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Assessing future overheating risk in buildings – the Low Carbon Futures tool

Mainstreaming Innovation Webinar, 29th Nov 2013

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School of the Built Environment ~100 academics

- Institute for Infrastructure & Environment
- Institute for Building & Urban Design
- Institute for Housing Urban and Real Estate Research

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Royal Academy of Engineering Centre of Excellence in Sustainable Building Design

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Urban Energy Research Group (~20 people)

Urban Energy Research Group - themes

- Building performance simulation/modelling
- Low and zero-carbon buildings
- Historic and traditional buildings
- Fuel poverty
- Life-cycle assessment
- Energy consumption monitoring / modelling
- Adaptation to future climates

UERG

Projects on dwellings, offices, schools, factories, wind farms, energy networks.

Total funding of £4m since 2004, 150 research publications

Research methods

- Building performance modelling and simulation
- Energy monitoring and analysis
- Life Cycle Assessment
- Integration of systems into buildings
- Economic methods – e.g. whole life costing
- Qualitative methods – interviews, surveys, questionnaires, focus groups, Delphi methods

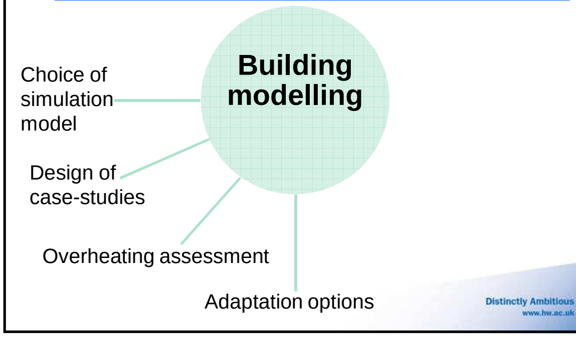
Low Carbon Futures (LCF) project

- **LCF** was a £0.7M research project funded by EPSRC through the Adaptation and Resilience in a Changing Climate (**ARCC**) Programme
  - 18 ARCC projects in total across the UK
- Projects facilitated by ARCC Coordination Network; see http://www.ukcip-arcc.org.uk/ for details

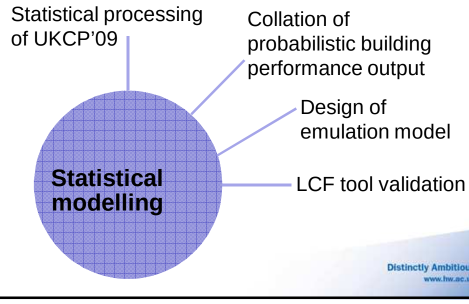
Low Carbon Futures (LCF) project

- The project attempted to answer:
  - How can dynamic building simulation use a probabilistic climate database?
  - How can this be used for designing adaptations to prevent buildings “failing” in a future climate?
  - How can all the above be incorporated into a method that is useful for industry for overheating (and cooling load) analyses?

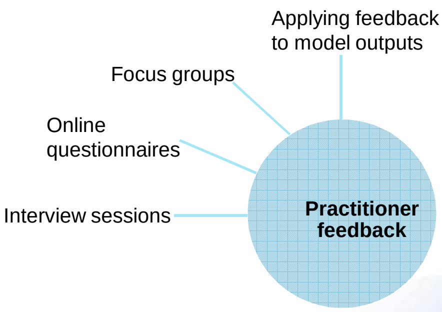
Low Carbon Futures (LCF) project



Low Carbon Futures (LCF) project



Low Carbon Futures (LCF) project



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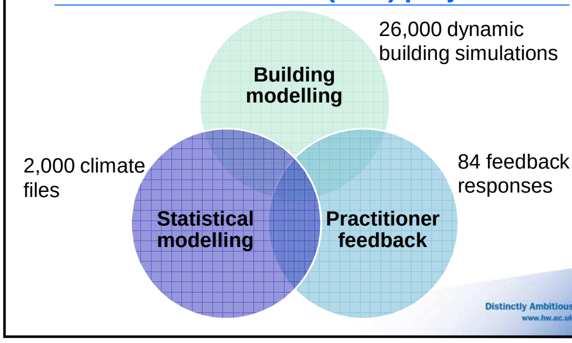

Mitigation and Adaptation

- **Mitigation** – Changes to a system to reduce carbon emissions associated with that system, thus reducing future climate change
- **Adaptation** – Change to a system to make it more suitable for a future climate (which has high probability of being warmer)
- Some measures can do both

Climate change causing building failure

- Poor thermal comfort during warmer summers
- Inadequate drainage during intense rainfall events
- Flooding/rising water table
- Transport and infrastructure (indirectly)

Adapting buildings for thermal comfort

- Overheating in buildings can be caused by:
  - Internally generated heat from people, lighting and equipment that we have some control over
  - External factors (i.e. climate) that we have no control over
- To combat these changing external factors, we need to make changes to the building
  - External shading
  - Change glazing
  - Improve ventilation etc

"Adaptations"

Distinctly Ambitious
www.hw.ac.uk

What is overheating?

- Different buildings have different definitions of overheating
  - High temperatures in a dwelling at night may cause discomfort
  - An office regularly 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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Mechanically-cooled buildings

- What is an appropriate measure of "failure" for buildings with mechanical cooling?
- For a future climate, failure could be:
  - Cooling plant becomes undersized (unlikely) during the summer
  - Operation of plant (e.g. part-loading of multiple units) is no longer optimum
  - Cooling energy consumption/CO_2 emissions are higher than originally designed

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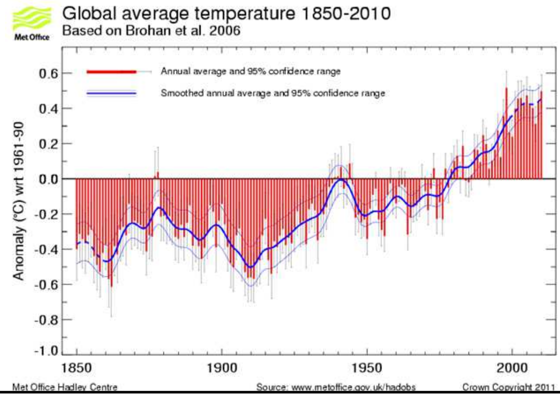
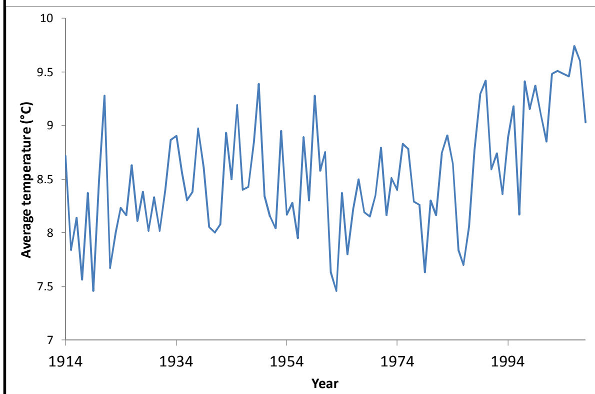
But what does climate look like?



Historical Met Office data for UK



Projecting the future

- **Deterministic** – Provide a single value climate projection with no associated probability of likelihood (UK Climate Impact Programme 2002 **UKCIP'02**)
- **Probabilistic** – Provide a range of projections with associated probabilities assigned to points in the range (UK Climate Projections 2009 **UKCP'09**)

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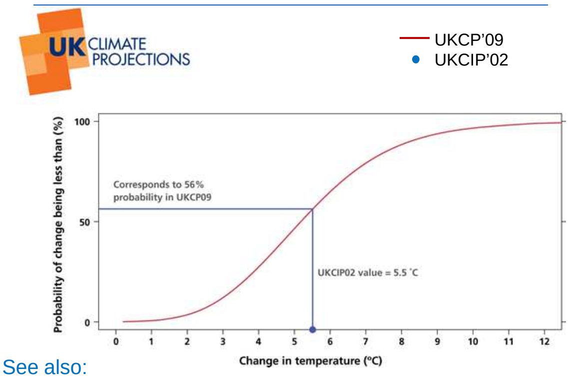
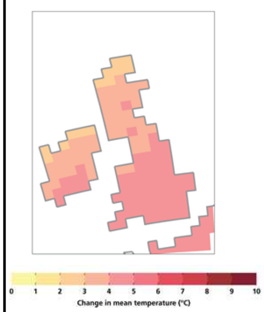
UKCIP'02 vs UKCP'09

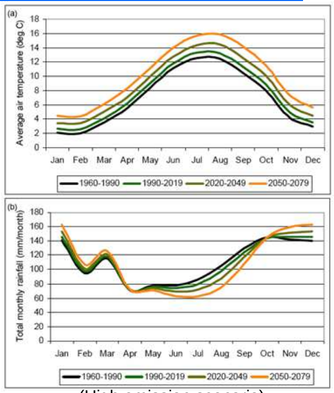


See also:
http://ukclimateprojections.defra.gov.uk/content/view/1984/500/

Examples of UKCIP'02 projections



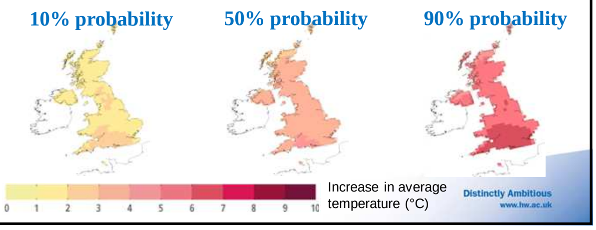
(summer)



(High emission scenario)

UK Climate Projections 2009 (UKCP'09)

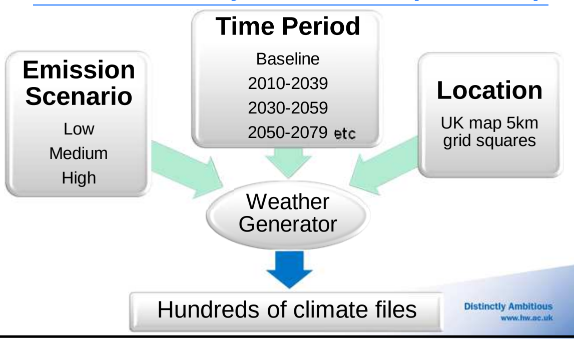
- Latest form of climate projection in UK
- Suggests the *probability* of different future climates occurring



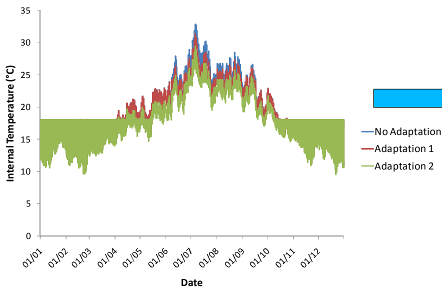
UK Climate Projections 2009 (UKCP'09)

- Obtaining data is more complex
  - Use a "Weather Generator"
- Projections are given for different percentiles of probabilities
  - Or user can obtain all possible iterations of a given scenario
  - Algorithms can be used to interpolate down to, e.g., hourly resolution

UK Climate Projections 2009 (UKCP'09)



Internal temperature outputs



26,000 data points for just one climate

x 100 climates = Too much information....

A solution? – Model emulation

- Choose 100 climates to describe a scenario
- Simplify climate data through Principal Component Analysis
  - Reduce the number of input variables
- Find relationship between these PCA climate variables and building simulation outputs
- Quantify relationship within a regression model

Making shortcuts....

- This would reduce the amount of building modelling dramatically
  - And therefore be suitable for probabilistic climate descriptions
- Presentation of output
  - Even with a regression tool, hundreds of output files would be produced, requiring collation in a way that is attractive and useful to the client
- Ideally this would integrate with existing design methods

Using the LCF tool: STEP 1

- Carry out hourly dynamic simulation (e.g. IES-VE or ESPr) for a single climate file
- From this, the tool will require two files as core inputs
  - Hourly climate file that was used in above simulation
  - Hourly results file (e.g. internal temperature of zone(s); cooling loads; heating loads)
- Need new simulation for any adaptation

Using the LCF tool: STEP 2

- The user then provides a series of inputs about the building, namely:
  - Times of occupancy (via input text file)
  - Definition of "failure" (e.g. 1% above 28degC)
  - Floor areas of zones (if more than one is being used)
  - Required assessment (overheating or load analysis)
  - Required future climate scenarios
  - Internal gain and ventilation profile (optional)

Using the LCF tool: STEP 3

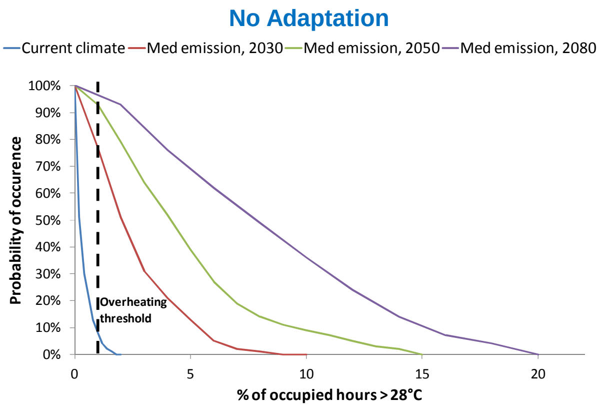
- Run tool (for each version of building)
- Tool incorporates up to 1000 climate files (100 x 10) from UKCP09 weather generator per run for
  - Baseline (i.e. Current climate)
  - 2030s (Low, Medium and High)
  - 2050s (Low, Medium and High)
  - 2080s (Low, Medium and High)
- Hourly results for all scenarios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

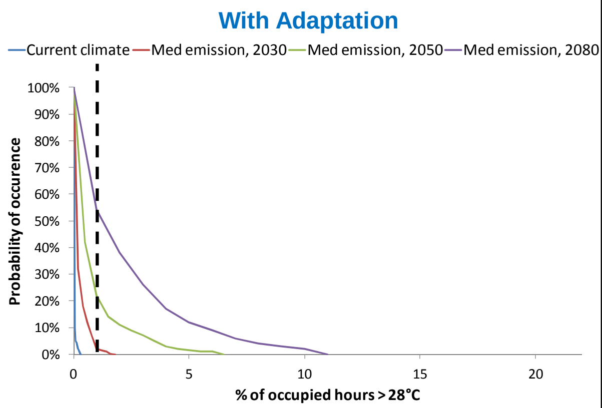
Notes on tool

- Originally set up for overheating analysis of naturally ventilated buildings
  - i.e. Hourly temperature outputs
- But works equally successfully for cooling and heating load analysis
  - Raises possibility of a probabilistic energy analysis of the building (work in progress...)

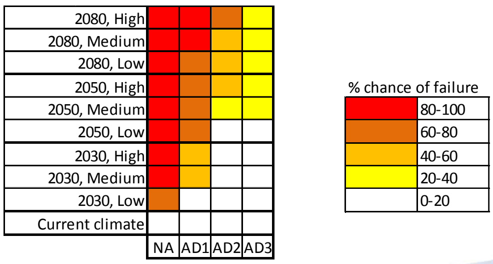
Disseminating work to industry

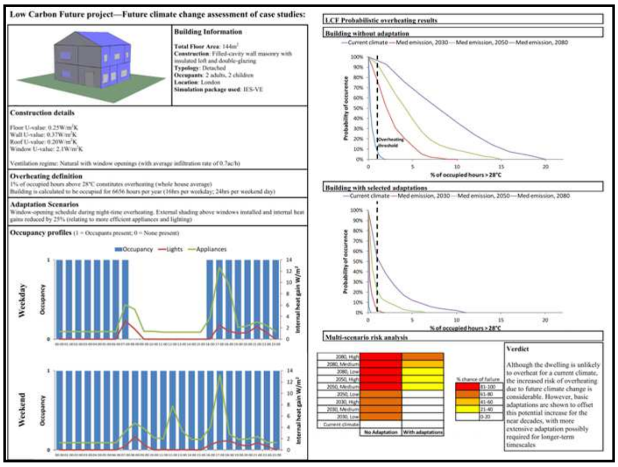
- What type of output might building designers use from the LCF tool?
- Focus group session carried out to gauge industry opinion
  - Graphical/Visual outputs provided for discussion and feedback provided on suitability
  - What is clear for clients and what is useful for designers?





Simplifying output



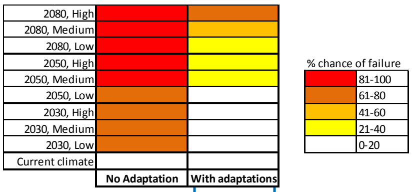


Analysed buildings

- Detached cavity-filled house
  - + Window openings
  - + External shading
  - + Reduced internal gains
- Naturally ventilated school
  - + 3 adaptation scenarios as above
- Mechanically cooled office
  - + External shading
  - + Reduced internal gains
- Low-energy house (CALEBRE project)
  - + Multiple refurb scenarios (incl. MVHR)

Detached house

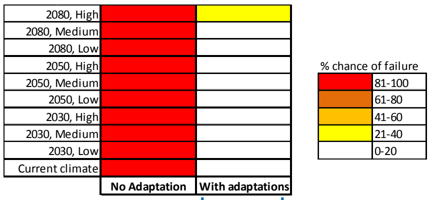
"Failure" = 1% of occupied hours > 28°C



Window opening at night
External shading
Reduced appliance/lighting

Primary School

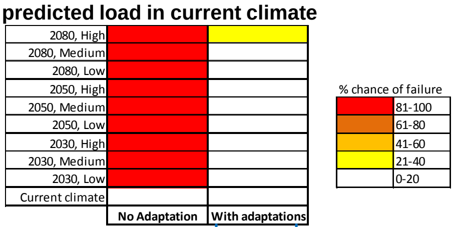
"Failure" = 120hrs of occupied period > 28°C
(Building Bulletin 101)



Increased natural ventilation strategy
External shading
Reduced appliance/lighting use

Mechanically cooled office

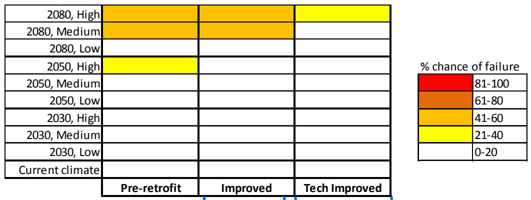
"Failure" = Greater cooling load than maximum predicted load in current climate



External shading
Reduced appliance/lighting by 60%

"CALEBRE" low-energy retrofit

"Failure" = 1% of occupied hours > 28°C



Low-carbon refurb
Insulation
Draughtproofing

Further draughtproofing
MVHR

Conclusions

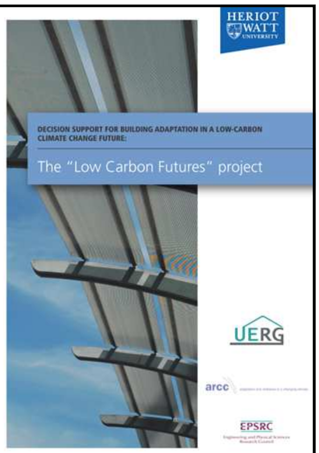
- Adaptations should be building-specific
  - And software should be sensitive to this fact
- The concept of adaptation should be applied to all low-carbon refurbishments
- Buildings overheat for a variety of reasons
  - But future climate might exacerbate this even if climate is not the prime driver for this problem
- But we must make sure the buildings are already working in a current climate!

Conclusions

- UKCP'09 can be used with appropriate building software
  - Statistical processing of complex climate information can produce relatively simple results
  - Translate the term "probability" to "risk"
- Suitable output can inform choices at building level for adaptation measures
  - Design for reduced future overheating risk
  - Useable within a building project timescale

- More detail available in our final project report

- This report and more info can be found at our **Low Carbon Futures** project website: http://www.sbe.hw.ac.uk/research/ibud/low-carbon-futures.htm



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