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Density, Energy and Metabolism of a proposed smart city

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A B S T R A C T
This paper reports on a detailed analysis of the metabolism of the Island City of Mumbai should the Indian Government's proposal for 'smart' cities be implemented. It focuses on the environmental impact of increased population density achieved by demolishing existing medium-rise (3-5 storey) housing and replacing it with the proposed high-rise (40-60 storey) towers. The resulting increase in density places a burden on the demand on such things as electricity and water and simultaneously increases the output flows of drainage, solid waste and greenhouse gas production.
An extended urban metabolism analysis is carried out on a proposed development in Mumbai (Bhendi Bazaar) that has been put forward as an exemplar case study by the Government. The flows of energy, water and wastes are calculated based on precedents and from first principles. The results of the case study are then extrapolated across the City in order to identify the magnitude of increased demands and wastes should the 'smart' city proposals be fully realised.
Mumbai is the densest city in the world. It already suffers from repeated blackouts, water rationing and inadequate waste and sewage treatment. The results of the study indicate, on a per capita basis, increasing density will have a significant further detrimental effect on the environment.
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1. Introduction

In the study of the relationship between urban form and resource consumption, there are differing conclusions concerning the impact of dense urban form. For example, reduced transport energy consumption has been shown to correlate with increased urban density (Newman & Kenworthy, 1989), household space heating energy consumption reduces with compact house forms (Rode et al, 2014) and more general unsupported claims are also made (Leung, 2016; Albino et al, 2015; Nia, 2017). However, other studies have indicated that CO_2 emissions from transport and electricity consumption per capita show little correlation with the density of urban areas (Hammer et al, 2011) and there is evidence that dispersed urban forms are more energy efficient when disruptive technologies such as photovoltaics to charge electric vehicles (the more likely technologies of the future) (Byrd et al 2013) are widespread and there is empirical evidence demonstrating that compact residential building forms are less energy efficient (Myers et al, 2005; Byrd et al 2012).

However, policies on urban form tend to favour compaction but there is little evidence of what densities urban form should target to optimise resource consumption (Steadman, 2015). While some studies have indicated an optimum density of about 18 dwellings per Ha (Gosh et al, 2006) most policies advocating increased density (Sridhar, 2010) stay clear of a density target which

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