Global Trends In Urban Energy Use: The Tropical Shift

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Motivation

Many of the world's **largest** and **fastest-growing** cities–from Karachi (pop. 14 million; 34.6% increase from 2000-2010) to Delhi (22m; 39.4%), Dhaka (15m, 45.2%), Jakarta (10m; 14.8%), Bangkok (8m, 29.1%), Lagos (11m; 48.2%) and Kinshasa (9m, 55.4%)–are located in South Asia and Sub-Saharan Africa with tropical to sub-tropical climates unlike those of most OECD member cities in the global North. As the tropics/sub-tropics become increasingly urban, inustrial and affluent, it is important to consider how energy demand–particularly for thermal comfort–will evolve differently in these places than it has historically across the OECD.

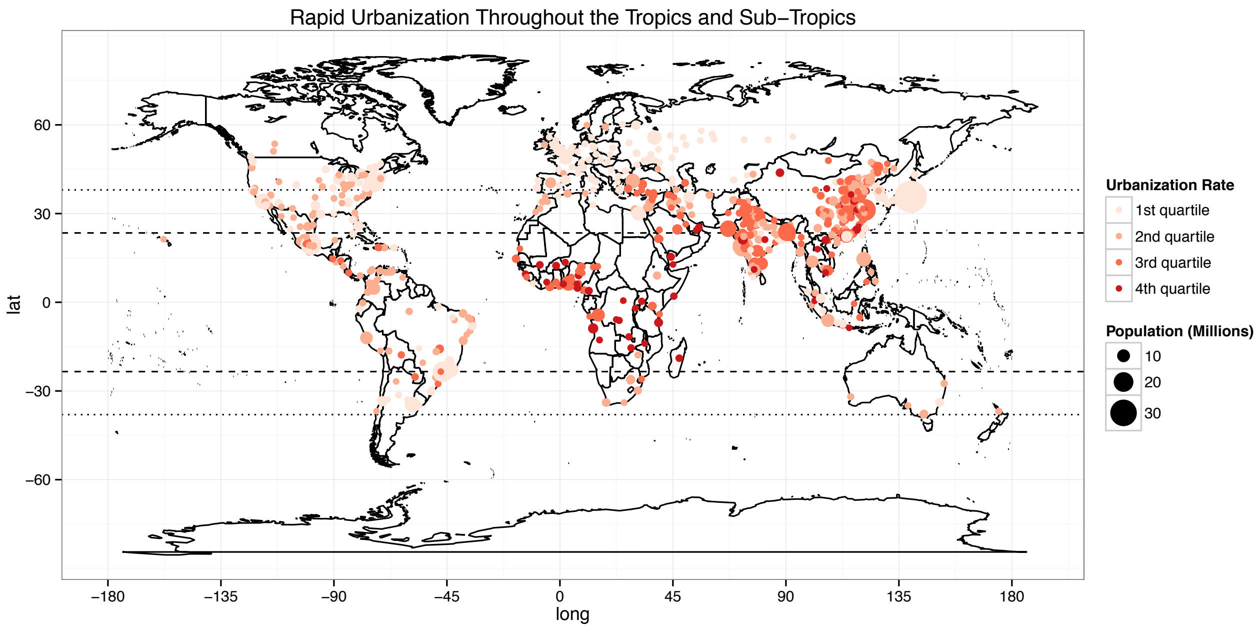
To illustrate the potential for vast differences in energy demand for thermal comfort between cities in the global North and cities in the Tropics/Sub-Tropics, consider Delhi, India. Delhi–with its massive population and very hot climate–is an outlier compared to OECD member cities but typical of South Asia: Peak summer temperatures routinely exceed 40 deg C. (104 F.), and intense heatwaves can approach 50 deg C. (122 F.). Given the huge temperature differential between outdoor (say 104 F.) and desired indoor air temperature (say 72 F), and the thermodynamic fact that energy for cooling scales linearly with the temperature differential, cooling a room in Delhi requires twice as much energy as cooling a room in New York where the summer outdoor-indoor temperature differential is typically half that.

In addition to higher temperatures, the summer season is also much longer: in the past year, Delhi had over **six** times as many cooling-degree days as New York City (again assuming a desired indoor air temperature of 72 deg F). Compounded by leaky building envelopes in developing world cities (designed for natural ventilation, not air conditiong), intense heat-island effects (typically less green space), and massive population growth, peak electricity demand in cities thourought the developing world could one day surpass that of their neighbors to the north–not only in aggregate terms because of their population, but also *per-capita* due to climate, building design and thermodynamics.

Implications of Global Energy Service Provision Parity

If we consider the trajectory of developing world cities as reaching eventual parity with OECD cities, and if we think in terms of energy *service provision* rather than just BTU or KWh, then we begin to appreciate the magnitude of future energy demand (and associated resource consumption and environmental impact). This has important implications not only for regional grid planning and supply reliability, but also the global transition to renewable energy given the limitations of meeting such large and 'peaky' demand with non-dispatchable resources such as wind and solar.

Figure 1 provides a map of urbanization rates for cities worldwide with a population greater than 750,000 (UN 2011). Urbanization rates are clearly highest in South Asia and Sub-Saharan Africa. Figure 2 shows the *distribution* of population growth rates for the same set of cities, grouped by latitude (global North, Tropics and Subtropics). The expected value (e.g. central tendancy) of urbanization rates in the Tropics and Sub-Tropics is clearly distinct from that of the North.

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## [1] "World's Largest Cities in 2015 (Population > 10 million)"

##        Continent            Country               Urban.Agglomeration Population [MM]
## 1           Asia              Japan                             Tokyo            38.2
## 2           Asia              India                             Delhi            25.6
## 3           Asia              China                          Shanghai            23.0
## 4  North.America             Mexico    Ciudad de México (Mexico City)            21.7
## 5  North.America              U.S.A                  New York-Newark            21.3
## 6           Asia              India                  Mumbai (Bombay)            21.2
## 7  South.America             Brazil                         São Paulo            21.0
## 8           Asia              China                           Beijing            18.1
## 9           Asia         Bangladesh                             Dhaka            17.4
## 10          Asia           Pakistan                           Karachi            15.5
## 11          Asia              India                Kolkata (Calcutta)            15.1
## 12 South.America          Argentina                      Buenos Aires            14.2
## 13 North.America              U.S.A Los Angeles-Long Beach-Santa Ana            14.1
## 14        Africa            Nigeria                             Lagos            13.1
## 15          Asia        Philippines                            Manila            12.9
## 16          Asia             Turkey                          Istanbul            12.5
## 17        Europe             Turkey                          Istanbul            12.5
## 18          Asia              China              Guangzhou, Guangdong            12.4
## 19 South.America             Brazil                    Rio de Janeiro            12.4
## 20          Asia              China                          Shenzhen            12.3
## 21          Asia Russian Federation                   Moskva (Moscow)            12.1
## 22        Europe Russian Federation                   Moskva (Moscow)            12.1
## 23        Africa              Egypt                Al-Qahirah (Cairo)            11.9
## 24          Asia              Japan                        Osaka-Kobe            11.8
## 25        Europe             France                             Paris            11.1
## 26          Asia              China                         Chongqing            11.1
## 27          Asia          Indonesia                           Jakarta            10.5
## 28        Africa              D.R.C                          Kinshasa            10.3
## 29          Asia              China                             Wuhan            10.3
## 30 North.America              U.S.A                           Chicago            10.2
## 31          Asia              India                         Bangalore            10.0
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## [1] "World's Fastest Growing Cities (2010-2015) with a Population > 750,000"

##    Continent       Country  Urban.Agglomeration Growth.Rate [%]
## 1       Asia      Thailand         Samut Prakan            9.15
## 2       Asia      Viet Nam             Can Tho            8.78
## 3     Africa       Somalia Muqdisho (Mogadishu)            8.01
## 4     Africa Côte d'Ivoire         Yamoussoukro            7.52
## 5       Asia         U.A.E Abu Zaby (Abu Dhabi)            7.22
## 6     Africa  Burkina Faso          Ouagadougou            6.88
## 7       Asia     Indonesia                Batam            6.78
## 8       Asia         U.A.E       Dubayy (Dubai)            6.75
## 9       Asia         U.A.E             Sharjah            6.51
## 10      Asia         China              Xiamen            5.93
## 11      Asia         China      Suzhou, Jiangsu            5.92
## 12    Africa         Niger              Niamey            5.86
## 13      Asia         China          Wuhu, Anhui            5.81
## 14      Asia         China               Hefei            5.78
## 15      Asia         China            Yinchuan            5.77
## 16      Asia     Indonesia            Denpasar            5.74
## 17    Africa       Nigeria               Abuja            5.74
## 18      Asia         China            Jinjiang            5.63
## 19      Asia         China           Zhongshan            5.58
## 20      Asia         India            Tiruppur            5.34
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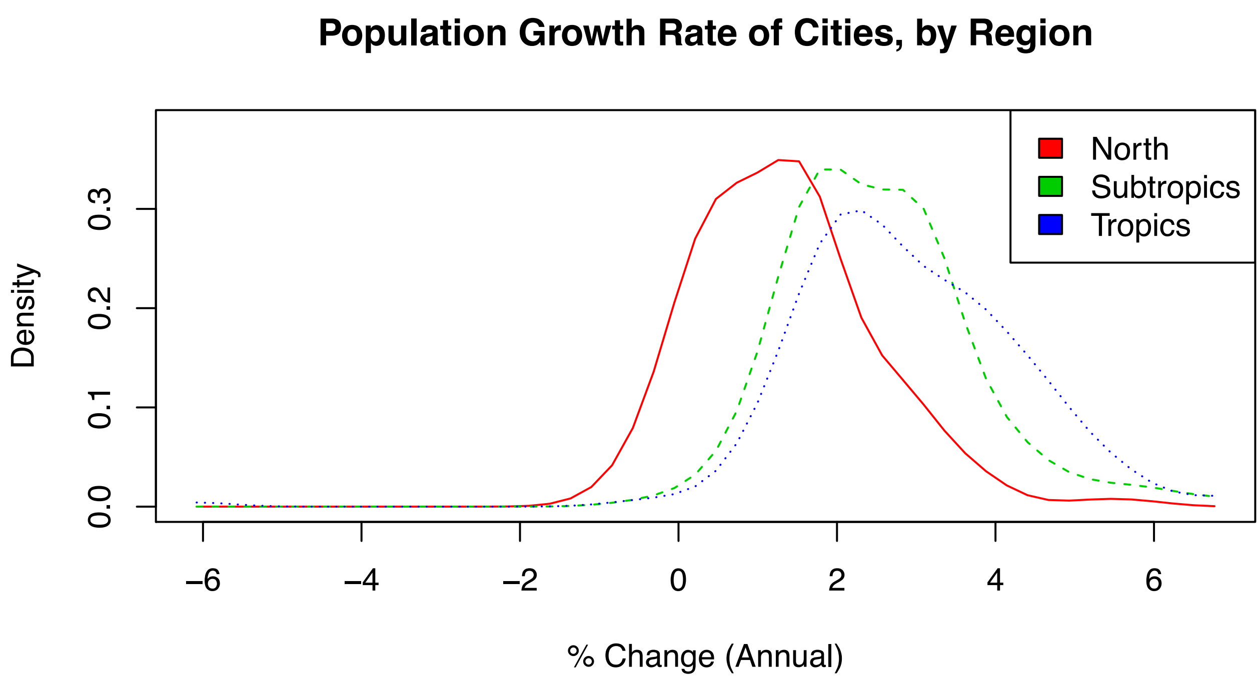

Rationale

Mid- to long-range global energy demand forecasts are typically reported as annual totals and provide little insight to the temporal distribution throughout the year. To address this shortcoming, we focus on the diurnal and seasonal distribution of energy demand and supply, which drive system cost but recieve relatively little attention in global energy outlooks. This requires more and better data than is typically available to researchers.