ENERGY DEMAND FOR SPACE COOLING IN GERMANY

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Workshop on Space Cooling

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- Influence of micro/macro climate on energy demand for space cooling
- Thermal comfort and user satisfaction
- Energy efficient concepts and technologies for cooling
- The transformation of the energy system requires “energy-flexible” buildings

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1 Energy demand for cooling buildings in the private and commercial sector

Situation today and predicted development

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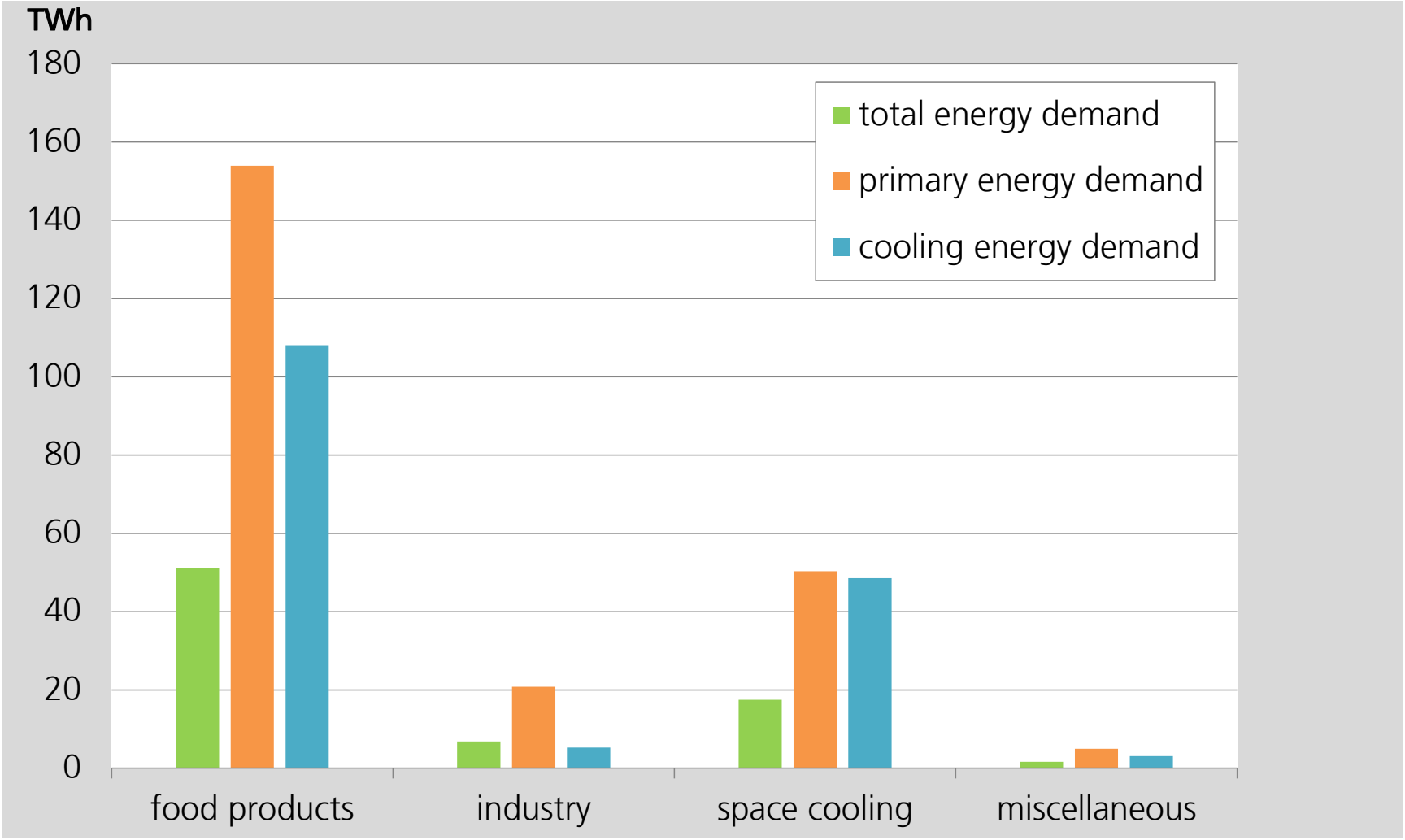
Cooling and Air Conditioning in Germany

Sectors



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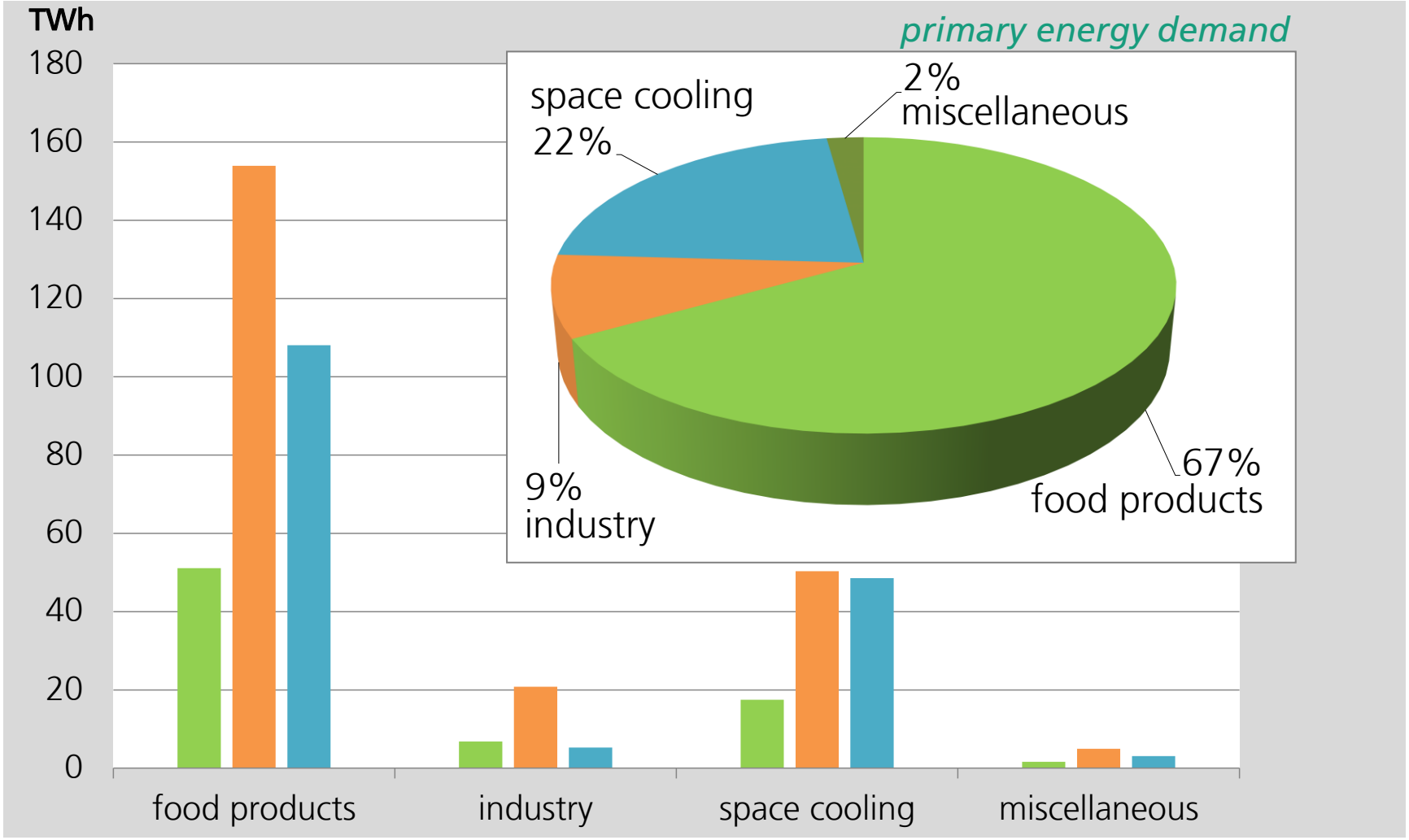
Source: Statusbericht des Deutschen Kälte- und Klimatechnischen Vereins Nr. 22, ISBN: 3-932715-06-3

Cooling and Air Conditioning in Germany

Sectors



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Source: Statusbericht des Deutschen Kälte- und Klimatechnischen Vereins Nr. 22, ISBN: 3-932715-06-3

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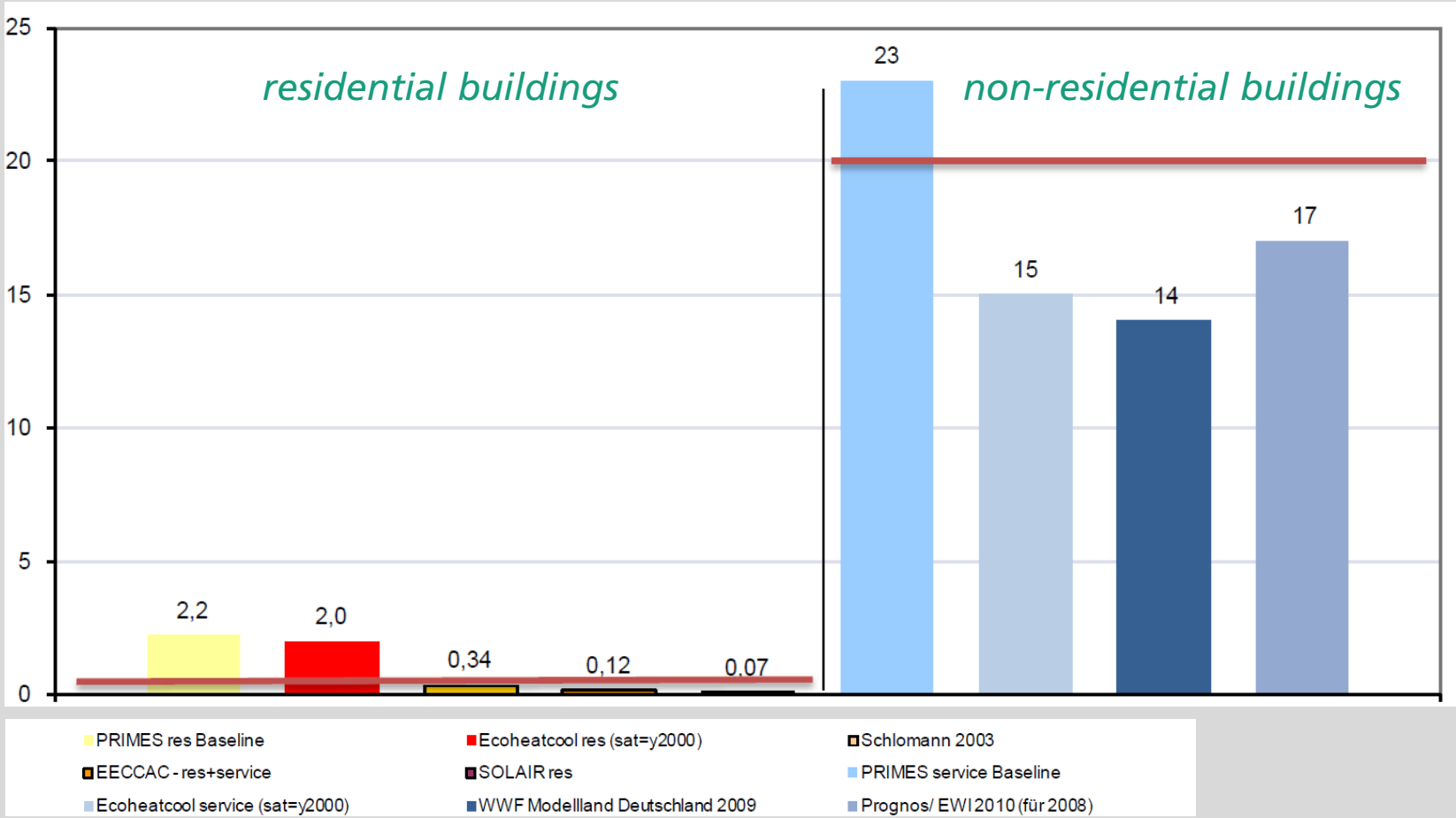
Cooling and Air Conditioning in Germany

Cooling energy use

Final energy use for space cooling [TWh_{final}]



Source: Bettgenhäuser et al. (2011) Klimaschutz durch Reduzierung des Energiebedarfs für Gebäudekühlung

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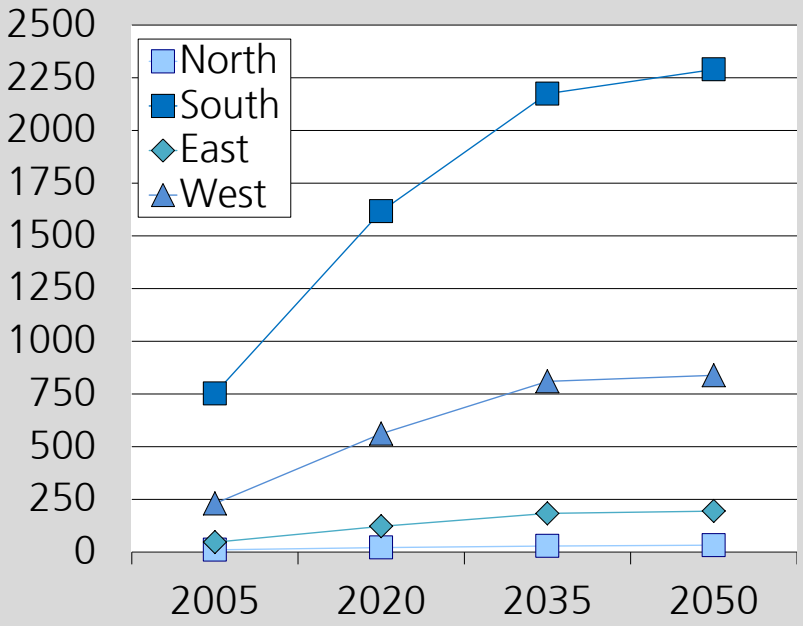
Cooling and Air Conditioning
Europe and Germany

EUROPE

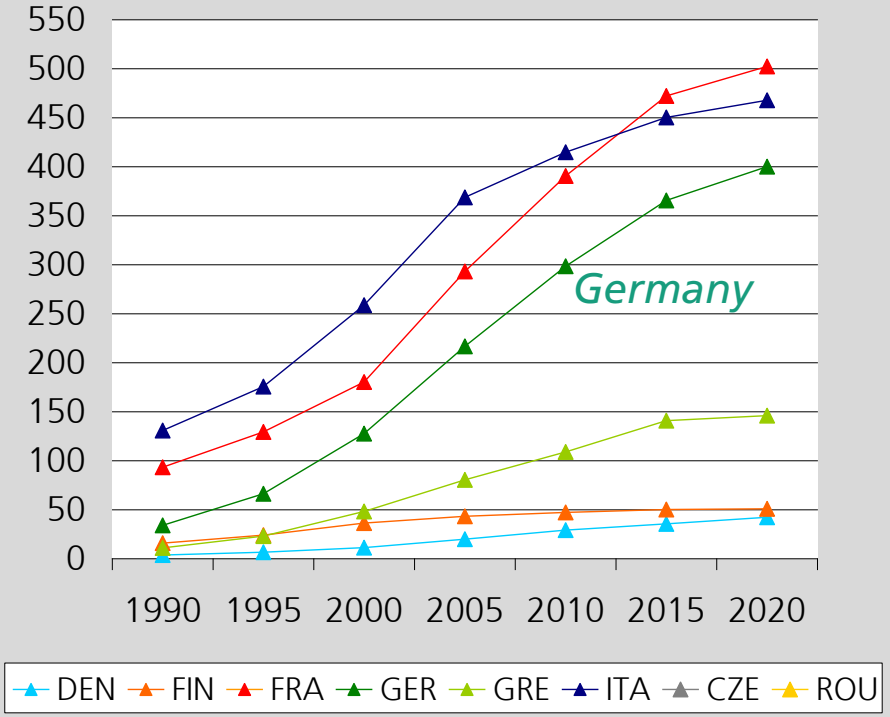
Electricity use for cooling and AC [TWh_{el}]



Source: Jochem and Schade 2009:Electrical-energy demand for cooling in four European regions (EU-27+2) [TWhel]

GERMANY

Area conditioned / cooled [million m²]



Source: JARN 2011: Total global air conditioner market in 2010 was 81.06 million units, a year-on-year increase of 9.6%. Figures shows global market share.

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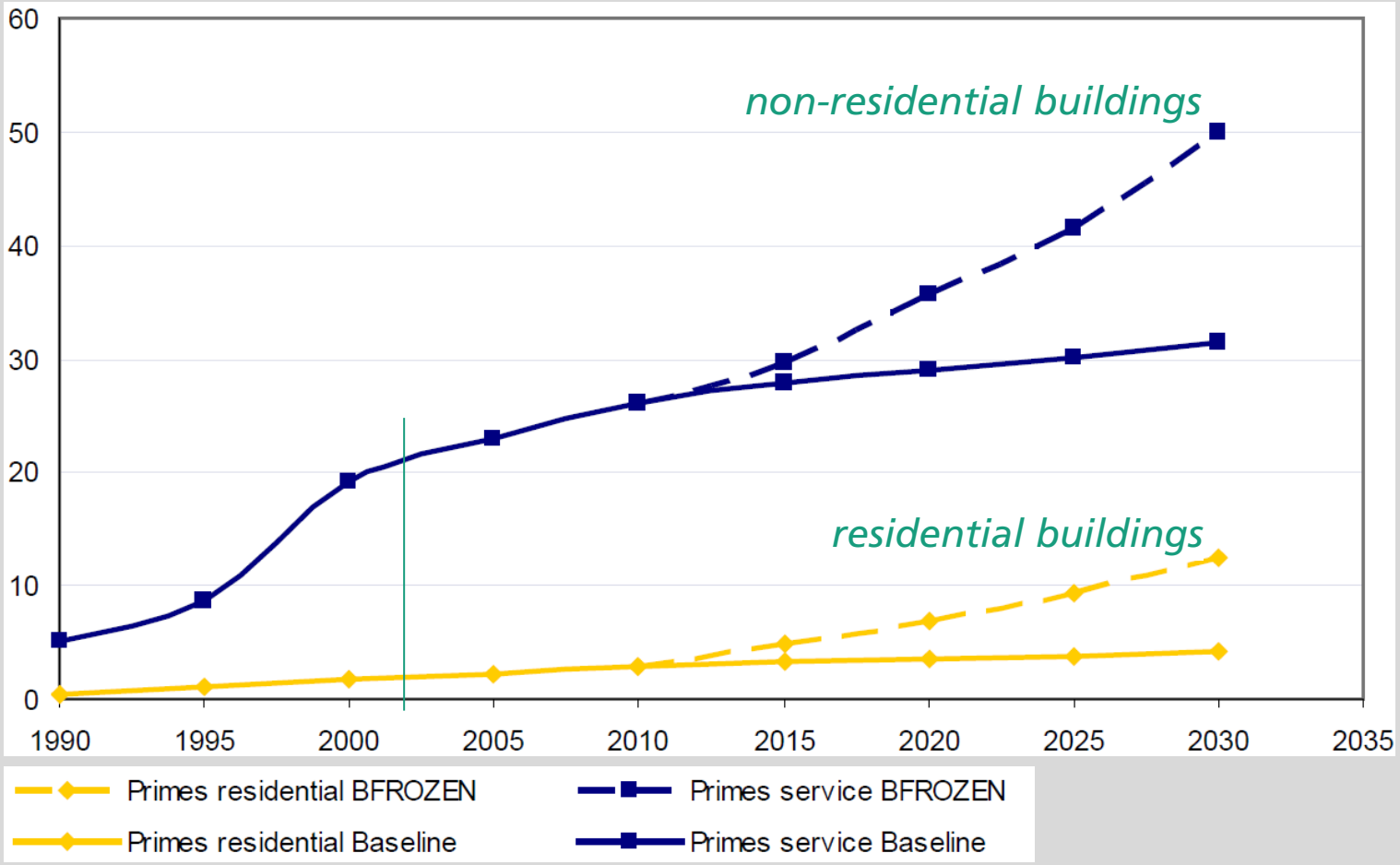
Cooling and Air Conditioning in Germany
today and 2030

Final energy use for space cooling [TWh_{final}]



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Source: Energy Efficiency and Certification of Central Air Conditioners (EECCAC) Final Report, April 203

Cooling and Air Conditioning in Germany

Installed cooling capacity [MW], 2002

technology	industry	offices	service	sports	hotels	gastro-nomy
window units	0	0	893	0	0	383
split units	0	2,871	883	0	0	663
mobile units	0	390	0	0	0	0
absorber	233	100	226	0	47	0
chiller	9,900	6,500	8,250	1,650	6,600	0
condenser	1,548	387	1,548	387	0	0

- Chiller w/ piston, scroll or screw compressor have a high share in the market

Source: **Behörde für Stadtentwicklung und Umwelt Unternehmen für Ressourcenschutz, 2010**

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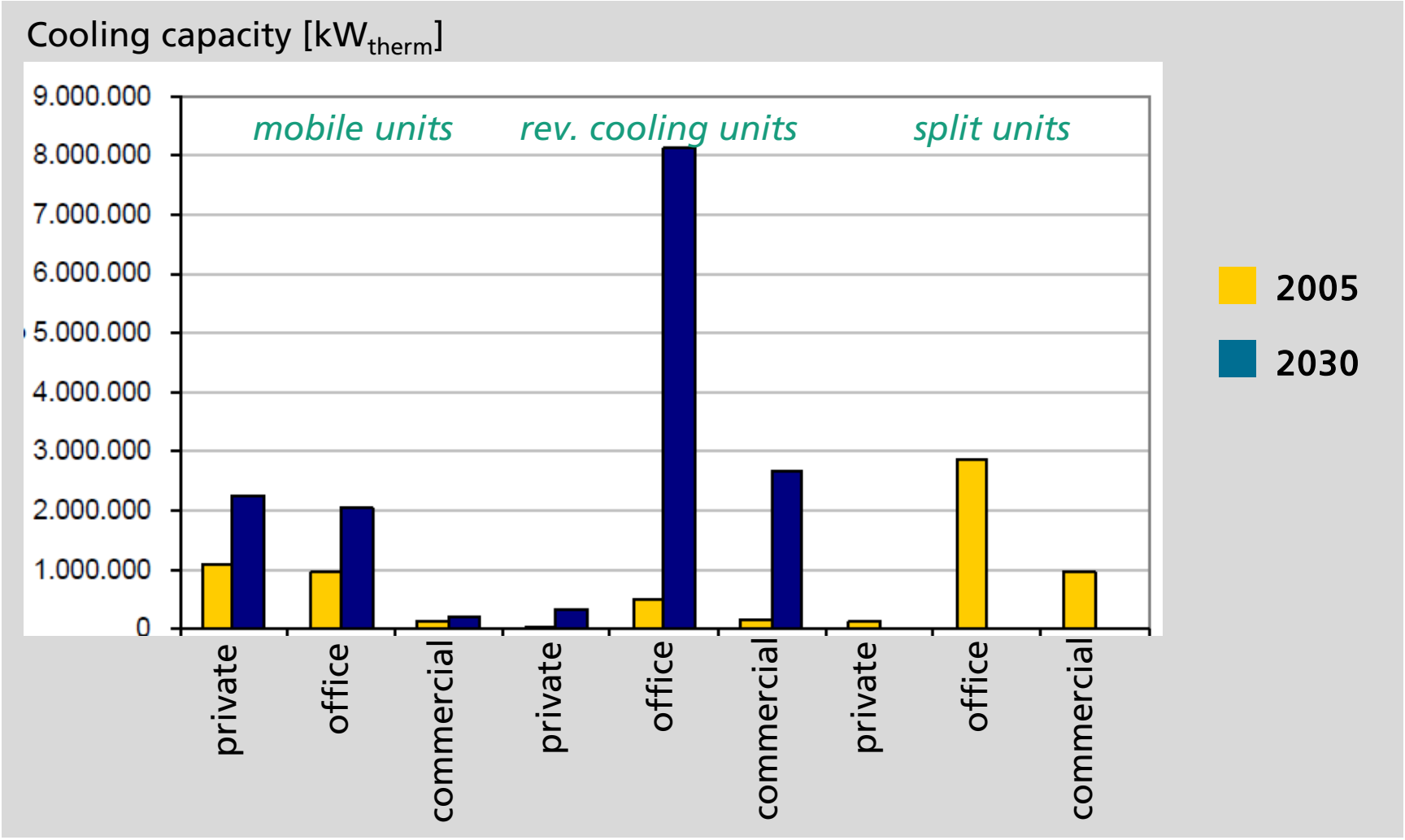
Cooling and Air Conditioning in Germany
today and 2030



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Source: Bettgenhäuser et al. (2011) Klimaschutz durch Reduzierung des Energiebedarfs für Gebäudekühlung

2 Micro and macro climate

Influence on energy demand for space cooling

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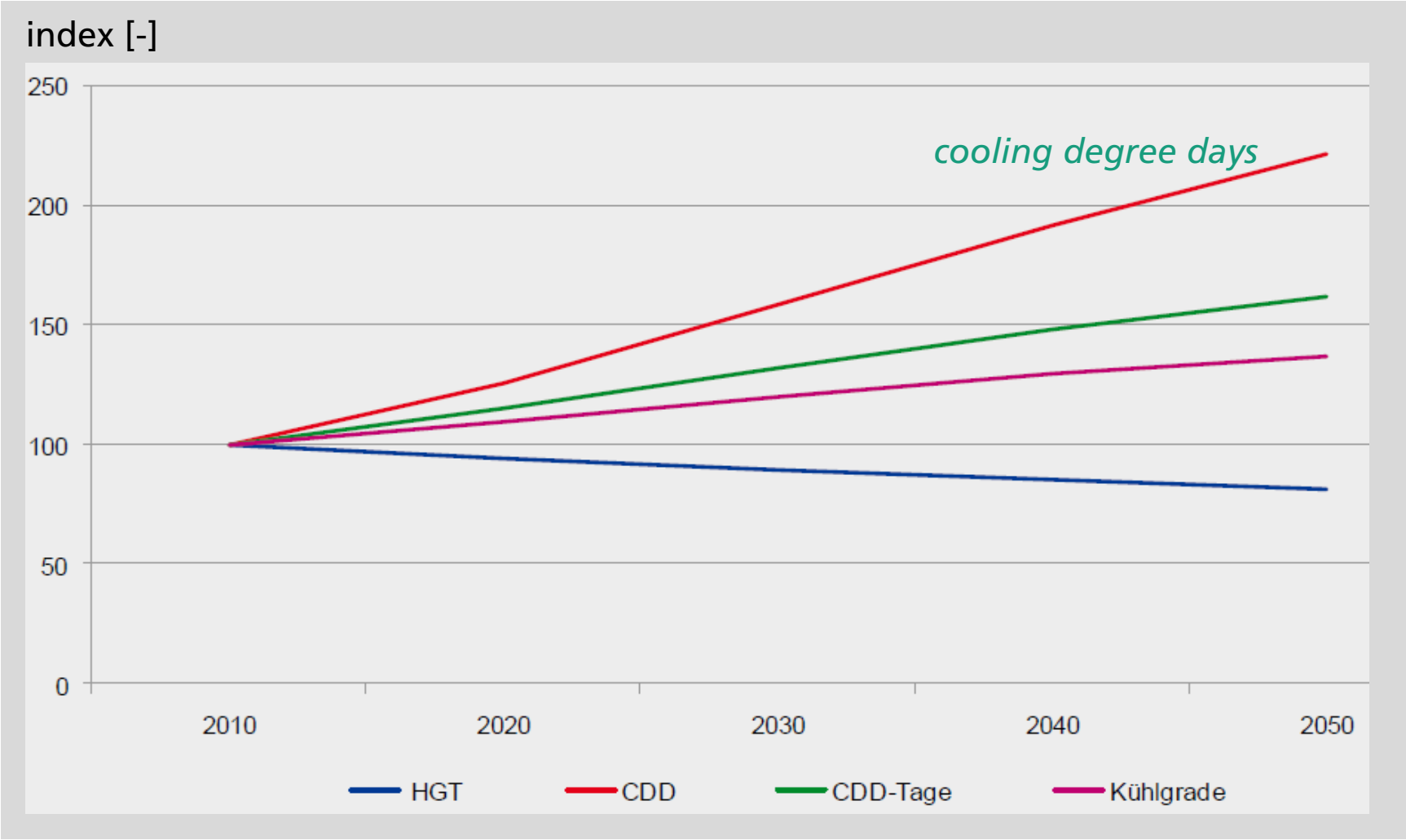
Influence of the weather conditions

Warmer summers with persistent heat waves



Source: IEA 2008, BFE 2007.

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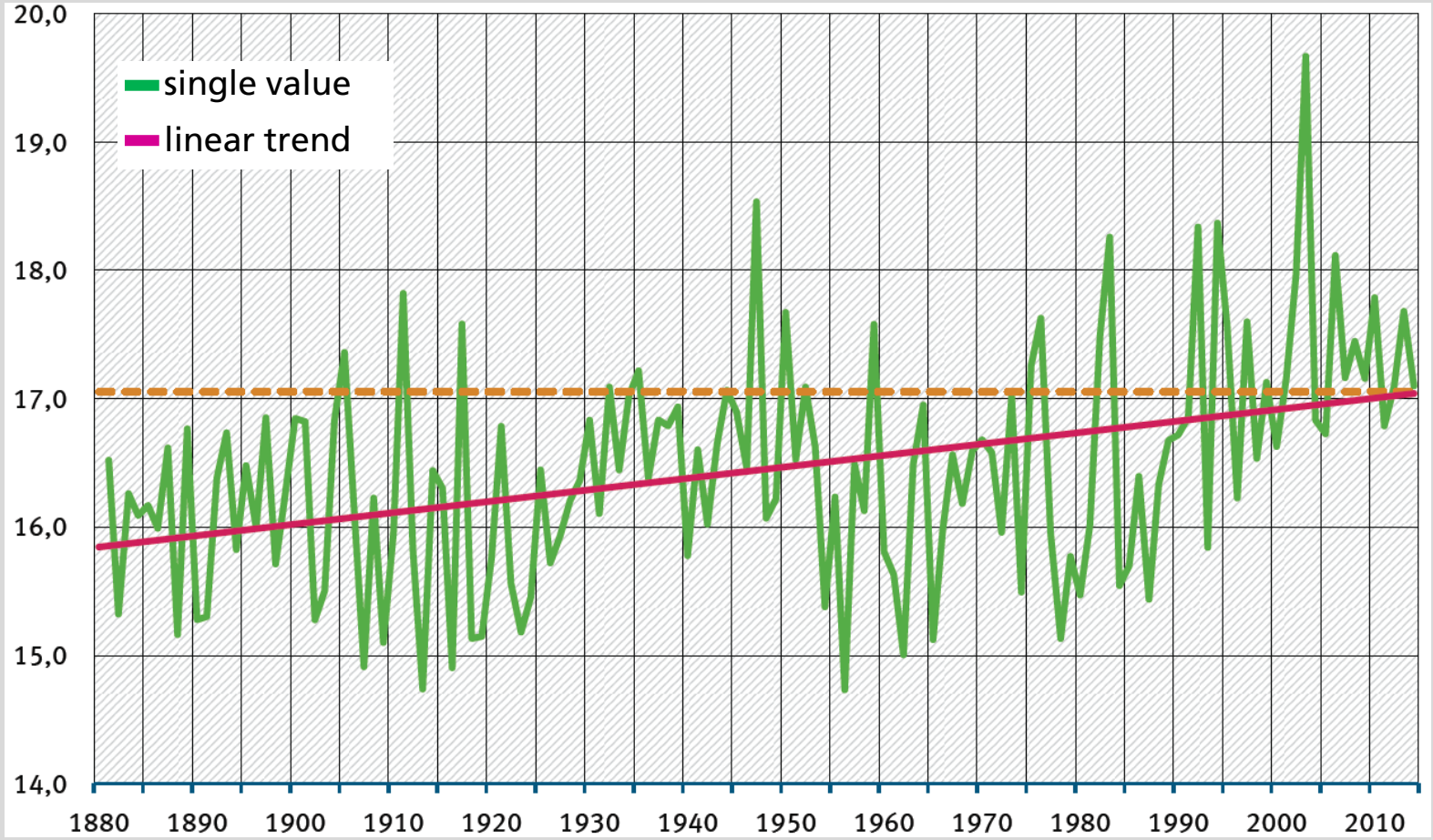
Influence of the weather conditions

Warmer summers with persistent heat waves

Average daily ambient air temperature in summer season [°C]



Source: Deutscher Wetterdienst. http://www.dwd.de

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3 Thermal comfort and user satisfaction

Requirements for workplaces in the summer season

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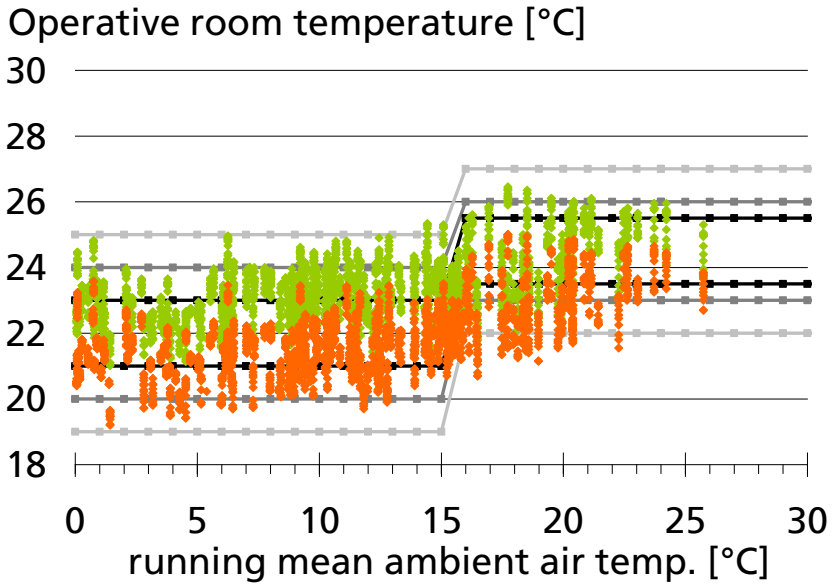
Cooling concepts in office buildings

Influence of user satisfaction: Guideline DIN 15251

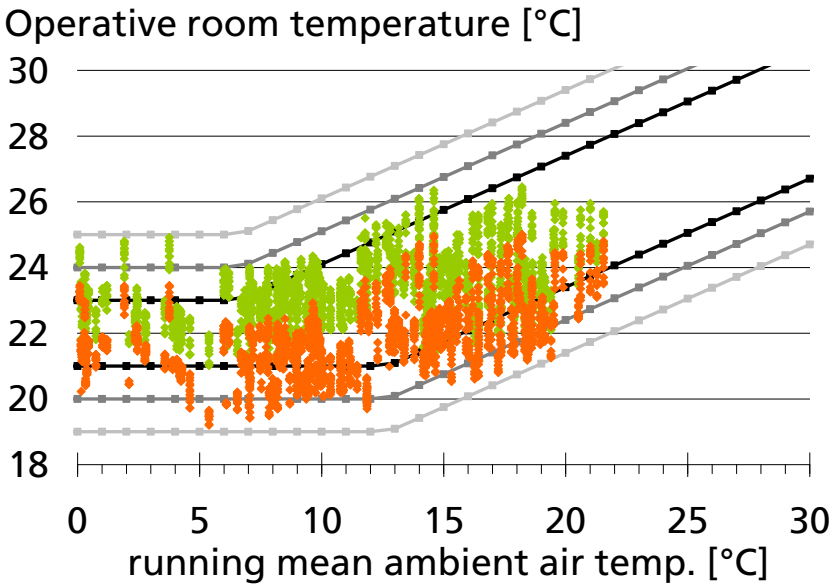
PMV Model



- Building: **with** cooling
- Room temperature independent of ambient air temperature

ORT = 24.5°C + 1 | 1.5 | 2.5K (I, II, III)

Adaptive Model



- Building: **without** cooling
- Room temperature independent of ambient air temperature

ORT = 18.8 + 0.33*AT_{rm} (+2 | 3 | 4 K) (I, II, III)

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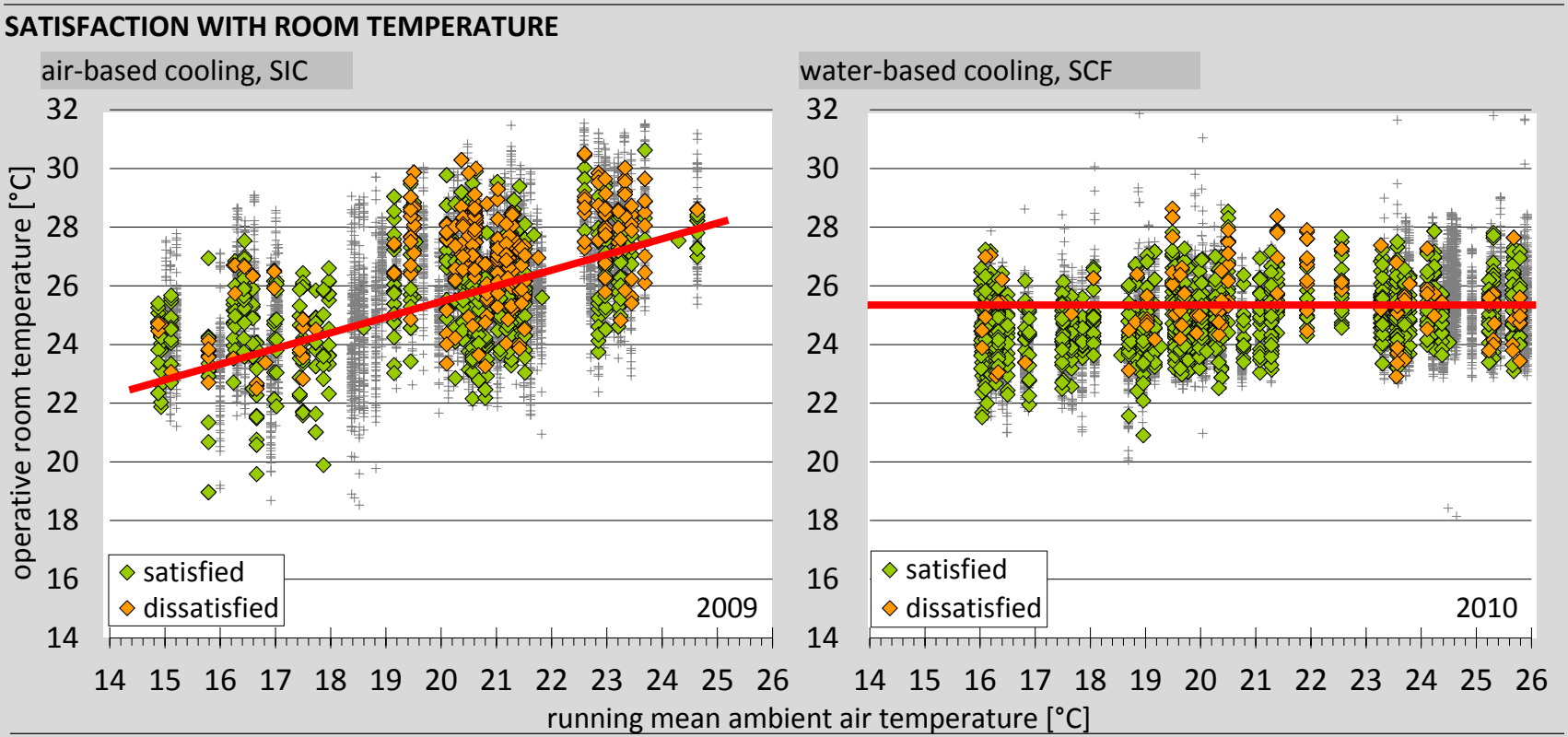
User satisfaction and user expectations

Depends on the cooling concept employed



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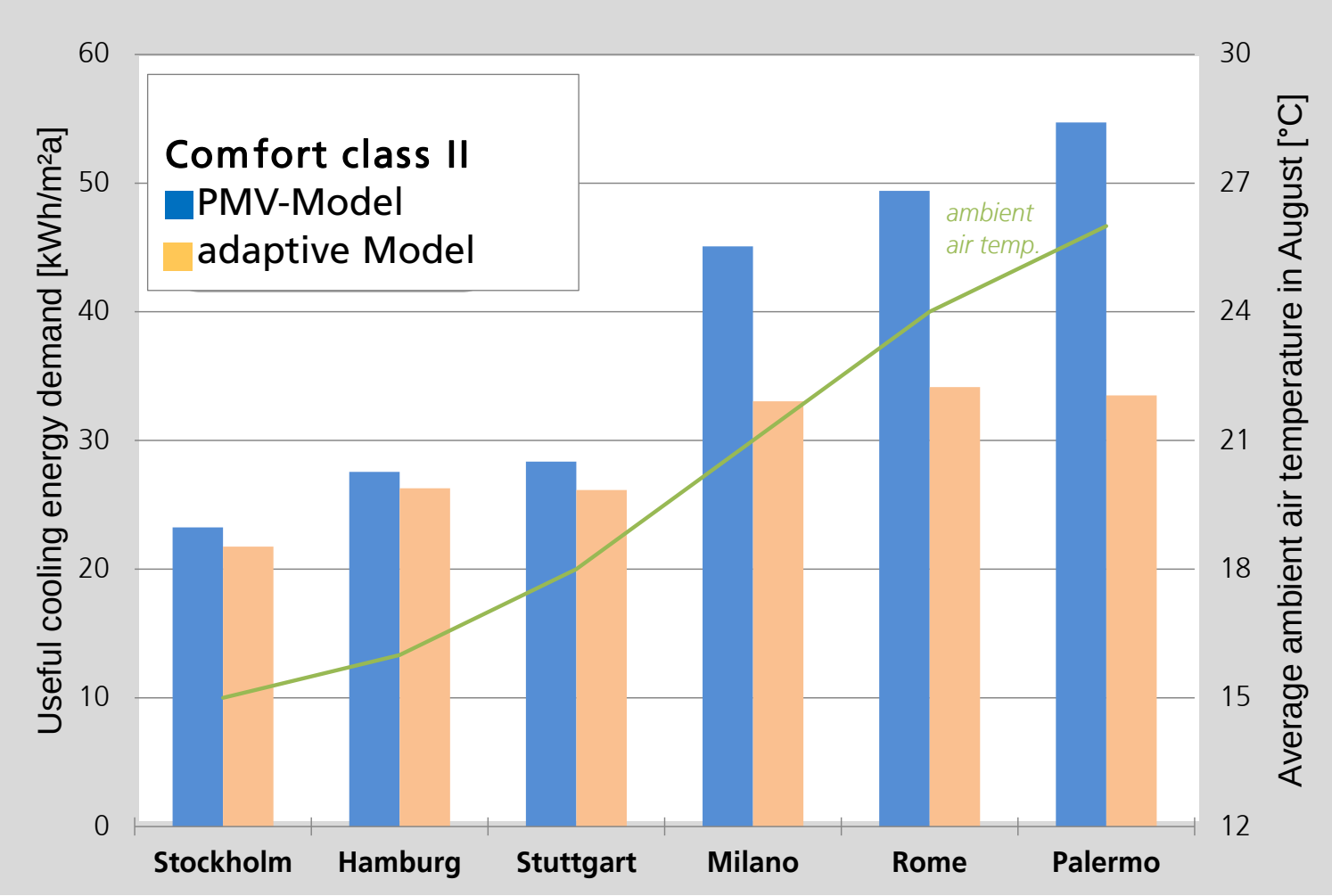
Comparison of cooling concepts: useful energy

Different climate zones



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4 Energy efficient concepts and technologies for cooling

Passive measures, environmental heat sinks and reversible heat pumps

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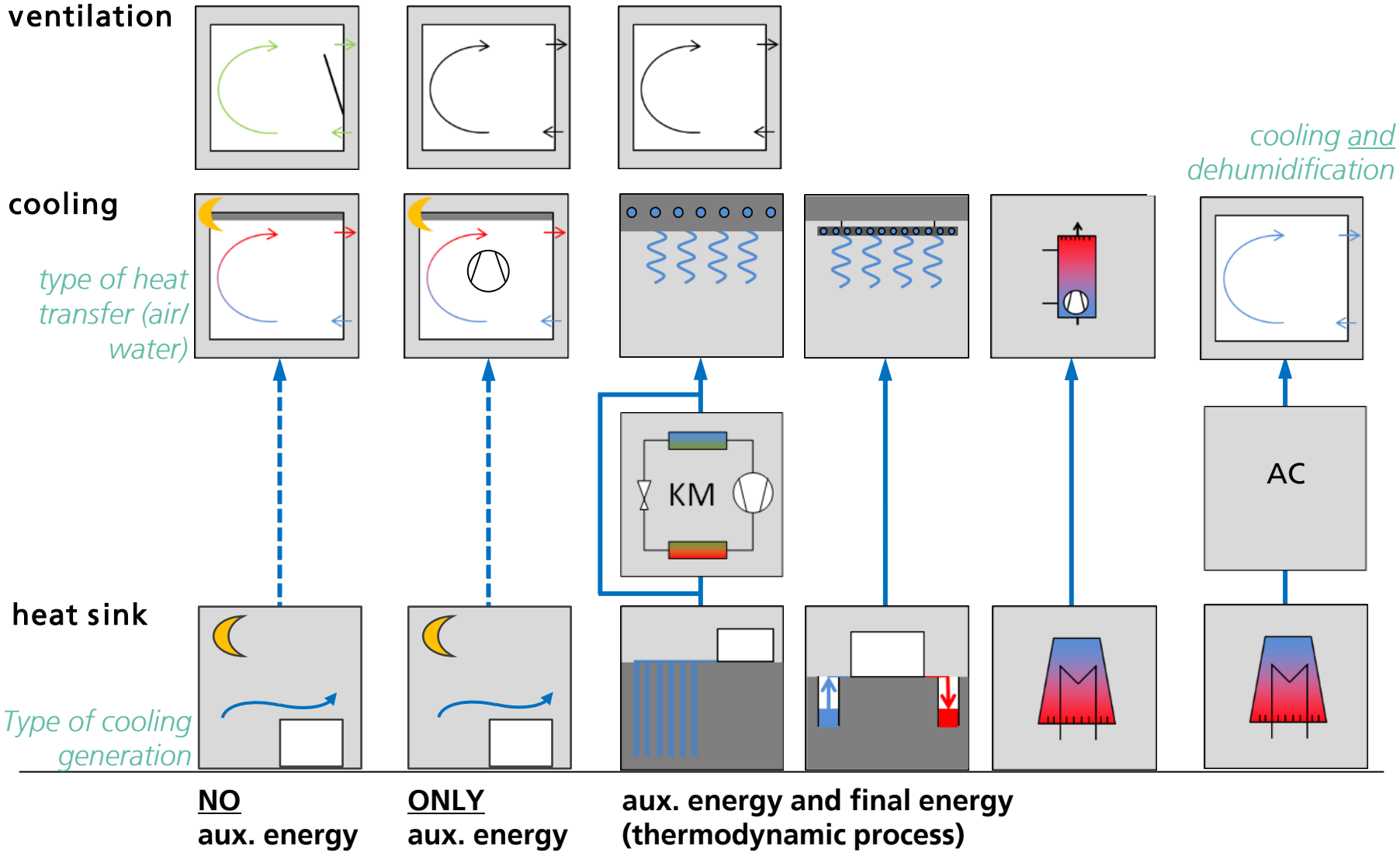
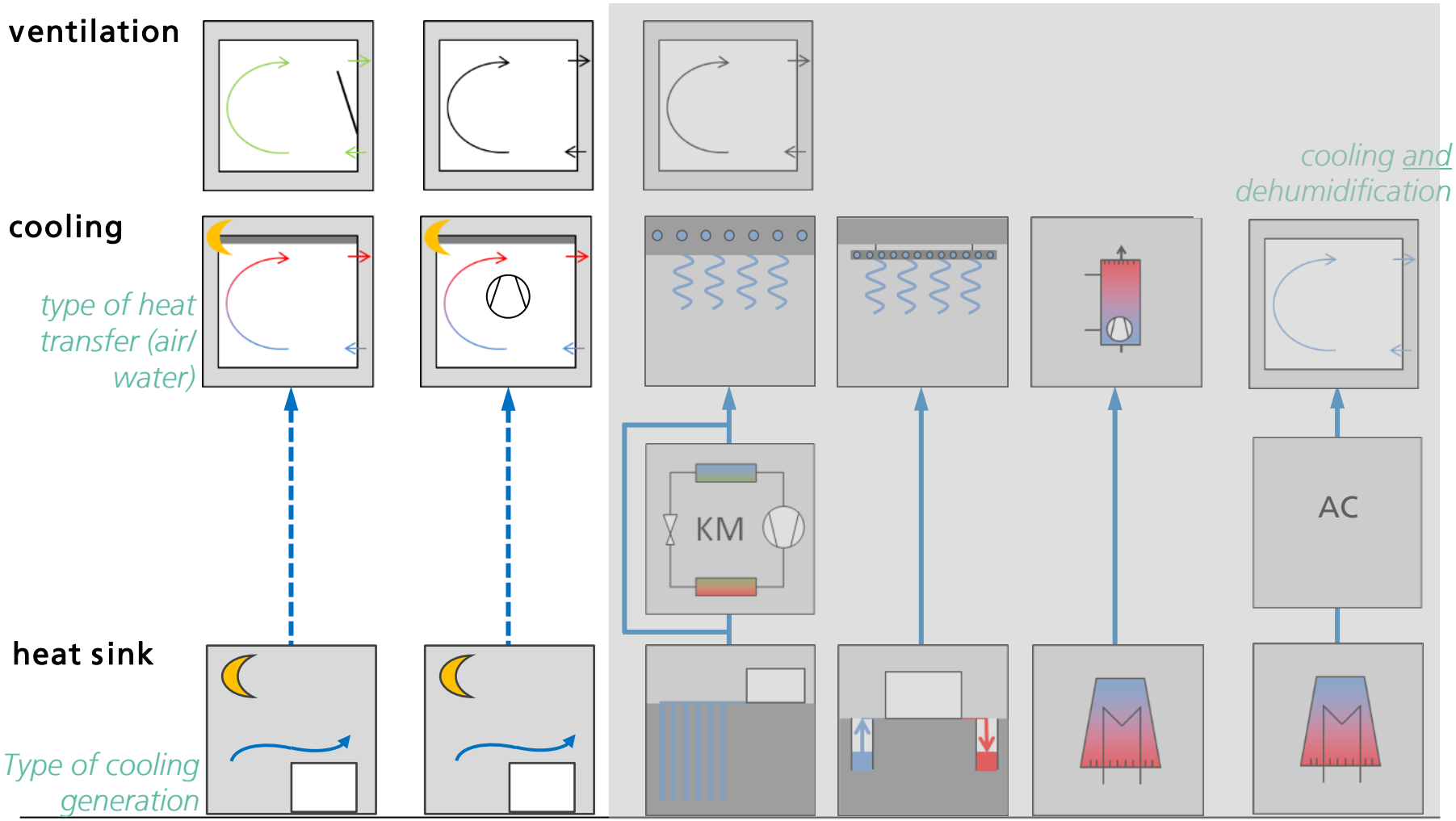
Space cooling

Common concepts and systems



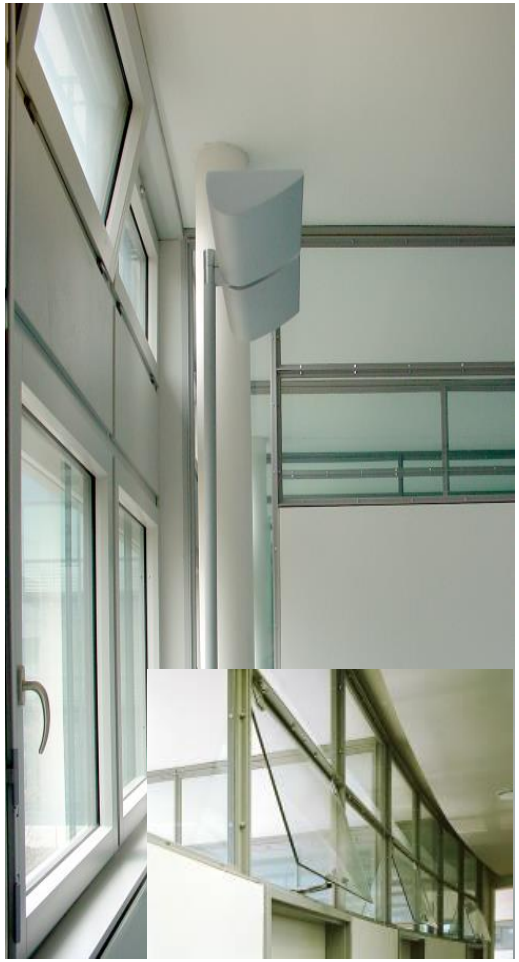
Source: Fraunhofer ISE.

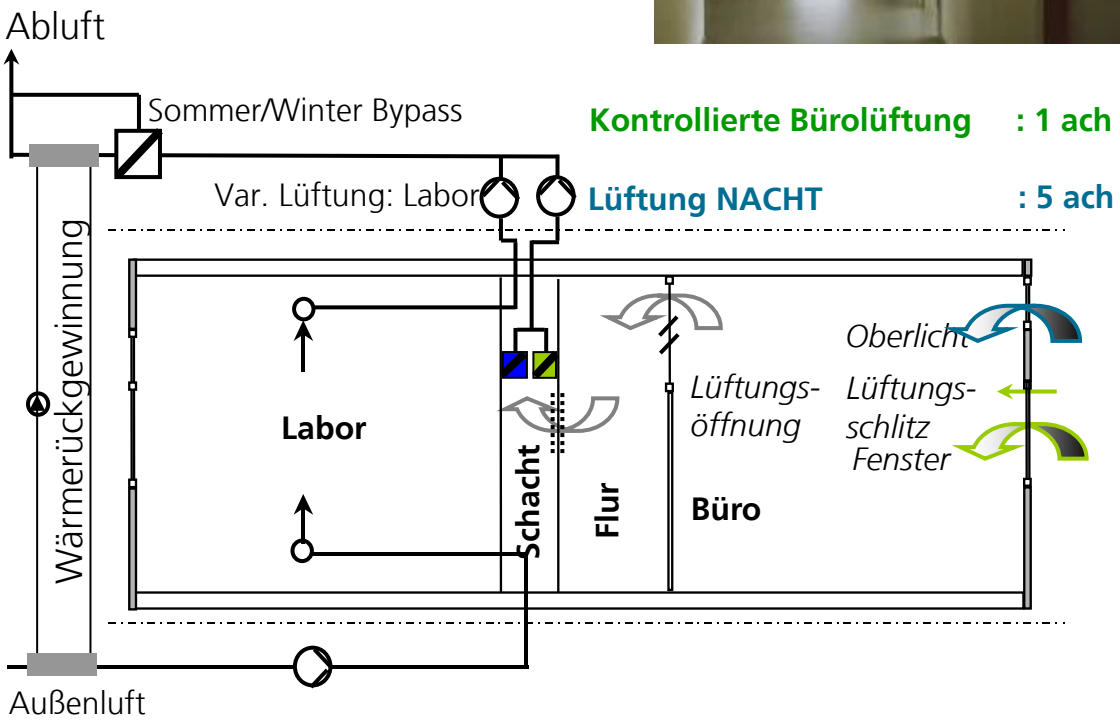
Space cooling
Concepts and systems



Source: Fraunhofer ISE.

Free and mechanical night ventilation





Kontrollierte Bürolüftung : 1 ach

Lüftung NACHT : 5 ach

Source: Fraunhofer ISE.

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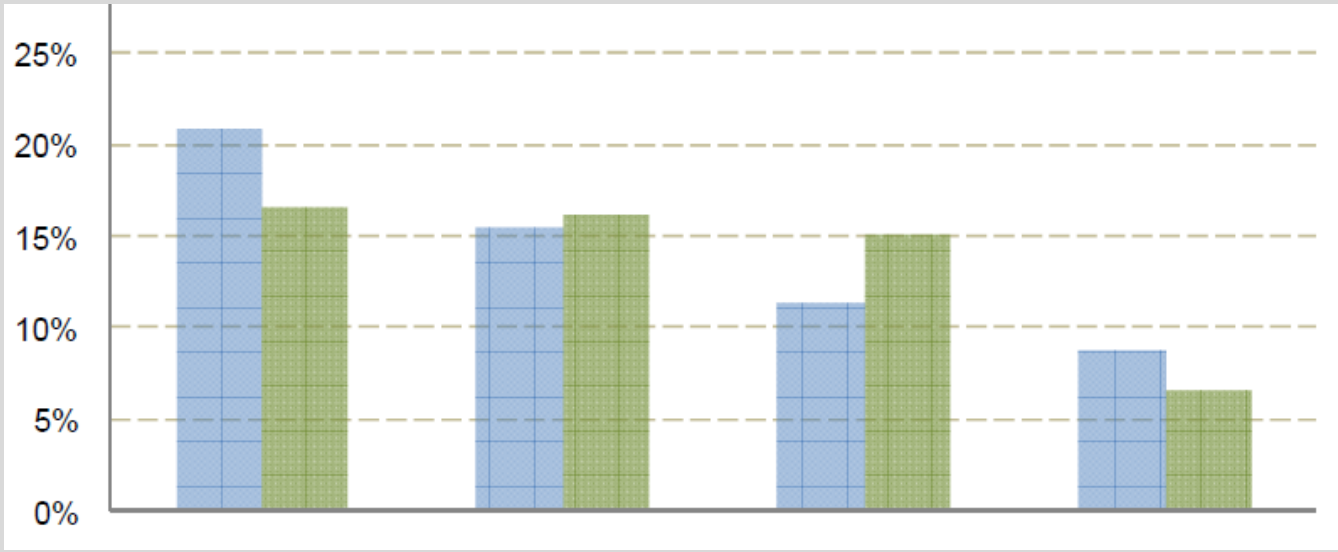
Free and mechanical night ventilation

Supportive cooling

Reduction of useful cooling energy demand by night ventilation [%]



Source: Schiller and Mai. Final Report: Berechnungs-Algorithmen für freie und regenerative Kühltechnologien in Nichtwohngebäuden.

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Free and mechanical night ventilation
Performance

+ Saving of energy costs and operation costs for ventilation and cooling system
+ In retrofit projects, no complex / extensive ducts
+ Auxiliary energy use is reduced
+ Thermal mass of the building is used

– Cooling capacity is reduced and depends significantly on user behavior, ventilation effectivity, ambient air temperature, thermal building mass
– Certain room temperature cannot be guaranteed
– Elevated room temperatures during long and persistent heat waves
– In combination with water-based cooling
– Energy efficiency varies: SPF 2 - 12 (derived from monitoring campaigns)

Source: Fraunhofer ISE.
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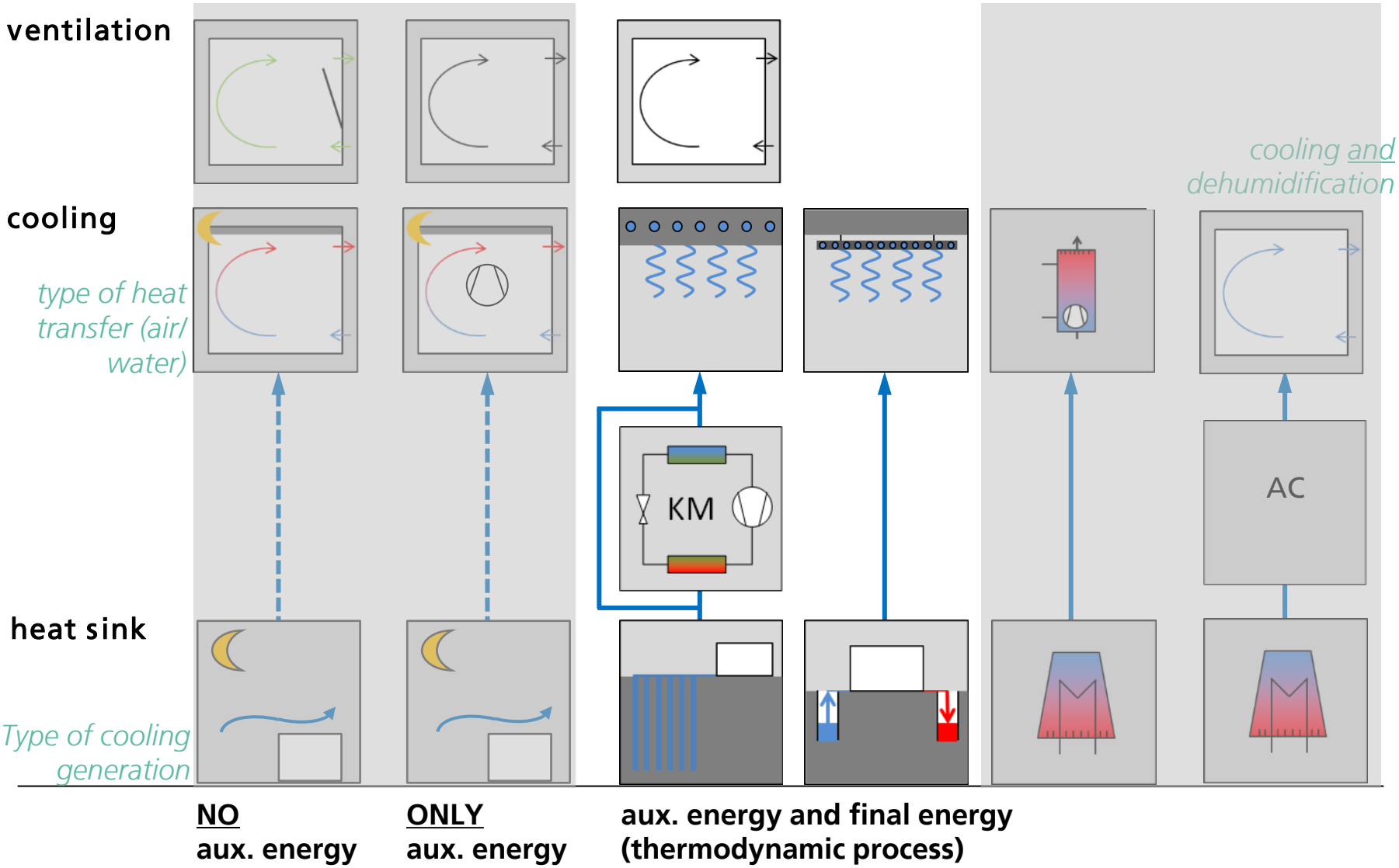
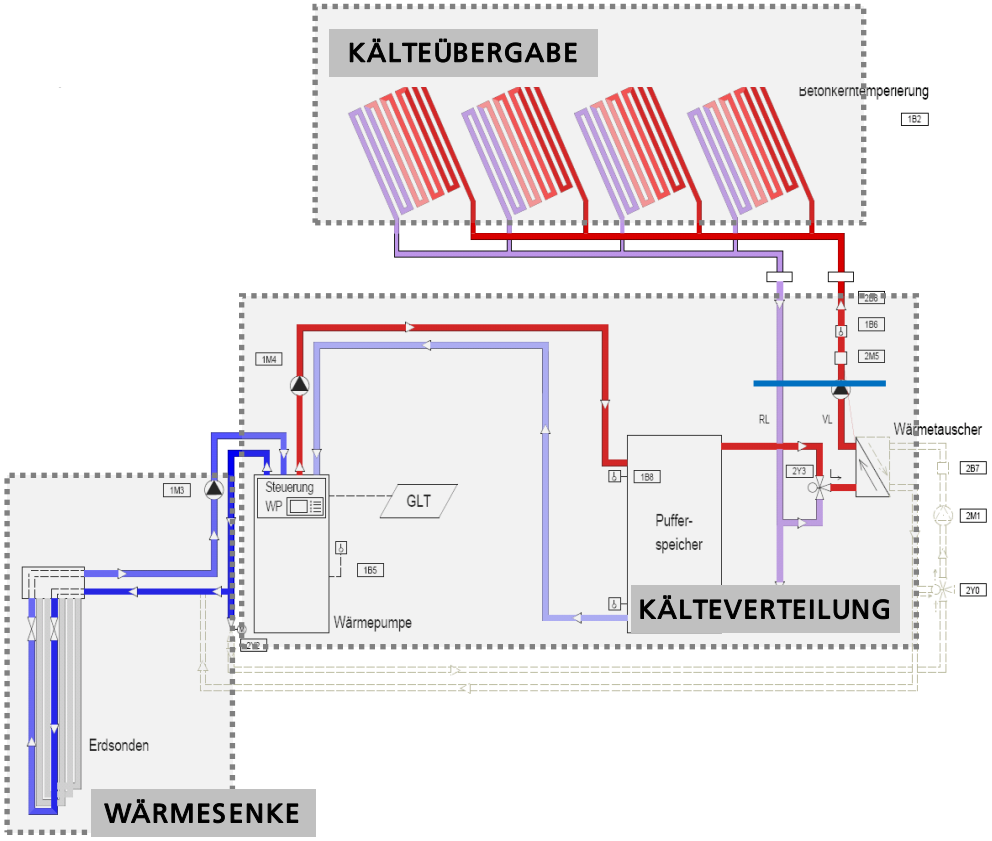
Space cooling
Concepts and systems



Water-based cooling and environmental heat sinks
Function



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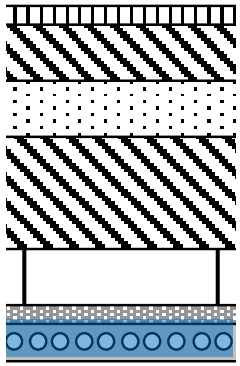
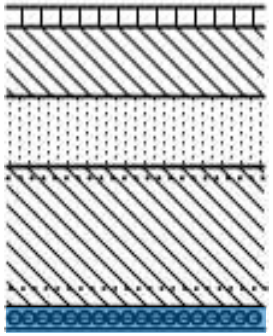
Water-based cooling

Radiant cooling with higher temperatures

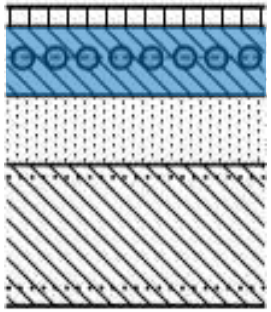
SUSPENDED PANELS



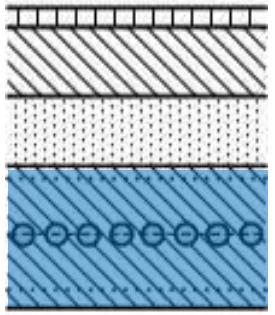
CAPILLARY MATS



FLOOR CONDITIONING



CONCRETE CORE CONDITIONING



RETROFIT

NEW CONSTRUCTION

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Water-based cooling with rev. heat pumps
Performance: Energy and Efficiency

- **Efficiency of rev. heat pumps**
  - EER 2.5 to 6.6
  - Share of active cooling 16 to 58%
- **Efficiency of rev. Heat pump system** (incl. auxiliary systems)
  - EER 2.1 to 6.0

Source: Fraunhofer ISE.

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Water-based cooling
Radiant cooling with higher temperatures

+ Integrated in construction, no additional space required
+ Low auxiliary energy use, high energy efficiency can be achieved
+ Thermal building mass is used, load shifting is possible
+ Combination of integrated and suspended systems
+ Systems can be used for heating and cooling purposes
+ High thermal comfort and user satisfaction

– Hydraulic in the secondary and primary circuits determines the efficiency
– Cooling capacity limited 40 W/m² (concrete core conditioning) to 70 W/m² suspended panels, dew point temperature and condensation need to be considered
– Individual control of ORT per room required combination of systems (slow and quick response)
– No treatment of air (de-/ humidification)

Source: Fraunhofer ISE.
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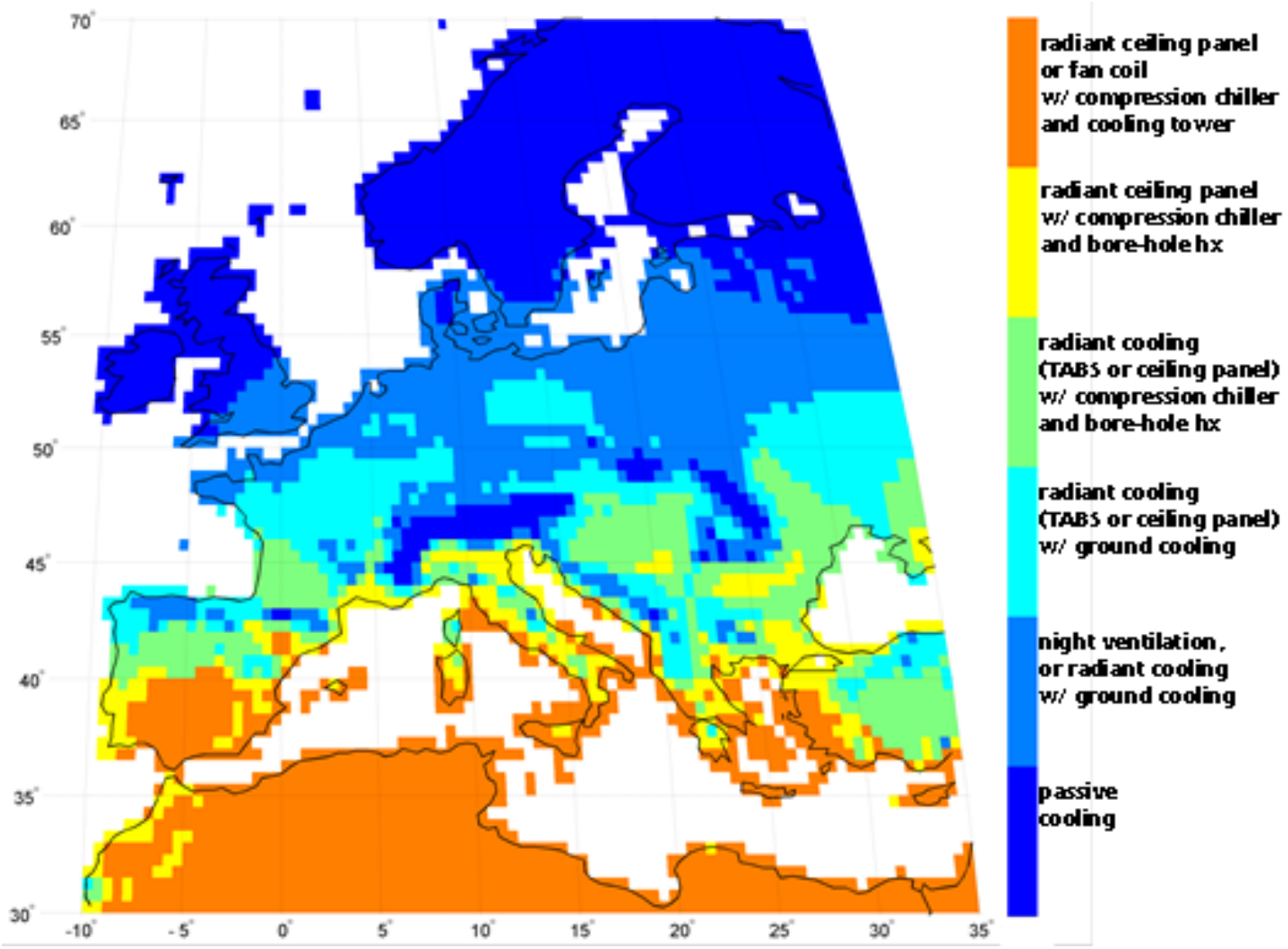
Comparison of cooling concepts

Different climate zones



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5 Outlook: The transformation of the energy system requires “energy-flexible” buildings

Load shifting, integration and management of storage systems and adjusted control

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Heat pumps and chillers
Long term monitoring campaigns

- Analysis of monitoring data from long-term campaings of heta pumps and chillers
  - 8 heat pumps in office buildings (4,5 – 58 kW_{el})
  - 4 chillers in office buildings (14,9 – 29 kW_{el})
  - 2 co-generation in multi-family houses (5,5 kW_{el})
  - 37 heat pumps in single family houses (heating and DWH; 1,3 – 6,1 kW_{el})
- **Electricity consumption of heat pumps and** chillers as they are installed and operated today

Source: Fraunhofer ISE.

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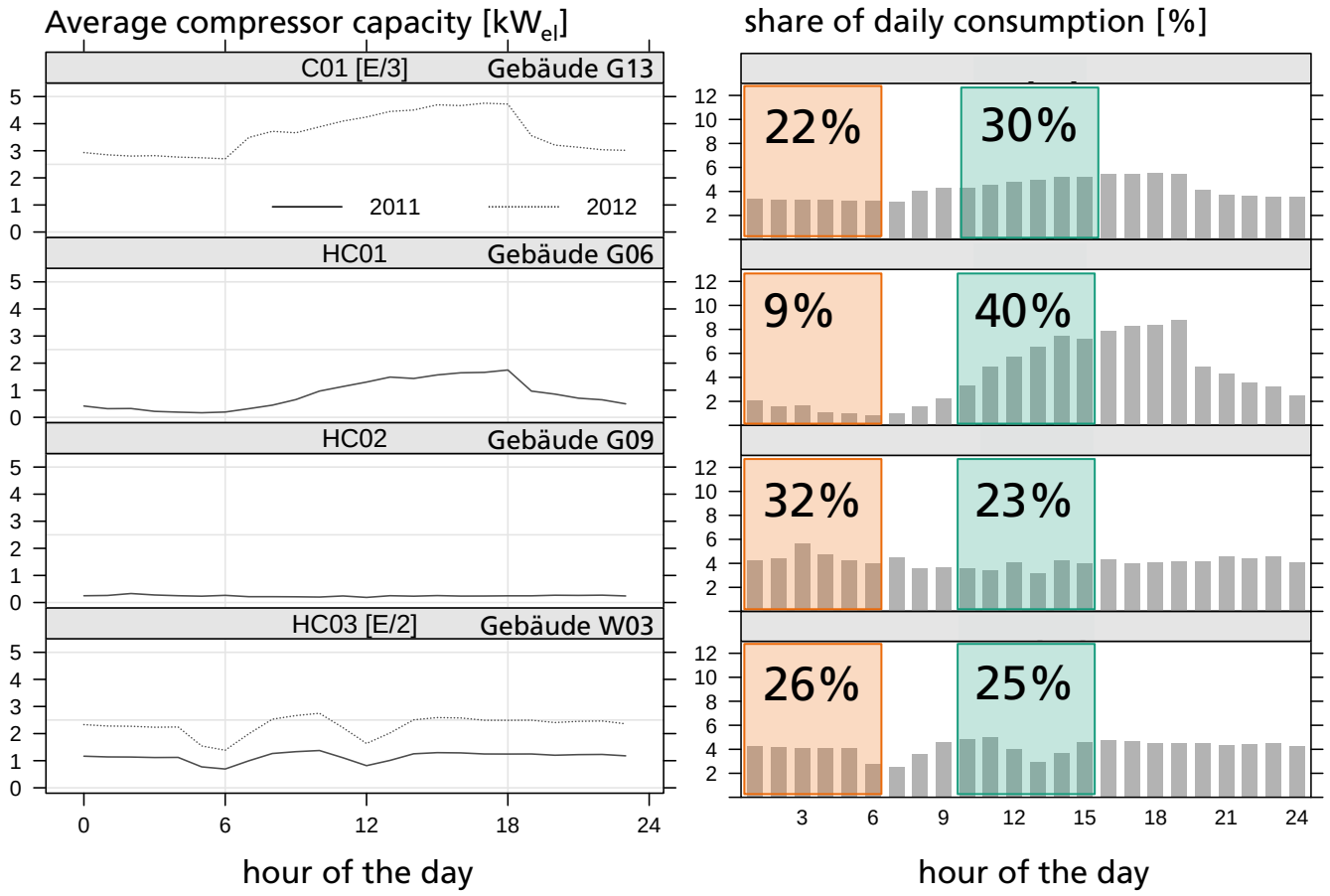
Monitoring data analysis of reversible heat pumps

Daily electricity consumption for cooling

use when share of **wind and PV** is **low**

use when share of **wind and PV** is **high**

- Operation of heat pumps in summer in cooling mode
- Consumption of electricity with high share of wind and PV in the grid
- Operation during daytime → lower efficiency with cooling tower
- Requires supply systems with quick response



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Source: Klein K, et al (2015) Grid support coefficients for electricity-based heating and cooling and field data analysis of present-day installations in Germany. Applied Energy 162:853-867.

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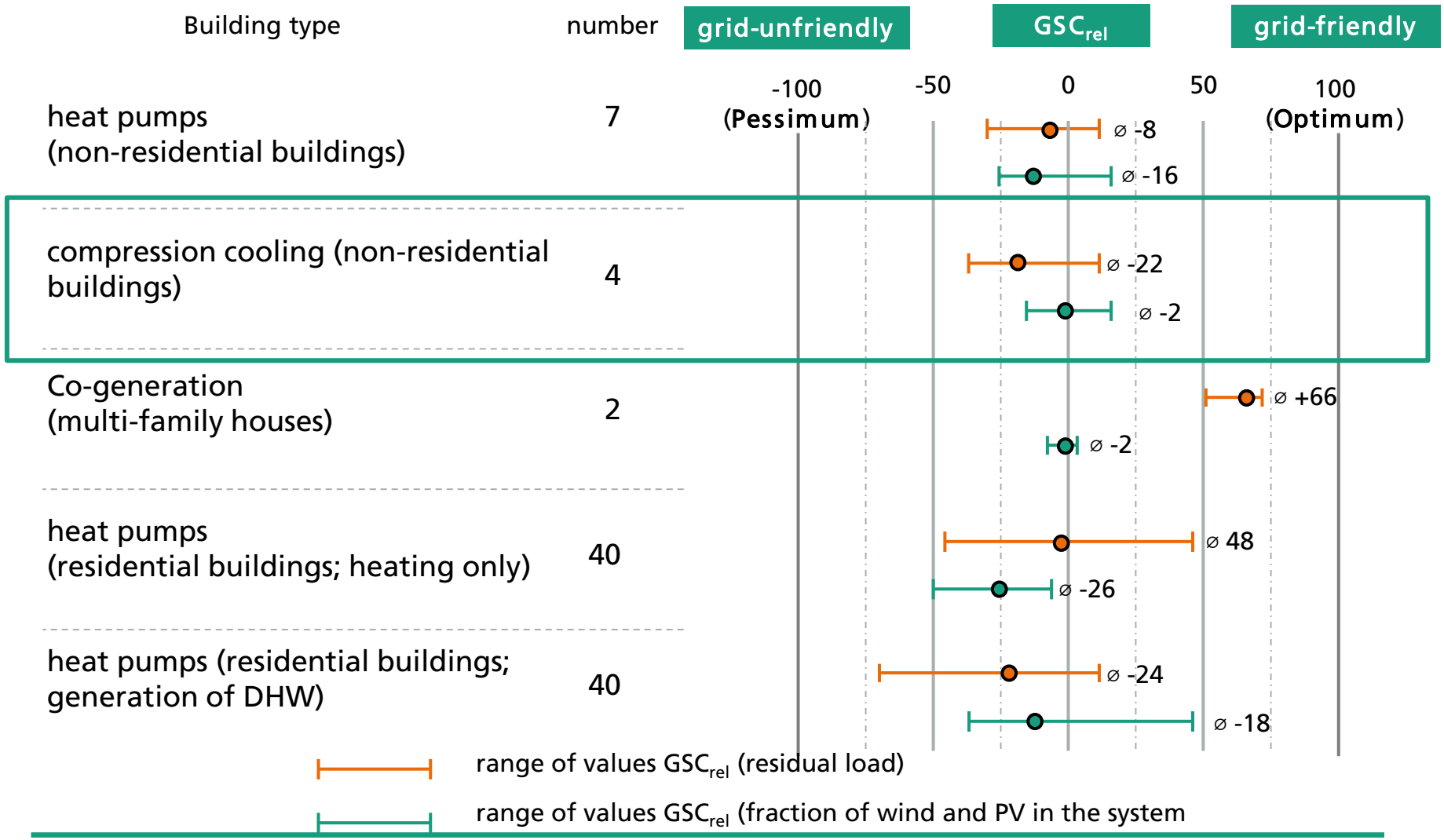
How grid-supportive are buildings today?

Relative grid support – comparison of technologies



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Source: Klein K, et al (2015) Grid support coefficients for electricity-based heating and cooling and field data analysis of present-day installations in Germany. Applied Energy 162:853-867.

6 Conclusions

Space Cooling

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Conclusion

- Share of energy for cooling is low compared to the overall energy consumption
- BUT
  - Thermal **cooling demand** for space cooling is **increasing** in both residential and commercial/service sector
  - Persistent **heat periods in summer**, heat island effect in bigger cities, elevated building standard (high quality building shell)
  - **Requirements of user** on thermal comfort is higher: individual room control, cooled spaces
- **Technologies**
  - Night ventilation additional to cooling concept
  - Use of environmental heat sinks
  - Water-based cooling approx. in every second to third new construction
- Additional requirements on cooling systems due to “energy-flexible” buildings

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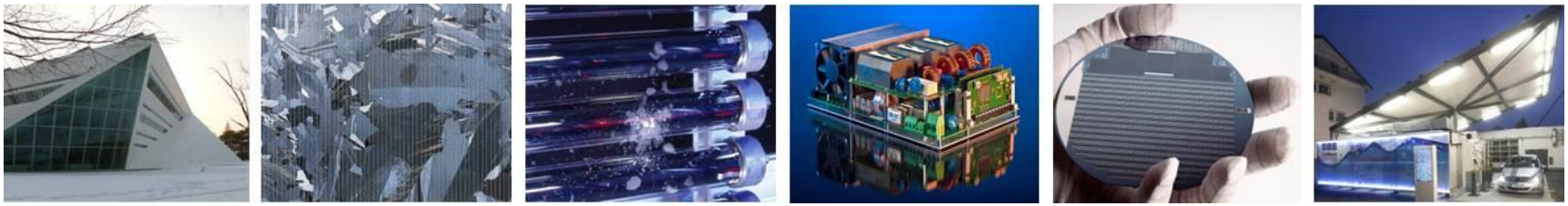
Thank you for your attention!



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