ARE CITIES REALLY MORE ENERGY EFFICIENT?

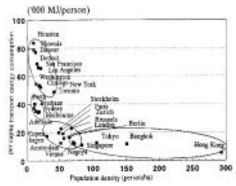
Lorraine Sugar[1] & Chris Kennedy[1,2]
1. Department of Civil Engineering, University of Toronto, Canada
2. Department of Civil Engineering, University of Victoria, Canada
contact information: lorraine.sugar@utoronto.ca

UNIVERSITY OF TORONTO

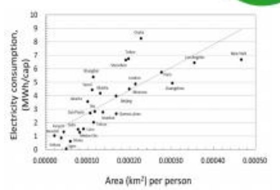
FOUR COMPETING ANSWERS

POPULATION DENSITY

Existing studies on global cities have demonstrated strong correlations between population density and lower energy consumption per capita.



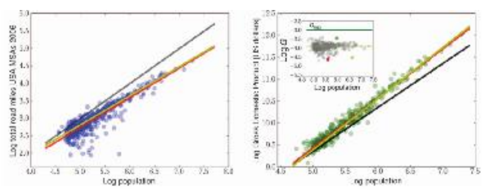
Variation in annual transportation energy consumption and population density between several global cities (Newman and Kenworthy, 1991).



Electricity consumption in megacities is strongly correlated with urbanized area per person (Figure S5 from Kennedy *et al*., 2015).

URBAN SCALING THEORY

Urban scaling theory shows that total energy consumption and wasted energy increase with city size, i.e., larger cities use and waste more energy than smaller cities in the same country.



Sublinear scaling of road miles and superlinear scaling of GDP for U.S. cities (Figure 1 from Bettencourt, 2013). Total energy consumption and dissipation scale superlinearly.

WEALTH EFFECTS

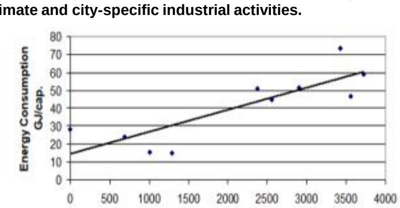
Existing studies on global megacities show that larger cities tend to be wealthier than smaller cities, and increased wealth leads to increased energy consumption.

	Electricity use	Heating/ industrial fuel	Transport fuel	Water consumption	Solid waste production	Heating degree-days	Area (km²) per person	GDP
Electricity use (MWh)	—							
Heating/industrial fuel (GJ)	0.36	—						
Transportation fuel (GJ)	0.58	0.56	—					
Water consumption (kL)	0.52	0.33	0.67	—				
Solid waste production (t)	0.37	0.03	0.30	0.04	—			
Heating degree-days	0.46	0.80	0.54	0.17	0.25	—		
Area (km²) per person	0.78	0.46	0.75	0.72	0.39	0.42	—	
GDP ($)	0.69	0.52	0.71	0.46	0.47	0.58	0.80	—

Simple (univariate) correlation coefficients between urban metabolism parameters and driving factors in a study of the world's 27 megacities (Table S2 from Kennedy *et al*, 2015).

CLIMATE & INDUSTRIES

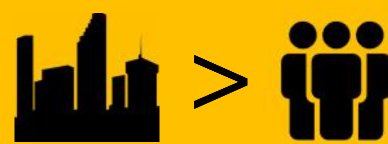
Other factors that impact energy use in cities are location-specific, such as climate and city-specific industrial activities.



Energy consumption from heating and industrial fuels increases with heating degree days, based on an 18°C base temperature (Figure 2 from Kennedy *et al*., 2009).

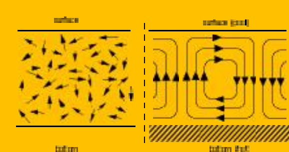
INTERPRETATIONS

Cities are more than the sum of their people



Urban living may be more energy efficient when it comes to meeting basic needs of individuals (i.e., density effects); however, the agglomeration effects of urban economies lead to even greater consumption in the city as a whole (i.e., scaling and wealth effects).

Cities are dissipative structures that build complexity as they grow



Formation of Bénard Cells

Cities are dissipative structures, similar to Bénard Cells or a tornado in a bottle. As cities become more efficient—by building transportation networks, for example—they transition to a higher order of complexity that drives even more economic activity, consuming more energy and making room for more people, who in turn consume more energy.

Urban energy needs will increase; low-carbon energy supply is a top priority

On their own, urbanization and efficiency may not actually help efforts to reduce our energy-related environmental footprint on the planet. Instead, we need strategies that can sustain potentially high energy use while reducing adverse impacts, such as a shift to low-carbon energy supplies.

References: Newman and Kenworthy, 1991, *Cities and automobile dependence: An international source book* | Kennedy *et al.*, 2015, *PNAS* 112(19): 5985-90 | Bettencourt, 2013, *Science* 340(6139): 1438-41 | Kennedy *et al.*, 2009, *Environ. Sci. Technol.* 43(19): 7297–302.