The risk of buildings overheating in a low-carbon climate change future

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ICEBO conference, 24th October 2012
Context

- New buildings currently being designed for a ‘normal design life’ of 60 years (UK) will be in use until 2080.
- The UK’s climate is changing.
- What will the climate of 2080 be like?
- Will those buildings still perform adequately?
- Against a background of minimising CO$_2$ emissions
Objectives of project

- How can building simulation use the UKCP’09 climate database?
- How can this be used for designing adaptations for buildings in the future?
- How can it be incorporated into a method that is useful for industry for overheating analyses?
  - And, by association, other types of building analysis (e.g. heating/cooling loads)
What is overheating?

- Different buildings may have different definitions of overheating
  - High temperatures in a dwelling at night may cause discomfort
  - An office constantly exceeding an afternoon threshold may be deemed unfit for purpose
- But thermal comfort should not be seen as completely prescriptive
  - People can “adapt” to different temperatures
Project overview

Probabilistic climate data on future scenarios

Building simulations to quantify overheating

Statistical regression

Climate and internal conditions

Overheating design tool “LCF tool”

Design professionals’ input
UK Climate Projections 2009 (UKCP’09)

- Cutting edge climate projection in UK
- Suggest the *probability* of different future climates occurring

10th percentile 50th percentile 90th percentile

Increase in average temperature (°C)
UK Climate Projections 2009

• Use the “Weather Generator” to obtain data
• Projections are given as different percentiles of probabilities
  • Or the user can obtain all possible iterations of a given scenario
  • Each “answer” is equally probable
  • Algorithms can be used to interpolate down to hourly resolution (for example)
UK Climate Projections 2009 (UKCP’09)

Emission Scenario
- Low
- Medium
- High

Time Period
- Baseline
  - 2010-2039
  - 2030-2059
  - 2050-2079 etc

Location
- UK map 5km grid squares

Weather Generator

Hundreds of climate files
If you want to model a building...

26,000 data points for a year in just one climate.

Percentile probabilities means at least 100 climates = a very arduous overheating analysis....
A solution? – Model emulation

• Simplify climate data through Principal Component Analysis
  • Reduces the number of input variables
• Find relationship between these PCA climate variables and dynamic building simulation outputs
• Quantify relationship within a regression model
  • Requires calibrating from just one building simulation
  • Then run regression model for as many climates as needed
Simplify climate input

Use of DSM for calibration

Probabilistic overheating regression analysis

UKCP09
Using the tool: STEP 1

- Carry out hourly dynamic simulation (e.g. IES or ESPr) for a single climate file
- From this, the tool will require two files as core inputs
  - **Hourly climate file** used in building simulation
  - **Hourly results file** e.g. internal temperature of zone(s)
- Need new simulation for any adaptation
Using the tool: STEP 2

- The two core input files are placed in model folders
- The user then provides a series of basic inputs about the building
Using the tool: STEP 3

- Run tool for specific building
- Tool incorporates up to 1000 climate files (100 x 10) from UKCP09 weather generator per run for
  - Baseline (i.e. Current climate)
  - 2030s (Low, Medium and High)
  - 2050s (Low, Medium and High)
  - 2080s (Low, Medium and High)
- Hourly results for all scenarios automated as text and graphical output
- Post-processing also possible
Probabilistic failure curve

- Cooler
- Warmer

96% "chance" of being warmer

72%

14%

% change in overheating metric compared to baseline (bins)

Cumulative Frequency

0% 20% 40% 60% 80% 100%

-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90

No adaptation

+ Window opening

+ Shading and reduced gains

Compares one future scenario with baseline

ESL-IC-12-10-50a

No Adaptation

- Current climate
- Med emission, 2030
- Med emission, 2050
- Med emission, 2080

User can define any criterion here

Overheating threshold

% of occupied hours > 28°C
With Adaptation

- Current climate
- Med emission, 2030
- Med emission, 2050
- Med emission, 2080

Probability of occurrence

% of occupied hours > 28°C
Model Validation

**Residual** = Difference between hourly temperatures estimated by Dynamic Building Simulation Software and Regression Model

London (Medium Emission Scenario) 2030s

Over 100 Representative Climates

Hourly data
Practitioner feedback

- In parallel to modelling work, industry feedback was obtained at various stages of the work
  - Interviews
  - Questionnaires
  - Focus Groups

- Used to investigate:
  - Type of overheating analysis currently carried out
  - Is “probability” a useful concept in overheating?
  - Does the LCF tool have an end use?
## Simplifying output

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### % chance of failure

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A summary report format...
Low Carbon Future project—Future climate change assessment of case studies:

**Building Information**
- **Total Floor Area:** 144 m²
- **Construction:** Filled-cavity wall masonry with insulated loft and double-glazing
- **Typology:** Detached
- **Occupants:** 2 adults, 2 children
- **Location:** London
- **Simulation package used:** IES-VE

**Construction details**
- **Floor U-value:** 0.25 W/m²K
- **Wall U-value:** 0.17 W/m²K
- **Roof U-value:** 0.20 W/m²K
- **Window U-value:** 2.1 W/m²K

**Ventilation regime:** Natural with window openings (with average infiltration rate of 0.7 air/h)

**Overheating definition**
1% of occupied hours above 24°C constitutes overheating (whole house average)

Building is calculated to be occupied for 6656 hours per year (16hrs per weekday; 2hrs per weekend day)

**Adaptation Scenarios**
- Window-opening schedule during night-time overheating
- External shading above windows installed and internal heat gains reduced by 25% (relating to more efficient appliances and lighting)

**Occupancy profiles** (1 = Occupants present; 0 = None present)

**Multi-scenario risk analysis**

**Verdict**
Although the dwelling is unlikely to overheat for a current climate, the increased risk of overheating due to future climate change is considerable. However, basic adaptations are shown to offset this potential increase for the near decades, with more extensive adaptations possibly required for longer-term timescales.
Conclusions 1

- We have built a tool that uses UKCP’09 to assess overheating risk with simulation software
  - Statistical processing of complex climate information can produce relatively simple results
  - LCF tool works for any overheating criterion
- Suitable output can inform choices at building level for adaptation measures
  - Design for reduced future overheating risk
  - Useable by practitioners and attractive to their clients
Conclusions 2

- Some concerns were expressed through practitioner feedback relating to time/complexity of method
  - But similar concerns exist for any form of overheating analysis involving more detailed simulation (e.g. DSM)
- Perceived importance of overheating, and therefore need for a tool, varied with respondents
  - Domestic vs Non-domestic
  - North vs South UK
Acknowledgements

• Co-authors: David Jenkins, Sandhya Patidar, Mehreen Gul, Gill Menzies, Gavin Gibson
• Financial support from EPSRC through the Adaptation and Resilience to Climate Change programme
• Numerous professionals who participated in focus groups and discussions
Thank you for listening

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