Urban Heat Island in London and impact on buildings energy demand

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What is the difference between cities and countryside?

Urban Pollution

air, thermal, noise
Air pollution

Example of photo of air pollution in the press

London, Friday 10 April 2015
Thermal pollution causes:

– Heat capacity
– Heat conductivity
– Solar absorptivity
– Sky factor
– Wind speed
– Energy consumption
– Vegetation
Heat capacity & conductivity

RURAL

- ground is less dense
- has a lower heat capacity
- and has an insulating layer above

URBAN

- high density materials
- with high heat capacity
- and high thermal conductivity
Solar absorptivity

Albedo (solar reflectivity) varies in both rural and urban areas
Sky factor

reduced effectiveness of long-wave radiation for cooling
Wind speed

Mean rural wind speeds are higher than urban ones because the ground surface is smoother.

The “rougher” urban surfaces reduce wind speeds, but there are local variations.

Wind flowing across a deep narrow street canyon will create little disturbance at ground level.
Energy consumption releases heat

Rural energy use is small compared to the energy received from the sun

Energy use density in urban areas is much higher
Vegetation

To evaporate water requires energy - this helps keep plants and the air around them cool.

Urban areas are "harder". They have less vegetation, less evaporative cooling and less shading of the ground. Parks can provide "rural" oases in the city.
What is the effect of these factors?

It is known as Urban Heat Island effect
Land Surface Temperature, 12 July 2006, 21.00 UT
ASTER satellite image

Source: The LUCID project
http://www.lucid-project.org.uk
Urban Heat Island in London

Body of work in hot climates, US, Europe and Asia

What happens in moderate climates such as London?

We measured it!
Measurement station
Figure 2: The variation in the UHI intensity for London over 24 hours for summer 2000. The solid red line indicates the average UHI intensity by hour while the shaded area shows the range of UHI intensity values for 68 percent of the observations.
Example of the variation in heat island intensity across London

Time: 02:00
Hourly mean UHI value with wind speed less than 5 m/s for Core Area (zone-1)
Variation in annual heating & cooling load

\[ y = -1.40x + 55600 \]

\[ r^2 = 0.56 \]

\[ n = 24, p=0.001 \]

22% reduction

25% increase
**LSSAT**

ANN model for 77 fixed temperature stations.

Features:
- Site specific hourly air temperature

**LondUM**

Atmospheric model at 1km grid.

Features:
- 1.5m height surface temperatures

**Arup Outdoor Room**

Urban canyon radiative exchange model. Linked to LondUM

Features:
- Air & surface temperature

**ADMS**

Atmospheric dispersion model. Linked to LondUM

Features:
- Perturbations on temperature & humidity
UHI, energy use and climate change
Using future weather files

we used CIBSE weather files for London 2050 (medium-high scenario, according to UKCP02)

despite these were constructed using the method developed by Hacker and Blecher to predict parameters on an hourly basis

we adapted air temperature based on the results of LSSAT model developed by Brunel. Everything else was kept the same over London.
UHI, energy use and climate change

HW-Cooling load, kWh/m²/year, 2000

HW-Cooling load kWh/m²/year, 2050
UHI, ventilation and climate change

HW-Heating load, kWh/m²/year, 2000

HW- Heating load, kWh/m²/year, 2050
Buildings’ energy use trends

- In the UK at present, most buildings are not air-conditioned so UHI is a ‘good’ effect in winter.
- Building will be air conditioned in the future because of higher temperatures and even higher in the city.
- Once AC is introduced internal temperatures will be regulated at 21-22 °C. At present, we tolerate higher.
- Estimations indicate a five-fold increase in carbon emissions by city buildings in 2050.
- This should be set against commitments of carbon reductions – international and country specific.
What can be done?

Improve energy efficiency of buildings – already regulated

Generate heat and electricity by building integrated renewables - nearly zero carbon buildings

Improve external thermal environment – mitigate urban heat island
Mitigate urban heat island

Reduce anthropogenic heat from buildings and transport; reduce air-conditioning, increase insulation etc, reduce cars, use electric vehicles etc

Increase vegetation, parks, green roofs, green walls

Increase albedo of surfaces, cool roofs and pavements
Cool Materials: how do they work?

- **Cool materials**
  - high solar reflectance
  - high infrared emittance
  - less solar radiation absorbed
  - faster release of heat (IR radiation)
  - lower surface T
  - less heat penetrates into the building
  - less heat transferred to ambient air
And other colours
Does it work in temperate regions such as London?

![Graph showing temperature variations](image)

- External Air Temperature
- Roof Surface Temperature
- Internal Ceiling Temperature

**1 June 2009**
- Avg day global solar radiation: 351 W/m²
- Avg day external temperature: 19.5 °C

**16 August 2009**
- Avg day global solar radiation: 350 W/m²
- Avg day external temperature: 19 °C
Cool Roofs and hot climates

Abu Dhabi – no heating demand

Wuhan, China – hot summer/cold winter
Summary

Urban buildings use more energy than rural buildings because of the Urban Heat Island Effect.

Technical knowledge on how to improve energy efficiency and integrate renewables to achieve nearly zero carbon buildings; this is encouraged by legislation and financial initiatives.

Less knowledge on how to improve thermal environment in cities, now and in the future, in particular moderate climates (such as London) and cold winter/hot summer climates (such as Wuhan in China) where requirements for heating might fight requirements for cooling.
Thank you