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

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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

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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

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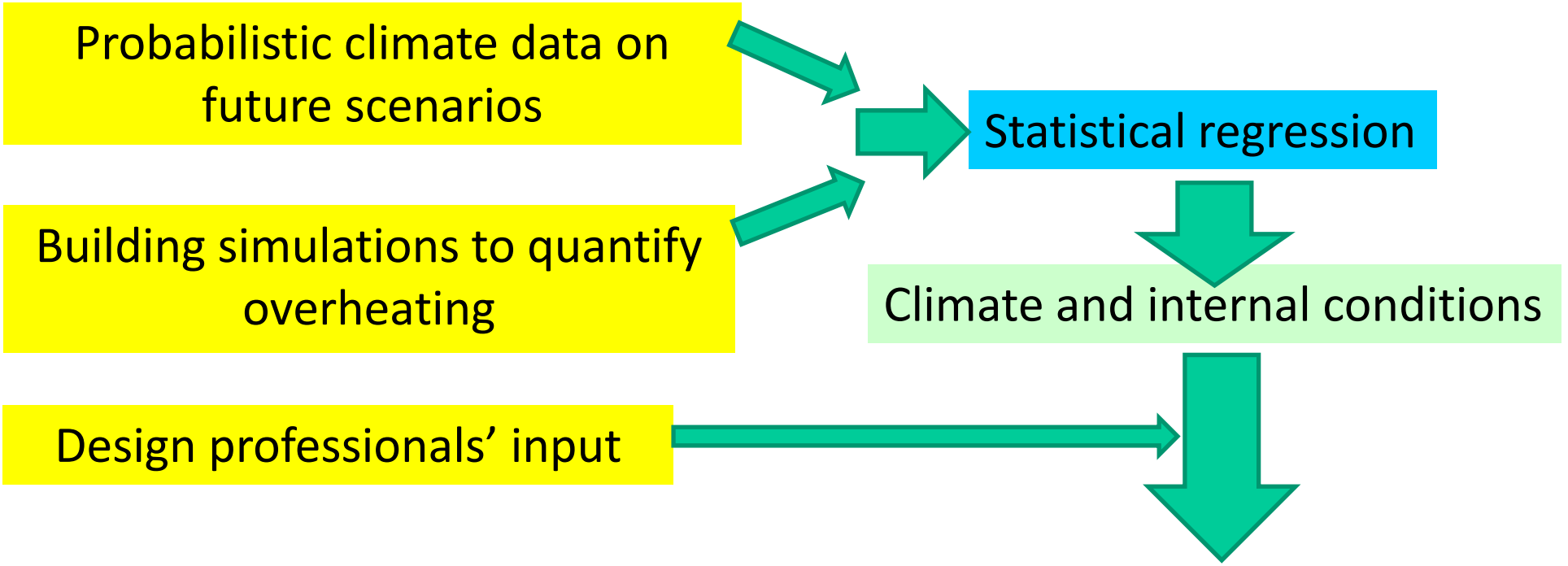
Project overview



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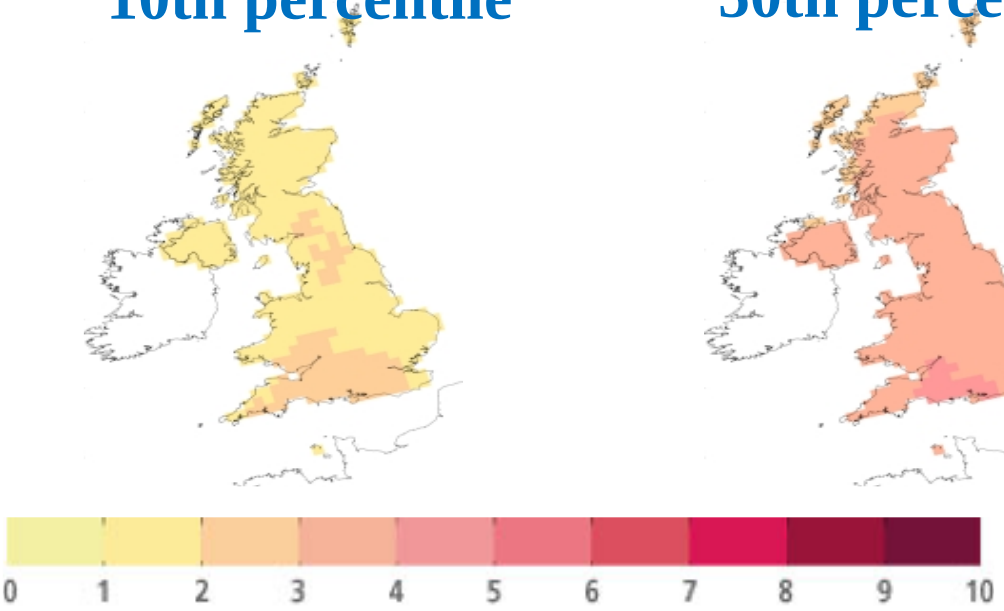
UK Climate Projections 2009 (UKCP'09)

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

10th percentile **50th percentile** **90th percentile**



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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)

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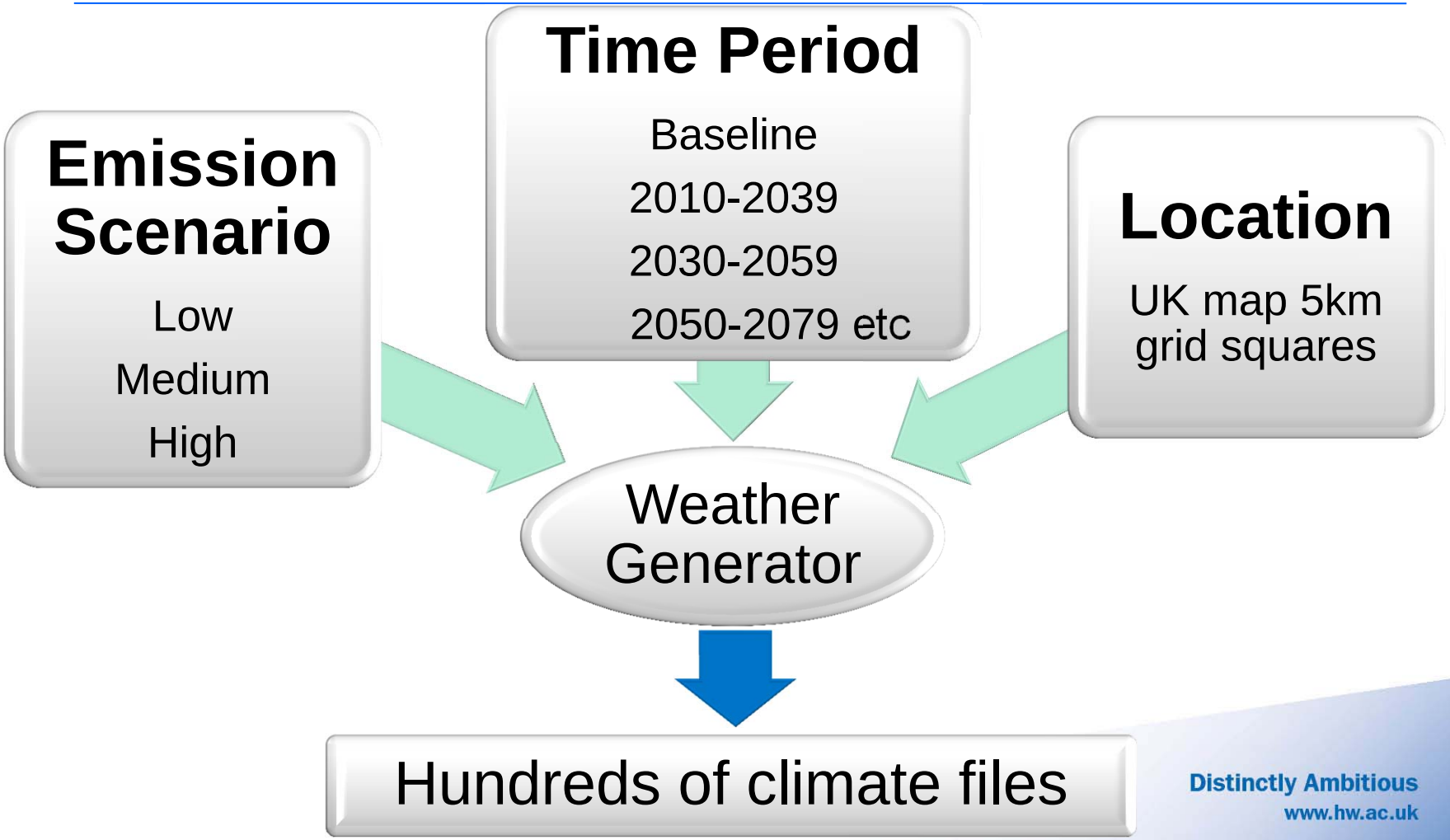
UK Climate Projections 2009 (UKCP'09)



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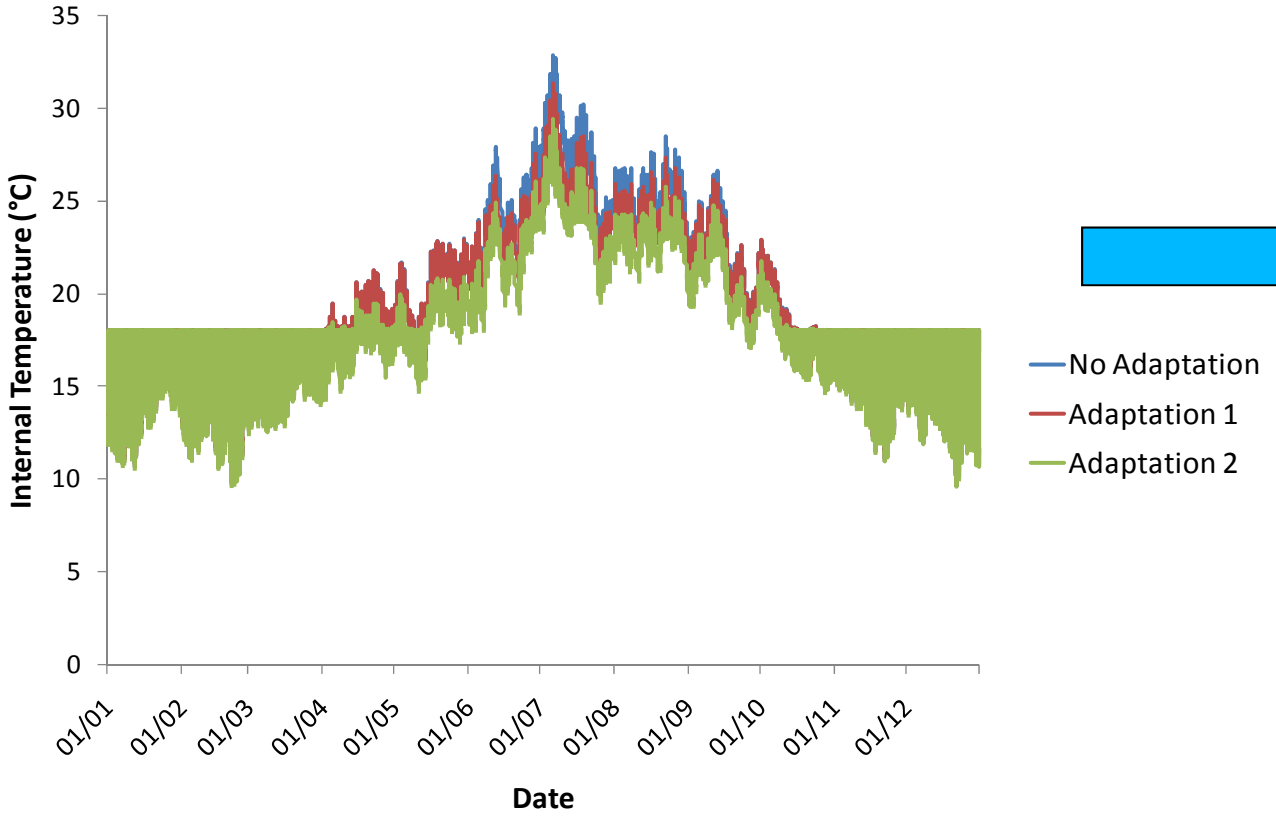
If you want to model a building...



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

Percentile probabilities means at least 100 climates = a very arduous overheating analysis....

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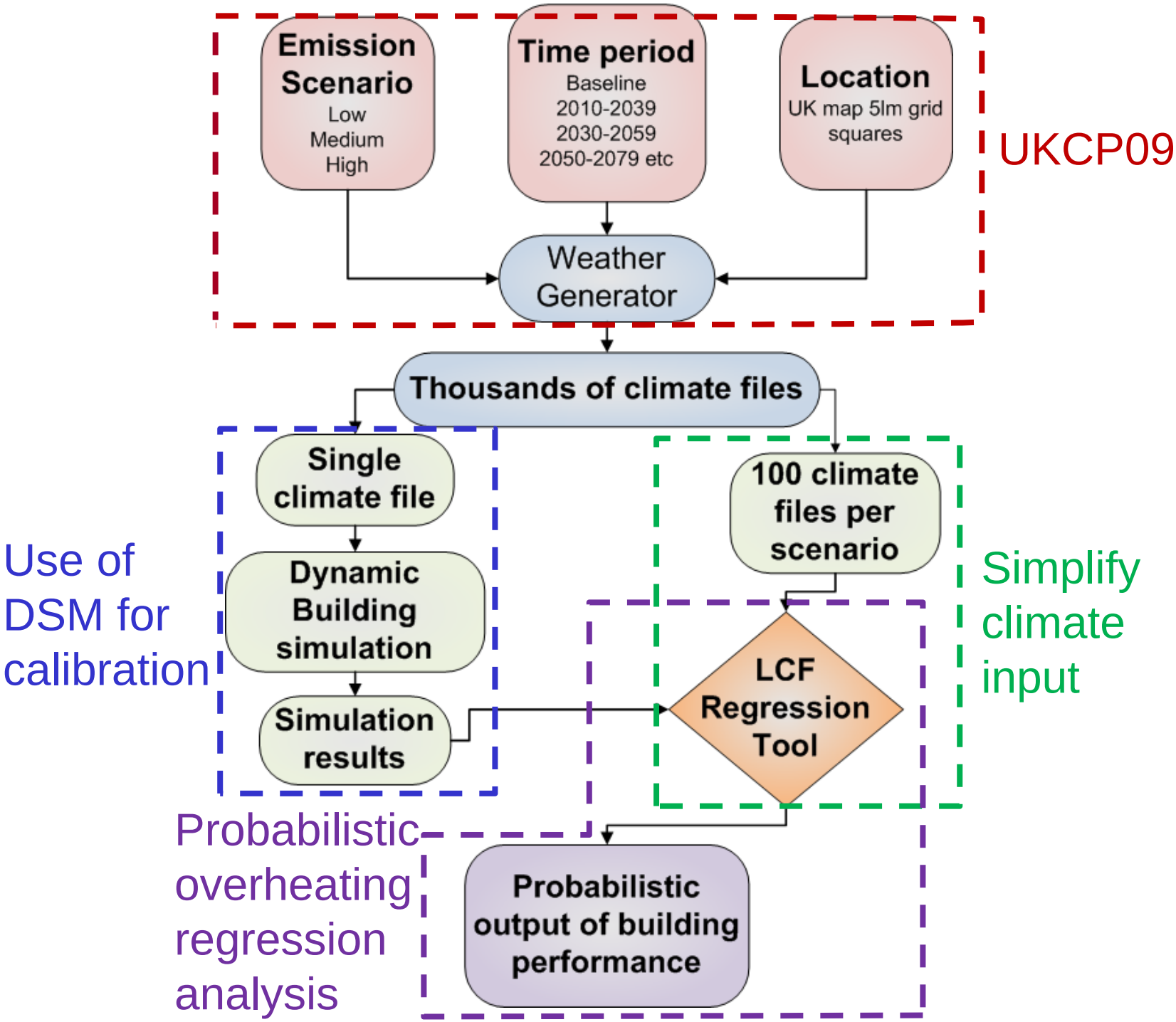
A solution? – Model emulation

- 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


Emission Scenario
Low
Medium
High
Time period
Baseline
2010-2039
2030-2059
2050-2079 etc
Location
UK map 5lm grid squares
UKCP09
Weather Generator
Thousands of climate files
Single climate file
Dynamic Building simulation
Simulation results
100 climate files per scenario
LCF Regression Tool
Probabilistic output of building performance
Use of DSM for calibration
Simplify climate input
Probabilistic overheating regression analysis

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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

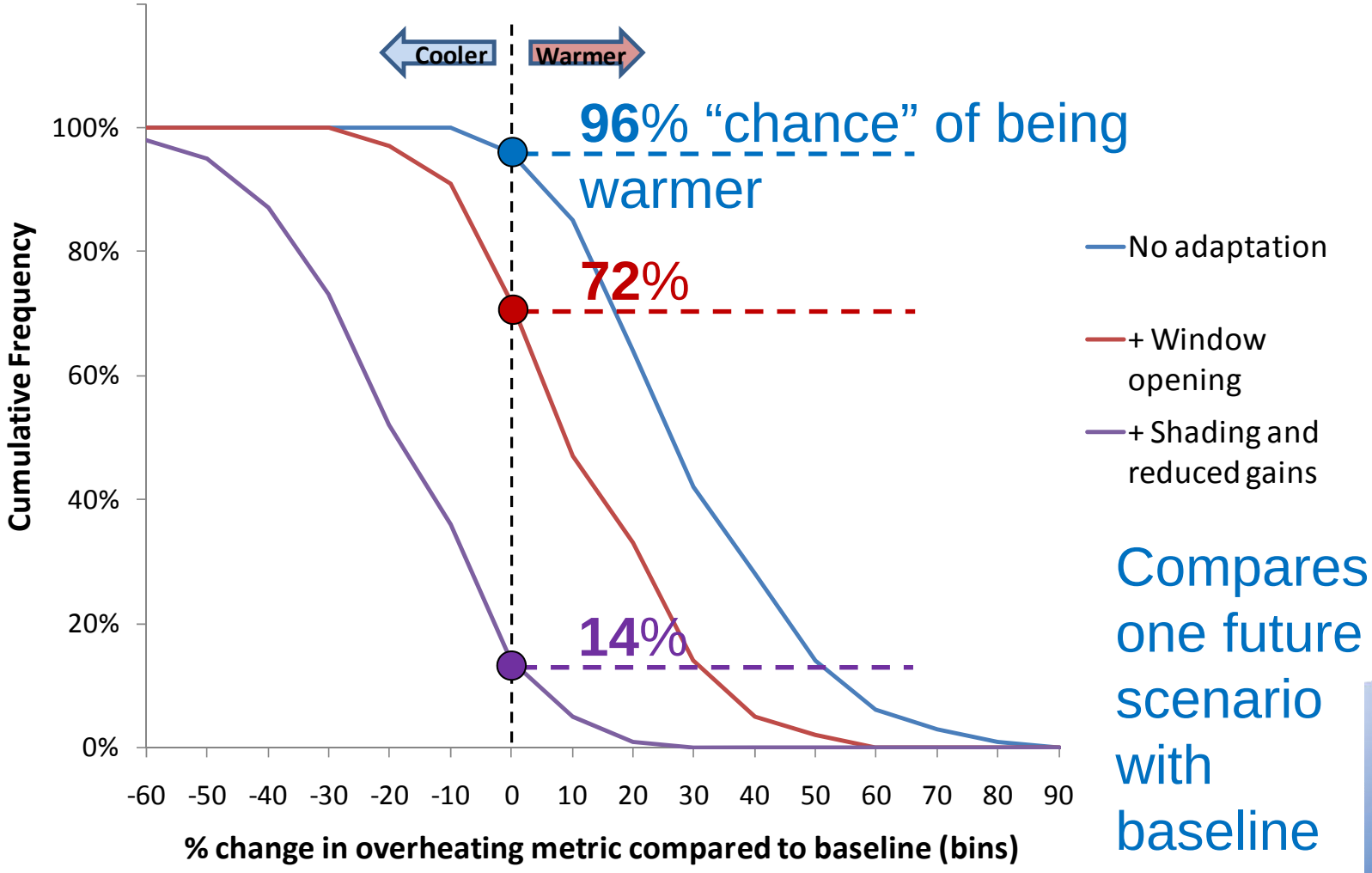
Using the tool: STEP 2

- 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

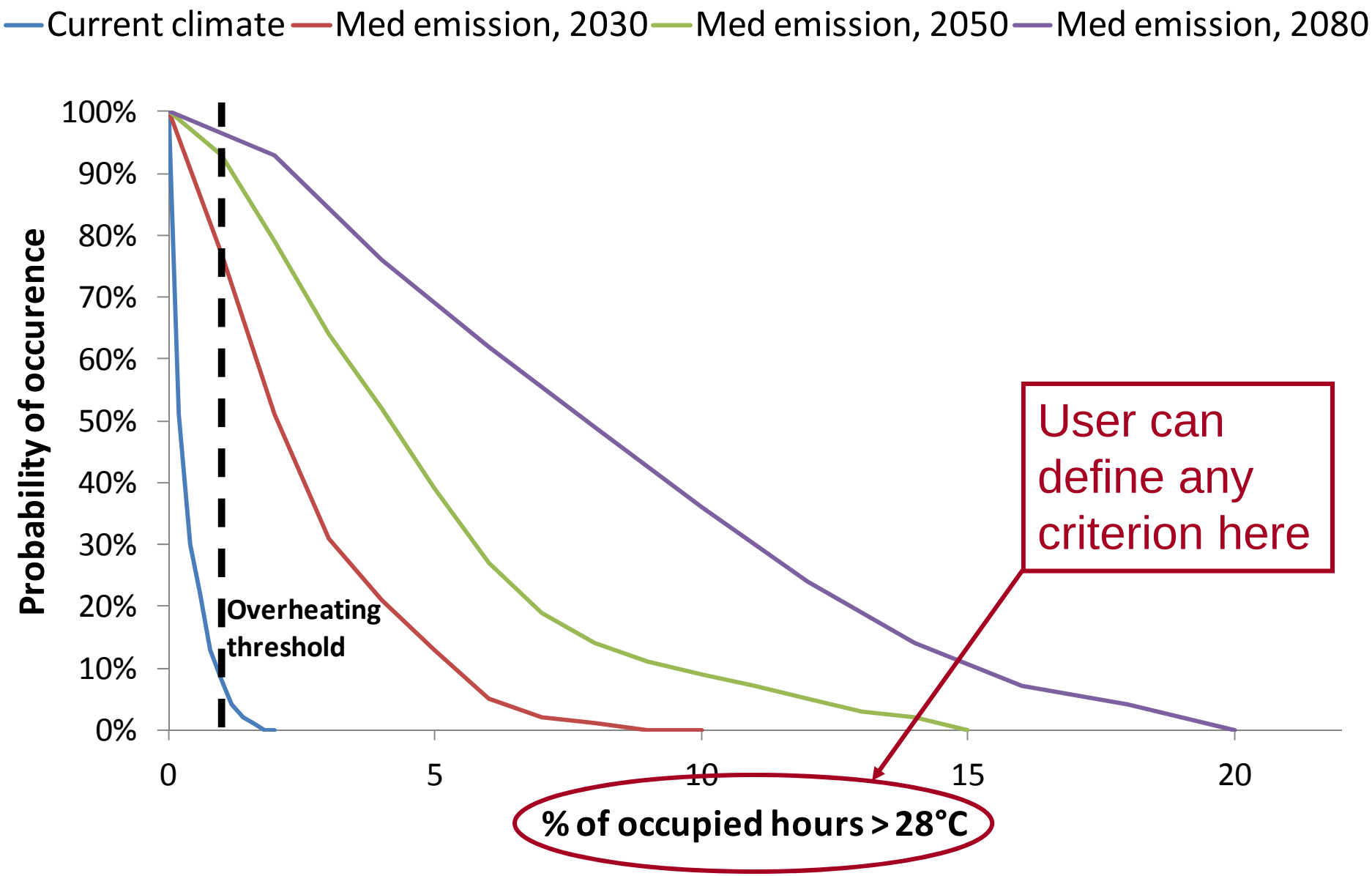
- Run tool for specific building
- Tool incorporates up to 1000 climate files (100 x 10) from UKCP09 weather generator per run for
  - Baseline (i.e. Current climate)
  - 2030s (Low, Medium and High)
  - 2050s (Low, Medium and High)
  - 2080s (Low, Medium and High)
- Hourly results for all scenarios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

Probabilistic failure curve

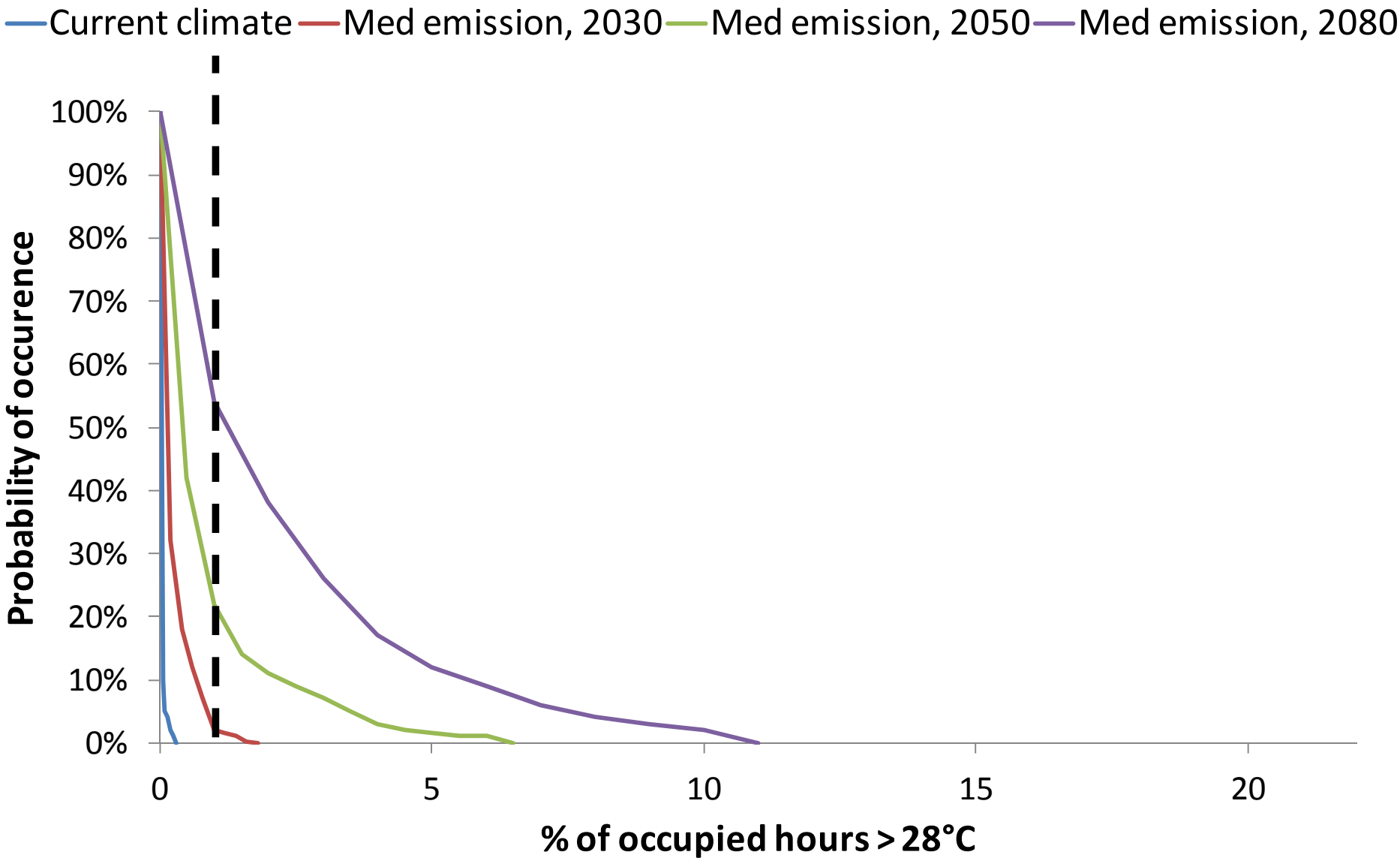


Compares one future scenario with baseline

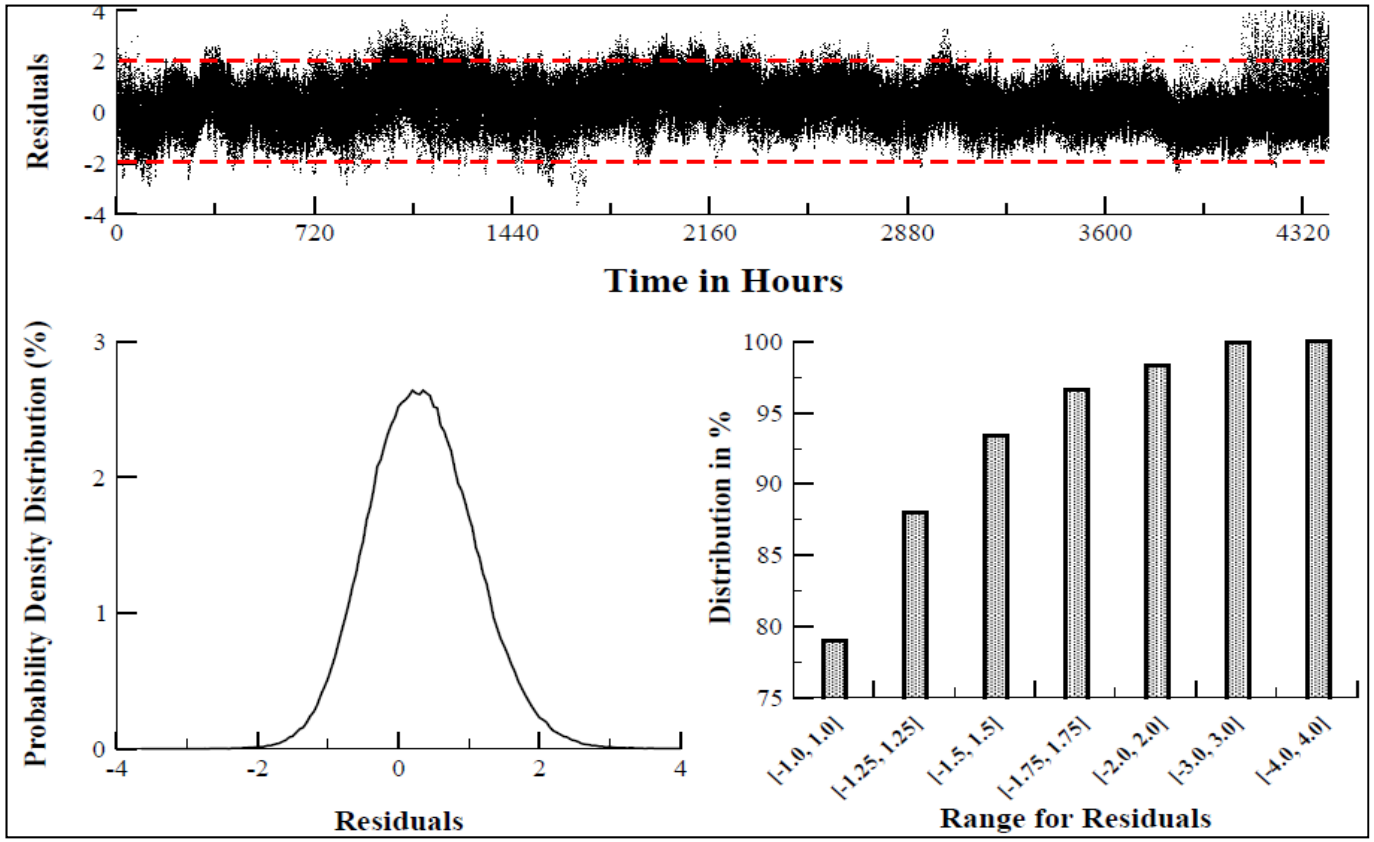
No Adaptation



With Adaptation



Model Validation



London (Medium Emission Scenario) 2030s

Over 100 Representative Climates

Hourly data

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

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?

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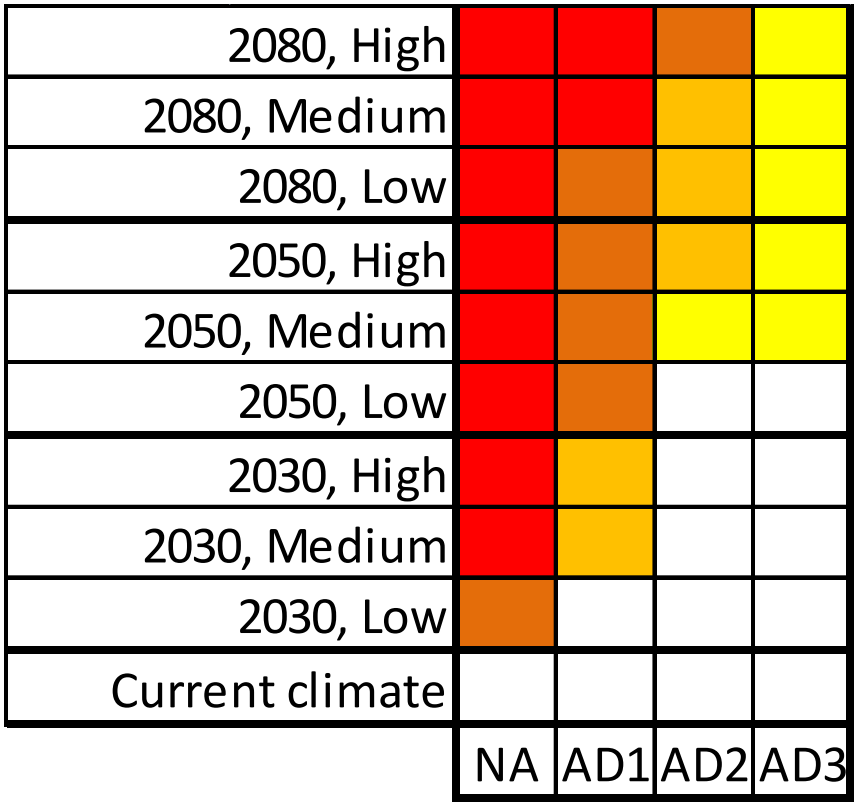
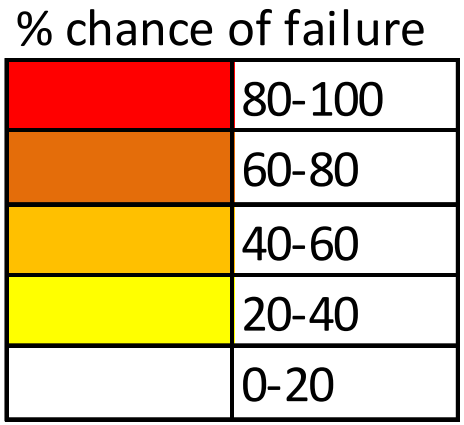
Simplifying output





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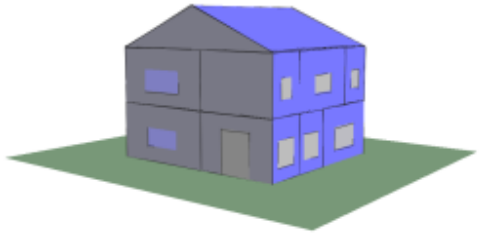
A summary report format…

Low Carbon Future project—Future climate change assessment of case studies:



Building Information

Total Floor Area: 144m^2
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: 0.25W/m^{2}K
Wall U-value: 0.37W/m^{2}K
Roof U-value: 0.20W/m^{2}K
Window U-value: 2.1W/m^{2}K

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

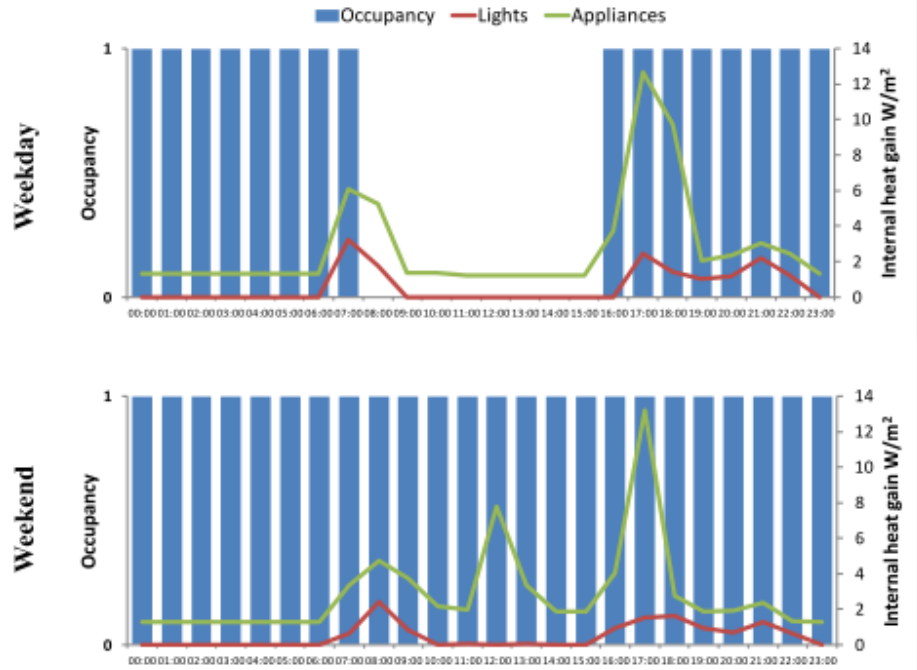
Overheating definition

1% of occupied hours above 28°C constitutes overheating (whole house average)
Building is calculated to be occupied for 6656 hours per year (16hrs per weekday; 24hrs per weekend day)

Adaptation Scenarios

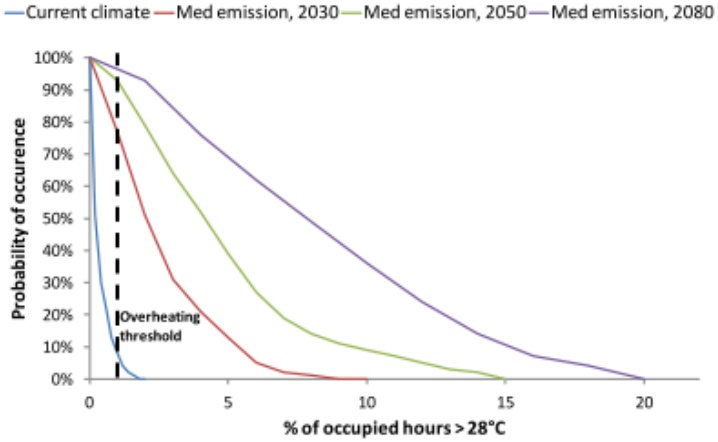
Window-opening schedule during night-time overheating. External shading above windows installed and internal heat gains reduced by 25% (relating to more efficient appliances and lighting)

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

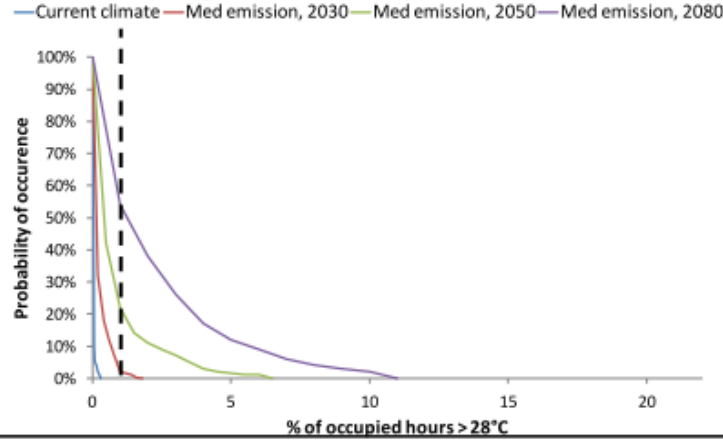


LCF Probabilistic overheating results

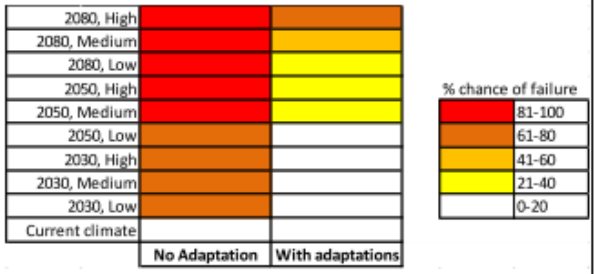
Building without adaptation



Building with selected adaptations



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 adaptation 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

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Acknowledgements

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- Numerous professionals who participated in focus groups and discussions

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Thank you for listening

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