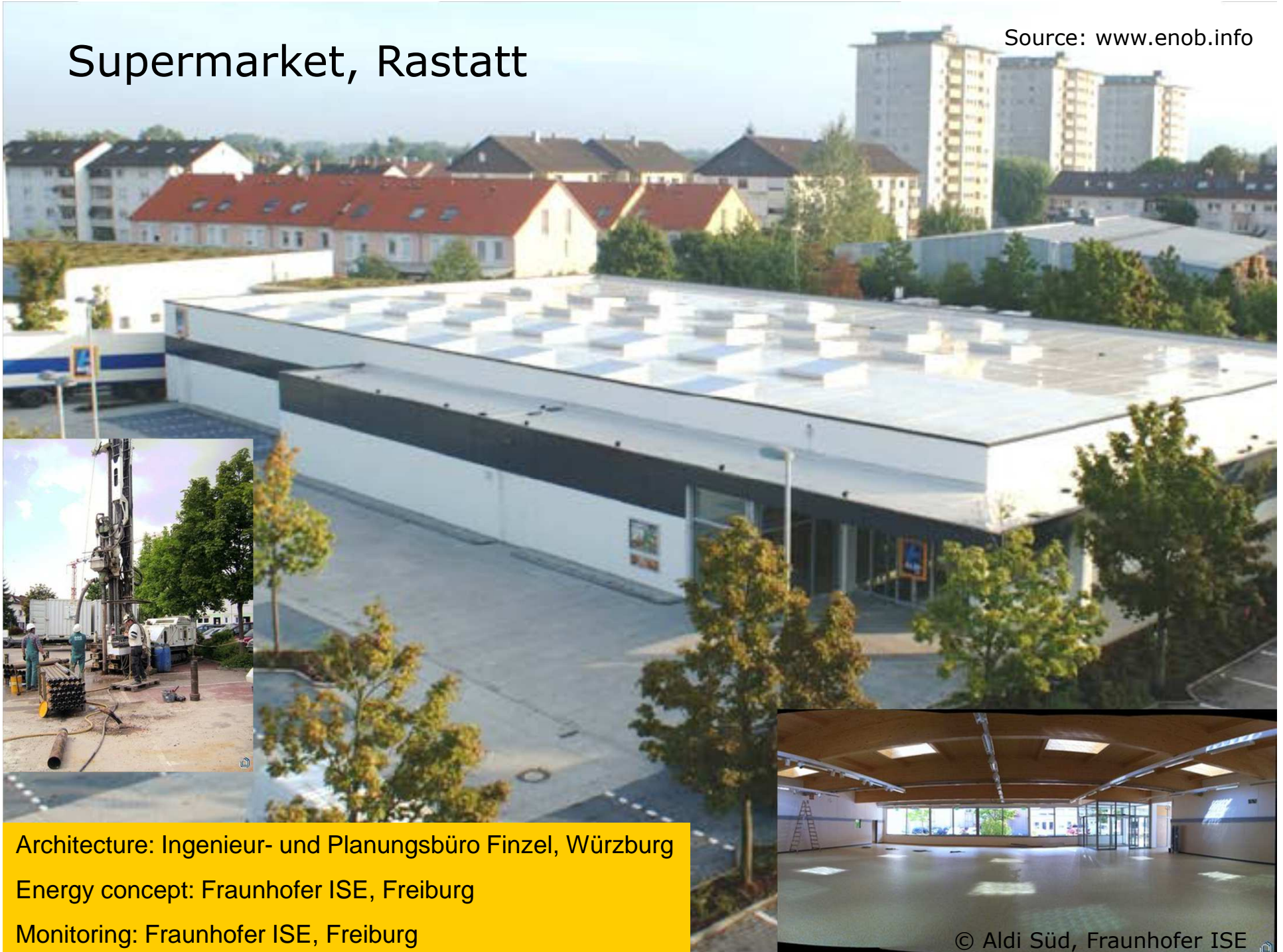
Monitoring: Steinbeis-Transferzentrum FH Ulm

© Software AG Stiftung, Steinbeis-  
Transferzentrum Energietechnik



# Supermarket, Rastatt

Source: [www.enob.info](http://www.enob.info)



Architecture: Ingenieur- und Planungsbüro Finzel, Würzburg

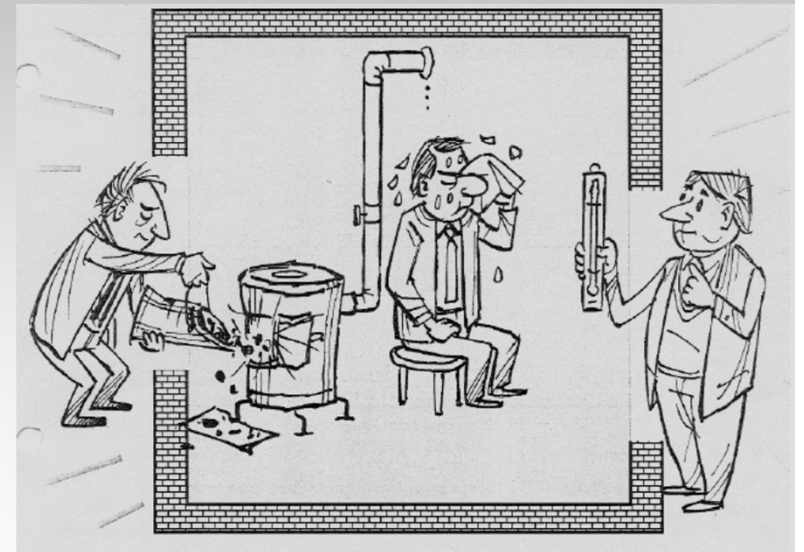
Energy concept: Fraunhofer ISE, Freiburg

Monitoring: Fraunhofer ISE, Freiburg

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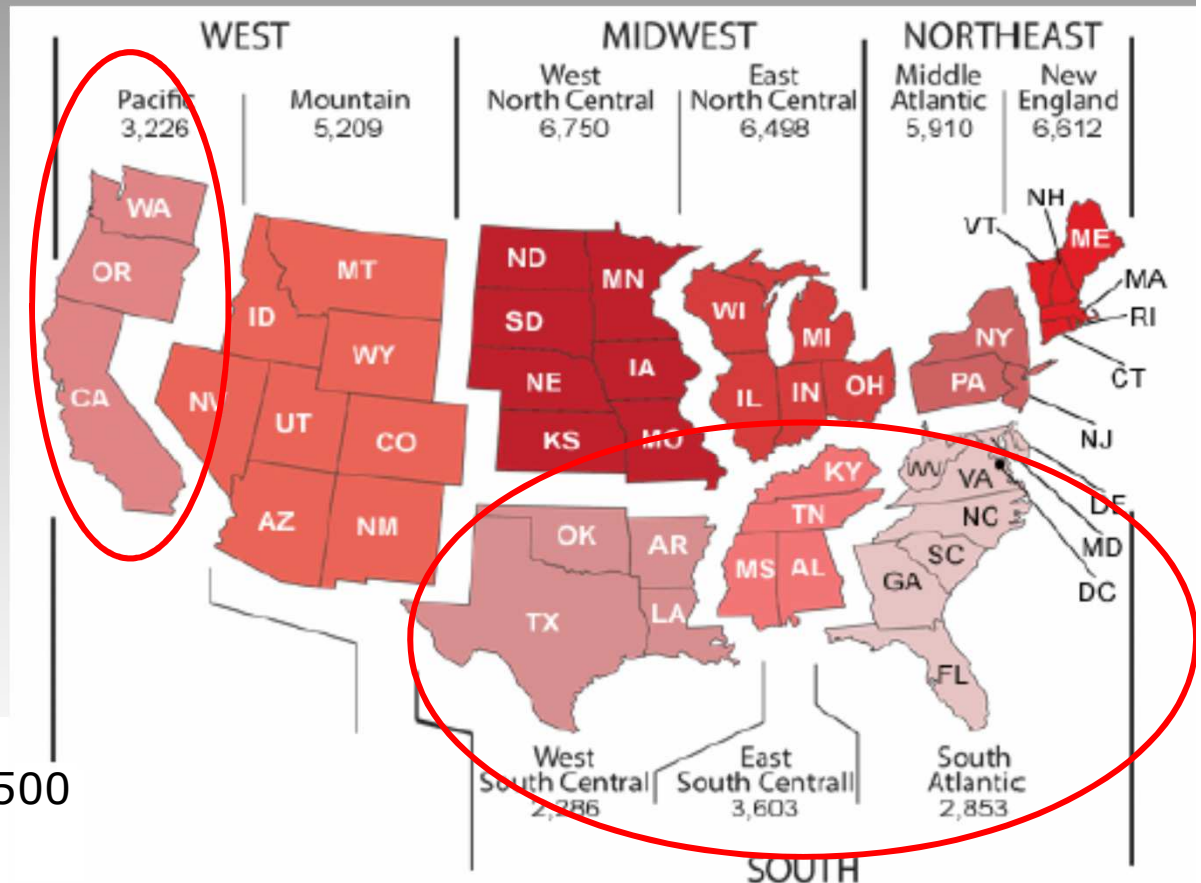




# Comparison of German and US climate

**Heating degree days**  
by census region  
based on 65°F (18.3°C)

Germany:  
approx.  $2300 < \text{HDD}_{18} < 3500$

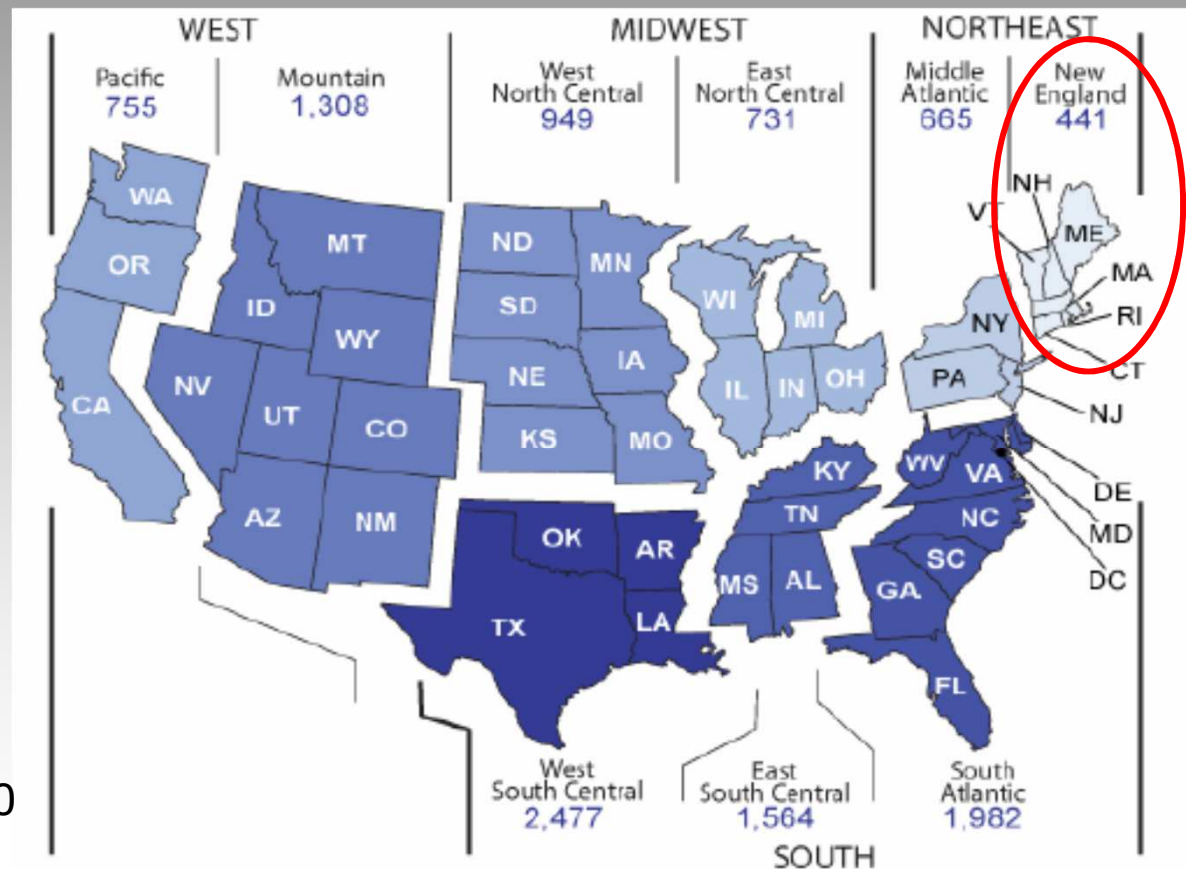


# Comparison of German and US climate

## Cooling degree days by census region

based on 65°F (18.3°C)

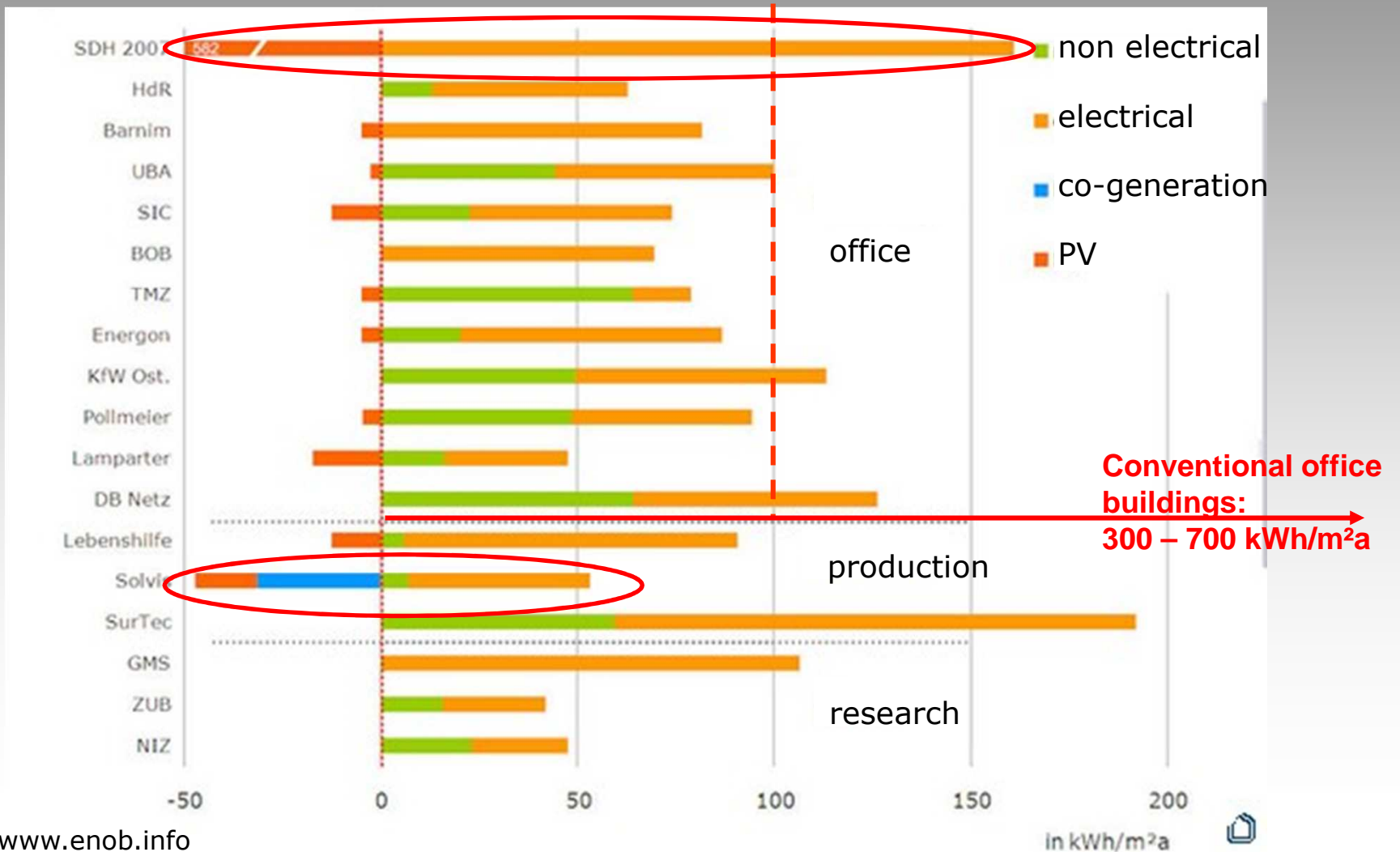
Germany:  
approx.  $170 < \text{CDD}_{18} < 450$



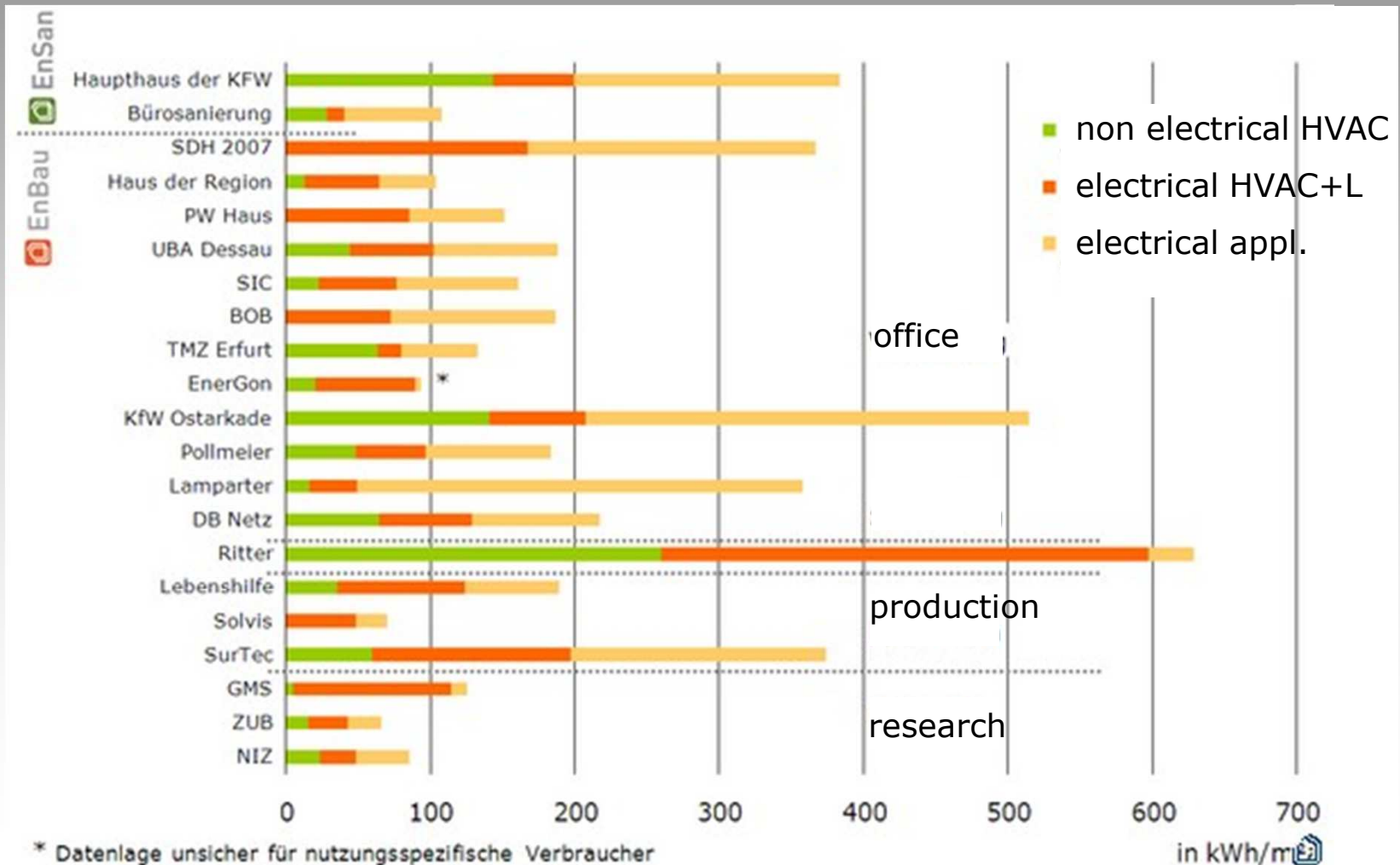
Source: Energy Information Administration (2008)



## Primary energy balance for HVAC+L (EnBau)



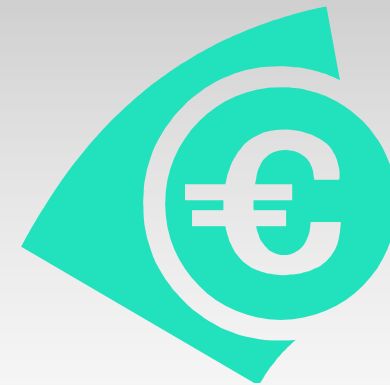
# Primary energy consumption incl. occupant appliances



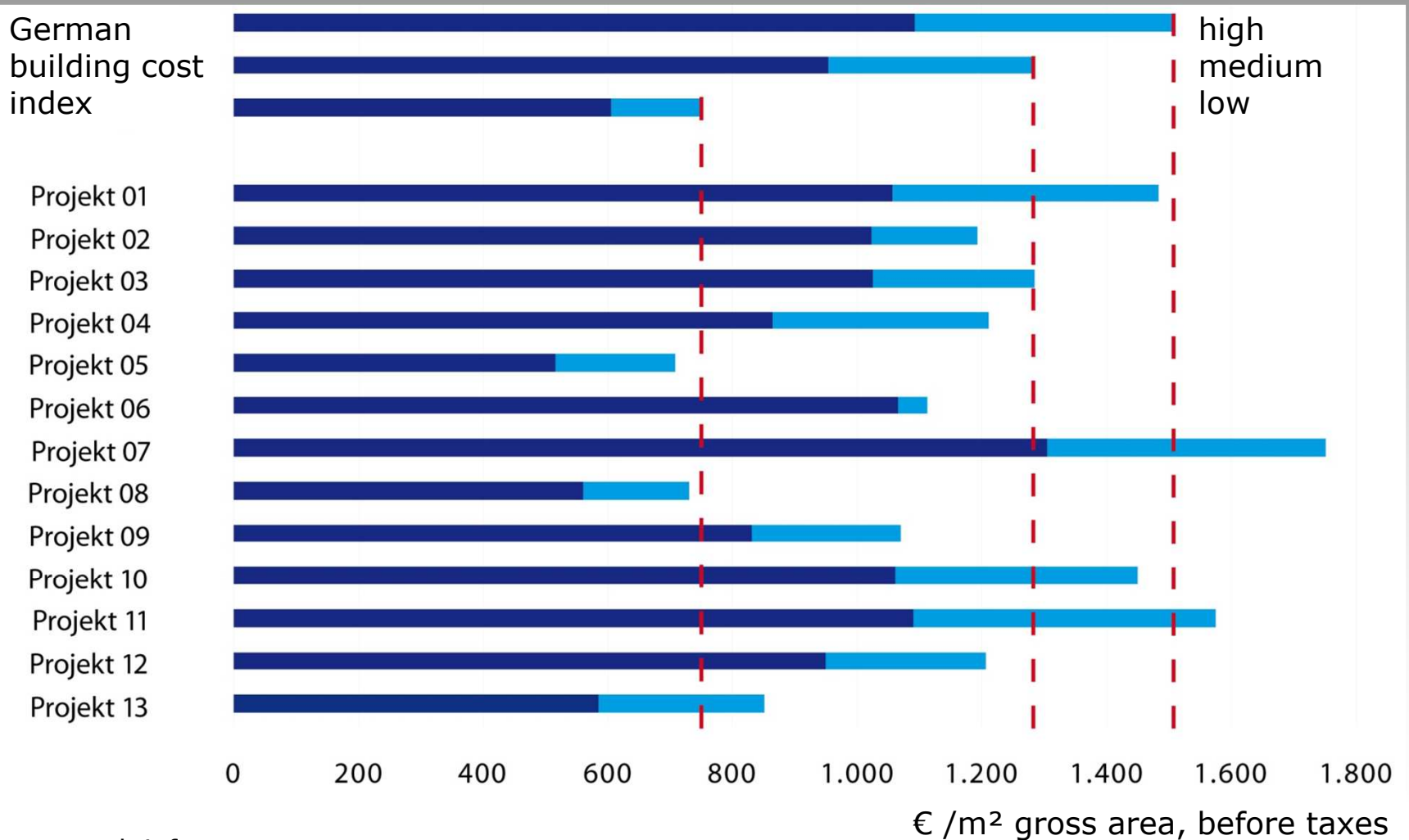


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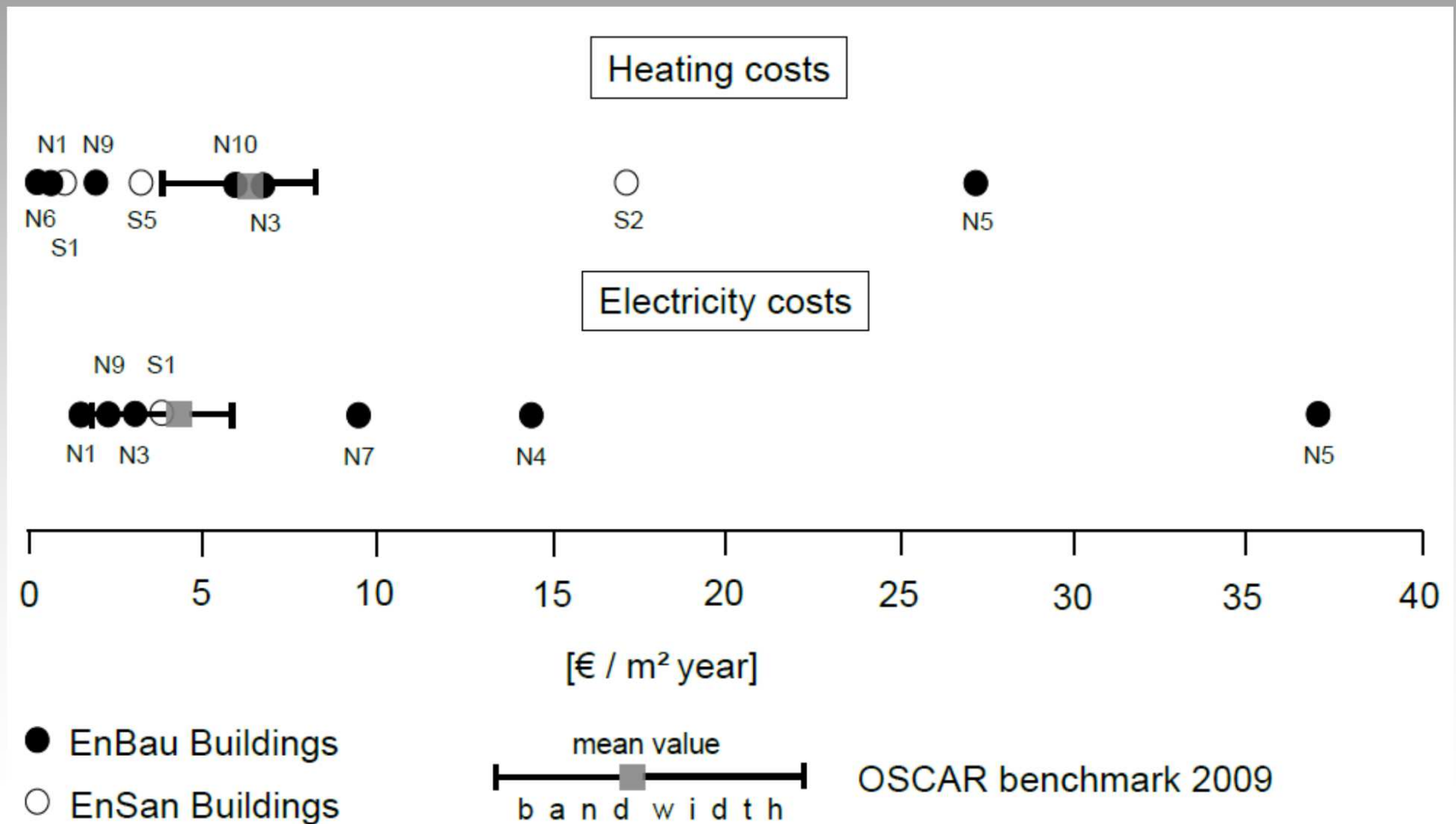


# Investment costs (construction and technical services)





# Heating and electricity costs for exemplary buildings



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EnOB

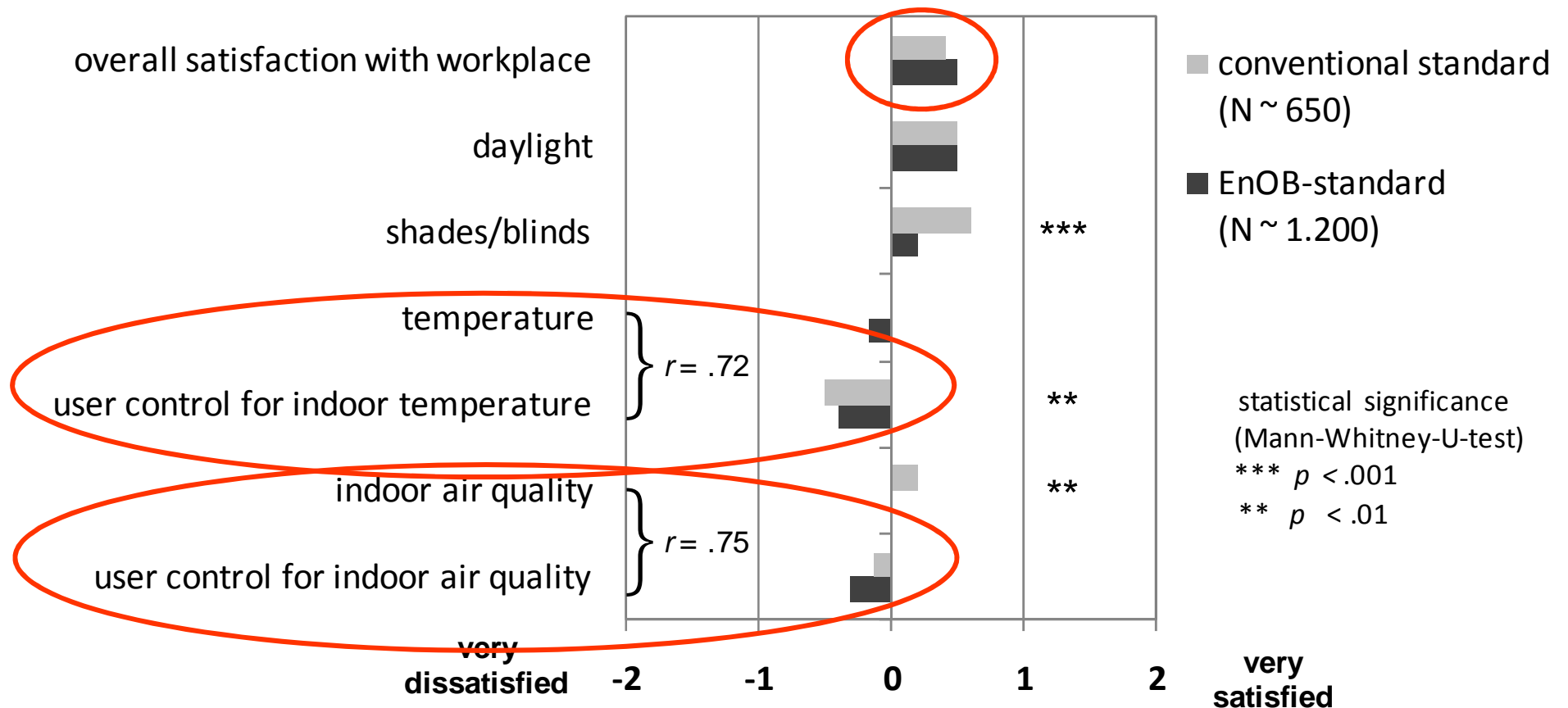
Forschung für  
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# Occupant satisfaction with specific items

## Results from summer surveys



Source: fbta / KIT

## Rating of the buildings by occupants

The following parameters were identified as dominating for the overall rating of a building:

- conditions determined by space design – privacy, noise level, interior design and furnishing of the rooms
- position of the room within the building
- air quality (together with the indoor air humidity)
- the daylight availability
- control options for glare protection and solar shading





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# Insulation standard

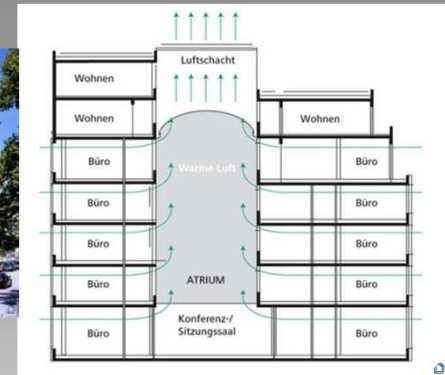
- Introduction of passive house standard in non-residential buildings between 1995 – 2000 (new facade technologies), new buildings and refurbishment
- Vacuum insulation from single elements to pre-fabricated systems



# Passive cooling

## Different heat sinks:

- between 1995 and 2005 cooling with (natural) night ventilation ...
- ... then increased application of thermally activated concrete slabs together with boreholes, earth piles or ground water
- until 2000 application of ground-to-air heat exchangers



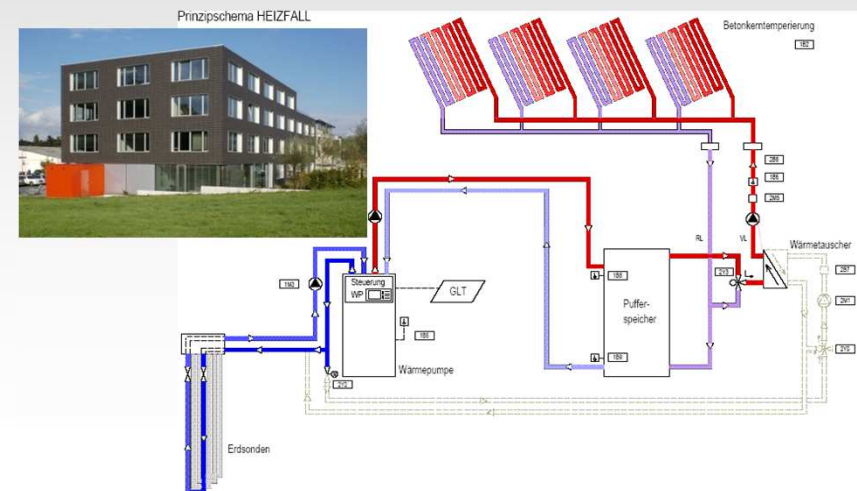
## Lighting

- Application of shading systems with daylighting option
- Very often application of lighting control systems with presence detection and daylight-dependence



## Energy Supply

- From 2005 on more heat pumps (synergy: ground as heat source and sink)  
→ all-electricity buildings?





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## Conclusions and outlook (I)

- New building technologies have to be integrated smartly into whole building concept → need for integrated design (regard to auxiliary energy, energy-optimized control, ...)
- Ambitious European/national energy-saving goals require much stronger focus on existing building stock in the future; need for combinations of measures on different scales (building → city)
- Occupant satisfaction and building life cycle costs have to be marketed as new property values in the real-estate sector

## Conclusions and outlook (II)

- With increasing decentralization and fluctuation of (renewable) energy supply, more flexibility on the demand side is required  
→ active role of buildings in load shifting and load management in connection with the grid (energy storage, PV, co-generation)
- High potential for improving building operation – new tools required (data processing and visualization, automated fault detection, model based optimization), market for new services





Thank you for listening.  
Dank u wel voor uw aandacht.  
Merci pour votre attention.  
Danke für Ihre Aufmerksamkeit.

More information: [ww.enob.info](http://ww.enob.info)

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