Cite as: C.A. Kennedy, S. Demoulin, E. Mohareb, 2012. Cities reducing their greenhouse gas emissions. *Energy Policy*, 49, pp. 774–777

Cities Reducing Their Greenhouse Gas Emissions

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For several reasons, cities are increasingly seen as critical actors in efforts to counteract global climate change [1-7]. The majority of global greenhouse gas (GHG) emissions can be attributed to the production and consumption activities of cities. Meanwhile, with high concentrations of people and infrastructure, cities are particularly vulnerable to the impacts of climate change. Given also their wealth and potential creativity, cities should be leaders in mitigation of GHG emissions, but just how well are they doing? We find that several major cities are reducing their per capita GHG emissions, primarily through changes to stationary combustion; and in some cases the cities are leading their nation states.

To assess their progress in reducing GHG emissions, we examined data from six cities for which repeat GHG emission inventories have been conducted. The six cities: Berlin, Boston, Greater Toronto Area (GTA; comprised of several municipalities), London, New York City (NYC) and Seattle were studied because they have open access inventories, with detailed sectoral information [8-13]. Inventory methodologies differ between cities with respect to the inclusion of *scope 3* [14] out-of-boundary emissions, including sources

such as: aviation; marine; exported waste; and imported food, materials and other goods. To overcome differences in accounting methodologies used by cities, we reformatted the inventories using the UNEP/UN-HABITAT/World Bank standard for reporting GHG emissions from cities [15].

We primarily looked at changes in emissions over the period from 2004 to 2009, where there is greater availability of emissions data for repeated years. In searching for inventories, we found other cities having repeat inventories, e.g., Barcelona, Chicago, Hong Kong, Philadelphia, Singapore, Stockholm, Tokyo and Vancouver, but these lacked sufficient, recent time series data. In many of these other cities, per capita GHG emissions were found to be declining. This is also the case for the six cities we study (Fig.1), although for Boston and Seattle total GHG emissions have risen with population, while for the other four total emissions have declined despite population growth.

Changes by Sector

The sector for which emissions reductions were most consistently and substantially reported was stationary combustion. This sector includes combustion of fuels for electricity use, industrial processes or direct heating/cooling of residential, commercial and industrial buildings. **S**tationary combustion accounts for the largest share of emissions in four of the cities; only in Seattle and GTA (for later years) does transportation contribute more GHG emissions.

Five of the cities have curbed emissions from stationary combustion, mainly through efforts to reduce the carbon intensity of source fuels for electricity generation and heating. e.g., shifting from coal or oil to natural gas or renewables. Annual percentage changes range from -6.60% for Berlin to +1.15% for Boston (Table 1). Berlin used to rely on lignite and hard coal for about one-third of its stationary energy requirements, but the hard coal has been aggressively reduced. The use of mineral oils has also dropped by one-third since 1990, with natural gas primarily used as a replacement. Boston pursued a similar strategy in 2006; electricity generation was switched from oil to natural gas when the price of natural gas fell. The associated decrease in carbon intensity caused a 12% reduction in GHG emissions from electricity. The following year, however, Boston switched back to oil-generated electricity, as the price of oil became more competitive again; hence the U-shape in Boston's emissions profile (Fig.1). Fuel switching has been a strategy for most of the cities. Only in the case of London was their evidence that emissions reductions were achieved more by diminishing consumption than a change of energy sources. London was also the only city where GHGs from commercial and institutional buildings have shrunk too. In all other cases the lower carbon intensity of the energy supply has not been sufficient to offset increased demands. For the other three cities, reductions in emissions from stationary combustion have been achieved through greening of the electricity supply. Carbon-intensive generation plants using coal and oil have been replaced by cleaner ones relying on natural gas, cogeneration, nuclear or renewable energy sources. The reductions in GHG emissions from electricity are substantial: 46% (over 4 years) for the GTA; 32% (over 4 years) for NYC; and 27% (over 3 years) for Seattle.

Four of the six cities have also reduced total emissions for mobile combustion, although the magnitudes are smaller in percentage terms compared to stationary combustion. The greatest reductions are again observed for Berlin at just over 3% per year. Unfortunately, no explicit vehicle mileage data is reported for Berlin, nor London, where perhaps the western extension of the congestion charging zone, in February 2007, may have had an effect. Generally the data reported by the cities is not detailed enough to determine whether changes are due to increasing vehicle efficiency, decreased travel, or switching to lower polluting modes; any of these mechanisms could be linked to rising oil prices.

NYC and GTA have seen their emissions from trucks drop by 14% and 11% respectively (both over 4 years). This could be related to the recession that started around September 2008, as the latest year of reporting for both is 2009. NYC's decrease may also be due in part to switching of waste transport from trucks to rail. Emissions from buses were only specially reported for two cities, decreasing for NYC and increasing for Seattle. NYC replaced approximately one-quarter of its diesel-powered buses with biodiesel and compressed natural gas vehicles, reducing emission by 15% over 4 years.

Reporting of aviation emissions is an area of contention for urban GHG inventories. Following the UNEP/UN-HABITAT/World Bank standard we have included GHG emissions for all fuels loaded onto planes in the GTA and NYC. Note that NYC does not include these emissions in its total, but provides them as a subsidiary item. London only includes fuels used for domestic flights in its inventory; these are but a small fraction of

fuels loaded at airports within London, which were equivalent to 3.1 t CO_2e/cap in 2005 [2], i.e., adding almost 50% to London's total emissions. Seattle's emissions are based on fuels used in grounds equipment and by jets during landing and take-off at King County International Airport; and fuel use on domestic flights out of Sea-Tac International Airport, weighted by the percentage of passengers travelling from Seattle. No aviation emissions are reported for Boston and Berlin. There is clearly variation in how emissions are reported, nevertheless where there is data changes in emissions varied from -1.1% (over 4 years) for NYC to +16.0% (over 4 years) for the GTA.

Only three of the cities record industrial process emissions in their inventories; this is likely because major industrial activities, e.g., cement, steel or chemical manufacturing, are absent, or possibly because data is unavailable. In Seattle and GTA emissions have fallen at rates of 4.1%/yr. and 3.7% /yr. respectively; in both cases industrial process emissions are primarily from cement plants. For Berlin, the emissions are mainly from mineral extraction and other extraction and processing activities. Table 1 shows these emissions have slightly increased between 2004 and 2007, but this is a mild fluctuation around a longer term downward trend; industrial process emissions for Berlin are now about 40% of 1990 values.

Changes in reported emissions from waste range from –4.1% for Seattle to +1.8% for GTA (Table 1), but these numbers need some interpretation. Seattle only reports on emissions from closed landfills located within city boundaries, i.e., Seattle does not include emissions from the waste it exports. The emissions for GTA include those from

exported waste; the region has made progress in diverting residential waste, but less attention is paid to commercial waste, which is approximately double in quantity. The reporting on waste emissions for other cities is also mixed. Berlin excludes waste from its inventory and London is missing residential waste. In NYC, landfill gas emissions, including exported waste, have decreased by 2% (over 4 years) through improvements to the methane capture process. This has partly been offset though by a rise in N_2O emissions from wastewater handling.

Comparison with Nation States

Our analysis shows that the cities have generally been reducing their GHG emissions, but were they performing any better than nations in this respect? Whether a result of deliberate policy or as a consequence of economic change, all of the four nations in which the cities are hosted have also decreased their emissions. In order to account for differences in population, a comparison between the cities and nations is made using per capita emissions (Table 2). There are still, however, some effects of size that persist. Even though the inventory method for cities broadly derives from the IPCC guidelines for nations, there are differences in which sectors are typically predominant. National inventories record higher per capita values because they include emissions from sectors such as agriculture, heavy industry (only seen in a few cities), and inter-city transportation, which are usually missing from urban inventories. Of course, much of these emissions may be associated with urban consumer demands, e.g., for food, construction materials or produced goods; and when such indirect emissions are

attributed to cities, their per capita emissions can be similar to their host nation [16, 17]. These indirect emissions can also be reported under the UN/World Bank tables [15], but have not yet become mainstream reporting for most cities.

The four nations in which the six cities are located have all experienced reductions in per capita emissions over the period 2004/5 to 2008. The greatest per capita reductions have been achieved by the USA (0.50 tCO_2e/cap/yr) and Canada (0.28 tCO_2e/cap/yr), but these two are starting from the highest levels. Rates of reduction for Germany (0.08 tCO_2e/cap /yr) and the UK (0.19 tCO_2e/cap/yr) are smaller. Nonetheless, on average the rates of reduction are slightly higher for the four nations (0.26 tCO_2e/cap/yr) than for the six cities (0.25 tCO_2e/cap/yr).

Only in GTA and Berlin is the reduction rate of per capita emissions for a city higher than for its host nation. Berlin's reduction rate of 0.36 tCO_2e/cap/yr, second highest with New York City, is substantially higher than that of Germany. Also, while NYC's reduction rate is lower than that of the USA, it is higher than those of the three other nations.

To correct for differences in the contents of national and city inventories, discussed above, it is perhaps fairer to make comparison in terms of annualized percentage changes in per capita emissions. By this measure, three of the cities GTA, NYC and Berlin are making faster progress in reducing emissions than their nation states; and London's rate of reduction (1.6%/yr.) is almost equal to that of the UK (1.7%/yr.). Only Boston (0.3%)

and Seattle (1.4%) are notably behind. On average, the percentage change in per capita emissions for the six cities (2.8%) is greater than that for the nations (1.5%).

Conclusion

It may be concluded that cities, or at least the six studied here, are reducing their per capita GHG emissions, and on average are doing so faster in percentage terms than their nation states. Care has to be taken though in attributing the success of the cities. Some of the most substantial decreases in emissions have arisen due to changes in sources of electricity generation; and in most cases this falls under the control of higher level governments (NYC is perhaps an exception). Moreover, the more modest reductions in transportation emissions achieved by most of the cities could be due to changing consumer preferences towards more efficient vehicles. Perhaps only London can claim to have made notable changes to transportation with its congestion pricing. Cities cannot take all the credit for reducing their emissions; they work within a multi-level governance context [18].

This examination of six city inventories also shows that some GHG emissions are not getting counted. Seattle does not include emissions from its exported waste; London is missing residential waste; and Berlin is missing waste emissions altogether. The differing approaches to aviation emissions suggest a misunderstanding of the importance of airports to urban economies. Some cities do not include aviation emissions, perhaps because they occur outside of their territory. Others include emissions from fuels loaded

for domestic flights only, to be consistent with the UNFCCC framework for nations. If, however, cities recognize their role as the control points and gateways between nations in a globalized economy [19-21] then emissions from international flights leaving city airports should be included. Then of course, there are the GHG emissions embodied in the food, construction materials, produced goods, etc., which are consumed cities. In short, cities are reducing their GHG emissions, but are not counting all sources.

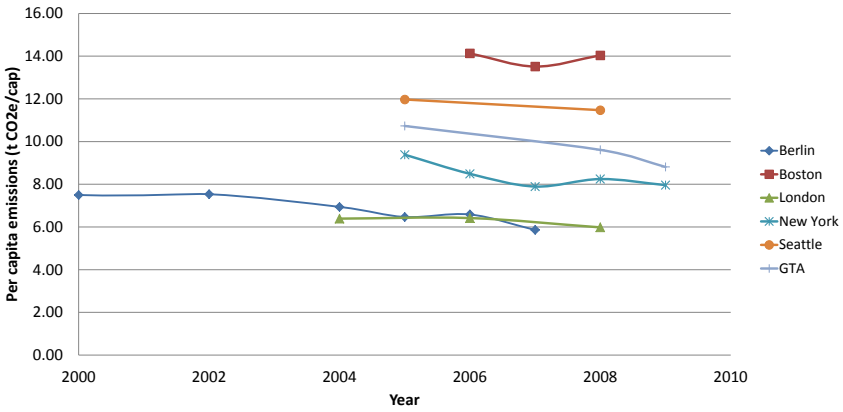

Figure 1. Changes in annual per capita greenhouse gas emissions for the six cities.

	Berlin 2004-07	**Boston 2005-2007**	**GTA 2005-2009**	**London 2004-08**	**NYC 2005-09**	**Seattle 2005-08**
ENERGY	-5.70 %	0.70 %	-2.45 %	-0.25 %	-2.73 %	0.80 %
a) Stationary Combustion	-6.60 %	1.15 %	-4.21 %	-0.18 %	-4.13 %	-0.67 %
b) Mobile Combustion	-3.07 %	-0.45 %	- 0.59 %	-0.50 %	-0.15 %	1.47 %
c) Fugitive Sources		-	-	-	-0.43 %	-
INDUSTRIAL PROCESSES	2.80 %	-	-3.69 %	-	-	-4.07 %
AFOLU		-	1.80 %	-	-	-
WASTE		-0.30 %	1.80 %	-1.00 %	-0.50 %	-4.13 %
TOTAL	**-5.07 %**	**0.65 %**	**-2.42 %**	**-0.90 %**	**-2.65 %**	**0.13 %**
Population	0.15 %	0.98 %	2.51 %	0.72 %	1.37 %	1.21 %

Table 1. Annual percentage changes in absolute values of annual GHG emissions for the six cities, 2004-2009.

							Rate of change (tCO_2e /cap /yr)		Percentage change in per capita emissions (% /yr)	
	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**Nations**	**Cities**	**Nations**	**Cities**
CANADA	23.16	22.62	21.99	22.74	22.03	-	-0.28		-1.2%	
GTA	-	10.73	-	-	9.61	8.81		-0.48		-4.5%
GERMANY	-	12.28	12.38	12.11	12.04	-	-0.08		-0.7%	
Berlin	6.94	6.47	6.58	5.86	-			-0.36		-5.2%
UK	11.03	10.90	10.75	10.53	10.26	-	-0.19		-1.7%	
London	6.39	-	6.42	-	5.98	-		-0.10		-1.6%
USA	21.77	21.75	20.43	20.60	19.77	-	-0.50		-2.3%	
Boston	-	14.13	13.51	14.04	-	-		-0.05		-0.3%
NYC	-	9.39	8.49	7.89	8.24	7.96		-0.36		-3.8%
Seattle	-	11.97	-	-	11.47	-		-0.17		-1.4%
Average							-0.26	-0.25	-1.5%	-2.8%

Table 2 Comparison of changes in annual per capita GHG emissions for cities and nations.

Acknowledgement

This research was supported by the Natural Sciences and Engineering Research Council of Canada.

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