Urban Form, Density & Microclimate:

How must planning and design change?

Introduction to Building Research & Information (BRI) Special Issue, 46(8)

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The ‘Problem’

- **Compact urban forms** are said to be more sustainable but questions about **local climate/air quality/comfort** consequences remain
- What specific *unintended* energy, thermal comfort, air quality and ventilation consequences of compact urban form?
- What is known about the *interactions* between these effects?
- Research, policy and practice implications

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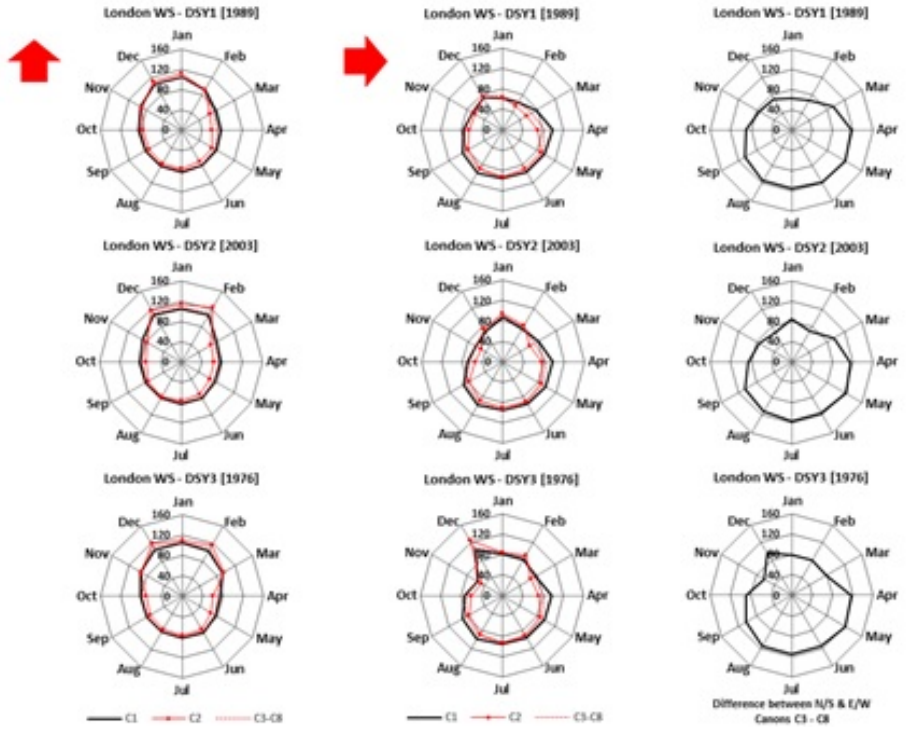
- Interactions between **urban form** and **ventilation/shading** - to highlight unintended air temperature, building energy use and thermal comfort consequences in high-density settings

Table 1. Authors and titles of articles in the special issue 'Urban Form, Density and Microclimate', *Building Research & Information* (2018), vol. 46(8); guest editors: Rohinton Emmanuel and Koen Steemers.

Authors	Title	doi
R. Emmanuel and K. Steemers	Connecting the realms of urban form, density and microclimate	10.1080/09613218.2018.1507078
J. Song, S. Fan, W. Lin, L. Mottet, H. Woodward, M. Davies Wykes, R. Arcucci, D. Xiao, J. Debay, H. ApSimon, E. Aristodemou, D. Birch, M. Carpentieri, F. Fan, M. Herzog, G. R. Hunt, R. L. Jones, C. Pain, D. Pavlidis, A. G. Robins, C. A. Short and P. F. Linden	Natural ventilation in cities: the implications of fluid mechanics	10.1080/09613218.2018.1468158
J. Futcher, G. Mills and E. Rohinton	Interdependent energy relationships between buildings at the street scale	10.1080/09613218.2018.1499995
D. Godoy-Shimizu, P. Steadman, I. Hamilton, M. Donn, S. Evans, G. Moreno and H. Shayesteh	Energy use and height in office buildings	10.1080/09613218.2018.1479927
M. Palme, L. Inostroza and A. Salvati	Technomass and cooling demand in South America: a superlinear relationship?	10.1080/09613218.2018.1483868
C. Chatzipoulka and M. Nikolopoulou	Urban geometry, SVF and insolation of open spaces: London and Paris	10.1080/09613218.2018.1463015
C. A. Short, J. Song, L. Mottet, S. Chen, J. Wu and J. Ge	Challenges in the low-carbon adaptation of China's apartment towers	10.1080/09613218.2018.1489465
L. S. Leo, R. Buccolieri and S. Di Sabatino	Scale-adaptive morphometric analysis for urban air quality and ventilation applications	10.1080/09613218.2018.1501797

Key lessons 1: Shading & urban form

- Modern office buildings, even in the cool, high latitude, maritime climates require cooling during the daytime period when they are occupied and functioning
- Increasing depth of street canyons (H:W ratio) in ‘commercial office’ areas is beneficial @ daytime (maximise solar shade at street façade)
- Caution against simply minimising UHI effect

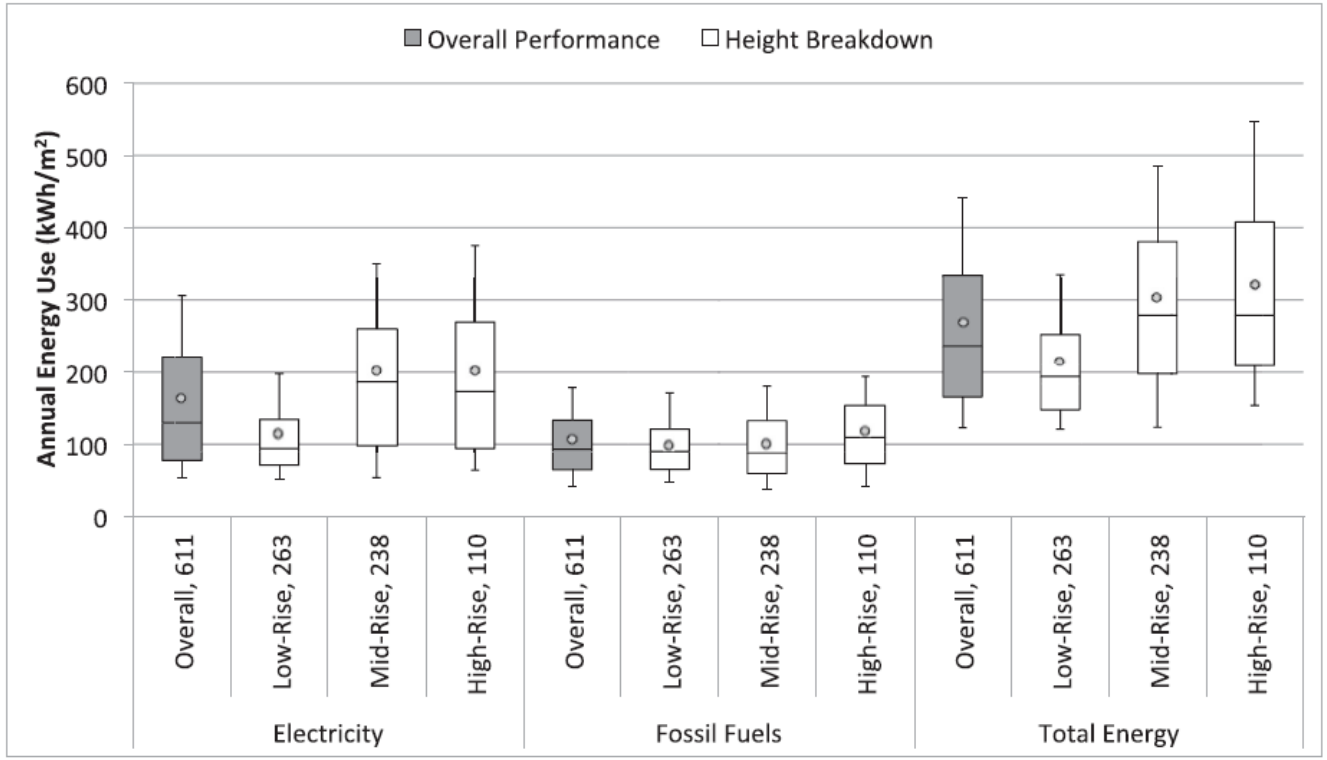


Futcher et al., 2018

Glasgow Caledonian University

Shading & urban form . . .

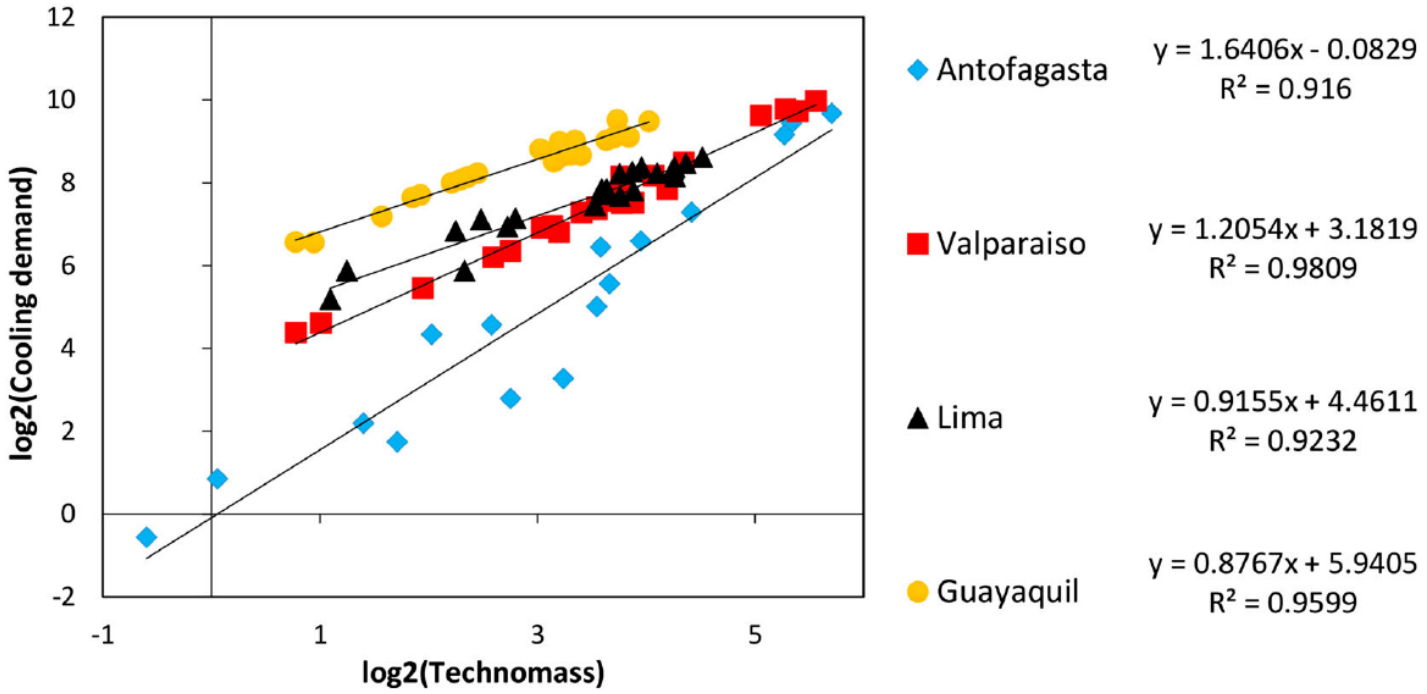
- Substantial increase in the mean intensity of electricity and fossil fuel use in taller buildings:
  - ≤5 stories vs. ≥21 stories leads to 137% increase in energy intensity and a 42% increase in fossil fuel use per unit of area
- Increased weather exposure (e.g. sun, wind, rain, i.e. lack of shade) is a potential contributor



Godoy-Shimizu et al., 2018

Key lesson 2: Density & cooling load

- Superlinear dependence of total cooling load on Technomass* in high density areas due to:
  - Increase in total energy needs
  - Higher air temperature due to the UHI effects

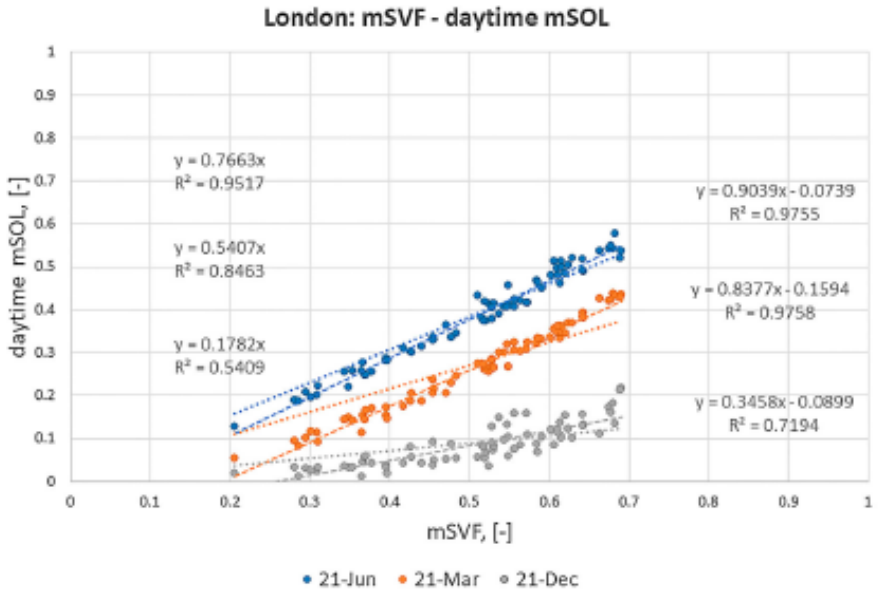


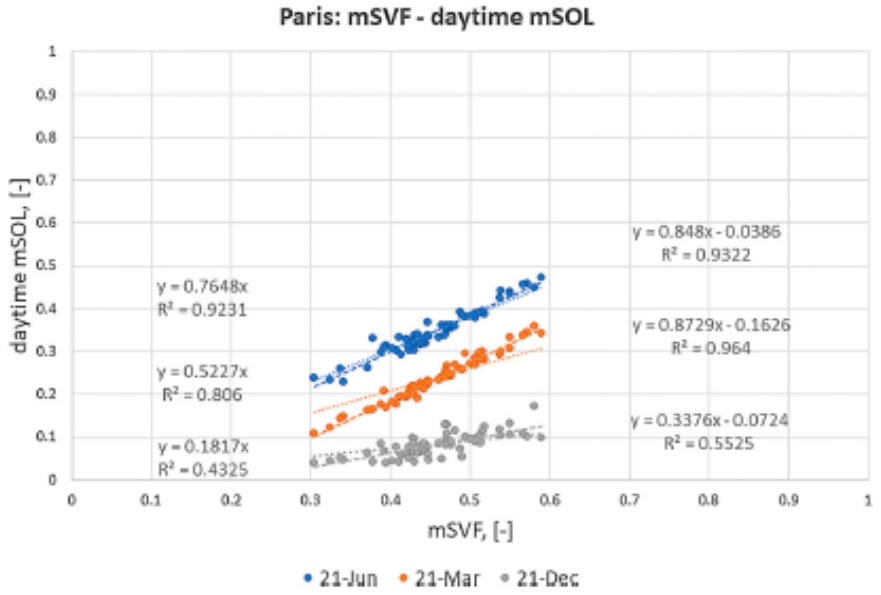
Palme et al., 2018

* Technomass ≡ Total anthropogenic matter per unit surface area; to account for urban form and function

Key lesson 3: Outdoor comfort & geometry

- ‘Openness to sky’ (ground-level sky view factor, mSVF) is affected by the quantity of site coverage and mean outdoor distances
  - mSVF → horizontal (site coverage) or the vertical (building height) density
- Outdoor climate ↔ urban form is context specific
  - in London - depends on site coverage, complexity and mean outdoor distance
  - in Paris - complexity, mean outdoor distance and mean building volume



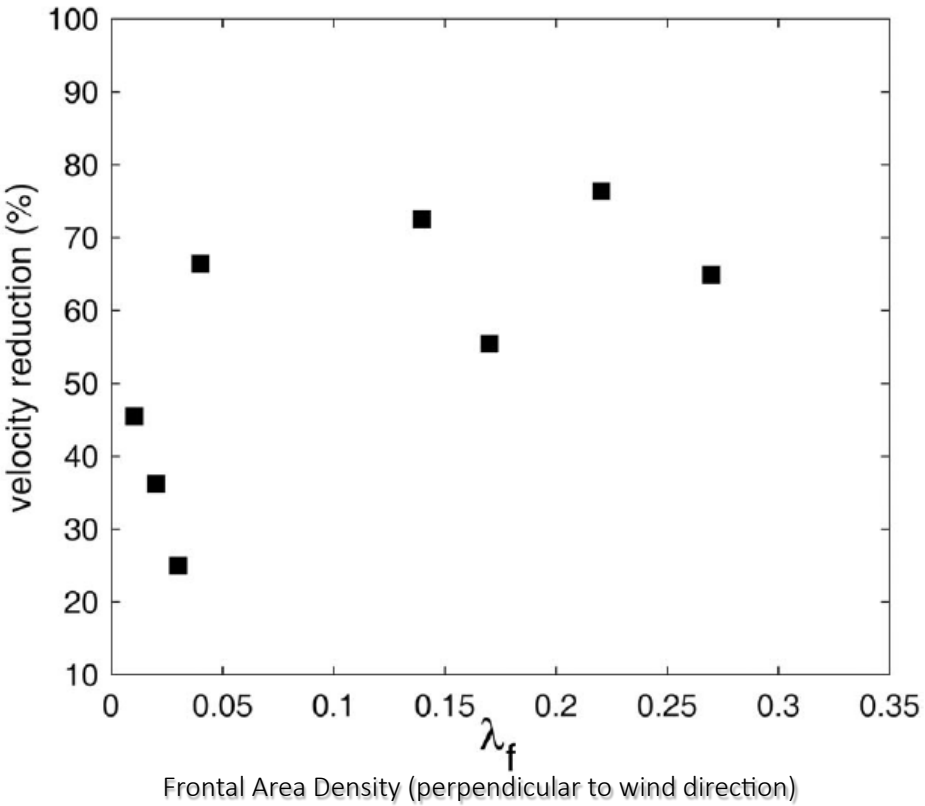


Chatzipoulka & Nikolopoulou, 2018

Glasgow Caledonian University

Key lesson 4: Density, wind flow & air pollution

- Tall bldgs. lead to wide fields of 'velocity deficit' and make it impossible / meaningless to model the ventilation field of future buildings proposed in the vicinity problematic
(Song et al., 2018)
- Frontal Area Densities (planar and perpendicular to wind direction) could identify 'wind corridors' and 'stagnant pools' (Leo et al., 2018)



Leo et al., 2018

Lessons for practitioners

- Varied building heights
  - Tall buildings freeing up more open space or,
  - ‘simpler’ form in tighter plan densities
  - Varied building heights are more or less useful based on street orientation
- Low-energy, low-carbon retrofit options for tall buildings
  - Novel external sun-shading devices
  - ‘modern’ wind catchers (Short et al., 2018)
- Control street geometry in relation to function
  - Increased H:W is useful in daytime occupied buildings but care needed to disentangle AQ effects
- High density areas with a ‘pollution problem’
  - Calculate FAD along predominant wind directions to identify ‘hotspots’

References

Emmanuel R, Steemers K. 2018. New challenges in urban form, density and microclimate, *Build Res Inf*, **46(8)**, pp. 804-808

Song J, Fan S, Lin W, et al. 2018. Natural ventilation in cities: the implications of fluid mechanics, *Build Res Inf*, **46(8)**, pp.829-844

Futcher J, Mills G, Emmanuel R. 2018. Interdependent energy relationships between buildings at the street scale, *Build Res Inf*, **46(8)**, pp. 829-844

Godoy-Shimizu D, Steadman P, Hamilton I, et al. 2018. Energy use and height in office buildings, *Build Res Inf*, **46(8)**, pp. 845-863

Palme M, Inostroza L, Salvati A. 2018. Technomass and cooling demand in South America: a superlinear relationship? *Build Res Inf*, **46(8)**, pp. 864-880

Chatzipoulka C, Nikolopoulou M. 2018. Urban geometry, SVF and insolation of open spaces: London and Paris, *Build Res Inf*, **46(8)**, pp. 881-898

Short CA, Song J, Mottet L, et al., 2018. Challenges in the low-carbon adaptation of China's apartment towers, *Build Res Inf*, **46(8)**, pp. 899-930

Leo LS, Buccolieri R, Di Sabatino S. 2018. Scale-adaptive morphometric analysis for urban air quality and ventilation applications, *Build Res Inf*, **46(8)**, pp. 931-951

https://www.tandfonline.com/toc/rbri20/46/8