CLIMATIC POTENTIAL FOR PASSIVE COOLING OF BUILDINGS BY NIGHT-TIME VENTILATION IN EUROPE

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NIGHT-TIME VENTILATION

- Decreasing heating and increasing cooling demand in buildings in Europe
  - Commercial buildings with high thermal insulation
  - High solar and internal heat gains
  - Increased comfort expectations
  - Cooling of buildings even in moderate and cold climates
- Passive cooling by night-time ventilation
  - Cooling the building structure overnight
  - Heat sink during occupancy period
  - Covering or reduction of cooling energy requirement
- Potential for night-time cooling in different climates?
- Impact of climate change on cooling potential?
CLIMATIC DATA

- ANETZ: Measured temperature data for Switzerland since 1981
- Meteonorm: Semi synthetic climatic data for worldwide 7400 stations
- Selection of 259 stations at densely populated locations in Europe

Mean daily minimum temperature (left) and mean daily temperature fluctuation (right) in July (Meteonorm data)
CLIMATIC COOLING POTENTIAL (CCP)

Degree hours of cooling potential

- Definition: Degree hours for the difference between building and external air temperature
- Variation in building temperature (sensible energy storage)
  - Sine oscillation: \( T_b = 24.5^\circ C \pm 2.5^\circ C \)
  - Standard for thermal comfort in offices (CR 1752; ISO 7730)
  - No building specific parameters
- Ventilation period: 7 pm to 7 am
- Critical temperature difference: \( \Delta T_{\text{crit}} = 3K \)

Climatic Cooling Potential during one week in summer 2003 for Zurich SMA (ANETZ data)
PRACTICAL SIGNIFICANCE OF CCP

Assumptions:
- Sufficient thermal capacity of building mass
- Closed loop: \( Q_{\text{charge}} = Q_{\text{release}} \)

Example:
- Effective air change rate: \( R \eta = 6 h^{-1}; \) \[ \left( \eta = \frac{T_{\text{out}} - T_e}{T_b - T_e} \right) \]
- Air properties: \( \rho = 1.2 \text{ kg/m}^3; c_p = 1000 \text{ J/(kgK)} \)
- Occupancy time: \( t_{\text{occ}} = 8h \)
- Room height: \( H = 2.5m \)

Heat flux per K h of CCP: \( \dot{q}_{\text{CCP}} = \frac{HR \eta \rho c_p}{t_{\text{occ}}} = 0.625 \frac{W}{m^2} \)

- Internal and solar heat gains: \( 20W/m^2 + 30W/m^2 = 50W/m^2 \)

Climatic cooling potential: \( \text{CCP} = 80Kh \)
CCP IN DIFFERENT TIME INTERVALS

Stochastic weather patterns

- High variation of CCP within few nights: \( \sim 100 - 200 \text{ K h} \)
- Variation of weekly mean values: \( \sim 50 - 100 \text{ K h} \)
- Heat waves with high daily cooling demand and low cooling potential during nights
- Example:
  First week of August \( \sim 0 \text{ K h} \)
  August mean \( \sim 50 \text{ K h} \)
High variation of monthly mean values over the years: \( \sim 100 - 150 \) K h

Outlook:
- Exceptionally hot summer in 2003
- Very low cooling potential in June and August
- Is this what a typical summer will be like at the end of this century?

Mean value, standard deviation, minimum and maximum of monthly mean CCP for Zurich SMA 1981 to 2002 and monthly mean for 2003 (ANETZ data)
Gradient from North to South

- Very high potential of 120 – 180 K h in Northern Europe (incl. British Isles)
- High CCP (60 – 140 K h) in Central, Eastern and parts of Southern Europe
- Low cooling potential in Southern Europe: 0 – 80 K h

Map of mean CCP (K h / night) in July
RESULTS – monthly mean and cumulative frequency

Monthly mean over the year

- Useable potential e.g. in Lisbon during colder periods: 100 – 180 K h from Oct. to May
- High variability in continental climates
- Less variability in maritime climates

Cumulative frequency

- Interesting information for planning engineers
- Bergen: always more than 75 K h
- Moscow: > 100 K h in 330 nights / year
- Ankara: > 100 K h in 300 nights / year few days without CCP
- Lisbon: > 100 K h in 220 nights / year 15 days without CCP (Hybrid systems)
OUTLOOK - impact of climate change

- Expectation of a significant increase in temperatures within service life of presently constructed buildings
- Need for a detailed analysis of the potential for night cooling in future climate
- PRUDENCE project provides climate projections for 2071 – 2100
  - Forcing scenarios
  - AOGCM (Atmosphere-Ocean General Circulation Models)
  - RCM (Regional Climate Model)
- High uncertainties of future climate models

Map of the mean daily minimum temperature shift in summer (JJA) modelled by the Danish Meteorological Institute (DMI) based on a HadAM3H A2 AOGCM simulation run (PRUDENCE project: http://prudence.dmi.dk)
CONCLUSION

- Degree hours method for quantifying the potential for cooling by night ventilation based on a variable building temperature
  - Very significant potential in Northern Europe (sufficient for most applications)
  - High potential in Central, Eastern and parts of Southern Europe (risk of thermal discomfort on a few days per year)
  - Insufficient potential in Southern Europe (still useful for hybrid systems)
- Quantification of cooling potential in first design phase
- Need for detailed analysis of transient thermal behaviour by building energy simulation
- Outlook
  - Impact of climate change on potential for night cooling
  - Improvement of simulation models for air exchange and cooling effect in building energy simulation codes
Thanks for listening

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VARIFICATION – Sensitivity on Parameters

- Building temperature amplitude: little impact for CCP < 20 K h
- Critical temperature difference: marginal for CCP > 90 K h
- Ventilation period (±1 h): ±10 K h

Cumulative frequency of CCP for different building temperature amplitudes (left), critical temperature differences (middle) and night ventilation periods (right)
VARIFICATION – semi-synthetic climatic data

Comparison of CCP based on Meteonorm data with CCP based on measured data for two locations


Cumulative frequency of CCP per night based on different datasets
RESULTS – cumulative frequency

Climatic Cooling Potential for Maritime Climate

- Bergen
- Helsinki Airport
- Copenhagen Taastrup
- Dublin Airport
- London Weather C.
- Paris Montsouris
- Bordeaux
- Rome Ciampino
- Lisbon
- Athens

Nights per year

CCP per night (K h)
RESULTS – cumulative frequency

Climatic Cooling Potential for Continental Climate

- Moscow
- Potsdam
- Warsaw
- Prague
- Vienna Hohe Warte
- Zurich SMA
- Dijon
- Belgrade
- Madrid Barajas
- Ankara

Nights per year

CCP per night (K h)