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All the way to the top! The energy implications of building tall cities

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Abstract

Density of urban form may be achieved under a variety of morphological designs that do not rely on tallness alone. Tall buildings have implications on the broader urban environment and infrastructure that lower buildings would not have, e.g. wind effects, sight-lines, or over-shading. They may also have an impact on energy use for reasons of buildings-physics, construction, and occupant practices. This study uses a statistical approach of neighbourhood level data to analyse the impact of building morphology (e.g. height, volume and density) on energy demand in 12 local authorities in London. The research shows that areas marked by tall buildings use more gas after adjusting for exposures surface area, volume, number of residents and other features. The implication for energy policy and planning is building taller without increasing density may have an energy penalty.

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1. Introduction

At the extreme, achieving a high urban density relies on buildings being closer together and taller. However, while tall buildings may be a necessity in areas of highly constrained land availability (e.g. Hong Kong or Manhattan), they are often also driven for other reasons such as prestige, profit motivation, economics of productivity and creativity among others. However, tall buildings by themselves are not necessary to increase density in most cities. Instead, density of urban form may be achieved under a variety of morphological designs that do not rely on tallness alone [1]. Many cities have restrictions on over-shading, massing, street setbacks, and sightlines that impact on the height of building form or its development location. London, for example, has all of these requirements and has led select areas of the city to experience high-rise growth. In London's case, there are cultural and visual sensitivities to tall buildings that have prioritized the creation of a skyline aesthetic where such buildings are 'deemed to be appropriate' but is recognized that tall buildings would not necessarily prevent suburban sprawl nor achieve higher densities than those of mid- or low-rise development [2].

Tall buildings have implications on the broader urban environment and infrastructure that lower buildings would not have, e.g. wind effects, sight-lines, or over-shading.[3,4] Several older cities around the world have experienced intense development overtop aging infrastructure that have meant significant investment is needed to maintain service and minimize the impact of increasing density and building height. They may also have an impact on energy use due to reasons of building-physics (e.g. wind exposure, temperature differences, unobstructed solar gains), infrastructure and construction (e.g. ventilation methods, heating system types), and occupant practices (e.g. window opening, lighting). There are also challenges around the embodied energy of building taller with the addition of more floors relating to higher embodied energy compared with lower buildings [5,6].

From a city level energy performance perspective, what might the impact of building height, at equivalent levels of density, have on energy demand? A recent study for London found that there was a positive relationship between energy demand in non-residential buildings and building plan depth, with areas characterized by deeper plan buildings using more electricity [7]. However, the study did not look at height of buildings for equivalent densities.

In this study we focus on London, which is an example of city with considerable growth pressures (estimated 10 million people by 2036)[8], has an urban form with a range of building heights, and is characterized by areas with considerable variation in urban density. London offers an interesting setting to examine the relationship between urban density and energy demand. In this study, we focus on the following research questions:

- How does building height vary across London?
- How does energy demand vary in areas characterized by different building heights?
- Do areas with taller buildings use more / less energy than areas characterized with less-tall buildings?
- What neighbourhood-level built environment factors affect energy demand in areas of tall / less-tall buildings?

2. Method

To address the above questions, an ecological study design is used to determine the variation in residential building height at the neighbourhood level and any association between indicators/measures of building tallness and energy demand. 12 local authorities in Greater London are used to examine the association between density and energy demand using data compiled on urban morphology, energy use and socio-economic features. They are Camden, City of London, Hackney, Hammersmith and Fulham, Islington, Kensington and Chelsea, Lambeth, Lewisham, Southwark, Tower Hamlets, Wandsworth, and Westminster. The study focuses on residential dwellings due to the constraints of available non-residential energy and socio-economic data. The study uses the lower super output area (LSOA) as the unit of analysis. An LSOA is a statistical geographic unit of analysis typically comprising an average of 650 households and 1500 people and is designed for both spatial compactness and social homogeneity. In this research, LSOA and 'neighbourhood' are used inter-changeably.

The study methods included:

- Calculating building height and density using detailed LiDAR data for all buildings within the study area;
- Classifying the height and density of the buildings in the local authorities to create a morphological description;