مجلـــس قطـــر
للمبانـــي الخضـــراء
QATAR GREEN BUILDING COUNCIL

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Urban Greening and the UHI:
Seasonal Trade-offs in Heating and Cooling Energy Consumption in Manchester, UK

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THE RESEARCHERS

Cynthia Skelhorn

PhD Physical Geography
Post-Doctoral Research Specialist
Qatar Green Building Council

- PhD thesis addressed greenspace impacts on building energy consumption.
- ENVI-met as a primary model for analysis of microclimate impacts, coupled with IES-VE for building energy modelling
- Current research – Qatar Passivhaus, FM for High Performance Buildings, and Urban Ecology Working Group

Sarah Lindley

Reader
Geography
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Geoff Levermore

Emeritus Professor
Building Physics & Engineering
University of Manchester

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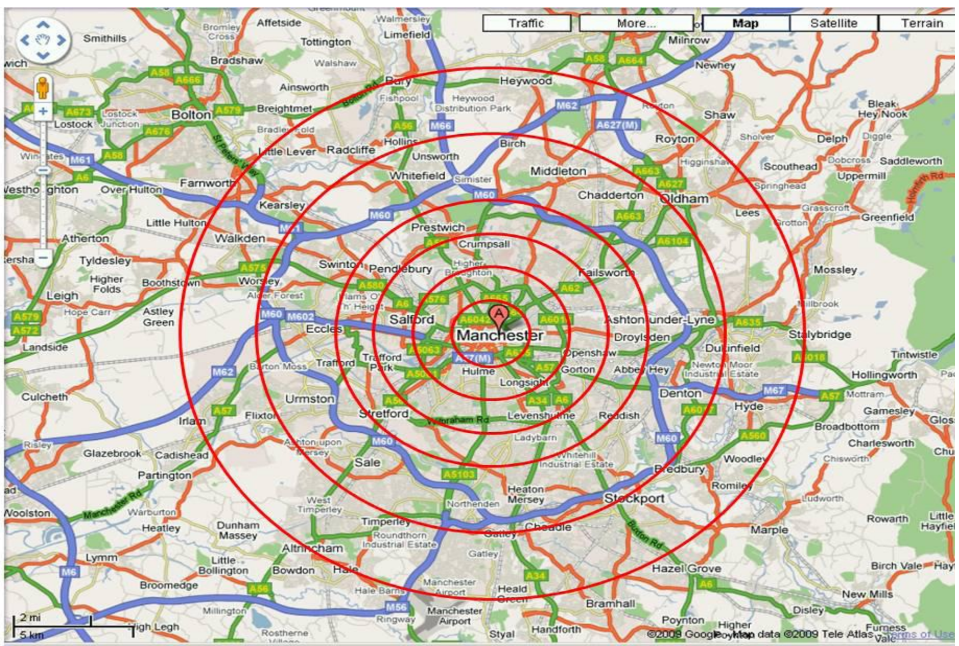
Context of Research

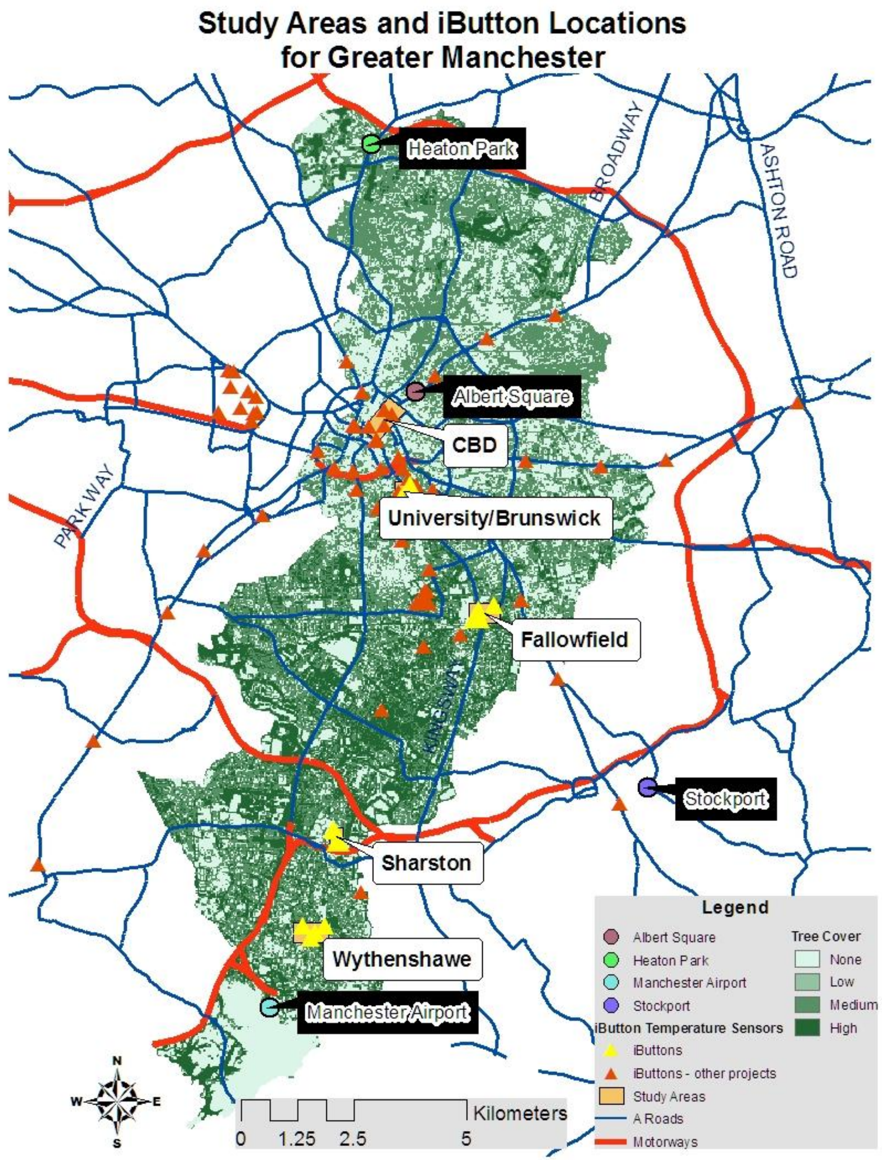
- **Building energy requirements** (heating and cooling loads) that will change due to increasing temperatures (climate change and UHI)
- Potential for **urban vegetation** to reduce cooling loads
- Debate in the UK about trade-offs between reduced heating loads in winter and increased cooling loads in summer due to UHI - which is most detrimental or beneficial?

Methods

iButtons - from a UHI study completed in 2011 by Henry Cheung and from 5 study areas for thesis

Served as later model validation and analysis of air temperature changes due to greenspace changes





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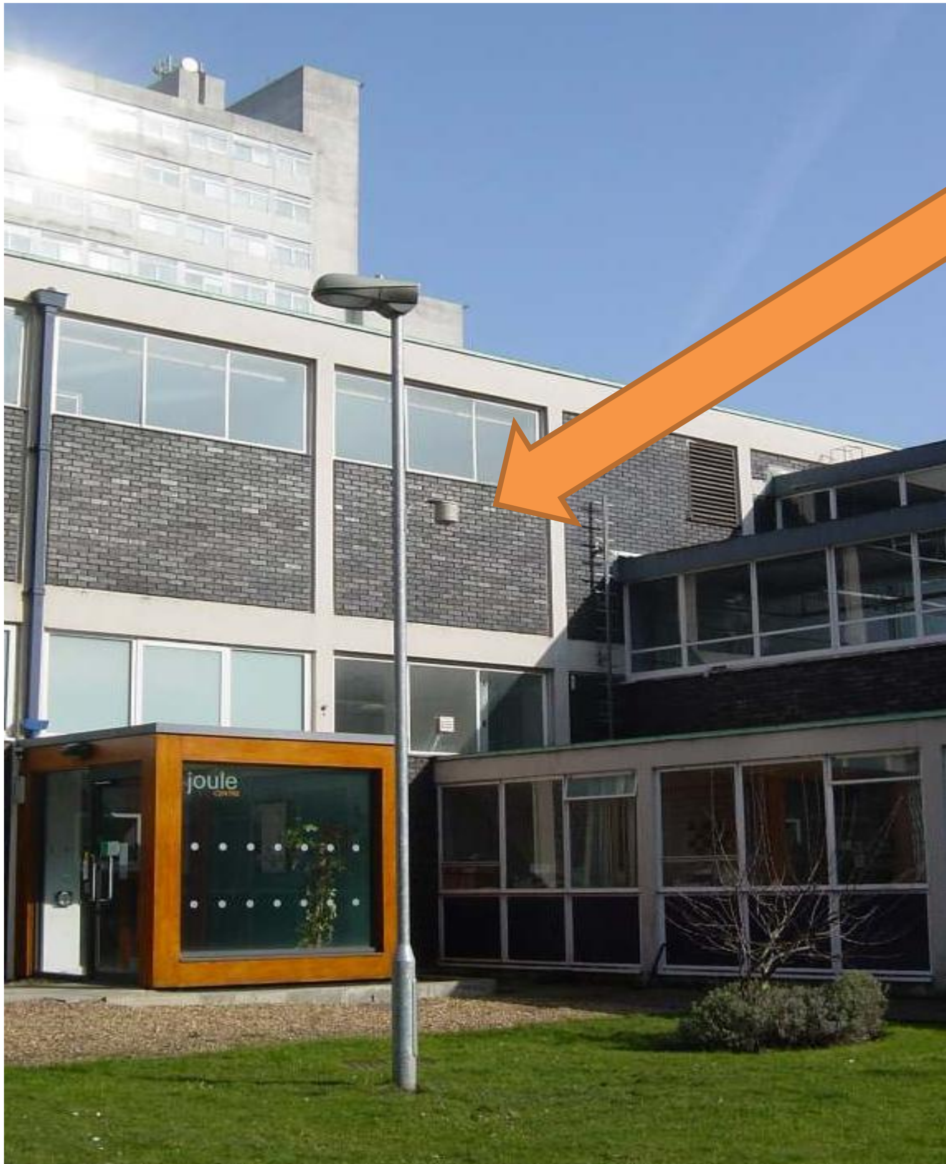
Air Temperature Measurements
iButtons on Lighting Columns



Maxim
DSM

Methods

Analysis of iButton data for correlations between air temperature and greenspace

Microclimate modelling in ENVI-met (with +5% mature trees) to determine changes for:

- Air temperature changes
- RH changes
- Wind speed changes

Building Energy Modelling in IES-VE

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Urban Morphology
Manchester - City Centre

- 668m x 544m, about 3% greenspace
- Office and Retail, av building height 20 m (max 118 m)
- Av SVF for study area (buildings only) 0.66

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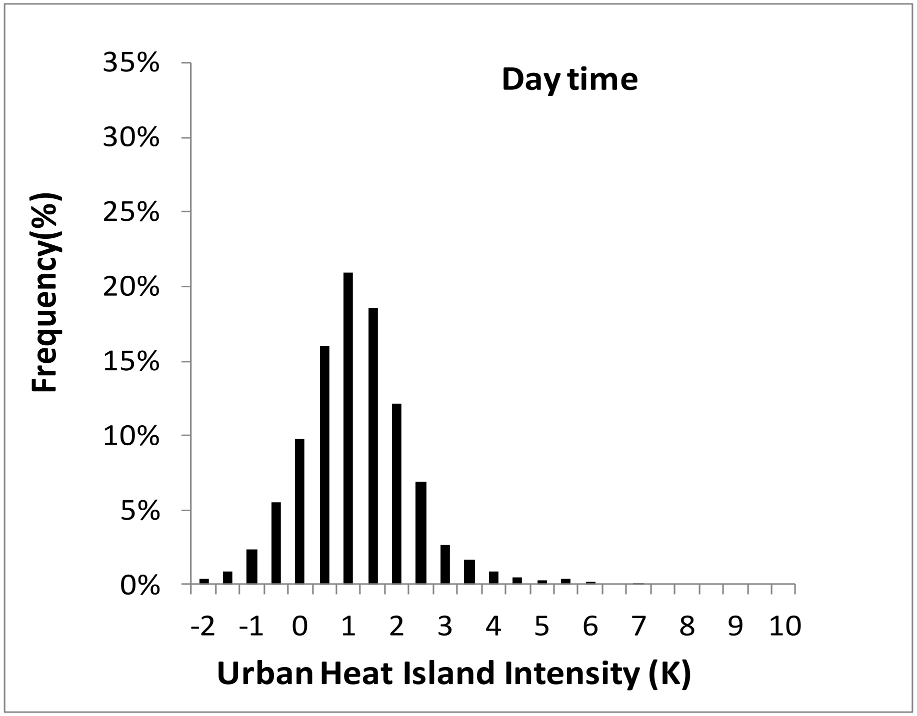
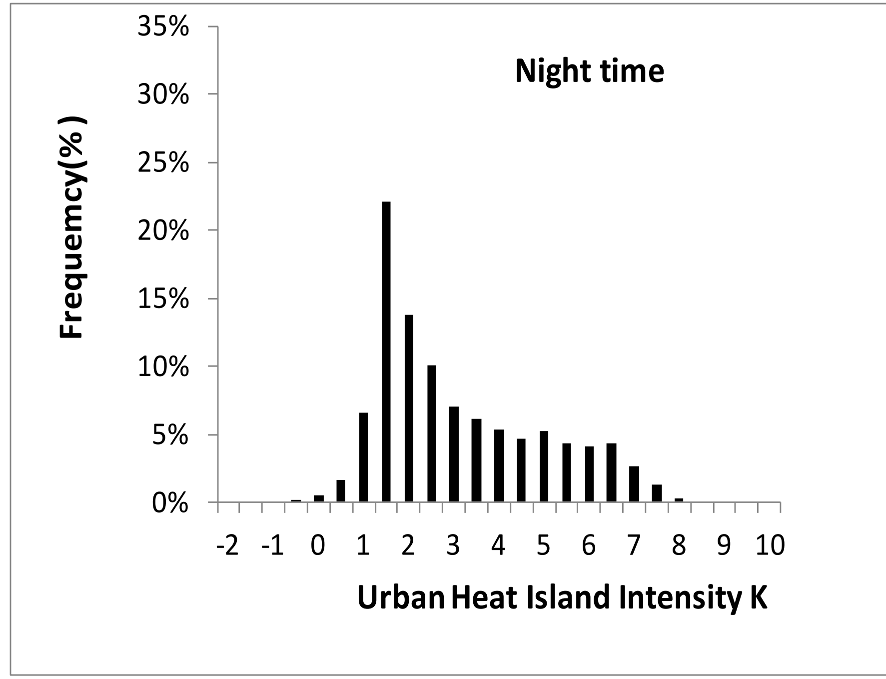
Summer UHII for Manchester city centre

May to August inclusive





Average = 0.91K
Mode = 1.0K
Median = 0.87K

Average = 2.86K
Mode = 1.5K
Median = 2.22K

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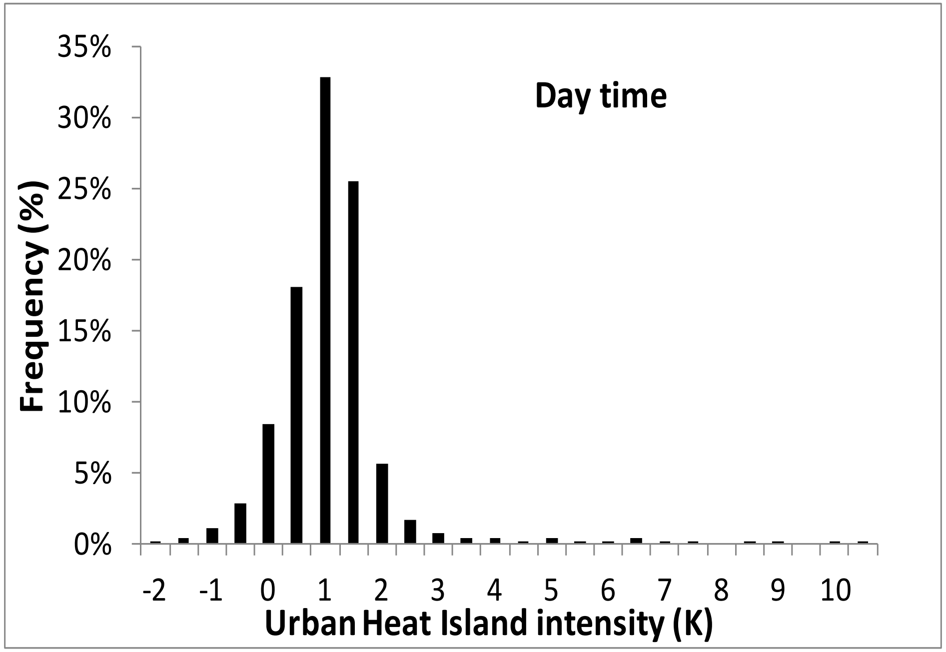
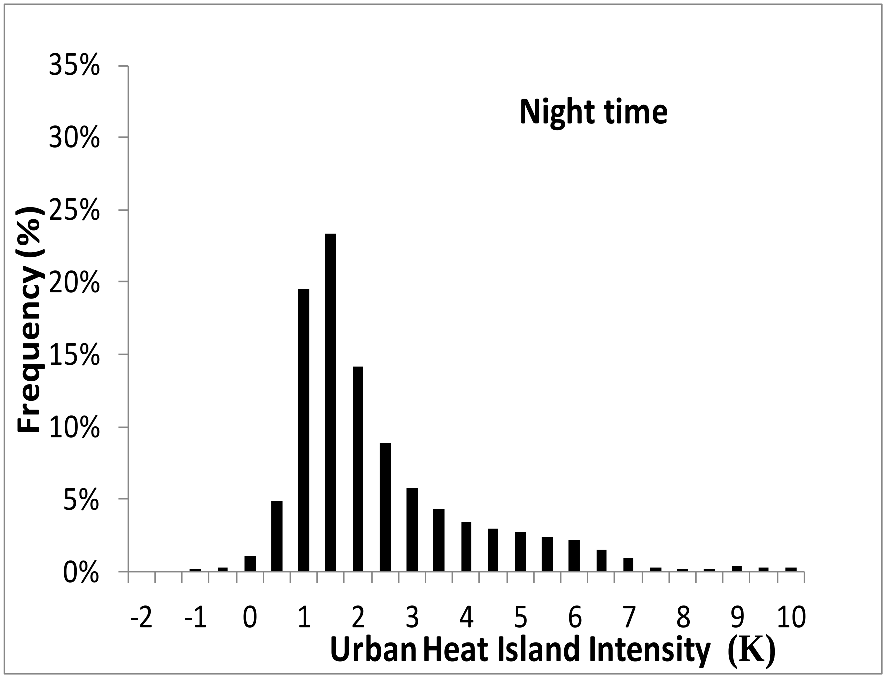
Winter UHII for Manchester city centre

January to April inclusive





Average = 0.86K
Mode = 1K
Median = 0.79K

Average = 2.13K
Mode = 1.50K
Median = 1.53K

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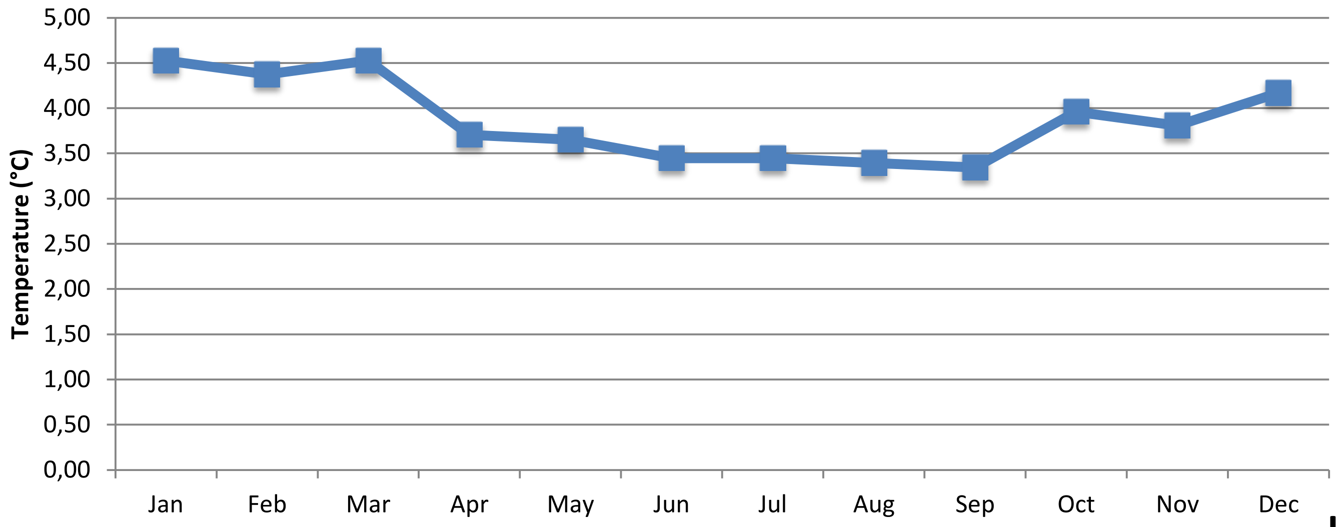
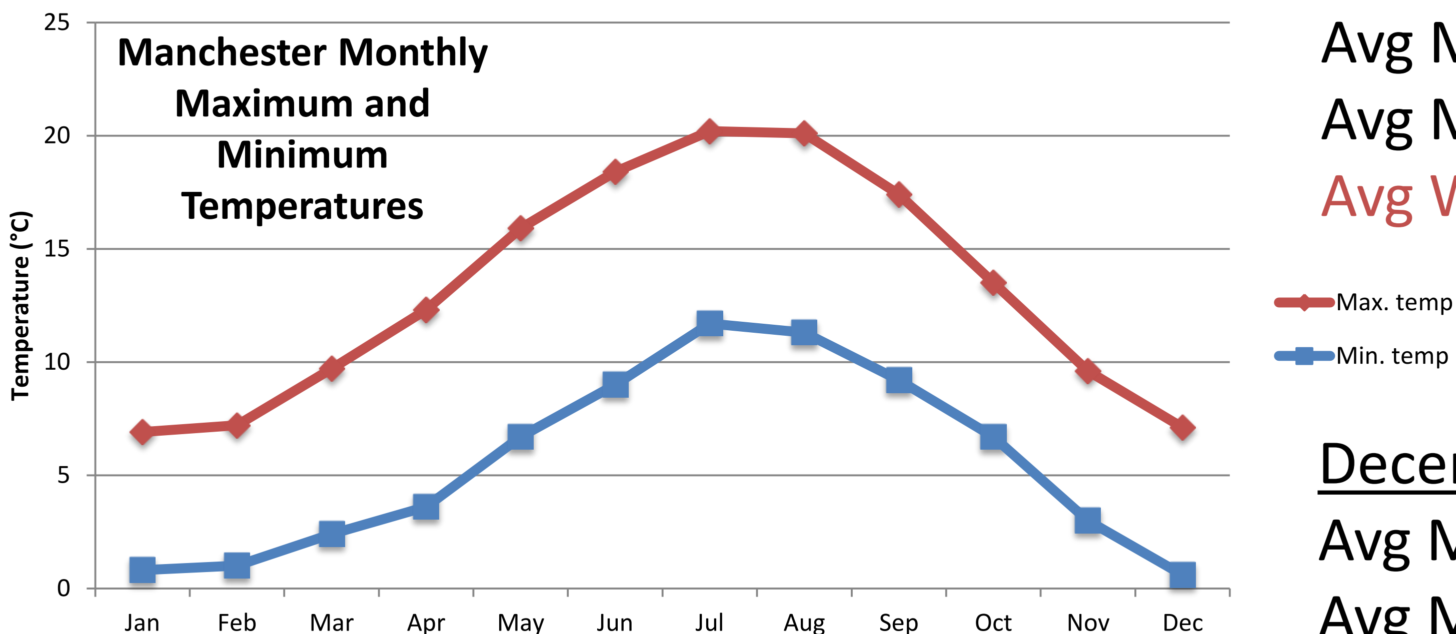


Manchester Monthly Wind Speed
Woodford, rural reference, 1981-2010 average



July:

Avg Max: 20.2 °C

Avg Min:11.7 °C

Avg Wind: 3.5 m/s

December:

Avg Max: 7.1 °C

Avg Min: 0.6 °C

Avg Wind: 4.2 m/s

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Building Energy Implications for Manchester

While the UHI is highest at night, for Manchester's temperate maritime climate and building energy, we need to consider:

- Daytime may be more important, as daytime maximums are those that most influence cooling energy requirements
- Even with a UHI of 1-2 °C in daytime, and with predicted climate change, it may only experience maximums of 23-25 °C. But if recent heat waves become more frequent, then adaptation measures become more important.
- Most frequently consider residential because of most people being in residential at night, need to consider commercial (institutional, retail, etc.) buildings as these are where people are likely to experience the highest temperatures, which will occur during the day.

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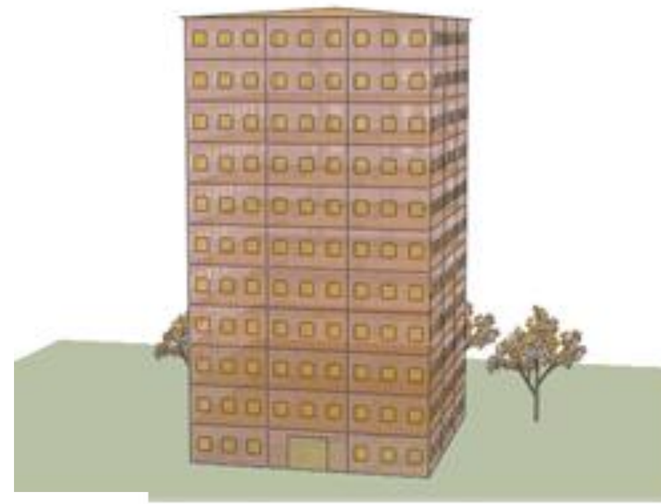
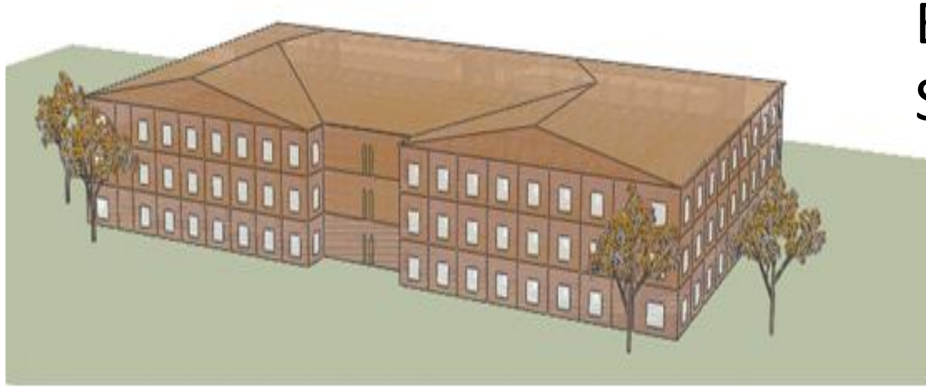
Building Models

Building A - Three-Storey Shallow Plan



Building B - Ten-Storey Shallow Plan



Building C - Three-Storey Deep Plan

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Building Settings

- Building constructions - 2002 Building Regulations for England and Wales (HM Government 2002), 20% glazing.
- Key thermal template settings were:

Setting	Value
Office occupancy	08:00-18:00
Cooling set point	23.0 °C
Heating set point	19.0 °C
Relative Humidity set point	70 % Max
Infiltration Air Change Rate	0.25 ACH
Internal Gains	Fluorescent lighting, 12 W/m^2; Occupancy 14 m^2/person; Equipment, 12 W/m^2

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UHI Building Energy Scenarios for Manchester

3 buildings in Manchester using “rural”Test Reference Year (TRY) for July.

- **Base** – Building in rural conditions, without shading
- **Shade – North** 4 trees added, 2 on the North, 1 on Northwest, 1 on Northeast. Shading about 20% of the building wall area
- **Shade - South** - 4 trees added, 2 on the South, 1 on Southwest, 1 on Southeast;
- **Urb_UHI** urban city weather adjusted TRY to show the effect of the UHI
- **Urb_UHI_green** tested the effect of greening the area around a building with shading
- **Urb_UHI_green_wind** assessed the reductions in wind speed due to the trees

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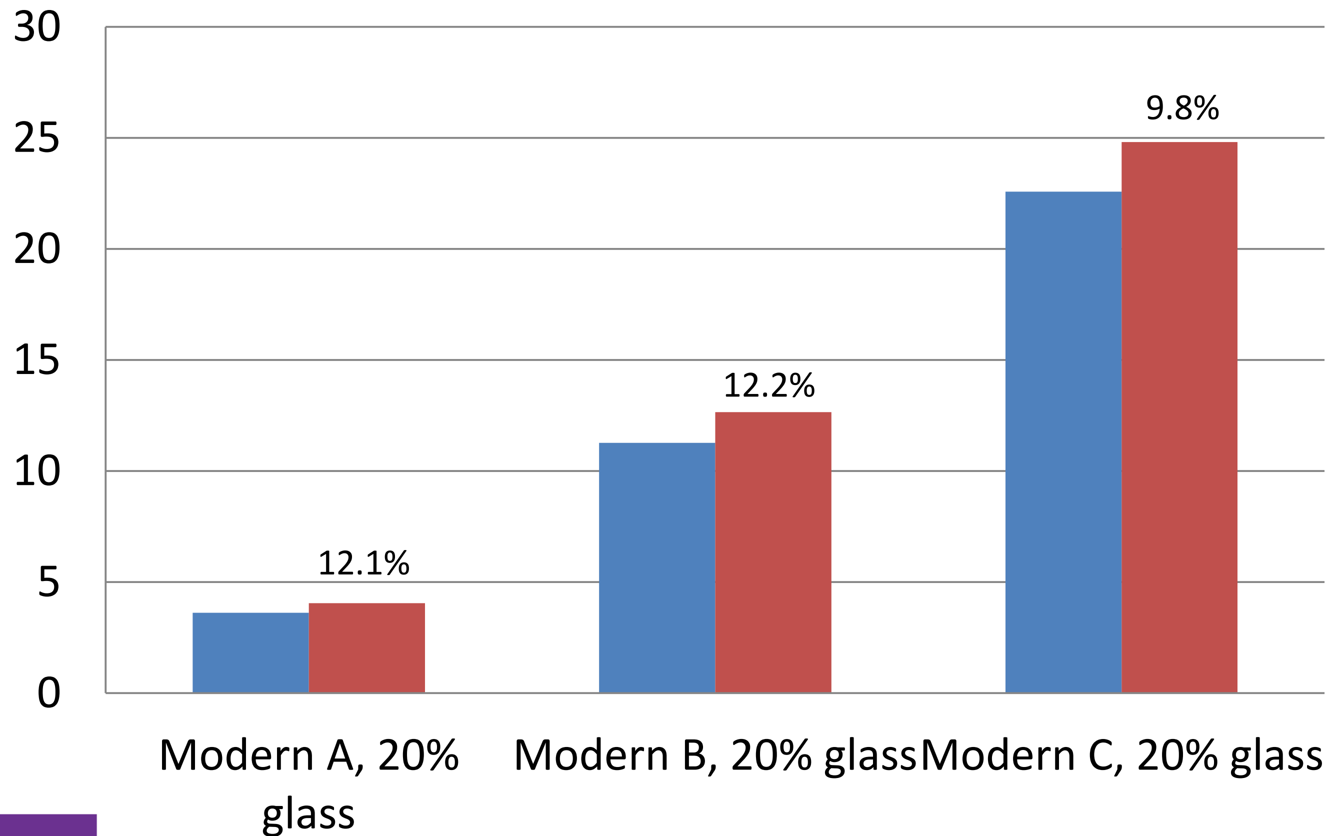
Effect of UHI on Summer Chiller Energy

- To find building's energy increase due to the UHI (ie, a building placed in urban conditions), a new weather file was created
- Daytime temperatures were increased by 1.0 °C, and nighttime by 2.9 °C
- July (16th-18th) are clear, calm and warm days, conditions for an intense UHI, so temperatures increased strongly, +3 °C for daytime, +6 °C for nighttime



Urb_UHI_green scenario

- To test the effect of shading plus reduced UHII peak hours (as evidenced from iButton analysis), a new weather file was created
  - peak days (16th-18th July) reduced by 1 °C
  - i.e., URB_UHI weather file with peak days +2 °C for daytime and +5 °C for nighttime

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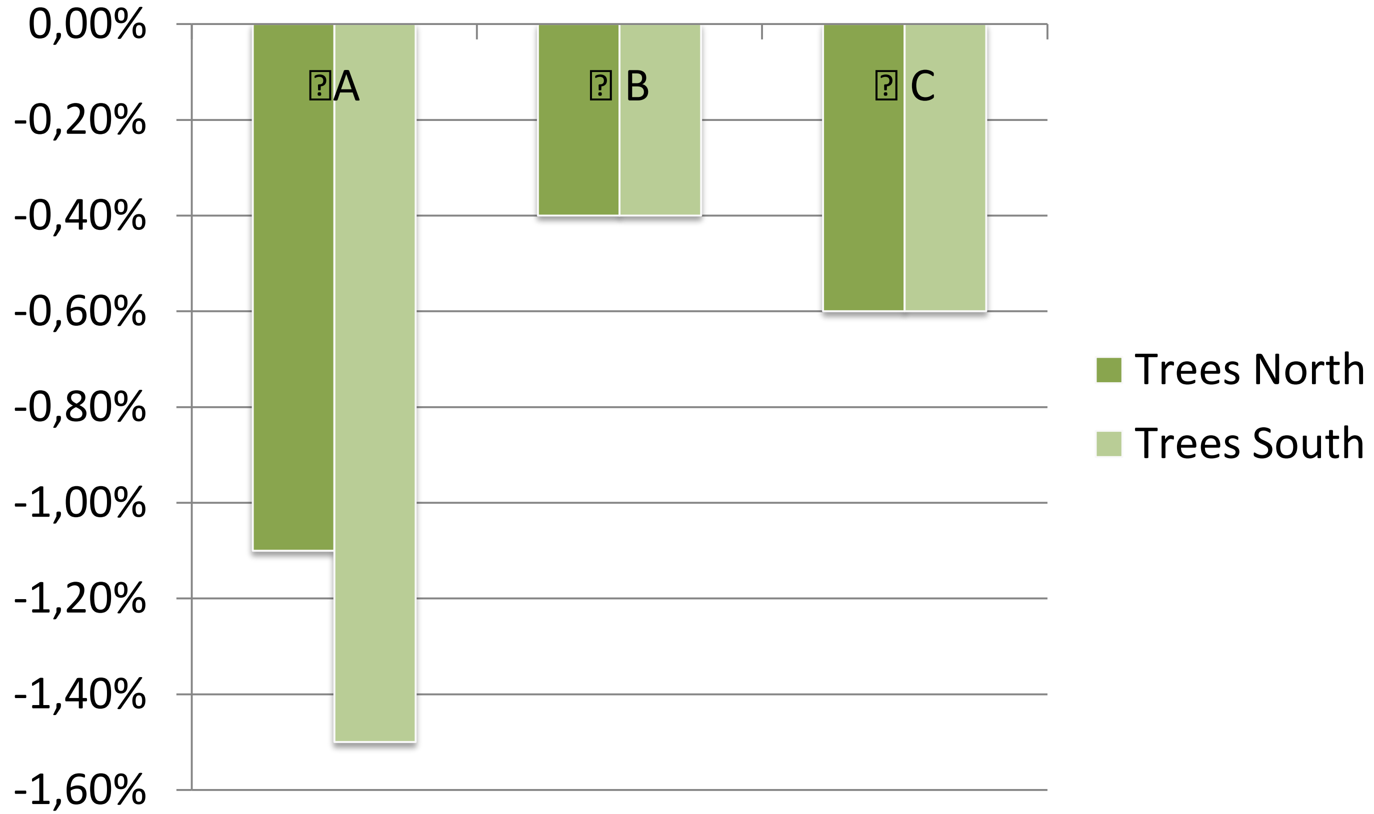
Effect of Tree Shading and Peak UHI Reduction

Trees placed in the model and shading simulated with SunCast in IES-VEshading plus reduced UHII peak hours (as evidenced from iButton analysis)



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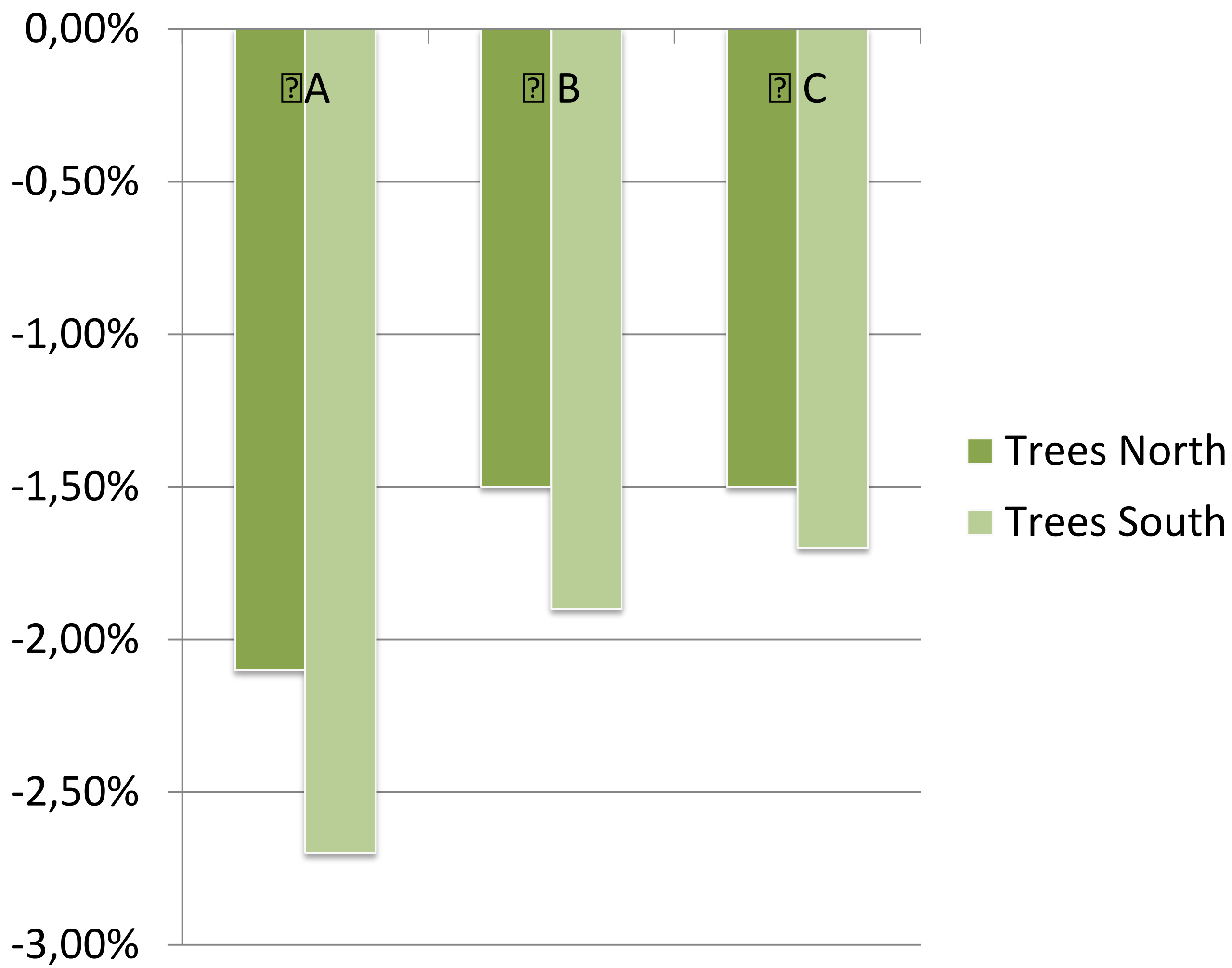
Peak UHI results (16th to 18th July)

Results begin to look more interesting on Peak days:

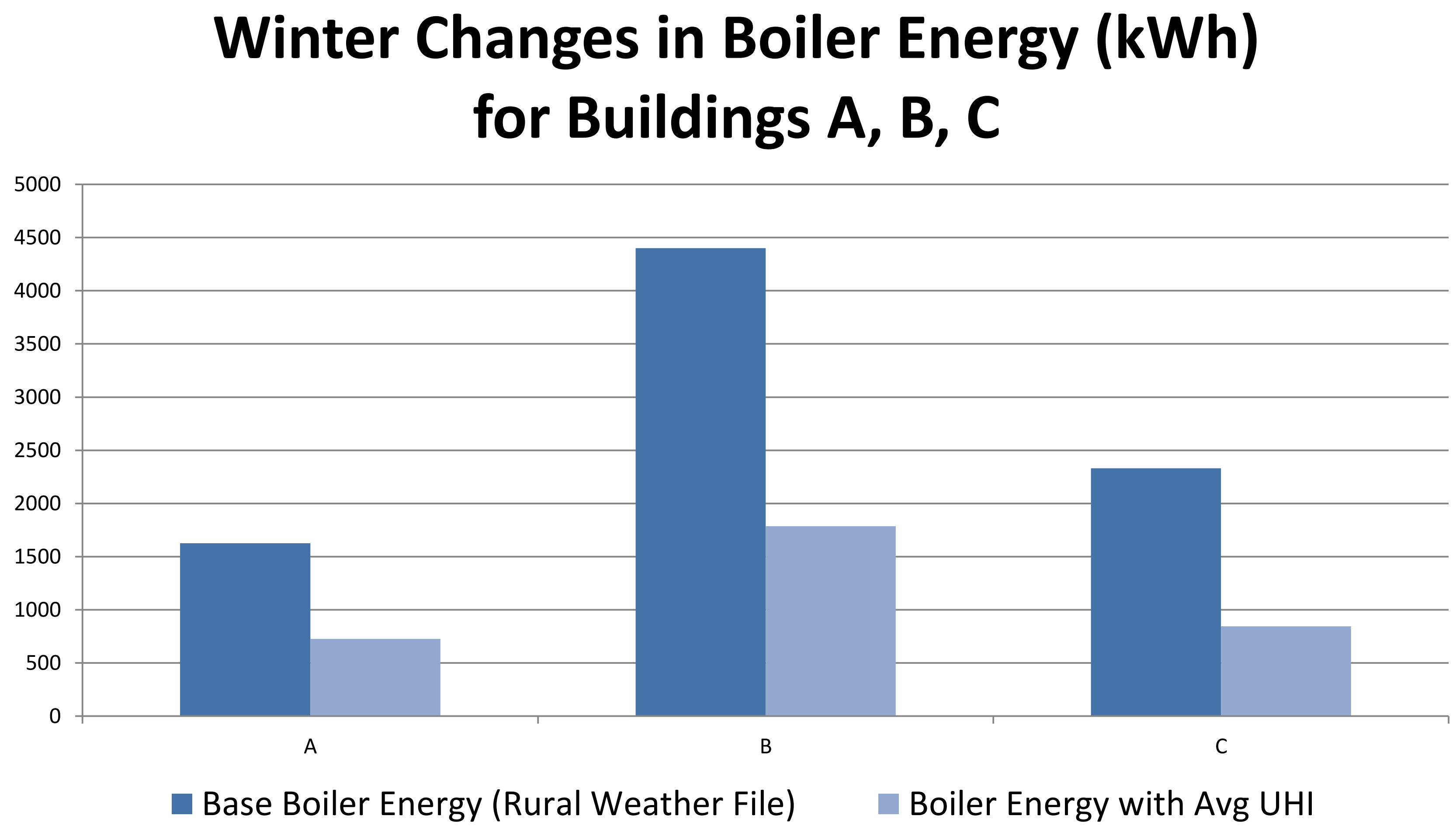
A - 4.8%

B - 3.4%

C - 3.2%



Winter Results



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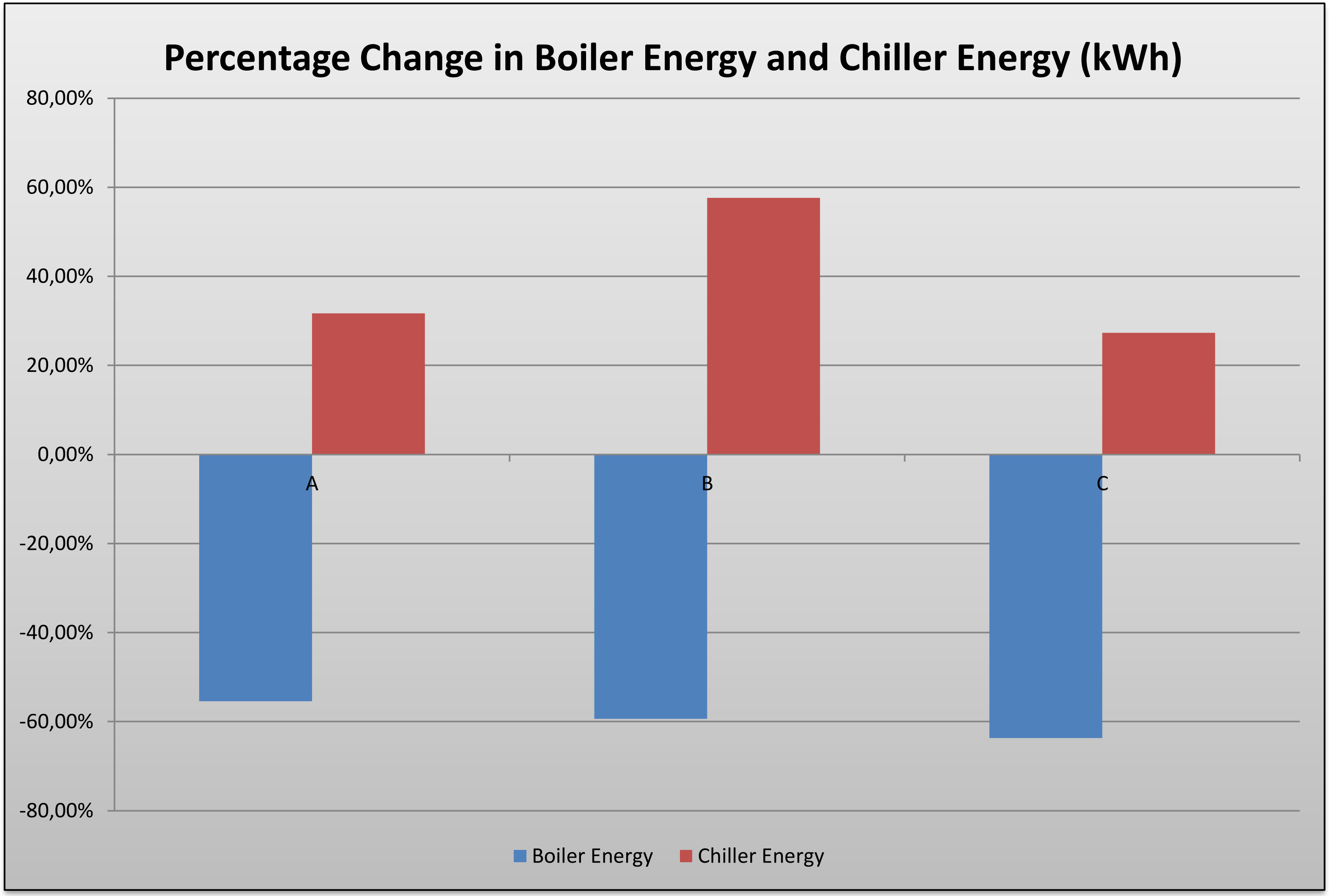
Winter Results, Boiler Energy



Carbon Emissions Change with Winter UHI

Total System CE (Electricity, kg CO_2)	Total System CE with Avg UHI	
kg	**kg**	**% Change**
640.24	563.04	-12.06%
1435.48	1243.44	-13.38%
4165.2	4882.52	17.22%

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Conclusions

Manchester UK has a UHI that is strongest in winter, at nighttime

For a temperate climate, such as Manchester's, the daytime summer UHI and its impact on commercial buildings is most important to consider in terms of long-term climate adaptation

UHI can increase the cooling energy requirement by up to 12% in July

Tree shading with 8 trees (4 N and 4 S), can reduce the cooling load by up to 2% in July and up to 4.8% for a 3-day period of peak UHI conditions

Tree shading is better for south than north facades

Winter heating loads for commercial buildings may be reduced by 55%-60% in urban, compared to rural settings, with an average nighttime UHI of 2C. However, chiller energy also increases by 27%-57%. The increase in chiller energy (in any season) will be a detriment in terms of carbons emissions, as electricity has a higher emissions factor.(.48 compared to .19 for natural gas)

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