Supplementary Material

Energy and Material Flows of Megacities

Chris Kennedy*[1]
Iain Stewart[1]
Angelo Facchini[2]
Igor Cersosimo[2]
Renata Mele[2]
Bin Chen[3]
Mariko Uda[1]
Arun Kansal[4]
Anthony Chiu[5]
Kwi-gon Kim[6]
Carolina Dubeux[7]
Emilio Lebre La Rovere[7]
Bruno Cunha [7]
Stephanie Pincetl[8]
James Keirstead[9]
Sabine Barles[10]
Semerdanta Pusaka[11]
Juniati Gunawan[11]
Michael Adegbile[12]
Mehrdad Nazariha[13]
Shamsul Hoque[14]
Peter Marcotullio[15]
Florencia Gonzalezo[16]
Tarek Genena[17]
Nadine Ibrahim[1]
Rizwan Farooqui[18]
Gemma Cervantes[19]
Ahmet Duran Sahin[20]

* corresponding author

1: Department of Civil Engineering, University of Toronto, 35 St. George Street, Toronto, Ontario. CANADA. M4J 3K1. Tel: +1 416 978 5978
2: Enel Foundation, 00198, Viale Regina Margherita n. 137, Rome, Italy
3: School of Environment, Beijing Normal University, China, 北京市海淀区新街口外大街19号 邮政编码: 100875
4: Department of Energy and Environment, TERI University, 10 Institutional Area, Vasant Kunj, New Delhi, DL 110070, India
5: Department of Industrial Engineering, De La Salle University, 2401 Taft Ave, Malate, Manila, 1004 Metro Manila, Philippines

6: Department of Landscape and Ecological Planning, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul, South Korea
7: COPPE, Federal University of Rio de Janeiro, Av. Pedro Calmon, 550 - Cidade Universitária, Rio de Janeiro - RJ, 21941-901, Brazil
8: UCLA Institute of the Environment and Sustainability, La Kretz Hall, Suite 300, Los Angeles, CA 90095-1496. USA
9: Dept. of Civil and Environmental Engineering, Laing O'Rourke Centre for Systems Engineering and Innovation, 407 Skempton Building, Imperial College, South Kensington, London, SW7 2AZ. UK
10: Institut de géographie, Université Paris 1 Panthéon Sorbonne 191 rue saint-Jacques 75005 Paris, France
11: Department of Accounting, Trisakti University, Jl. Kyai Tapa No.1, Grogol, Jakarta Barat, DKI Jakarta 11440, Indonesia
12: Department of Architecture, University of Lagos, Dan Fodio Blvd, Lagos 23401, Nigeria
13: Department of Environmental Engineering, College of Engineering, University of Tehran, Enghelab Ave. Tehran, Iran. P.O.Box: 11365-4563
14: Department of Civil Engineering, Bangladesh University of Engineering & Technology, Dhaka-1000, Bangladesh
15: Department of Geography, 1003E Hunter North, Hunter College, 695 Park Ave.,New York, NY 10065. USA
16: Gerenta Operativa de Cambio Climático y Energía, Dirección General de Estrategias Ambientales, Agencia de Protección Ambiental, Gobierno de la Ciudad de Buenos Aires, Argentina
17: EcoConServ Environmental Solutions, 12 El-Saleh Ayoub St., Zamalek, Cairo, Egypt 11211
18: Department of Civil Engineering, Faculty of Civil Engineering and Architecture, NED University of Engineering & Technology, Karachi 75270, Pakistan
19: Department of Civil Engineering, Universidad de Guanajuato, Av. Juárez 77. Col. Centro. CP 36000. Guanajuato, México
20: İstanbul Technical University, Uçak ve Uzay Bilimleri Fakültesi, Maslak, 34469, İstanbul, Turkey

1. Extended Analysis

Figure S1. The number of megacities at the start of each decade since 1960, with authors' projection to 2020. (Figure 1 from ref. 1; data source: www.citypopulation.de/world/Agglomerations.html)

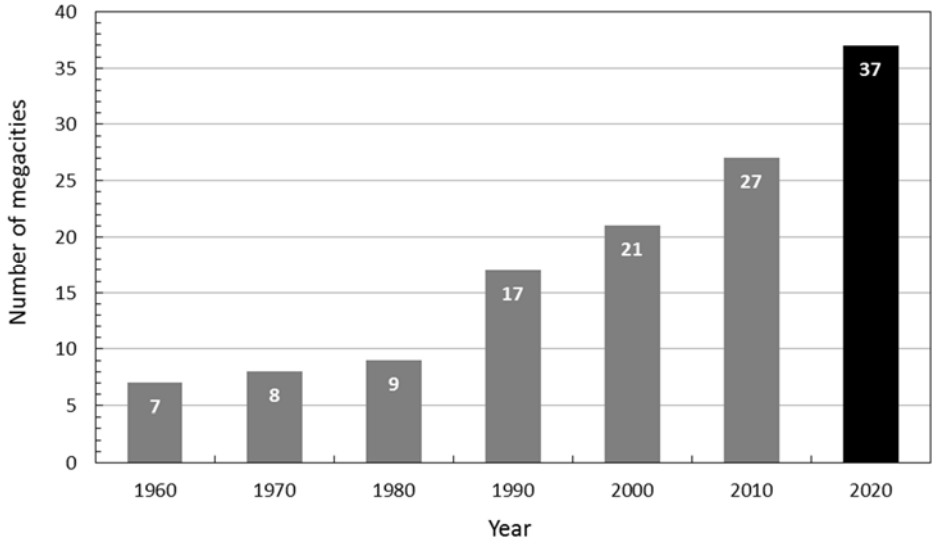

Figure S2. Surveyed megacity population compared with Brinkhoff 2010 values (2).

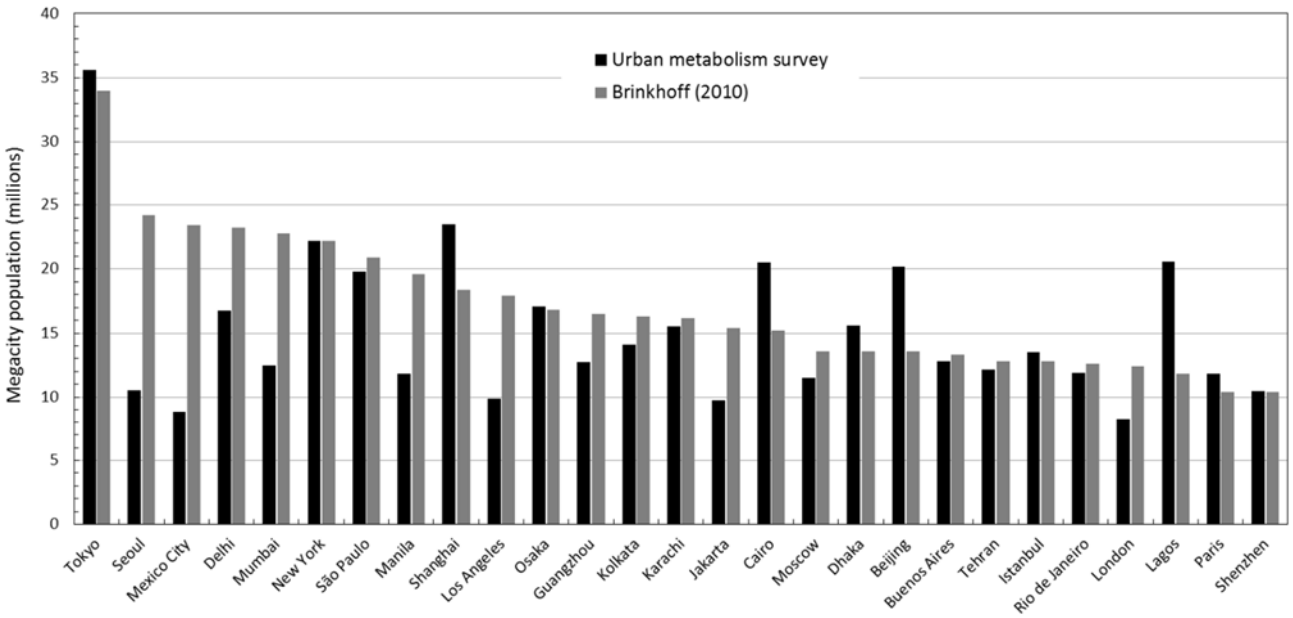

Figure S3. Ground transportation energy use in relation to urbanized area per capita.

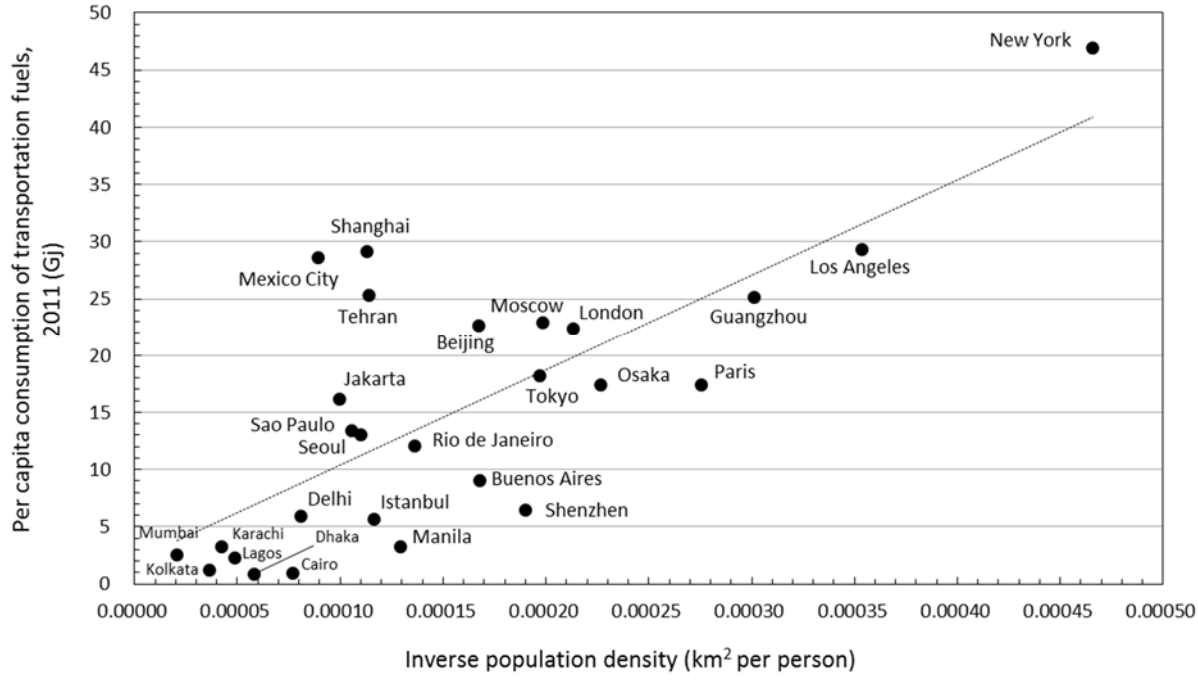

Figure S4. Heating and industrial fuel consumption in relation to heating-degree-days.

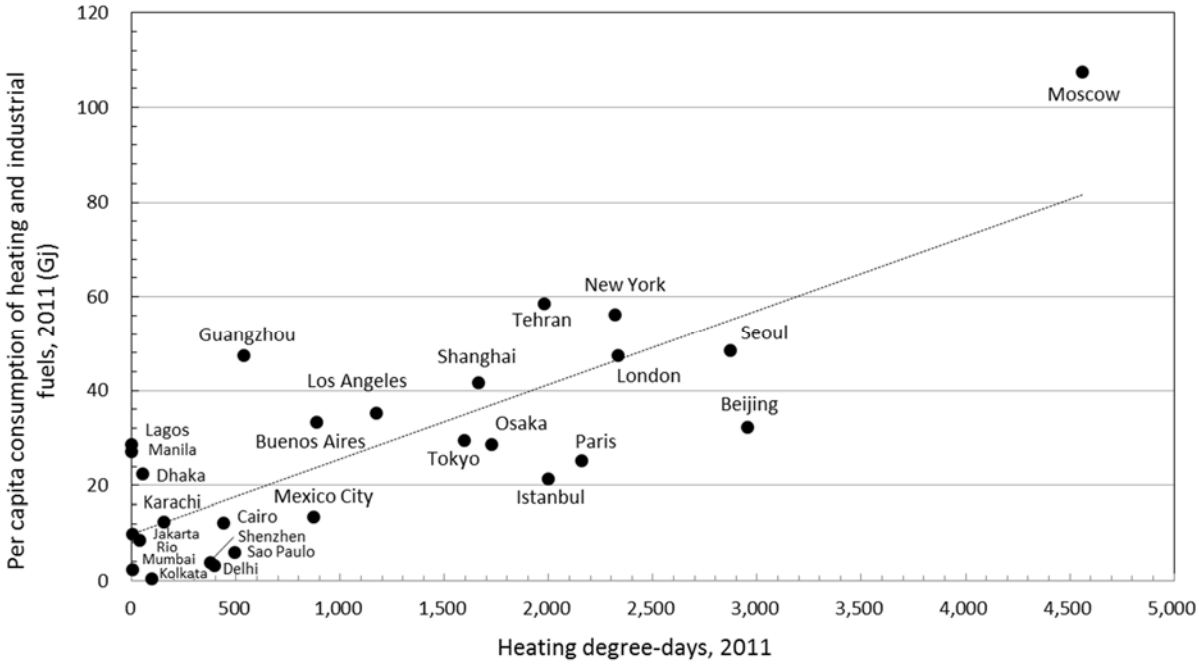

Figure S5. Electricity use (including line losses) in relation to urban area per person.

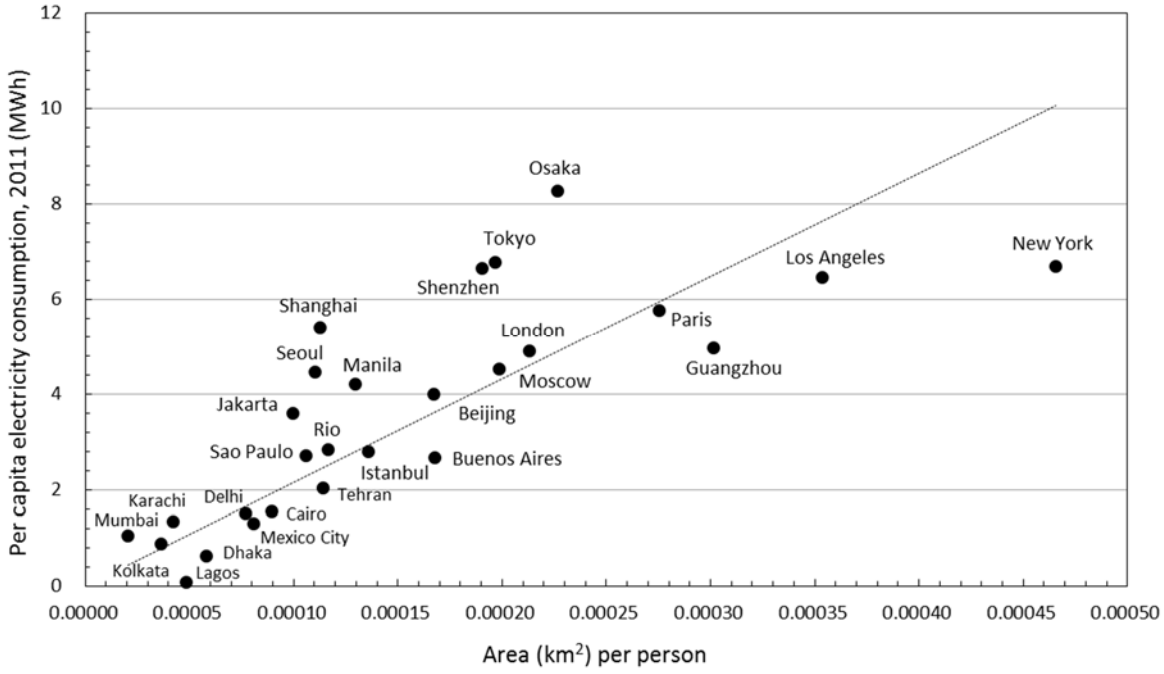

Figure S6. Waste disposal in relation to megacity GDP.

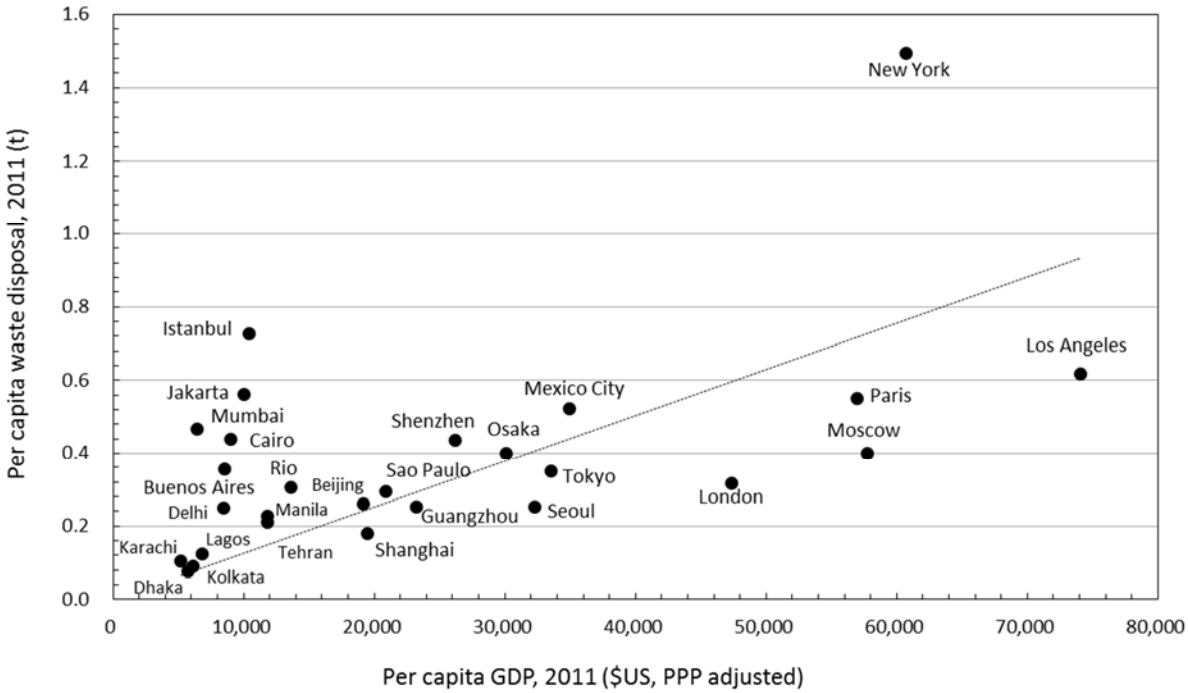

Figure S7. Electricity use in relation to PPP adjusted megacity GDP.

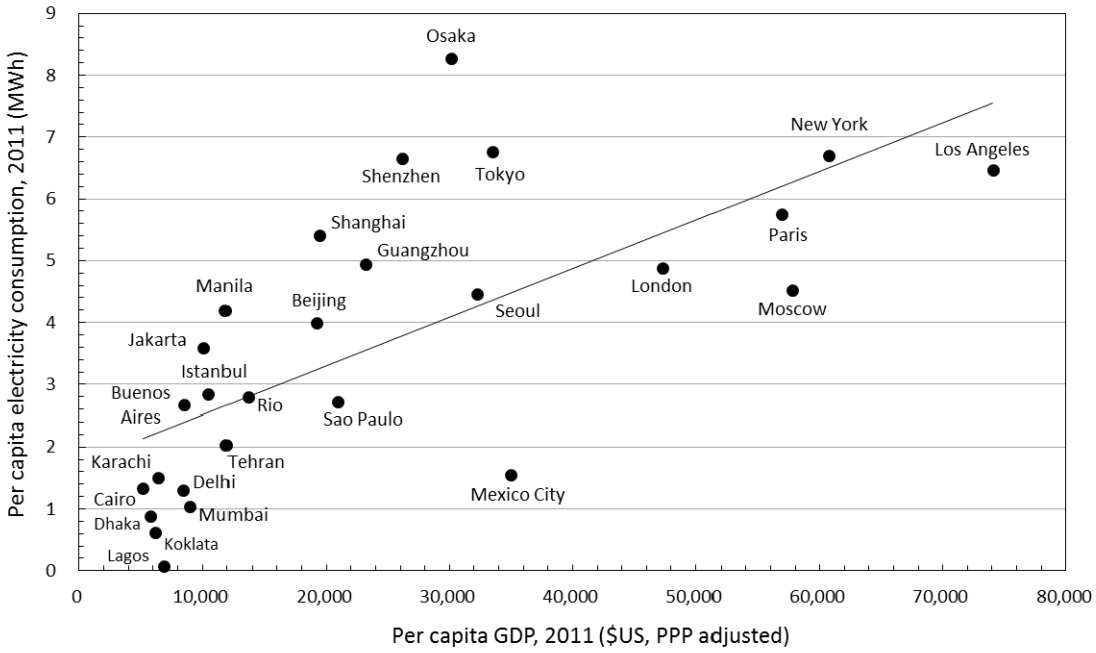

Figure S8. Steel consumption in relation to 10-year population growth.

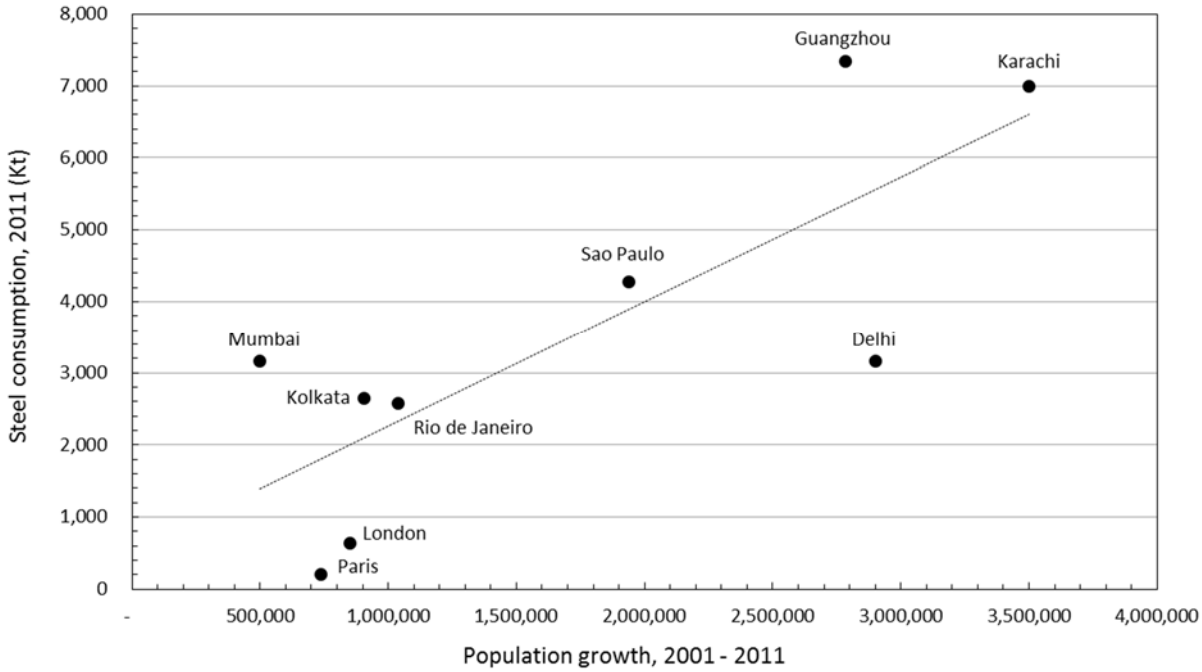

Figure S9. Residential electricity use in the local boroughs of London is weakly correlated with median household income (t= 3.28; P = 0.00267; R^2=0.27).

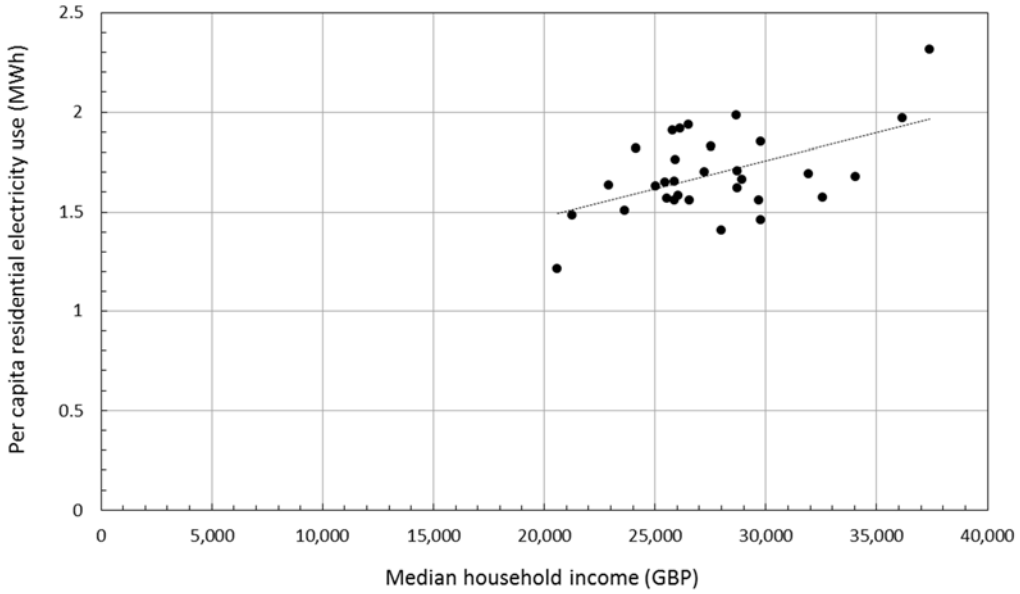

Figure S10. City GDP in relation to urban area per person.

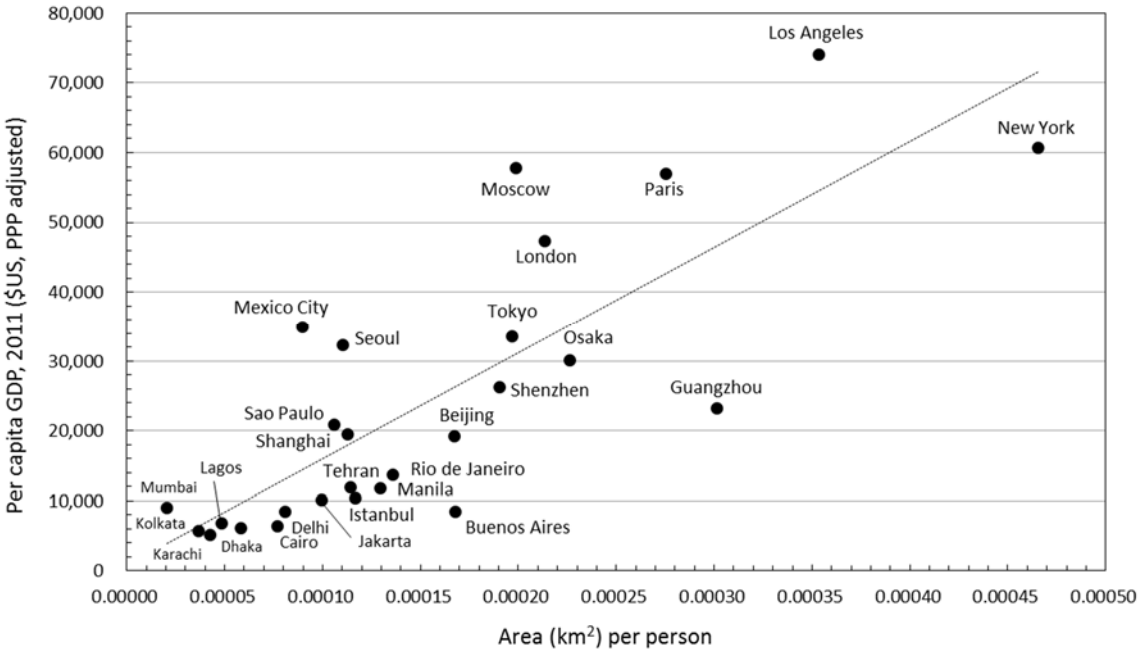

Figure S11. Residential land area per capita has no correlation with median household income for London boroughs.

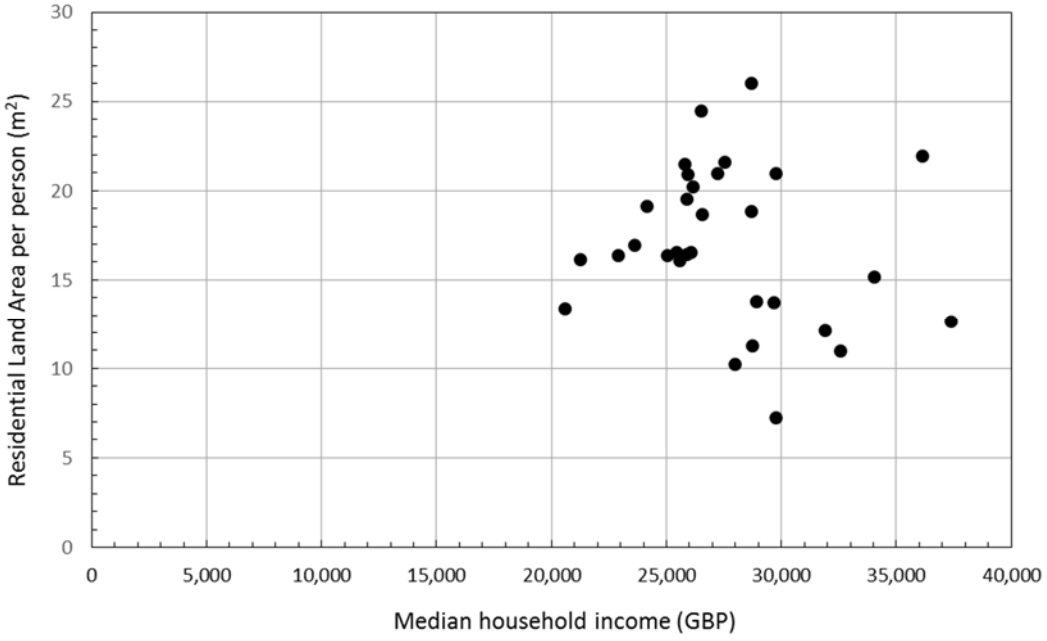

Figure S12. Residential gross floor area per capita correlates with urbanized area per capita.

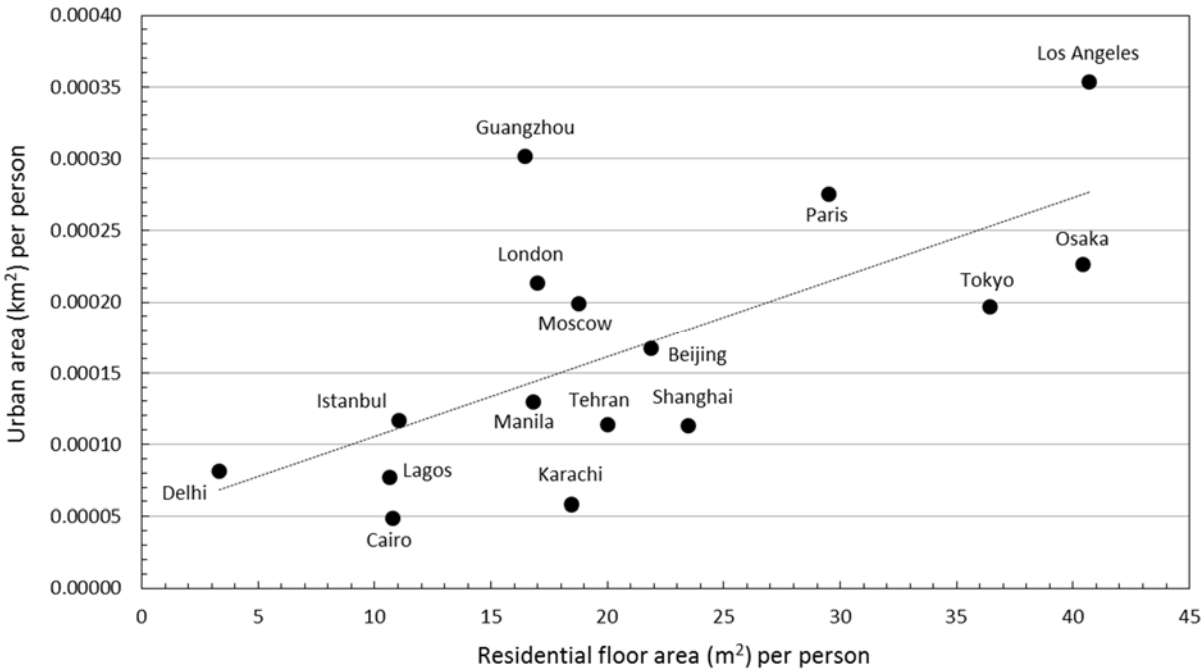

Figure S13. Total building gross floor area per capita correlates with urbanized area per capita.

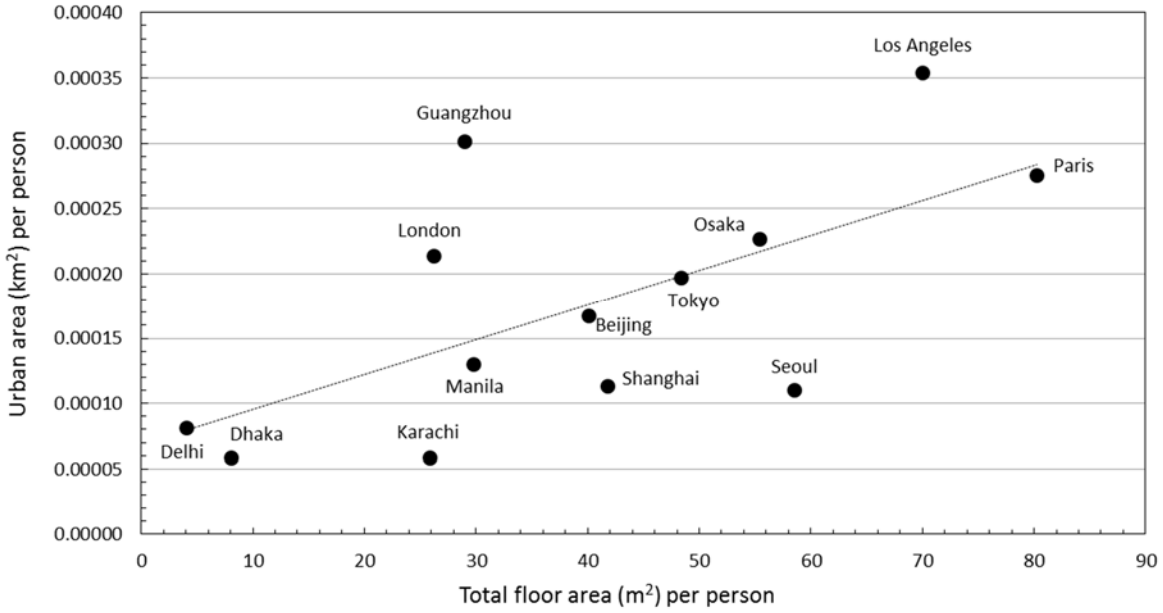

Figure S14. Access to the electricity grid in megacities and per capita electricity consumption (percentage of population without grid access in Lagos is unknown).

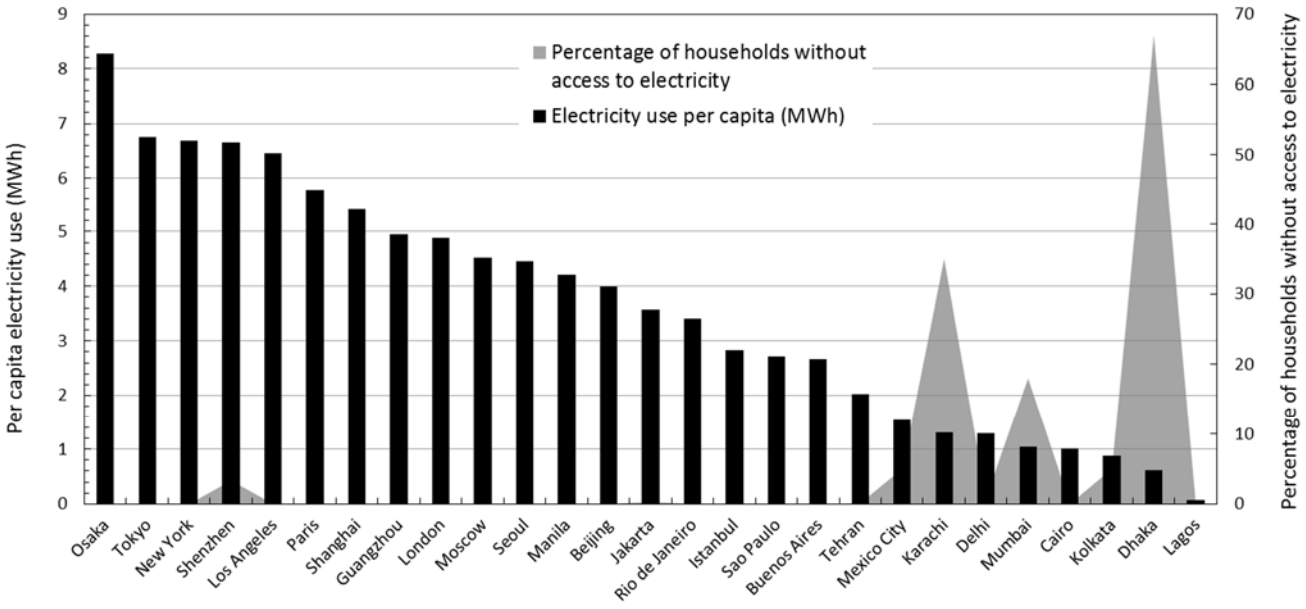

Figure S15. Population growth rates for megacity study areas, 2001 to 2011.

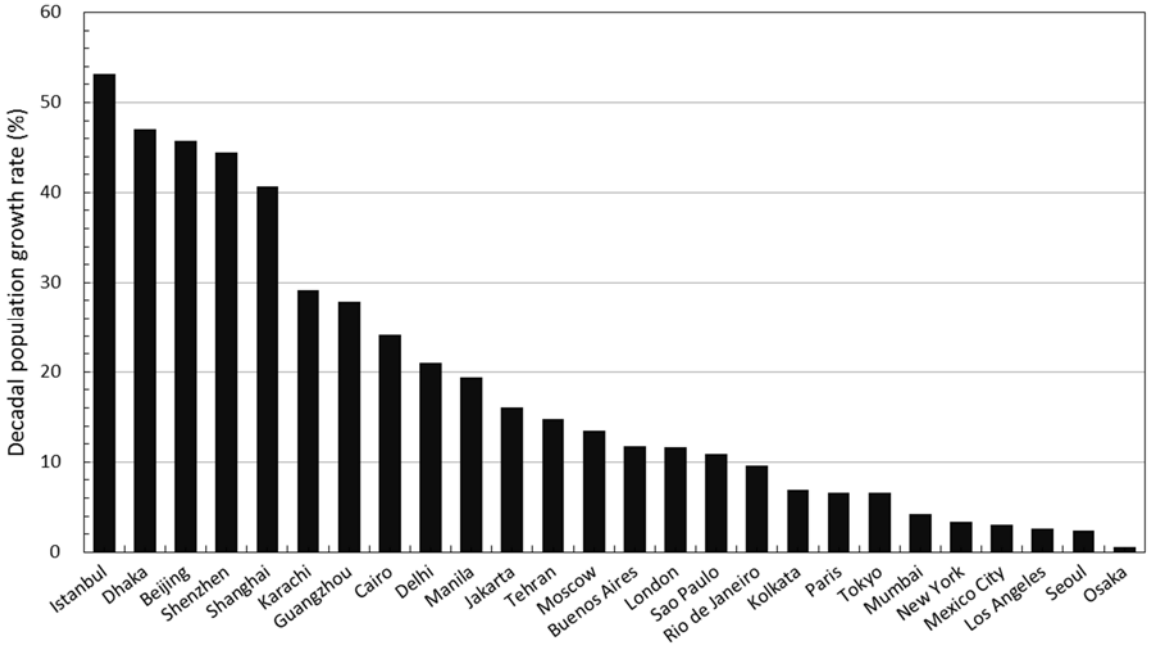

Figure S16. Growth rates for water consumption from 2001 to 2011.

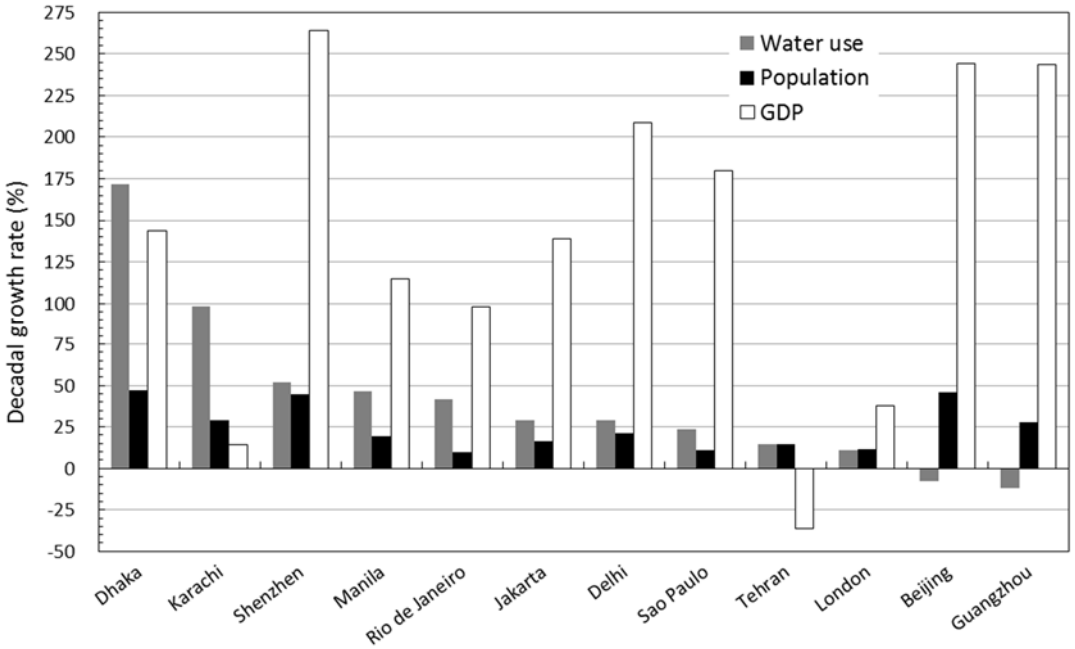

Figure S17. Growth rates for waste disposal from 2001 to 2011

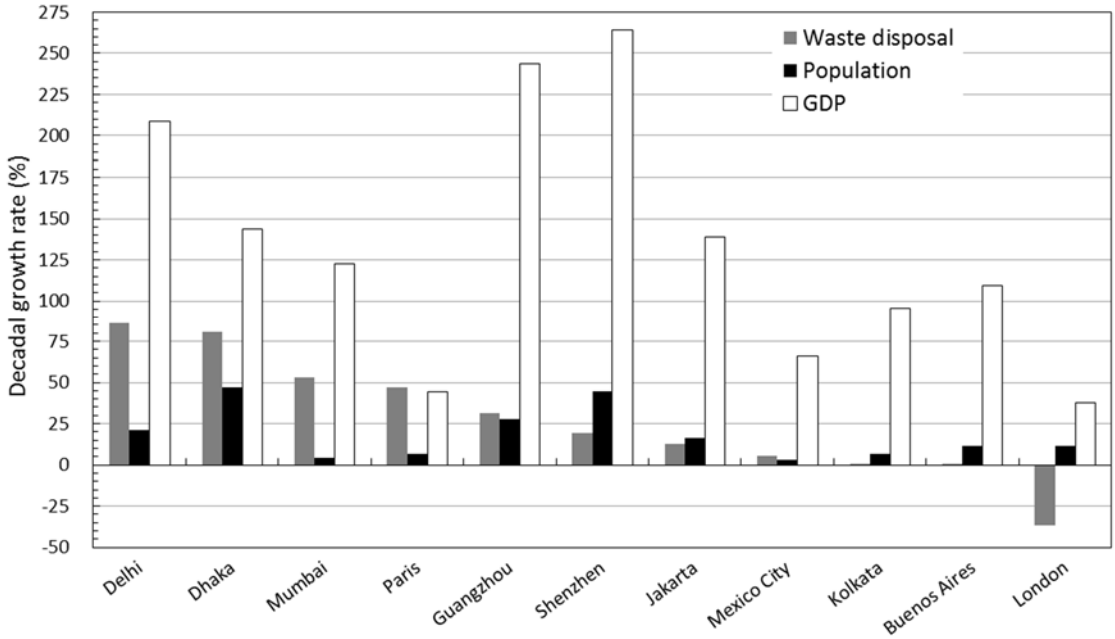

Table S1. Initial trial regression models.

Variable	t Stat	Coefficient	95 % CI
Electricity consumption (R^2 = 0.63; R^2 adjusted = 0.58; n = 27)			
Constant	1.76	0.91	-0.16 to 2.0
Heating-degree-days	0.85	0.0002	-0.0004 to 0.0009
Area per person	3.11	14337.96	4794.93 to 23880.99
GDP	0.34	9.1×10^{-6}	4.70×10^{-5} to 6.52×10^{-5}
Heating and industrial fuels (R^2 = 0.66; R^2 adjusted = 0.61; n = 27)			
Constant	1.14	5.97	-4.78 to 16.71
Heating-degree-days	5.00	0.01	0.009 to 0.02
Area per person	1.05	48586	-46732 to 143903
GDP	-0.40	-0.0001	-0.0007 to 0.0005
Ground transportation fuels (R^2 = 0.63; R^2 adjusted = 0.58; n = 27)			
Constant	0.39	1.04	-4.51 to 6.58
Heating degree days	1.45	0.002	-0.001 to 0.005
Area per person	2.44	57930	8730 to 107130
GDP	0.69	9.69×10^{-5}	-0.0002 to 0.0004
Water consumption (R^2 = 0.58; R^2 adjusted = 0.50; n = 27)			
Constant	-0.83	-56.58	-197.72 to 84.56
GDP	-0.81	-0.002	-0.005 to 0.002
Precipitation	0.68	0.02	-0.04 to 0.08
CDD	0.57	0.04	-0.09 to 0.17
Area per person	4.23	1291425.83	658844.63 to 1924007
Solid waste production (R^2 = 0.60; R^2 adjusted = 0.53; n= 20)			
Constant	2.89	0.20	0.05 to 0.35
GDP	2.78	4.27×10^{-6}	1.01×10^{-6} to 7.53×10^{-6}
10-yr GDP growth rate (%)	3.91	0.001	0.0005 to 0.0017
10-yr pop growth rate (%)	-2.45	-0.006	-0.0113 to -0.0008
Steel consumption (R^2 = 0.80; R^2 adjusted = 0.60; n = 9)			
Constant	1.51	2169.21	-1824 to 6162
10-yr pop growth rate (%)	0.50	113	-508.46 to 734.47
10-yr pop growth (# people)	0.15	0.0003	-0.005 to 0.005
GDP	-1.53	-0.09	-0.26 to 0.08
Area per person	0.76	8841090.86	-2.33×10^{-7} to 4.10×10^{-7}
Cement consumption (R^2 = 0.57; R^2 adjusted = 0.23; n = 10)			
Constant	2.78	7748.31	596.42 to 14900.2
10-yr pop growth rate (%)	-1.19	-282.39	-894.94 to 330.17
10-yr pop growth (# people)	1.08	0.003	-0.004 to 0.009
GDP	0.50	0.09	-0.39 to 0.58
Area per person	-1.02	-41288482.93	-1.45×10^{8} to 6.27×10^{7}

Table S2. Access to services in megacities (all values are percentages).

Megacity	*Households without direct access to water*	*Households without direct access to drinkable water*	*Water line losses as a share of total water consumption*	*Households without sewerage*	*Wastewater subject to treatment*	*Households without public waste collection*	*Households without grid electricity connection*
Mumbai	21	21	3.7	64	94	48	18
Delhi	20	22	40	64	56	n.d.	0.9
Dhaka	7	31	33.1	65	65	10	67
Kolkata	n.d.	39	22	37	24	n.d.	5
Karachi	40	60	40	43	22	40	35
Jakarta	8	24	n.d.	12	n.d.	n.d.	0.3
Cairo	8	19	6.1	23	6	n.d.	n.d.
Tehran	0	0	33.3	55	n.d.	0	0.1
Rio de Janeiro	1	11	54.2	26	32	9	0
São Paulo	2	2	71.4	8	43	5	0
Buenos Aires	11	11	76.1	14	42	5	0
Mexico City	4	n.d.	n.d.	0.5	15	n.d.	5
Guangzhou	0.3	2	n.d.	15	4	1	15
Shenzhen	5	6	n.d.	30	20	1	15
Shanghai	0	0.6	15	10	14	1	0
Beijing	0	0.3	15.3	5	5	0	0
Lagos	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

***** n.d. = no data

2. Correction for Multiple Inferences

As we established six regression models from a single data set we conducted a second analysis correcting for possible simultaneous statistical inferences. A correlation matrix was calculated for interactions between all variables, and the associated p-values were calculated. The p-values were then corrected for multiple inference using the Benjamini & Hochberg approach. Results using the final set of variables (as in Table 1) are shown in the supplementary materials. With the Benjaminin & Hochberg correction, all variables in the six regression models are found to be valid, except for the GDP growth variable in the solid waste production model. The correlation matrix also shows significant variables that are dropped in the step-wise regression. In particular, GDP and area per person are significant in most of the models, when the correction is applied. As these two variables are highly correlated (ρ=0.8), one of them usually gets eliminated in the step-wise regression. Overall, the regression models shown in Table 1 stand up well to examination for simultaneous inference when using the Benjaminin & Hochberg correction.

Correlations

	Electricity Cons.	Heating & Indust. Fuel	Transp. fuel	Water Cons.	Solid Waste	Steel Cons.	Heating Degree Days	Area per pers.	GDP	10-yr GDP growth rate
Electricity consumption (MWh)	-									
Heating & industrial fuel (GJ)	0.40	-								
Transportation fuel (GJ)	0.61	0.70	-							
Water consumption (kL)	0.51	0.51	0.69	-						
Solid waste prod (t)	0.44	0.23	0.57	0.45	-					
Steel consumption (Kt)	-0.28	0.03	-0.07	0.47	-0.55	-				
Heating degree days	0.45	0.59	0.50	0.17	0.27	-0.60	-			
Area (km2) per person	0.78	0.60	0.79	0.72	0.68	-0.12	0.42	-		
GDP ($)	0.68	0.41	0.68	0.46	0.55	-0.57	0.58	0.80	-	
10-yr GDP growth rate	0.09	-0.13	-0.18	0.12	0.37	0.43	0.15	-0.02	-0.21	-
10-yr pop growth (# people)	-0.08	0.07	-0.15	0.05	-0.31	0.79	0.06	-0.27	-0.43	0.52

p-values (No correction)

	Electricity Cons.	Heating & Indust. Fuel	Transp. fuel	Water Cons.	Solid Waste	Steel Cons.	Heating Degree Days	Area per pers.	GDP	10-yr GDP growth rate
Electricity consumption (MWh)	-									
Heating & industrial fuel (GJ)	**0.042**	-								
Transportation fuel (GJ)	**0.001**	**0.000**	-							
Water consumption (kL)	**0.006**	**0.008**	**0.000**	-						
Solid waste prod (t)	**0.025**	0.260	**0.002**	**0.020**	-					
Steel consumption (Kt)	0.472	0.941	0.854	0.205	0.125	-				
Heating degree days	**0.018**	**0.002**	**0.008**	0.401	0.180	0.087	-			
Area (km2) per person	**0.000**	**0.001**	**0.000**	**0.000**	**0.000**	0.755	**0.028**	-		
GDP ($)	**0.000**	**0.037**	**0.000**	**0.015**	**0.004**	0.106	**0.001**	**0.000**	-	
10-yr GDP growth rate	0.711	0.572	0.427	0.616	0.097	0.247	0.518	0.928	0.364	-
10-yr pop growth (# people)	0.706	0.767	0.500	0.836	0.148	**0.011**	0.800	0.207	**0.041**	**0.015**

p-values (Benjamini & Hochberg Correction)										
	Electricity Cons.	Heating & Indust. Fuel	Transp. fuel	Water Cons.	Solid Waste	Steel Cons.	Heating Degree Days	Area per pers.	GDP	10-yr GDP growth rate
Electricity consumption (MWh)	-									
Heating & industrial fuel (GJ)	0.083	-								
Transportation fuel (GJ)	**0.004**	**0.001**	-							
Water consumption (kL)	**0.021**	**0.024**	**0.001**	-						
Solid waste prod (t)	0.058	0.376	**0.010**	**0.048**	-					
Steel consumption (Kt)	0.619	0.941	0.886	0.316	0.214	-				
Heating degree days	**0.046**	**0.006**	**0.024**	0.552	0.291	0.165	-			
Area (km2) per person	**0.000**	**0.006**	**0.000**	**0.000**	**0.001**	0.844	0.062	-		
GDP ($)	**0.001**	0.078	**0.001**	**0.040**	**0.013**	0.189	**0.006**	**0.000**	-	
10-yr GDP growth rate	0.814	0.700	0.573	0.737	0.179	0.368	0.647	0.941	0.513	-
10-yr pop growth (# people)	0.814	0.844	0.640	0.885	0.247	**0.031**	0.862	0.316	0.083	**0.040**

3. Definition and Notes on Megacities

* Brinkoff's populations for 2010 are given in parentheses.
**GDP values are in PPP adjusted US dollars for 2011

London

- Study area population: 8,173,941 (Megacity: 12,400,000)
- Per capita GDP: 47,333
- Constituent cities: Camden, Greenwich, Hackney, Hammersmith and Fulham Islington, Royal Borough of Kensington and Chelsea, Lambeth, Lewisham, Southwark, Tower Hamlets, Wandsworth, Westminster, Barking and Dagenham, Barnet, Bexley, Brent, Bromley, Croydon, Ealing, Enfield, Haringey, Harrow, Havering, Hillingdon, Hounslow, Kingston upon Thames, Merton, Newham, Redbridge, Richmond upon Thames, Sutton, Waltham Forest, City of London

Paris

- Study area population: 11,852,851 (Megacity:10,400,000)
- Per capita GDP: 56,943
- Constituent cities: Paris, Seine-et-Marne, Yvelines, Essonne, Hauts-de-Seine, Seine-Saint-Denis, Val-de-Marne, Val-d'Oise
- Mobile energy consumption values for 2006 were substituted for 2011.

Moscow

- Study area population: 11,503,501 (Megacity: 13,600,000)
- Per capita GDP: 57,758
- Constituent cities: Central Borough, Northern Borough, North-Eastern Borough, Eastern Borough, South-Eastern Borough, Southern Borough, South-Western Borough, Western Borough, North-Western Borough, Zelenograd Borough
- Solid waste generation for 2011 is estimated to be 400 kg per person per year, 13 percent of which is incinerated and the remainder sent to landfill (*Future Watch Report*, 2013).
- Heating and industrial fuel consumption data were scaled by population from national to megacity level (values represent heating component of combined heat and power system)

New York City

- Study area population: 22,214,518 (Megacity: 22,200,000)
- Per capita GDP: 60,751
- Constituent cities: New York City (Bronx, Brooklyn, Manhattan, Queens and Staten Island); West Connecticut (Fairfield, Litchfield and New Haven counties); North New Jersey (Bergen, Essex, Hudson, Hunterdon, Mercer, Middlesex,

Monmouth, Morris, Ocean, Passaic, Somerset, Sussex, Union and Warren counties), Long Island (Nassau and Suffolk counties); Mid-Hudson region (Dutchess, Orange, Putnam, Rockland, Sullivan, Ulster and Westchester counties)
- Energy consumption data were scaled by population (from 20,314,077 people to 22,214,518 people)
- New Jersey energy consumption data for 2006 were used in the total energy consumption calculation for New York Metropolitan region for 2011

Los Angeles

- Study area population: 9,889,000 (Megacity: 17,900,000)
- Per capita GDP: 74,045
- Constituent cities: Los Angeles, Pasadena, Santa Monica, Monrovia, Pomona, Long Beach, South Pasadena, Compton, Redondo Beach, Whittier, Azusa, Covina, Alhambra, Arcadia, Vernon, Glendale, Huntington Park, La Verne, Hermosa Beach, Sierra Madre, Claremont, Inglewood, Burbank, San Fernando, Glendora, El Monte, Manhattan Beach, San Gabriel, San Marino, Avalon, Beverly Hills, Monterey Park, El Segundo, Culver City, Montebello, Torrance, Lynwood, Hawthorne, South Gate, West Covina, Signal Hill, Maywood, Bell, Gardena, Palos Verdes Estates, Lakewood, Baldwin Park, Cerritos, La Puente, Downey, Rolling Hills, Paramount, Santa Fe Springs, Industry, Bradbury, Irwindale, Duarte, Norwalk, Bellflower, Rolling Hills Estates, Pico Rivera, South El Monte, Walnut, Artesia, Rosemead, Lawndale, Commerce, La Mirada, Temple City, San Dimas, Cudahy, Bell Gardens, Hidden Hills, Palmdale, Hawaiian Gardens, Lomita, Carson, Rancho Palos Verdes, La Cañada-Flintridge, Lancaster, La Habra Heights, Westlake Village, Agoura Hills, West Hollywood, Santa Clarita, Diamond Bar, Malibu, Calabasas
- Stationary energy consumption data (excluding electricity) were scaled by population from state (California) to megacity level
- Mobile energy consumption data for diesel and jet fuel were scaled by population from state (California) to megacity level

Mexico City

- Study area population: 8,851,080 (Megacity: 23,400,000)
- Per capita GDP: 34,973
- Constituent cities: Azcapotzalco, Coyoacán, Cuajimalpa de Morelos, Gustavo A. Madero, Iztacalco, Iztapalapa, La Magdalena Contreras, Milpa Alta, Álvaro Obregón, Tláhuac, Tlalpan, Xochimilco, Benito Juárez, Cuauhtémoc, Miguel Hidalgo, Venustiano Carranza, Tizayuca, Acolman, Amecameca, Apaxco, Atenco, Atizapán de Zaragoza, Atlautla, Axapusco, Ayapango, Coacalco de Berriozábal, Cocotitlán, Coyotepec, Cuautitlán, Chalco, Chiautla, Chicoloapan, Chiconcuac, Chimalhuacán, Ecatepec de Morelos, Ecatzingo, Huehuetoca, Hueypoxtla, Huixquilucan, Isidro Fabela, Ixtapaluca, Jaltenco, Jilotzingo, Juchitepec, Melchor Ocampo, Naucalpan de Juárez, Nezahualcóyotl, Nextlalpan, Nicolás Romero, Nopaltepec, Otumba, Ozumba, Papalotla, La Paz, San Martín de

las Pirámides, Tecámac, Temamatla, Temascalapa, Teotihuacán, Tepetlaoxtoc, Tepetlixpa, Tepotzotlán, Tequixquiac, Texcoco, Tezoyuca, Tlalmanalco, Tlalnepantla de Baz, Tultepec, Tultitlán, Villa del Carbón, Zumpango, Cuautitlán Izcalli, Valle de Chalco, Solidaridad, Tonanitla

- Stationary energy consumption data (excluding electricity) were scaled by population from national to megacity level
- Jet fuel data were scaled by population from national to megacity level

Lagos

- Study area population: 20,546,999 (Megacity: 11,800,000)
- Per capita GDP: 6,834
- Constituent cities: Agege, Ajeromi-ifelodun, Alimosho, Amuwo Odofin, Apapa Badagry, Epe, Eti-osa
- Stationary energy (excluding electricity) and mobile energy consumption data were scaled by population from national to megacity level

Sao Paulo

- Study area population: 19,822,559 (Megacity: 20,900,000)
- Per capita GDP: 20,916
- Constituent cities: Arujá, Barueri, Biritiba Mirim, Caieiras, Cajamar, Carapicuiba, Cotia, Diadema, Embu das Artes, Embu-Guaçu, Ferraz de Vasconcelos, Francisco Morato, Franco da Rocha, Guararema, Guarulhos, Itapevi, Itapecerica da Serra, Itaquaquecetuba, Jandira, Juquitiba, Mairiporã, Mauá, Mogi das Cruzes, Osasco, Pirapora do Bom Jesus, Poá, Ribeirão Pires, Rio Grande da Serra, Salesópolis, Santa Isabel, Santana de Parnaíba, Santo André, São Bernardo do Campo, São Caetano do Sul, São Lourenço da Serra, São Paulo, Suzano, Taboão da Serra, Vargem Grande Paulista

Rio de Janeiro

- Study area population: 11,909,897 (Megacity: 12,600,000)
- Per capita GDP: 13,653
- Constituent cities: Belford Roxo, Duque de Caxias, Guapimirim, Itaboraí, Itaguaí, Japeri, Magé, Maricá, Mesquita, Nilópolis, Niterói, Nova Iguaçu, Paracambi, Queimados, Rio de Janeiro, São Gonçalo, São João de Meriti, Seropédica e Tanguá

Buenos Aires

- Study area population: 12,806,866 (Megacity: 13,300,000)
- Per capita GDP: 8,503
- Constituent cities: Almirante Brown, Avellaneda, Berazategui, Esteban Echeverría, Ezeiza, Florencio Varela, General San Martín, Hurlingham, Ituzaingó, José C. Paz, La Matanza, Lanús, Lomas de Zamora, Malvinas Argentinas, Merlo,

Moreno, Morón, Quilmes, San Fernando, San Isidro, San Miguel, Tigre, Tres de Febrero, Vicente López

Cairo

- Study area population: 20,495,461 (Megacity: 15,200,000)
- Per capita GDP: 6,440
- Constituent cities: Cairo Governorate, the urban parts of Giza Governorate, and Qaliubia Governorate
- Wastewater volumes for 2006 and 2011 include sewerage and industrial waste.
- Electricity consumption data were scaled by number of customers from national to megacity level

Tehran

- Study area population: 12,183,391 (Megacity: 12,800,000)
- Per capita GDP: 11,860
- Constituent cities: Boomehen, Pardis, Firuzkooh, Varamin, Shahriar, Islamshahr, Robatkarim, Damavand, Pakdasht, Karaj, Nesa, and Savejbolagh
- Water consumption values are based on an estimated consumption rate of 250 litres per day
- Electricity line losses are estimated to be 15 % of electricity consumption values
- Water line losses are estimated to be 25 % of water consumption values

Istanbul

- Study area population: 13,483,052 (Megacity: 12,800,000)
- Per capita GDP: 10,444
- Constituent cities: Adalar, Arnavutköy, Ataşehir, Avcılar, Bakırköy, Beylikdüzü, Beykoz, Beşiktaş, Beyoğlu, B.Evler, B.Paşa, Başakşehir, Bağcılar, B.Çekmece, Çatalca, Çekmeköy, Esenyurt, Eyüp, Esenler, Fatih, G.O.Paşa, Güngören, Kadıköy, Kartal, K.Çekmece, Kağıthane, Maltepe, Pendik, Sancaktepe, Sarıyer, Sultangazi, Sultanbeyli, Şişli, Şile, Silivri, Tuzla, Ümraniye, Üsküdar, Zeytinburnu

Manila

- Study area population: 11,855,975 (Megacity: 19,600,000)
- Per capita GDP: 11,788
- Constituent cities: Caloocan, Malabon, Navotas, Valenzuela, Quezon City, Marikina, Pasig, Taguig, Makati, Manila, Mandaluyong, San Juan, Pasay, Parañaque, Las Piñas, Muntinlupa
- Mobile energy consumption data were scaled by population from national to megacity level

Jakarta

- Study area population: 9,786,372 (Megacity: 15,400,000)
- Per capita GDP: 10,040
- Constituent cities: Central Jakarta (Jakarta Pusat), North Jakarta (Jakarta Utara), East Jakarta (Jakarta Timur), South Jakarta (Jakarta Selatan), West Jakarta (Jakarta Barat), Thousand Islands (Kepulauan Seribu)
- When converting solid waste units from volume to mass, one cubic metre of waste is assumed to be equivalent to 600 kg
- Fuel oil consumption values for 2006 were substituted for 2011
- Mobile energy consumption values (excluding gasoline and diesel) for 2006 were substituted for 2011

Delhi

- Study area population: 16,753,235 (Megacity: 23,200,000)
- Per capita GDP: 8,443
- Constituent cities: Municipal Corporation of Delhi, New Delhi Municipal Corporation, Delhi Cantonment Board
- It is estimated that line losses for water are 40 % of water consumption values

Mumbai

- Study area population: 12,478,447 (Megacity: 22,800,000)
- Per capita GDP: 8,971
- Constituent cities: Greater Mumbai, Navi Mumbai, Thane, Kalyan-Dombivali, Vasai-Virar, Mira-Bhayandar, Bhiwandi-Nizampur, Ulhasnagar
- Electricity line losses are estimated to be 15 % of electricity consumption values
- Water line losses are estimated to be 20 % of water consumption values (Reddy, 2013)

Kolkata

- Study area population: 14,112,536 (Megacity: 16,300,000)
- Per capita GDP: 5,765
- Constituent cities: Kolkata Municipal Corporation, Howrah Municipal Corporation, Chandan nagar Municipal Corporation
- GDP values for 2011 were scaled by the national cumulative GDP growth rate (2000 to 2009)
- Water consumption values include private water tapping (which has no proper accounting) and are therefore said to be unreliable

Karachi

- Study area population: 15,500,000 (Megacity: 16,200,000)
- Per capita GDP: 5,161

- Constituent cities: Bin Qaism, Gadap, Malir, Gulberg, Liaquatabad, North Karachi, North Nazimabad, Jamshed, Lyari, Saddar, Baldia, Kemari, Orangi, Site, Gulshan, Korangi, Landhi, Shah Faisal
- Stationary energy (excluding electricity) and mobile energy consumption data were scaled by population from national to megacity level

Dhaka

- Study area population: 15,616,562 (Megacity: 13,600,000)
- Per capita GDP: 6,139
- Constituent cities: Dhaka City Corporation (North), Dhaka City Corporation (South), Narayangonj, Savar, Gazipur, Tongi
- Stationary energy consumption data (excluding electricity) were scaled by GDP from national to megacity level
- Mobile energy consumption data were scaled by population from national to megacity level
- Building materials data were scaled by population from national to megacity level

Seoul

- Study area population: 10,528,774 (Megacity: 24,200,000)
- Per capita GDP: 32,261
- Constituent cities: Dobong, Dongdaemun, Dongjak, Eunpyeong, Gangbuk, Gangdong, Gangnam, Gangseo, Geumcheon, Guro, Gwanak, Gwangjin, Jongno, Jung, Jungnang, Mapo, Nowon, Seocho, Seodaemun, Seongbuk, Seongdong, Songpa, Yangcheon, Yeongdeungpo, Yongsan

Tokyo

- Study area population: 35,622,000 (Megacity: 34,000,000)
- Per capita GDP: 33,521
- Constituent cities: Tokyo, Kanagawa, Chiba and Saitama prefectures
- Water consumption data were scaled by population from metropolitan to megacity level
- Solid waste data were scaled by population from metropolitan to megacity level

Osaka

- Study area population: 17,089,000 (Megacity: 16,800,000)
- Per capita GDP: 30,124
- Constituent cities: Osaka, Kyoto, and Hyogo prefectures
- Water consumption data were scaled by population from metropolitan to megacity level
- Solid waste data were scaled by population from metropolitan to megacity level
- Solid waste disposal on land includes residue from incineration.

Shenzhen

- Study are population: 10,467,400 (Megacity: 10,400,000)
- Per capita GDP: 26,171
- Constituent cities: Futian, Luohu, Nanshan, Yantian, Baoan, and Longgang districts
- Heating and industrial fuels, and ground transportation fuels use scaled from provincial values.Mobile energy data for jet fuel include marine fuel

Guangzhou

- Study area population: 12,751,400 (Megacity: 16,500,000)
- Per capita GDP: 23,197
- Constituent cities: Yuexiu Area, Haizhu Area, Liwan Area, Tianhe Area, Baiyun Area, Huangpu Area, Huadu Area, Panyu Area, Luogang Area, Nansha Area, Conghua City, Zengcheng City
- All diesel oil is assumed to be used for transportation, although it is possible that some diesel is used for stationary energy

Shanghai

- Study area population: 23,474,600 (Megacity 18,400,000)
- Per capita GDP: 19,470
- Constituent cities: Pudong New District, Xuhui District, Changning District, Putuo District, Zhabei District, Hongkou District, Yangpu District, Huangpu District, Luwan District, Jingan District, Baoshan District, Minhang District, Jiading District, Jinshan District, Songjiang District, Qingpu District, Nanhui District, Fengxian District, Chongming County
- All diesel oil is assumed to be used for transportation, although it is possible that some diesel is used for stationary energy
- Mobile energy data for gasoline and diesel include jet and marine fuel

Beijing

- Study area population: 20,186,000 (Megacity: 13,600,000)
- Per capita GDP: 19,169
- Constituent cities: Dongcheng District, Xicheng District, Chaoyang District, Haidian District, Fengtai District, Shijingshan District, Mentougou District, Fangshan District, Daxing District, Tongzhou District, Shunyi District, Changping District, Pinggu District, Huairou District, Miyun County, Yanqing County
- All diesel oil is assumed to be used for transportation, although it is possible that some diesel is used for stationary energy
- Mobile energy data for gasoline and diesel include jet fuel

4. References

1. Kennedy CA, Ibrahim N, Stewart I, Facchini A, Mele R (2014) Developing a multi-layered indicator set for urban metabolism studies in megacities, Ecological Indicators, 47, 7-15.
2. City Population, http://www.citypopulation.de/world/Agglomerations.html, accessed April 1, 2013