THE SPECTRUM OF RESIDENTIAL COOLING DEMAND – MODELED DEMAND VERSUS REAL-LIFE NEEDS

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Who Defines the Cooling Demand – Buildings or Residents?
The Mixed-Methods Study

Diversity of
- building structures
- social structures
- microclimates

Household survey in summer 2020 (n=731) → SPSS analysis, geocoding
The Mixed-Methods Study

**Objective Heat Stress Index**
- $T_{\text{mean}}$, overtemp. DH, $T_{\text{max}}$ timelag
  - (Reliability: Cronbach’s Alpha 0.972)

**Diversity of**
- building structures
- social structures
- microclimates

**Household survey**
- in summer 2020 (n=731)
  - SPSS analysis, geocoding

**Air temperature monitoring**
- in August 2020 (n=342)
  - overheating analysis
  - matched with survey data
  - SPSS analysis, geocoding

Legend:
- no / very low overheating
- low overheating
- moderate overheating
- considerable overheating
- permanent / strong overheating
The Mixed-Methods Study

Diversity of
- building structures
- social structures
- microclimates

Household survey in summer 2020 (n=731)
  → SPSS analysis, geocoding

Air temperature monitoring in August 2020 (n=342)
  → overheating analysis
  → matched with survey data
  → SPSS analysis, geocoding

Computer simulation (n=40)
  → overheating analysis
  → cooling demand model
Input data:
- weather data
- building geometries
- materials, windows
- air exchange rate
- shading by buildings
- threshold 26°C
Comparing Heat Exposures: Filling the Gaps

**Presumed** Heat Exposure

- modeled / potential cooling demand

**building characteristics** (building type, age class, shading by buildings...)

- **user behaviour** (simplified assumptions based on norms)

- **weather data**
Comparing Heat Exposures: Filling the Gaps

**Presumed** Heat Exposure

- modeled / potential cooling demand

**Objective** Heat Exposure

- measured / calculated cooling demand

**Building characteristics**
- building type, age class, shading by buildings...

**User behaviour**
- simplified assumptions based on norms

**Weather data**

**Apartment characteristics**
- orientation, equipment, floor level...

**User behaviour**
- ventilation, shading, presence...

**Neighbourhood context**
Comparing Heat Exposures: Filling the Gaps

Presumed Heat Exposure
modeled / potential cooling demand

building characteristics (building type, age class, shading by buildings...)

user behaviour (simplified assumptions based on norms)

weather data

Objective Heat Exposure
measured / calculated cooling demand

apartment characteristics (orientation, equipment, floor level...)

user behaviour (ventilation, shading, presence...)

neighbourhood context

Subjective Heat Exposure
subjective / perceived cooling demand

individual characteristics (thermal preference, health, age...)

psychological aspects (sense of control, life satisfaction...)

social context
First results

modeled / potential cooling demand

measured / calculated cooling demand

subjective / perceived cooling demand

Significance level: „n.s.“ (not significant) \( p > 0.06 / „m.s.“ \) (marginally significant) \( p < 0.06 / „*“ \) (weakly significant) \( p < 0.05 / „**“ \) (significant) \( p < 0.005 / „***“ \) (strongly significant) \( p < 0.001 \)
Filling the Gaps: An Example from the Real World

Overtemperature hours

Modeled Overheating Hours

Cooling demand

Modeled Cooling Demand
Filling the Gaps: An Example from the Real World

Measured Overheating Hours

Modeled Overheating Hours

Overtemperature hours

Measured Overheating Hours

- **no / very low overheating**
- **low overheating**
- **moderate overheating**
- **considerable overheating**
- **permanent / strong overheating**
Filling the Gaps: An Example from the Real World

Modeled Overheating Hours

Overtemperature hours

Measured Overheating Hours

### Apartment characteristics & user behaviour:
- 2-room apartment (73m²)
- 4th floor without balcony
- western orientation of bedroom
- no shutters, no A/C, no awnings, no parasol
- curtains and autom. fan used
- cross-ventilation at night

### Modeled Overheating Hours vs. Measured Overheating Hours

- no / very low overheating
- low overheating
- moderate overheating
- considerable overheating
- permanent / strong overheating
Filling the Gaps: An Example from the Real World

Modeled Overheating Hours

Subjective Heat Stress Index

- no/very low heat stress
- low heat stress
- moderate heat stress
- considerable heat stress
- permanent/strong heat stress

Overtemperature hours
Filling the Gaps: An Example from the Real World

Individual characteristics & satisfaction:
- 59 year old lady
- rents the apartment with her partner
- poor health
- not at all satisfied with her living situation
- dislikes the neighbourhood
- would like to have A/C and shutters
Filling the Gaps: An Example from the Real World

Individual characteristics & satisfaction:
- 59 year old lady
- rents the apartment with her partner
- poor health
- not at all satisfied with her living situation
- dislikes the neighbourhood
- would like to have A/C and shutters
Conclusion: The Devil is in the Details

modeled / potential cooling demand

subjective / perceived cooling demand

measured / calculated cooling demand

Significance level: “n.s.” (not significant) $p > 0.06$ / “m.s.” (marginally significant) $p < 0.06$ / “*” (weakly significant) $p < 0.05$ / “**” (significant) $p < 0.005$ / “***” (strongly significant) $p < 0.001$
Thank You – Questions Welcome!

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Backup
Methodological Overview

Survey
- Occupant behavior
- Survey time
- Building address / orientation / floor level of the apartment
- Perceived thermal comfort and cooling demand

Matching points
- Period of investigation
- Investigated buildings/apartments
- Refinement

Thermal building simulation
- Simulation boundaries
  - Internal heat gains, occupancy schedules etc.
- Weather data
- Building geometry from CityGML data
- Building materials based on building age class

Visualization
- percieved/simulated thermal comfort and cooling demand

Modeled thermal comfort and cooling demand
Subjective Heat Stress

Objective Heat Stress

A/C Demand

\[ r^2 = 0.161^* \]

A/C Demand

\[ r^2 = 0.317^* \]

Sensitive User

A/C Demand

n.s.

Privileged User

A/C Demand

no A/C demand

A/C demand
Subjective Heat Stress

Objective Heat Stress

○ 3 Cluster K-means shb ohb

1
2
3