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ABSTRACT

The original goal of the research presented here was to quantify by world region, the contribution of urbanized areas to global greenhouse gas (GHG) emissions (EDGAR, 2011). Regressions on population density and growth rate, GDP, and heating/cooling degree days, as well as a row of other non-significant variables, show that the contribution of urban extents is between 38% and 49% of total emissions (Marcotullio et al., 2012). In spite of using very liberal definitions of urban extents (GRUMP, 2011) this is at the low end of academic estimates (Satterthwaite, 2008; WEO, 2008; Dhakal, 2010). It is no surprise that the relative weight of individual variables varies by world region and economic development. We were, however, very surprised to find that around the world, the highest levels of GHG emissions are in a belt 20-40 km around urban centres. This result is consistent using both traditional fixed-effects and spatial regression techniques, which will be discussed in detail in this paper. There are variations (e.g. the role of African suburbs is smaller than that of their Asian and European counterparts) but the signature prevails. We suggest that this has consequences for both planning and geography theory as well as for policy. In spite of globalization, we have very few local indicators that are so consistently the same across cultures, economic and physical regimes. On a practical level, our results are an urgent reminder that cities by and large are rather efficient constructs while the biggest impacts on minimizing GHG emissions can be achieved by optimizing suburban energy use and transport.

1 GLOBAL GREENHOUSE GAS EMISSIONS AND REGIONAL PLANNING

Global greenhouse gas (GHG) emissions are a major driver of global warming, which has been recognized by the United Nations and many national governments as a significant threat to mankind (UN, 2004). While some emissions are the result of natural processes, the far majority of those that we observe today are caused by manmade land use and production processes (Griggs et al., 2013). There is little doubt that policies to reduce GHG emissions are necessary; however, past research has concentrated on countries (Cole and Neumayer, 2004; Shi, 2003), and to a lesser extent on the role of cities and urbanized areas (Romero-Lankao, et al. 2009; Parshall, et al. 2010; Kennedy, et al. 2011).

1.1 Urban Greenhouse Gas Emissions

Carbon dioxide (CO_2) was recognized early on as a main driver of global warming (EPA, 2013) and as manmade CO_2 is the product of heating (or cooling) and transportation, it is understandable that cities with their concentration of housing and people movements became the centre of research attention. While actual measurements are sparse, the literature is full of estimates that put cities and urbanized areas at 50% to 70% (and more) of all GHG emissions worldwide (Satterthwaite, 2008). Most of these studies are extreme extrapolations or back-of-the-envelope calculations based on untested assumptions.

Part of the problem is the vagueness in terminology and lack of actual empirical data, especially when it comes to the inclusion of other more potent GHGs and an exhaustive enumeration of all the sectors recognized by the IPCC (2007) as contributing to global warming.

The availability of a new data set compiled by the Joint Research Centre (EDGAR, 2011), prompted the authors of the research presented here to investigate the role of urbanized areas in general (Marcotullio et al., 2011) and by sector (Marcotullio et al., 2013). One of the surprise results of that research is that no matter how one defines urbanized areas, there is a ring of 20-40 km around them that showed significantly higher rates of GHG emissions than expected. Although there are regional differences, this phenomenon showed consistently around the world and prompted a refocusing on the role of suburbs.

1.1.1 The Underreported Role of Suburbia

Urban planners are well familiar with the notion of environmental externalities of suburban lifestyles and have been advocating for compact neighbourhoods and urban intensification Dempsey, 2010; Mindali, Raveh, and Salomon, 2004; Neuman, 2005). Beyond energy and hence CO_2 emissions savings in the transportation sector, there have however been virtually no studies looking into the contribution of suburbs to the overall GHG emissions budget.

2 APPROACH

2.1 Greenhouse Gas Emissions Data

This research has been enabled by the availability of a relatively new unique dataset of urban greenhouse gas emissions from the Emissions Database for Global Atmospheric Research (EDGAR), version 4.1. EDGAR compiled national-level emissions inventory data for the major greenhouse gases covered by the Kyoto Protocol, across fifty source categories. EDGAR spatially-allocated the national-level emissions inventory data to global grids with a spatial resolution of 0.1 degree, using various algorithms based on source category. For instance, the EDGAR team spatially allocated national emissions from road transportation according to a road network density map; aviation emissions were spatially allocated according to prevalent flight patterns across four altitude layers (take-off and landing, climbing and descent, cruising, and supersonic); and non-road and domestic navigation emissions were spatially allocated according to population density maps. Thus, the EDGAR gridded emissions data represent modelled values rather than observed measurements and their methodology introduces uncertainty and likely measurement bias discussed in detail at Marcotullio et al. (2012).

We use the global gridded emissions datasets for the year 2000 for the four most significant GHGs globally: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and sulphur hexafluoride (SF6). We convert emissions by gas from their original units into metric tons of carbon dioxide equivalents (CO2e), using the IPCC's 4th Assessment 100-year global warming potentials.

2.2 Urban / Suburban Boundaries

Identifying the exact urban boundaries for measurement is of particular importance in generating measurements that represent conceptually comparable spheres of economic and social activity. For comparative international studies, the definition of urban creates challenges, as countries define "urban" in different ways (see for example, United Nations, 2010) and obtaining relevant and comparable data at similar "urban" geographies is difficult.
Urban GHG studies use a number of fundamentally different urban definitions. Urban analysts sometimes restrict measurements to political or administrative borders of a

municipality, often to help in sustainability or climate change action plans (City of Sydney, 2008). Such approaches risk missing important drivers of energy demand that are outside of their administrative boundaries. In the USA, some researchers suggest that the county is the best definition for urban, as it matches policy maker needs and is the smallest unit for which energy data are collected (Parshall et al., 2010). Other studies open analysis to the wider metropolitan region (Chicago Climate Task Force, 2008) or use urban agglomerations as the geographic boundary for GHG emission inventories (Brown et al., 2008).

Studies of GHG emissions from cities often focus on the large urban centres such as New York, Tokyo, London, Paris, Delhi, Sao Paulo, and Barcelona. This trend has emerged partially because data for these cities are readily available, often based on inventories compiled to address air quality concerns. Some authors suggested that larger cities are disproportionate contributors of GHG emissions globally (Dhakal, 2009). Nevertheless, results restricted to large cities may be misleading for policy, as most of the world's urban population lives in smaller urban centres and smaller urban areas typically face more intense environmental challenges than larger cities (Satterthwaite, 2007; Hardoy et al., 2001).

Many emissions inventories focus on emissions from activities located within the spatially defined study area, known as ‘‘direct’’ emissions (Dodman, 2009; Gurney et al., 2009). Alternatively, measurements may also include activities and resulting emissions located outside the local jurisdiction, but closely related to economic activities that are conducted within the jurisdiction, known variously as ‘‘indirect’’ or ‘‘deemed’’ emissions (Lebel et al., 2007). For instance, power production and waste disposal may be conducted outside of cities but relate to the energy and waste disposal needs of urban residents and businesses.

The World Resources Institute together with the World Business Council for Sustainable Development (WRI/WBCSD) have prepared a reporting protocol for corporations (WBCSD and WRI, 2004), which is used by researchers examining urban GHG emissions (Kennedy et al., 2009a). The protocol distinguishes between three scopes of emissions. Scope 1 emissions are those from sources under the direct control of the organization, such as finances, factories or vehicles. In the urban context, Scope 1 emissions are typically produced within the geographical boundary of the city. Scope 2 emissions are from energy consumed by the organization, where the emissions are produced elsewhere. In the urban context, Scope 2 emissions include releases outside the geographical boundary of the city that relate to energy consumption within the city, including electricity and district heat. Scope 3 emissions, also called upstream or embodied emissions, are associated with extraction, production and transportation of products or services used in urban activities. These emissions include those from waste, aviation and marine transport, and embodied in fuel, food, building material, and water.

The notions of Scopes 2 and 3 suggest that emission estimates should be consumption based. That is, researchers argue that reliable carbon ‘footprints’ not only identify where GHG emissions are produced, but where goods and services that create the emissions are consumed (Bader and Bleischwitz, 2009; Dhakal, 2010). In response to these concerns, researchers argue that urban GHG inventories should, at least, include emissions from thermal power plants located outside urban areas (Kennedy et al., 2011), which would translate into a Scope 2 analysis. Scope 3 analysis would additionally require researchers to not only include the upstream emissions embodied in goods and services imported and consumed within the city, but also to subtract those emissions of exported goods and services consumed elsewhere, to balance the net-effect of trade and avoid double counting of emissions. Methodologies for such analysis include material flow analysis, life cycle analysis, and extended input–output analysis but are virtually impossible today at a global scale and fine-grained individual urban / suburban area resolution.

While urban areas are major contributors to climate change, there is a large variation in GHG emissions among cities. Some of the variation is due to urban factors or those related directly to the urban area (population size, density and growth rate). Several studies emphasize various features of cities and their impact on energy consumption and GHG emissions (Sadownik and Jaccard, 2001; Lefevre, 2009; Permana et al., 2008; Li, 2011; Lebel et al., 2007).

For the purpose of this study, the world has been divided into five categories of land use; (1) core urban areas, (2) urbanized areas according to GRUMP, (3) a 10 km buffer around the GRUMP area designated as an inner ring of suburbs, (4) another 10 km buffer around that inner ring to form an outer ring of suburbs, and finally (5) the remaining land area that is clearly neither urban nor suburban in land use, i.e., either rural or uninhabited. The core city data has been compiled by the Dutch company AND International Publishers and is distributed by ESRI as part of their ArcGIS software. It uses the legal boundaries of villages, towns and cities but excludes internal water bodies, parks, and other uninhabited areas. GRUMP compiles a global database of cities and towns of 1,000 persons or more, where each settlement is spatially represented as a point and has associated tabular information on its population and data sources. GRUMP derives the geographic boundaries of settlements largely from NOAA's Night-time lights dataset (Elvidge, Baugh et al. 1997). The authors have found GRUMP to be the most expansive definition of urbanized area currently in use.

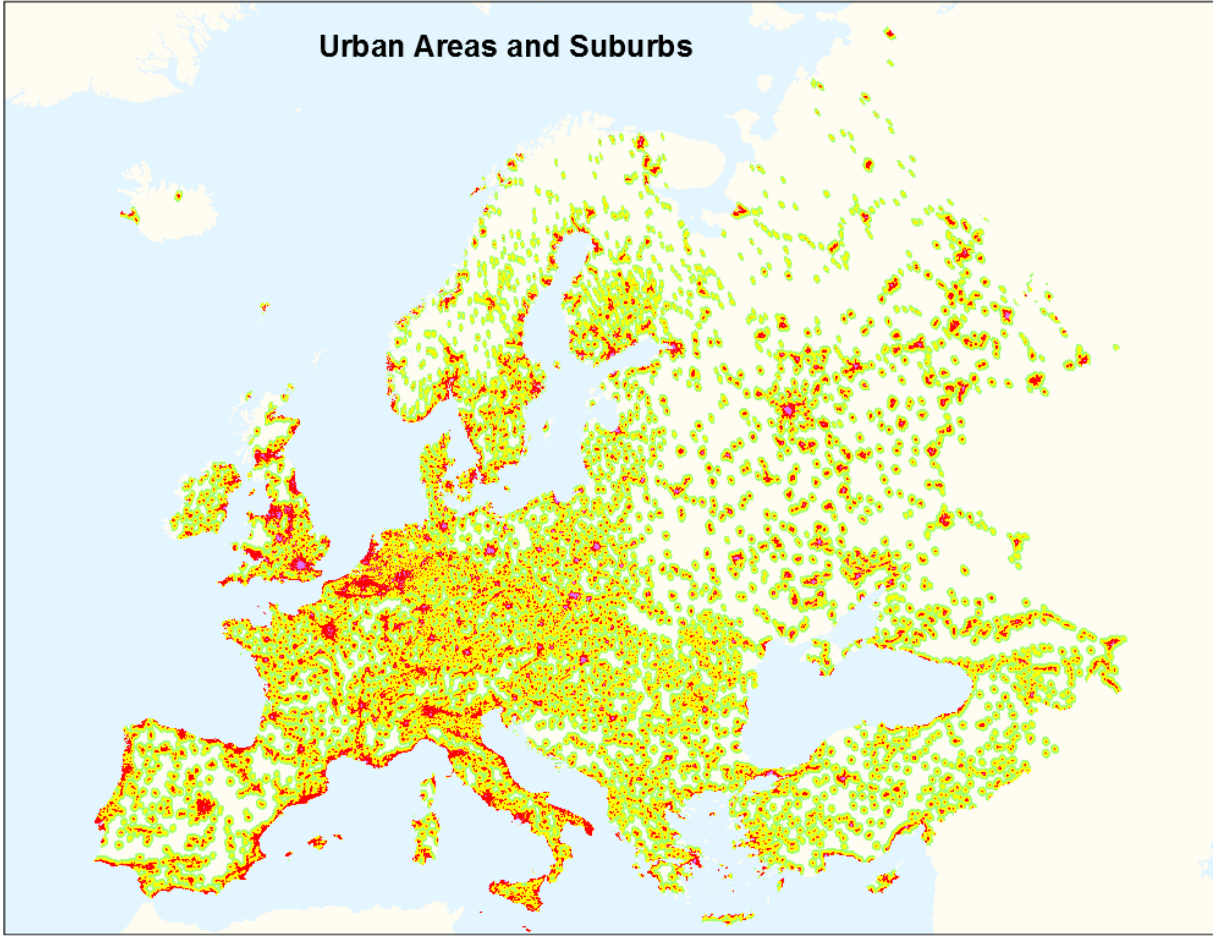
More important, related studies by the authors of this research revealed that in many parts of the world, especially but not limited to developing countries, the zone of largest GHG emissions is in a buffer of 20 km around the GRUMP urbanized areas. This prompted the current research described in the following sections.

3 METHODOLOGY

The European Joint Research Centre publishes annual model results from EDGAR version 4.1 for the years 1970-2008. The data is disaggregated to 0.1 degree and is available for some two dozen gases with global warming potentials as well as for a wide range of emission sources as per IPCC (2007). For this analysis, we use emissions in tons for the year 2008 for carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O) and sulphur hexafluoride (SF6). We transform each compound into carbon dioxide equivalents. The sum of GHGs is aggregated to eight IPCC source sectors: 1A1 and 1A2 energy and energy from manufacturing and construction, 1A3 energy from transport, 1B and 1A4 energy from other sources and fugitive emissions, 2 and 3 industrial processes, 4 agriculture, 5 land use change, 6 waste, and 7 other anthropogenic sources. For transportation, we include road, non-road, aviation emissions across urban extents (mostly take-offs and landings) and navigation sources. We exclude emissions from large scale biomass burning (forest, grassland and other vegetation fires and decay of wetlands and peat lands), as such information is (a) not available at a spatially disaggregate scale and (b) not relevant to the research question at hand.

The vector data for both the urban centres and the GRUMP urban extents was rasterized to a resolution of 0.0083 degrees or approximately 600 metres at 50 degrees latitude. Suburban rings of 10 km and 20 km were created using a buffer around the GRUMP urban extents. Everything not covered by any of these four areas is then defined to be rural or remote. Using the United Nations' definition of Europe and excluding city states and dependent territories such as the Channel Islands or Svaland, we then calculated the area and population for the five ones of interest in some 53 countries (see Figure 1). While on average, core city areas make up less than one percent of a country's area, this value goes up to five percent in the Netherlands. The GRUMP urbanized areas cover on average some thirteen percent of a European country but this value goes up to 37% in Belgium. The first ring of suburbs covers on average some 35% of European countries with Slovakia taking the crown at 57%. The outer ring and rural areas have typical a similar share of 25% each, with Armenia ranking first for the outer suburbs (40%) and Iceland having the largest share of remote areas (94%). In terms of population, on average, some 14% of a European nation's population lives in core cities, 36% in urbanized areas, 28% in the first ring of suburbs, 12% in the outer suburbs, and only 10% in rural and remote areas.

Figure 1. European Urban Areas and Suburbs



We then mapped the CO_2 equivalent emissions for each of the eight source sectors and overlaid them with the five zones, which were in turn clipped by a mask of uninhabitable areas (water bodies and very steep terrain). Summary statistics were run for both absolute sums and per capita sums in each of the resulting zones. The following section discusses the findings of these.

4 FINDINGS

4.1 General Observations

On average, suburban areas produce more CO_2 equivalent emissions than urban areas, not just in per capita terms, which matches the literature cited in section 2, but also in absolute terms. Table 1 lists the percent contribution of each sector in each zone in absolute terms. Table 2 shows how each zone differs from the respective national average.

Table 1. Europe-wide Emissions by Sector and Zone in Percent

Source	City Core	Urbanized	First Ring	Second Ring	Rural
1A1, 1A2	14.59	49.89	25.57	6.04	3.91
1A3	15.95	42.16	25.71	8.77	7.41
1B, 1A4	12.94	31.17	34.42	9.60	11.87
2, 3	9.76	47.76	32.71	5,79	3.99
4	0.96	12.14	38.68	24.56	23.66
5	1.56	10.18	44.29	24.80	19.17
6	11.43	37.63	29.96	10.88	10.10
7	1.27	11.97	35.02	23.16	28.58
Total	7.91	27.74	34.72	14.81	14.83
	≈ 36%		≈ **47%**		

Source: calculations of the authors

Table 2. Europe-wide Per Capita Emissions by Sector and Zone in Percent

Source	City Core	Urbanized	First Ring	Second Ring	Rural
1A1, 1A2	25.21	32.61	21.31	11.81	9.07
1A3	24.85	24.86	19.33	15.47	15.49
1B, 1A4	19.00	17.31	24.38	15.95	23.35
2, 3	17.59	32.55	28.43	11.80	9.63
4	1.15	5.49	22.29	33.20	37.88
5	1.94	4.78	26.53	34.85	31.90
6	17.33	21.58	21.91	18.67	20.52
7	1.46	5.19	19.37	30.05	43.93
Percent below/above country per capita average:	58%	77%	123%	123%	146%

Source: calculations of the authors

4.2 Regional Differences

It comes as no surprise that countries as different as Luxemburg and Russia will show very different rates and distributions of GHGs. Geography, as well as economic regimes matter a lot and the authors have several publications based on regression models for different world regions and sectors in press (Marcotullio et al., 2012, 2013a, b). We can distinguish countries by their degree of (sub-) urbanization (Table 3) as well as, and pertinent to the argument made in this paper, their rank as suburban polluters (Table 4). Marked in red, are countries, whose share of inner ring CO$_2$ equivalent emissions is higher than their area shares, and in green those countries that have relatively efficient suburban land uses.

Table 3. Categorization of European Countries (top ten in each category)

City		Urban		Suburban 1			Suburban 2		Rural	
	% area		% area		% area	% CO$_2$		% area		% area
NLD	5.07	BEL	37.39	SVK	58.35	67.82	ARM	40.13	ISL	94,79
BEL	3.32	NLD	31.94	NLD	57.05	**50.48**	MDA	37.55	RUS	74.04
GBR	3.16	LUX	31.38	CZE	56.39	**48.30**	LTU	36.31	BLR	67.78
DEU	2.38	CYP	24.50	DNK	54.57	**51.51**	HUN	35.39	AZE	60.96
POL	1.98	ITA	23.89	DEU	53.64	**44.38**	ALB	35.05	NOR	57.40
HUN	1.61	GBR	21.10	CHE	52.94	58.56	LVA	34.88	UKR	55.58
DNK	1.57	DNK	19.37	SVN	51.55	60.81	SCG	34.50	EST	48.79
CZE	1.50	CHE	19.02	ITA	50.94	**44.09**	POL	33.68	SWE	45.31
SVK	1.32	DEU	15.25	ALB	49.02	55.15	ROU	33.27	FIN	45.30
SVN	1.27	FRA	15.15	MDA	48.19	53.45	MKD	32.88	BIH	42.82

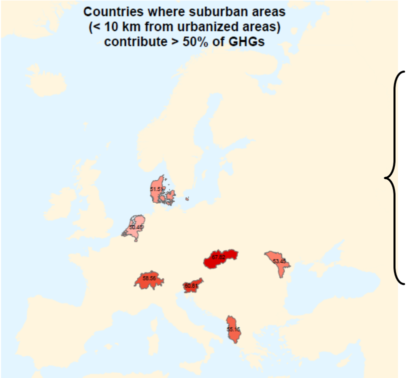
Source: calculations of the authors

4.2.1 Main Sources of Suburban Greenhouse Gas Emissions

Of particular interest, however, is what the main sources are that cause a country to rank high as a suburban polluter. Greece and Germany, for instance, have over 50% of their GHGs from agriculture coming from within the 10 km inner ring of suburbs (and an additional

20% from the outer 20 km ring), which points to the kind of intensive agriculture (orchards, vineyards) found near urbanized areas. The same figure for the Netherlands amounts to almost 60%, where however it has to be noted that almost all non-urbanized territory is characterized as suburban because of the high population density throughout the country.

Table 4. Top Suburban Polluters



Suburban 10km		Suburban 20km	
	% CO_2		% CO_2
SVK	67.82	SCG	31.61
SVN	60.81	ARM	29.99
CHE	58.56	ALB	29.16
ALB	55.15	IRL	28.20
MDA	53.45	TUR	27.96
DNK	51.51	MDA	26.37
NLD	50.48	AZE	25.03
CZE	48.30	BGR	23.75
ROU	48.29	HUN	22.26
LUX	46.20	ROU	22.26

Source: calculations of the authors

France, Spain and Italy have only recently experienced an increase in suburbanization, which explains why some 40% of inner ring suburban GHGs stem from IPCC source class 5, land use change. That number jumps in Ireland to almost 78% for the outer ring, 10-20 km apart from urbanized areas. In Romania, about 50% of all emissions from waste are located within the inner ring. Sweden has with some 47% almost as many GHGs from industrial production in the inner ring suburbs as it has from within the urbanized areas (49%). In Finland and Iceland, this number jumps to 60%. One has to keep in mind that the urbanized areas in Iceland are tiny and most human activities take place in a comparatively small inner ring of suburbs, however, the same cannot be said for Finland. Slovenia tops all of these though with over 90% of its industrial emissions originating from the inner ring of suburbs.

In Turkey, some 40% of GHG emissions from transportation originate in the inner ring, in Albania, this number jumps to 60%. Armenia has almost ¾ of its GHGs coming from suburban areas; witness to the dramatic changes throughout the country is also the 55% of GHGs from land use change in the remote rural areas. In the Czech Republic, GHG emissions from the inner ring are significantly higher than those from urbanized areas in all sectors other than energy generation and transportation. This is topped though by their neighbour Slovakia, where 65% of the national GHG emissions originate from the inner ring as opposed to only 16% from its urbanized areas. Neighbours are not always alike though: in Belarus, the urbanized areas produce almost twice the national average of per capita GHGs (with the inner ring producing only 78%), whereas in neighbouring Ukraine, the numbers reverse.

An extreme case of per capita GHG increase as one travels away from city centres is Ireland, where core cities and urbanized areas produce only 20% and 29% of average national per capita GHGs, whereas the numbers increase to 172% and 219% in the inner and outer ring, and finally a whopping 242% in rural areas. Similar extremes, especially in the rural areas, can be found in Luxemburg, Spain, Portugal, the United Kingdom and especially Switzerland. Relatively even distributions of GHGs across land use zones can be found in Russia, Austria, Hungary, Sweden, Turkey, and Albania.

5 CONCLUSIONS

This research has two important outcomes. The first one is of relevance to planning education and scholarship, as it points to the understudied contribution of suburbia to GHGs and helps to address misconceptions about the role of different settlement regimes in our understanding of global climate change. If nothing else (and there are a few caveats to this research, which will be addressed beneath), this study points to gaps in our understanding of different kind of socio-economic practices and their effect of the generation of GHGs.

Second, this research informs policy makers as to what measures provide the biggest bang for the buck in the mitigation of GHGs. The fine resolution of the EDGAR data set (7 km) allows for the first time to pin point to GHG emission sources at the NUTS-3 level, while coordinating efforts on a continental or European Union scale.

5.1 Limitations of This Study

There are mainly two limitations to the work presented here. The first is with the nature of the EDGAR data set itself, which in the end is the result of a model, not terribly well documented and hence resulting in some black boxes in the model documentation itself (EDGAR 2011). The authors of this paper, for instance, have for other publications added GHG emissions from non-urban electricity production to the budget of urbanized areas to capture more of the consumption based emissions. This typically shifts the balance from suburban areas to urbanized areas. The other lies in the definition of urban versus suburban itself. The authors have made a cogent but not unassailable argument for their classification. A less generic classification that takes into account the legal and policy constraints of each individual country would likely result in different outcomes. Nevertheless, given the expansive definition of urbanized areas, the sometimes shocking results of the role of suburban emissions may actually turn out to be conservative.

REFERENCES

Andrews, C., 2008. Greenhouse gas emissions along the rural-urban gradient. Journal of Environmental Planning and Management 51(6): 847-870.

Bader, N., and R. Bleischwitz. 2009. Measuring urban greenhouse gas emissions: The challenge of comparability. Survey and Perspectives Integrating Environment & Society 2 (3):7-21.

Brown, M. A., F. Southworth, et al. (2008). Shrinking the carbon footprint of metropolitan America. Washington DC, Brookings Institute Metropolitan Policy Program.

CARMA, 2012. Carbon Monitoring for Action. Center for Global Development, Washington, DC. Available at: <http://carma.org/api/> [Accessed 13 January 2013].

City of Sydney. 2008. Local government area greenhouse gas emissions. Sydney: http://www.cityofsydney.nsw.gov.au/environment/GreenhouseAndAirQuality/CurrentStatus/GreenhouseGasEmissions.asp (asscessed on 20/09/11).

Cole, M. and E. Neumayer, 2004. Examining the impact of demographic factors on air pollution. Population and Environment 26(1): 5-21.

Dempsey, N., 2010. Revisiting the Compact City? Built Environment 36(1): 5-8.

Dhakal, S. 2009. Urban energy use and carbon emissions from cities in China and policy implications. Energy Policy 37 (11):4208-4219.

Dhakal, S. 2010. GHG emission from urbanization and opportunities for urban carbon mitigation. Current Opinion in Environmental Sustainability 2 (4):277-283.

Dodman, D. 2009. Blaming cities for climate change? An analysis of urban greenhouse gas emissions inventories. Environment and Urbanization 21 (1):185-201.

EDGAR, 2011. European Commission Joint Research Centre (JRC)/Netherlands Environmental Assessment Agency (PBL), 2011. Emission Database for Global Atmospheric Research (EDGAR), release version 4.2. Available at <http://edgar.jrc.ec.europa.eu/> [Accessed 13 January 2013].

Elvidge, C. D., K. E. Baugh, E. A. Kihn, H. W. Kroehl, and E. R. Davis. 1997. Mapping City Lights with Nighttime Data from the DMSP Operational Linescan System. Photogrammetric Engineering and Remote Sensing 63 (6):727-734.

EPA, 2013. Inventory of the U.S. Greenhouse Gas Emissions and Sinks 1990-2011. Washington, DC: Environmental Protection Agency. Available at < http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2013-Main-Text.pdf> [Accessed 13 June 2013]

Griggs, D., Stafford-Smith, M., Gaffney, O., Rockström, J., Öhman, M., Shyamsundar, P., Steffen, W., Glaser, G., Kanie, N. and I. Noble, 2013. Policy: Sustainable development goals for people and planet, Nature, 495: 305-307, doi:10.1038/495305a.

GRUMP, 2011. Global Rural-Urban Mapping Project, Version 1 (GRUMPv1): Urban Extents Grid. Center for International Earth Science Information Network (CIESIN), Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). Available at: <http://sedac.ciesin.columbia.edu/data/set/grump-v1-urban-extents> [Accessed 13 January 2013].

Gurney, K. R., D. L. Mendoza, Y. Zhou, M. L. Fischer, C. C. Miller, S. Geethakumar, and S. De La Rue Du Can. 2009. High resolution fossil fuel combustion CO2 emission fluxes for the United States. environmental Science & Technology 43 (14):5535-5541.

Hardoy, J. E., D. Mitlin, and D. Satterthwaite. 2001. Environmental Problems in an Urbanizing World. London: Earthscan Publications Ltd.

IPCC. 2007. Climate Change 2007: Synthesis Report. Geneva, Switzerland: IPCC.

Kennedy, C. A., A. Ramaswami, S. Carney, and S. Dhakal. 2011. Greenhouse gas emission baselines for global cities and metropolitan regions. In Proceeding from Cities and Climate Change: Responding to an Urgent Agenda, 28-30 June. Marseille, France: World Bank, Government of France.

Lebel, L., P. Garden, M. R. N. Banaticla, R. D. Lasco, A. Contreras, A. P. Mitra, C. Sharma, H. T. Nguyen, G. L. Ooi, and A. Sari. 2007. Integrating Carbon Management into the Development Strategies of Urbanizing Regions in Asia: Implications of Urban Function, Form, and Role. Journal of Industrial Ecology 11 (2):61-81.

Lefevre, B. 2009. Long-term energy consumptions of urban transportation: A prospective simulation of ‘‘transport–land uses’’ policies in Bangalore. Energy Policy 37 (3):940-953.

Li, J. 2011. Decoupling urban transport from GHG emissions in Indian cities—A critical review and perspectives. Energy Policy 39 (6):3503-3514.

Marcotullio, P. J., J. Albrecht, Sarzynski, A., and N. Schulz, 2011. The geography of greenhouse gas emissions from within urban areas of India: A preliminary assessment. Resources, Energy and Development 8(1): 11-35.

Marcotullio, P.J., Sarzynski, A., Albrecht, J. and N. Schulz, 2012. The geography of urban greenhouse gas emissions in Asia: A regional analysis. Global Environmental Change http://dx.doi.org/10.1016/j.gloenvcha.2012.07.002.

Marcotullio, P.J., Sarzynski, A., Albrecht, J., Schulz, N. and J. Garcia, 2013. A top-down regional assessment of urban greenhouse gas emissions in Europe. Ambio, in review.

Mindali, O., Raveh, A. and Salomon, I., 2004. Urban density and energy consumption: a new look at old statistics. Transportation Research Part A: Policy and Practice, 38(2): 143-162.

Neuman, M., 2005. The Compact City Fallacy. Journal of Planning Education and Research 25:11-26, DOI: 10.1177/0739456X04270466.

Pachauri, S. and L. Jiang, 2008. The household energy transition in India and China. Energy Policy 36(11): 4022-4035.

Parshall, L., K. Gurney, et al., 2010. Modeling energy consumption and CO2 emissions at the urban scale: Methodological challenges and insights from the United States." Energy Policy 38(9): 4765–4782.

Permana, A. S., R. Perera, and S. Kumar. 2008. Understanding energy consumption pattern of households in different urban development forms: A comparative study in Bandung City, Indonesia. Energy Policy 36 (11):4287-4297.

Romero-Lankao, P., J.L. Tribbia, et al., 2009. Testing theories to explore the drivers of cities' atmospheric emissions. Ambio: A Journal of the Human Environment 38(4): 236-244.

Sadownik, B., and M. Jaccard. 2001. Sustainable energy and urban form in China: the relevance of community energy management. Energy Policy 29 (1):55-65.

Satterthwaite, D. 2007. The transition to a predominantly urban world and its underpinnings. In IIED Human Settlements Discussion Paper Series, 91. London.

Satterthwaite, D., 2008. Cities' contribution to global warming: notes on the allocation of greenhouse gas emissions. Environment and Urbanization 20(2), pp.539-549.

Shi, A., 2003. The impact of population pressure on global carbon dioxide emissions, 1975-1996: Evidence from pooled cross-country data. Ecological Economics 44(1): 29-42.

United Nations, 2004. A more secure world: our shared responsibility. Report of the Secretary-General’s High-level Panel on Threats, Challenges and Change. New York, UN.

United Nations, 2010. World Urbanization Prospects: 2009 Revisions. New York, DESA, UN.

WBCSD and WRI. 2004. A Corporate Accounting and Reporting Standard. Conches-Geneva and Washington, DC: World Business Council for Sustainable Development and World Resources Institute.

WEO, 2008. World Energy Outlook. International Energy Agency, Paris. Available at: <http://www.worldenergyoutlook.org/media/weowebsite/2008-1994/WEO2008.pdf>
[Accessed 13 January 2013]