Green Cities vs. Green Countries

An analytical comparison of Cities' Relative Carbon Footprint

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Highlight

- We use Relative Carbon Footprint (city/country GHG emissions) as unit of analysis
- We compare GHG inventories of two cities and two countries
- RCF is driven by: range of economic activities, level of income and energy matrix
- Important implications in terms of national and local urban policy making

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By Nicola da Schio

Abstract

Since 2008 more than half of the world's population lives in urban areas. At the same time, the contribution to both economic output and to climate change made by cities is far greater than the proportion of the global population they host. Cities, however, are not all the same, and the per capita carbon footprint of cities is a powerful indicator of the great variety between different cities in terms of their impact on climate change. The literature on this topic has made a useful contribution to our understanding of urban areas in these terms, how they represent a solution for reducing anthropogenic carbon emissions, or conversely how they represent themselves the problem. On the other hand, much has been said on the difference among the world's cities, in terms of their contribution to climate change. The main drivers range from the physical shape of the city, to its socio-economic profile.

This study, however, will push the debate in a different direction in an attempt to seek a more complete perspective by placing cities in their proper national context, and takes the ratio between a city's and its country's per capita carbon footprint as unit of analysis. Two explorative case studies, on Sao Paulo and on Cape Town, shed light on the dimensions that explain the relative performance of cities. In particular, the findings of the research draw attention to the economic structure of the city and of the country (i.e. the array of economic activities), the level of income and the range of sources used to produce energy. The present reflection is particularly useful for national and local urban policy makers. The former will gain insights to understand under which conditions cities are a solution to lower the national level of emissions, i.e. what are the particularities of a specific urban form vis-à-vis its own national context. The latter will have indications on how to draw environmental priorities, based on the feasibility and the expected returns.

Keywords: Carbon Footprint; Cities; Sao Paulo; Cape Town

TABLE OF CONTENT

Introduction

Cities host, since 2008, more than half of the world's population (UNFPA, 2007). At the same time, the contribution to both economic output and to climate change made by cities is far greater than the proportion of the global population they host. Cities generate more than 80 per cent of the global GDP (McKinsey Global Institute 2011) and are said to be accountable for 75 per cent of global energy consumption and 80 per cent of GHG emissions (UN, 2007). It is therefore evident, as the executive director of UNEP Achim Steiner has said, that "the decoupling of economic growth from the consumption of natural resources will only happen if cities are committed and on board" (uncsd2012.org). Cities, however, are not all the same, and the per capita carbon footprint of cities is a powerful indicator of the great variety between different cities in terms of their impact on the climate. The literature on the topic has made a useful contribution to our understanding of urban areas in these terms, how they represent a solution for reducing anthropogenic carbon emissions or how they represent themselves the problem. On the other hand, much has been said on the difference among world's cities, in terms of their contribution to climate change. Important drivers range from the physical shape of the city, to its socio-economic profile.

This study, however, will push the debate in a different direction in an attempt to seek a more complete perspective by placing cities in their proper national context, and takes the ratio between a city's and its country's per capita carbon footprint as unit of analysis. Going beyond the consideration of the particularities of the urban form and the ranking between cities' carbon footprint, this study suggests a new approach at the meeting point between these two perspectives. Through two explorative case studies, the aim of this approach is to understand what are the factors that make a specific city performing, on a per capita basis, better or worse than the country it belongs to, and to compare the two cities in these terms. In an historical moment where the world is becoming urban and cities are protagonists of social, economic and cultural dynamics, the present reflection is particularly useful for national and local urban policy makers. At the national level, policy makers will gain insights to understand under which conditions cities can be a solution to lower the national level of emissions, i.e. what are the peculiarities of a specific urban form vis-à-vis its own national context. At the local level, they will have indications on how to draw environmental priorities, based on the feasibility and the expected returns.

1. Material and methods

1.1. Measuring the Urban Impact on the Environment

Cities are complex social and ecological systems that interact with the rest of the world. Cities are nodes where flows of people, energy, goods, as well as immaterial flows of ideas, money and modes of life converge. While all these flows are linked, studies on the environmental performance of cities concentrate rather on the flows of materials and energy and on the so called urban metabolism (see for instance Decker et al., 2000). Nested in this concept, the estimation of the ecological footprint is the calculation of the "amount of biologically productive land and sea required to produce the renewable resources this population consumes and assimilate the waste it generates" (Wackernagel et al., 2006:104). The ecological footprint is composed of different dimensions, to include the solid, liquid and gaseous in and out-flows. One important dimension of the ecological footprint is the level of emissions of greenhouse gases (GHG) in the atmosphere, also called the carbon footprint[1]. This has been taken as unit of analysis for this study, as it represents one of the most significant "out-flows" from a city with consequences worldwide. The scope of this analysis, moreover, requires a degree of comparability and data availability. In this sense, the level of GHG emissions, for which data are increasingly available for cities and countries, can be taken as a "common currency" to which most anthropogenic contributions to climate change are converted, allowing for quantitative analysis and correlation to other variables.

A way of presenting a city's carbon footprint is the compilation of a GHG inventories. Hoornweg et al. have recently put together what is today one of the broadest lists of comparable GHG inventories of world's cities, and their respective countries (Hoornweg et al., 2011). This list represents the starting point

[1] According to the survey of the literature developed by Wiedmann and Minx on the different uses of the expression it is broadly accepted that "carbon footprint stands for a certain amount of gaseous emissions that are relevant to climate change and associated with human production or consumption activities" (Wiedmann, and Minx, 2008:2)

of the present research. To date, there is no method for allocating GHG emissions to cities that has reached consensus, the main issue concerning the determination of the boundaries of analysis. GHG emissions, in fact, can be attributed to the spatial location of the actual release, or to the location of the activity that led to the GHG release (Vandeweghe and Kennedy, 2007). At the national level, the IPCC guidelines on how to compile annual inventories of GHG emissions (and removals) recommend considering only the emissions that originate within the legal boundaries (IPCC, 2006). On the other hand, the methodology developed by WRI/WBSCD[2], for calculating the GHG emissions of corporations and other institutions, has introduced the concept of 'scope' of emissions enabling companies to distinguish between emissions from facilities that they own or control, and emissions that result from broader company activities.

According to Kennedy et al. (2009b:6), "procedures for attributing GHG emissions to urban areas lie somewhere between those used for national inventories and those for corporate inventories". Similarly to national inventories, urban inventories calculate the emissions of a spatially defined area such as that within a municipal boundary. Similarly to the WRI/WBCSD reporting, in turn, urban inventories might include emissions occurring outside the legal area, if they are a consequence of urban activities, acknowledging in this fashion the multiple cross-border flows of energy, goods and people (KATES et al., 1998). Finally, an alternative methodology (not very common, indeed) is to base the attribution of the emissions on place of residence of the individuals responsible for them (See for instance Brown et al., 2008). This study is based on GHG inventories that include the emissions taking place within the city boundary and those deriving from the production of energy and waste, even if they are released outside of the city, such as the ICLEI's International Local Government GHG Emissions Analysis Protocol (See Kennedy et al., 2010).

This methodology looks at sources of GHG release from a "production" perspective: while it includes the emissions deriving from the production of goods and services that take place in a city (the only exception being energy and waste), it does not take into account the emissions from goods and services

[2] World Resources Institute / World Business Council for Sustainable Development

which are consumed inside the city but come from outside (from a "distant elsewhere" according to Rees words, 1992:121). The use of the production perspective in this study is due to data availability, yet its use is not immune from critiques (for discussion on these themes see, among others, Dodman 2009a, Kates et al. 1998, Ramaswami et al. 2008, Satterthwaite 2008). The production perspective is blamed to be unjust, as it distorts the actual responsibility of those cities which "outsource" polluting activities, purchasing from the outside carbon-intensive goods and energy (Dodman 2009a). On the other hand, this methodology has advantages in terms of policy implications, as it highlights opportunities for reducing GHG emissions where local institutions can successfully intervene (Kates et al. 1998). In terms of fairness, moreover, it is to be questioned if the actual responsible for GHG emission is a consumer of a carbon-intensive good, or a producer that does not adopt energy-saving production techniques.

To offer a solution, UNEP, UN-HABITAT, and the World Bank have recently developed a standard for measuring GHG in cities which partly takes into account both perspectives (2010). They recommend that GHG inventories for cities use the principles and methods developed by the IPCC (production perspective). However, they also recognise that "the vitality of cities gives rise to the production of GHG emissions outside of urban boundaries" (consumption perspective). While it might be too complex to quantify all of the emissions associated with the myriad of goods and materials consumed in cities, urban GHG inventories should be including out-of-boundary emissions from the generation of electricity and district heating consumed within the boundary of the city, emissions from aviation and marine vessels carrying passengers or freight away from cities; out-of-boundary emissions from waste that is generated inside cities. Finally the GHG emissions embodied in the food, water, fuels and building materials consumed in cities should also be reported as additional information items. As soon as the number of urban GHG inventories using these standards will increase, it will be possible to compare cities taking better into account the 'consumption' side of the carbon footprint.

1.2. The rationale behind the "Relative Carbon Footprint"

There are different ways to analyse and to compare cities level of GHG emissions. The first concerns the potential of the urban form to magnify or to reduce the human impact onto the environment. This approach focuses on characteristics of cities, such as the concentration of people and resources, and assesses whether the way of life they lead to has a lower or a higher impact on the environment than the rural or sub-urban way. The second type of analysis concerns the absolute level of a city's GHG emissions. This approach leads to rank different cities according to their level of GHG emissions, and to analyse the variables related to cities good or bad performance. The present study suggests a different entry point, which combines these two perspectives on cities. Starting from the urban GHG inventories, the unit of analysis is a city's 'Relative Carbon Footprint' (RCF), defined as the ratio between a city's per capita level of GHG emissions and the respective country's level, expressed in tonnes of Carbon Dioxide equivalent (tCO2e[3]).

RCF (tCO2e)= City per capita GHG emissions / Country per capita GHG emissions

Studying the RCF means exploring the difference between the per capita level of GHG emissions of a city and the level of the country as a whole, and then the difference between cities in these terms. This perspective allows ranking different cities of the world, while taking in consideration their national context and the potential of their specific urban profile. On the other hand, it also allows measuring the potential of one concrete urban reality. This goes beyond the mere analysis of the peculiarities of the urban reality, and "localises" the analysis on specific cases.

The study of cities' RCF and the comparison between cities according to this value can be particularly useful for policy makers to address both urbanisation and environmental issues. At the national level this offers concrete insights on the conditions under which cities are a driver of the national GHG emissions or are a solution for reducing them. At the local level this may offer indications on the issues that need to be prioritised for achieving environmental goals, based on the feasibility of certain policies and the expected returns. For instance, policies to improve the city performance in a certain sector by uniforming it to the national level are more likely to succeed than policies going against the national trends. Furthermore, data on the relative performance of cities offer a useful indications, as they highlight the achievements of a city,

[3] "concentration of CO2 that would cause the same amount of radiative forcing as a given mixture of CO2 and other GHG" – IPCC 2001

regardless of its absolute level of GHG emissions which might depend on its degree of development or its geographic location.

The measurement of the carbon footprint of cities comes in a context where the governance and management of urban areas becomes increasingly sophisticated and data on the state of a city and on major urban dynamics are required. These include statistics of urban competitiveness, gross metropolitan product and material flows, among others. In other words, many of the measures that are currently recorded for nations are also needed for urban areas (Kennedy et al., 2009b). This research contribute to fill that gap. The analysis of the drivers of RCF is useful to develop a new perspective for looking at cities environmental impact. This has been carried out through the study of two cities, with a per capita level of emissions respectively lower and higher than the national level. The achievement of the research is twofold: on the one hand it contributes to collect and record the data at the city level to gain a better understanding of the RCF of these cities, on the other it helps identifying what are the indicators that need to be collected to draw more complete environmental profile of cities.

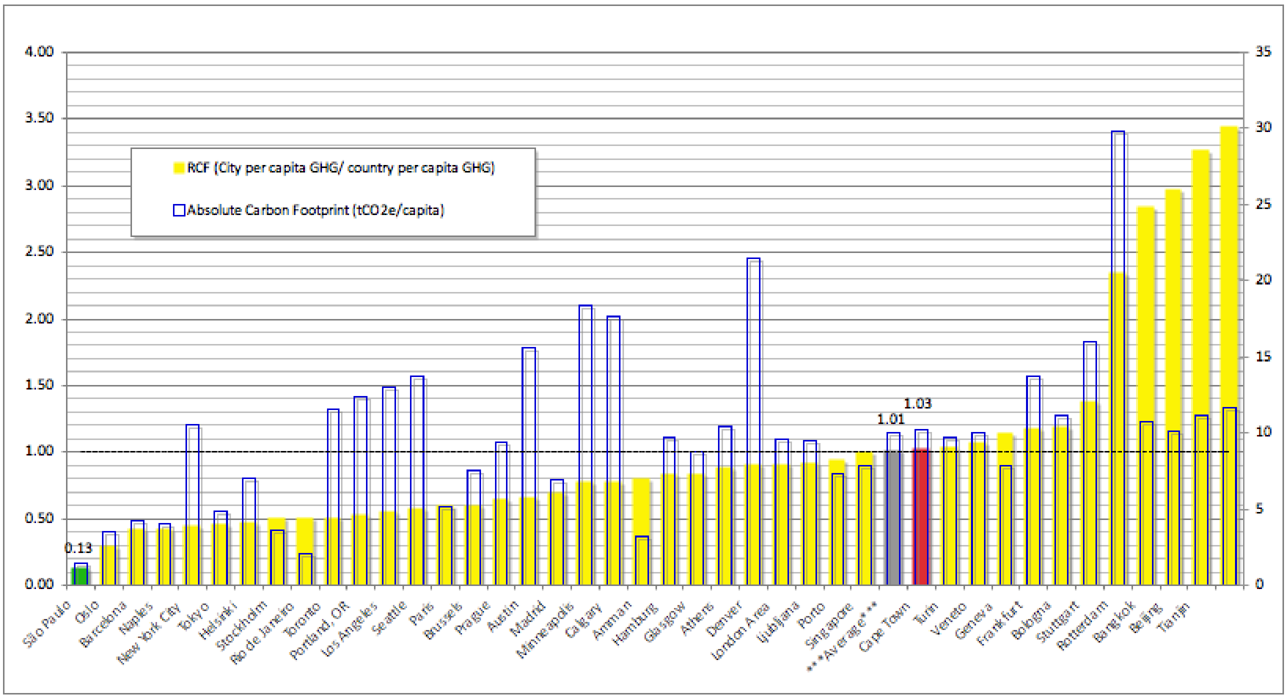

Figure 1. City ranking in terms of Relative Carbon Footprint and Absolute Carbon Footprint

1.3. Methodology

After a broad overview of the research on the carbon footprint of cities, this study develops two explorative case studies. The two cities that have been analysed are Sao Paulo (GHG/capita = 1.47 tCO_2e; RCF=0.125) and Cape Town (GHG/capita = 10.21tCO_2e; RCF = 1.030). The motivations of the choice of these two cities are diverse. The first criterion concerns the availability and the comparability of data on the level of GHG emissions. The paper of Hoornweg et al. (2011) mentioned above, presents a list of the per capita level of GHG emissions of ninety-three cities. From this list, only the data of forty cities are peer reviewed and considered to be comparable, which limits significantly the choice of cities. To explore the RCF in a comparative way, moreover, it has been useful to select two cities that present similar conditions, except for the relative carbon footprint. This helps identifying what might be the characteristics of the city, which are distinctive of its particular situation. In fact, while they present very different RCF, Sao Paulo and Cape Town present similar demographic and economic characteristics, at least in comparison to the other cities of the list.

First of all, the countries where the two cities are located, Brazil and South Africa, are relatively similar in terms of human development (UNDP 2011). Sao Paulo and Cape Town are also relatively similar. While the total population of the two cities is quite different (Sao Paulo has 11,038,000 inhabitants and Cape Town 3,497,000 [4]), they both host a similar share of the national population, respectively six and the seven per cent. Their economic performance in relation to their countries is also relatively similar. It is estimated that Sao Paulo produces 14.2% and Cape Town produces 18.5% of the respective national GDP. Finally the income per capita that is calculated for the two cities is also relatively similar, and equals to 20,384 current US Dollars for the Brazilian city and to 21,446 US Dollars for the South African one. Respectively this level of income corresponds to the 352% and the 392% of the national income. To be clear, it is not assumed that the two cities are necessarily more representative of the total than any other couple of cities, as the

[4] Except when it is specified otherwise, all data at the city level are from citymayor.com; and all data at the national level are from databank.worldbank.org

purpose of this research is the identification of relevant dynamics that play a role in determining the relative performance of cities, rather than providing a general answer.

The data of the GHG inventories of the two cities and the two countries have been disaggregated and recombined in order to have comparable categories[5]. For each of the categories a specific Relative Carbon Footprint has been calculated. These data have provided an immediate picture of the details of RCF, including the contribution of each of the categories to the final result (see Appendices). An analysis of the physical and socio-economic profile of the city and of the country has allowed explaining the results. Finally, comparing the findings of each of the cities has led to the identification of the commonalities between the two cities as well as the discrepancies, which helps explaining the different value of RCF.

2. Results

2.1. The Unicity of the Urban Form

Cities are often blamed to be a major contributing factor for climate change, in statements such as the following. "Cities only occupy two percent of the world's land mass yet contribute more than two-thirds of global greenhouse gas emissions" (Clinton Climate Initiative). Or again "...cities influence the climate on a global scale, for around 80 per cent of the greenhouse gases that affect the climate are emitted in cities…" (Munich Re Group 2004:2)[6]. In other circumstances, cities are considered to be the solution for reducing the anthropogenic impact on the environment, and they are defined as "incubators of green innovation" (UNEP2011a:464), or the "greatest invention to makes us greener", thanks to the higher concentration of population and resources (Glaeser 2011). In fact, the urban form leads to lower per capita lower consumption of energy in several parts of the world. It has been calculated that the per capita energy demand in cities equals to 94% of the regional level in European Union, 88% in Australasia, and 99% in the

[5] The fact that the various inventories are not directly comparable highlights, once again, the need of developing a common standard in the field

[6] See Satterthwaite 20089, for a comprehensive review of the topic

United States (IEA and OECD 2008:182). However, this might be due to a simple shift of polluting activities outside the city boundaries, to other parts of the country and of the world.

In his recent book on “the Triumph of the City”, Glaeser shows how the population density allows for shorter car trips while moving between house, work and places of leisure. He also points out that in cities housing units are normally smaller and thus need less energy for heating and cooling (Glaeser 2011). Similarly Dodman (2009b:6), highlights how the urban form can lead to an overall reduction of human related carbon emissions. The fact that cities concentrate economic activities and people might produce economies of scale in the provision of services and encourage the use of means of transport other than the private car. The proximity of people and activities, moreover, leads to a greater exchange of opportunity and ideas, where an already highly networked environment allows testing and scaling new technologies for an average of renewable technologies patents much higher than in the countryside (UNEP2011a:464; Kamal-Chaoui and Robert 2009). Similarly to this principle of knowledge spillover, cities often present patterns of “resource spillover” and “metabolic efficiency”. This allows to take advantage of the externalities of the activities of other people, provided that they are physically nearby, for an overall lower use of economic and environmental resources (Mehaffy, 2012).

Different dynamics, however, might contribute to the low use of energy that characterises many cities today, i.e. industries that have been driving the prosperity of cities in the past are now operating elsewhere. This appears evident when looking at the case of Chinese cities, where the per capita energy consumption in cities is 1.8 times higher than at the national level (IEA and OECD 2008:182), because often industries are still located inside cities. In other cities, relocating polluting activities in the suburbs might have been used as a strategy to reduce environmental problems in cities, while maintaining the same pattern of consumption (Bai, 2002). The higher level of per capita income that is often present in cities, in fact, might lead to higher levels of consumption and to related pollution, whether or not the actual release of emissions takes place in cities. In any case, the existence of these different (and indeed contradicting) trends highlights the need of an adequate methodology to explore the underlying issues, and develop analysis and comparison between different cases

2.2. The carbon footprint of cities, a varied panorama

Whatever is the actual level of emissions that can be allocated to cities, individual cities present very different levels, e.g. ranging from cities like Rotterdam, in the Netherlands, with 29.8 tCO2e/capita, to other like Rajshahi, in India, with 0.8 tCO2e/capita (Hoornweg et al., 2011). It is difficult to identify one single variable that explains clearly and univocally the different levels of emissions. The literature, however, indicates a series of dimensions that play a role in lowering or increasing a city's GHG emissions. In very general terms, there are two factors that contribute to the absolute level of emission in a city. These are the mode of energy production, i.e. the type of fuel that is used to produce energy, and the amount of energy consumed by the urban activities, including, for instance, the energy used to produce electricity and the energy which is directly employed to move machines and cars, and to heat buildings. The former often depends upon national or regional dynamics, and has only marginally to do with urban policy making. The latter, on the other hand, is directly dependent upon the characteristics of the city itself, and is therefore more relevant for the governance of the city and for the policies to direct urban development. These characteristics either refer to the physical aspect and geography of the city, or to or the socio-economic activities taking place in the city.

One of the most important characteristics, which has been among the first ones to be explored, is the population density. This has a direct impact on the use of private car as a mean of transport and on average fuel consumption (Newman and Kenworthy, 1989). Increased density, moreover, reduces the energetic and financial costs of linear infrastructure provision (Dodman, 2009b; Rickwood et al., 2008). Similarly, the urban shape and the level of connectivity play an important role in accentuating or reducing the consequence of the urban density, as it is strictly intended (Dodman, 2009b:4). Also the design of the buildings (e.g. the number of floors, the age of a building or the construction material) has a direct impact on energy related GHG emissions, both during the construction and maintenance of the building shell (embodied energy) and during the use of the building for commercial or residential purposes (operational energy) (Rickwood et al., 2008). Finally, an important factor is the average temperature, which directly depends upon the geographic location of the city, (e.g. latitude and altitude), but also on endogenous factors, such as the so called urban “heat island” effect (Among other, OECD 2010:70-71). While average temperature influences the city emissions in different ways, e.g. the average use of non-motorised means of transport and the emission from waste, the most important dimension is to be found within the building sector. Colder cities are likely to have higher emissions related to heating systems in winter, whereas warmer cities are likely to have higher emissions related to cooling system in summer (Glaeser and Kahn, 2010; UN-Habitat, 2011).

The second type of factors driving GHG emissions in cities concerns the urban socio-economic profile. One of the most evident factors falling into this category is the level of income of the city. Oftentimes, higher income leads to higher levels of consumption, including energy consumption and generation of waste, which in turn leads to higher GHG emissions per capita (Satterthwaite, 2008). The cultural dimension has also an important impact onto the urban dynamics, as it has the potential of shaping the behaviour of individuals. The UNDP, for instance, recognizes that public awareness of the condition of the environment might be one of the most important driving forces for environmental improvement worldwide (UNDP, 2002). This is particularly clear in the cases where the “green political culture” drives the environmental performance of the city (see for instance Walker, 2007, for San Francisco, California). Finally, restrictive legislation in matters of land use and real estate development leads to a lower level of emissions related to energy consumption, as it shapes the characteristics of the built environment and the consequent energy consumption (Glaeser and Kahn, 2008) . While they have been illustrated separately, it is important to acknowledge that geographic and socio-economic factors are in continuous mutual relation. For instance, the geographic characteristics of a city (e.g. its position near by the coast or a river) are likely to have an impact on its economic prosperity; on the other hand the urban demography might lead to direct consequences on the population density.

2.3. Sao Paulo and Cape Town. Two case studies to explore RCF

The previous sections have illustrated the peculiarities of cities and their potential of magnifying or reducing the human impact onto the environment, and the variety that exists among different cities and their carbon footprint. This section goes further, and merges the two perspectives by exploring the RCF as unit of analysis and of comparison. The graph below (Figure 2) is an elaboration of the data from Hoornweg et al. (2011:5-6). The horizontal axis reports the level of GHG emissions measured at the city level, and the vertical axis reports the level of GHG emissions for the country where the city is located in. The graph gives an immediate picture of the cities' footprint as opposed to the national one. On the left of the bisector, there are the cities that are performing better than the country they are located in (i.e. RCF < 1). The majority of the cities for which the data is available is positioned in this region of the graph, including the totality of North American and Latin American cities, Sydney and some European Asian cities. On the right side of the bisector, there are the cities that have a higher per capita footprint than the national one (i.e. RCF > 1). These are the Chinese cities, Cape Town, and some European cities, including Rotterdam which is the worst performing. There is a group of South Asian cities, positioned in the bottom right corner of the graph. These cities present a very low level of GHG emission and the difference to the national level is minimal, whether this is positive or negative. Singapore is on the bisector, as the urban area of the city of Singapore basically corresponds to the area of the country. As mentioned above, the two cities which will be analysed in depth are Sao Paulo and Cape Town. The former has a level of emissions of 1.4 tons of CO2e per capita, which is equal to the 33.7 % of the national level (Brazil's level of emissions is 4.6 tCO2e/capita). The latter, on the other hand, has a level of emissions of 10.21 tons of CO2e per capita, which is equal to the 103 % of the national level (South Africa's level of emissions is 9.91 tCO2e/capita).

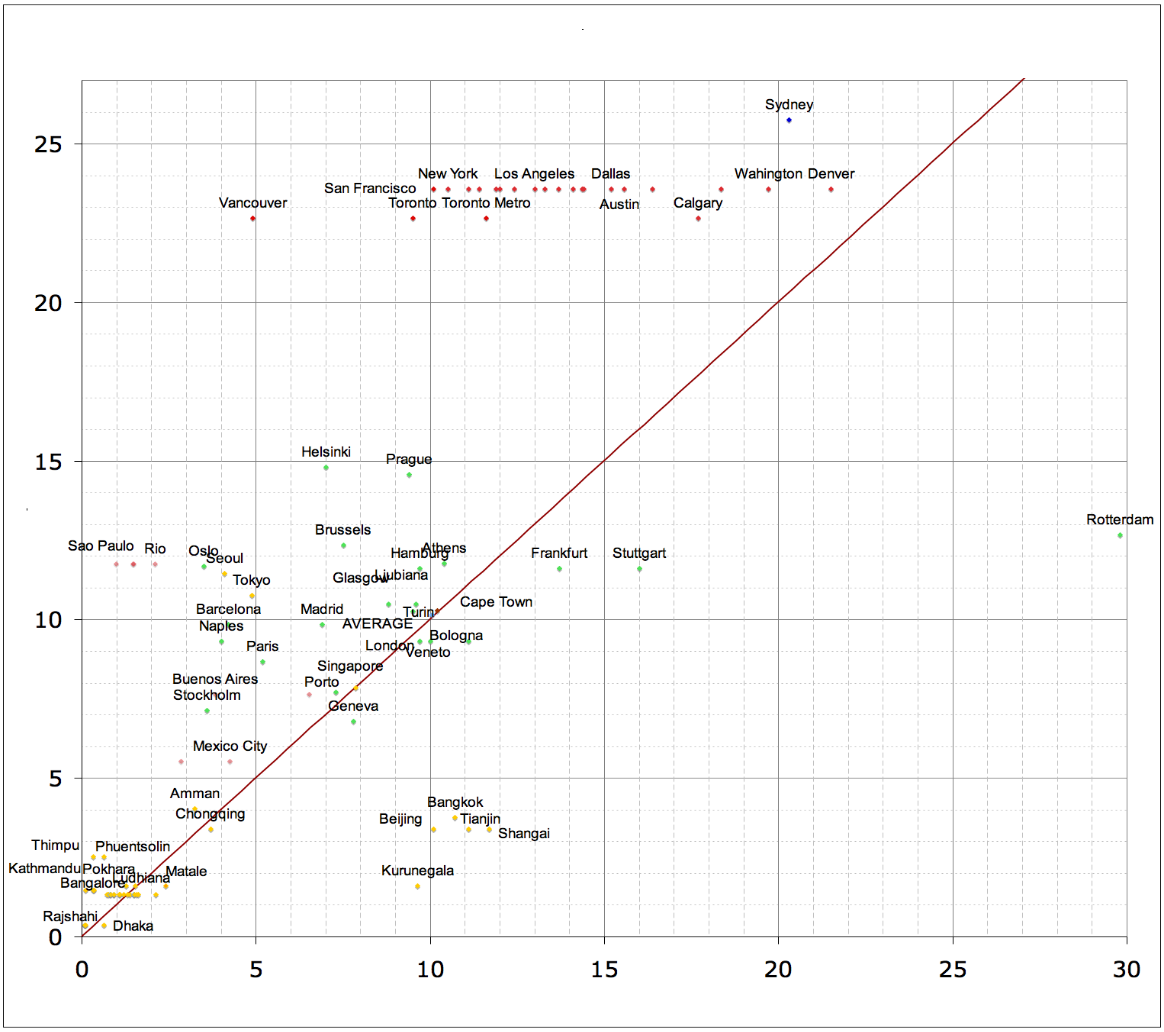

Figure 2. National and Local GHG emissions (tCO2e/capita)

2.3.1. Sao Paulo

Sao Paulo is at the heart of the largest urban agglomeration in Latin America, and one of the most populous cities in the world. The municipality of Sao Paulo has a population of 11 million, concentrating around six per cent of the national population (Vom Hove, undated). Even though it is the largest city in the country, Sao Paulo is also the youngest among the Brazilian metropoleis, having grown massively in the last 150 years, as a consequence of the massive urbanisation experience by the whole country (Santos and Câmara, 2002:170). Sao Paulo has been the heart of Brazilian industrialisation process, attracting investments and migrants from the whole region (Deák, 2001). According to a recent report of UN-Habitat (2012), its most evident characteristic is the striking inequality, made evident by pronounced socio-economic as well as spatial segregation which have contributed to building the conditions of a real ‘social apartheid’ (Whitaker Ferreira, 2010).

The economic prosperity of the Sao Paulo depends, among other things, upon the national macro economic situation. The Brazilian economy is the largest of Latin America (in 2004, Brazil represented almost a third of the continent GDP (De Faccio Carvalho, 2006)) and is the seventh wealthiest economy of the world. The national economy is characterised by a relatively developed service sector, representing just over the half of the country's GDP (51.3%); by the largest industrial sector of the continent (representing 38.6% of the GDP); and finally by an agricultural sector (10.1 %), which allows the country to be largely self-sufficient in food and counts one of the largest herd of the world, producing large quantities of meat and milk for domestic consumption and exportation (De Faccio Carvalho, 2006). As opposed to the national situation, the <u>*Paulista*</u> economy is dominated by the service sector (e.g. banking and finance) which today produces 75.8% of the value added of the GDP. It is followed by the industrial sector, with 24.2% and finally the primary sector with less than 0.01%, almost absent in the city (prefeitura.sp.gov.br, 2012).

2.3.2. The carbon footprint of Sao Paulo and Brazil[7]

The per capita level of emissions of Sao Paulo equals to 1.47 tons of CO2e, as opposed to the level of the country which is 11.76 tCO2e/capita, for a RCF value of 0.125. The difference between the city and the country level of per capita GHG emissions is largely explained by looking at the value of agriculture, forestry and land use activities. GHG emissions falling into these categories account for almost 80% of the Brazilian total GHG emissions and at the same time they are negligible in the Sao Paulo inventory. The reason is to be found in the profile of the city and of the country: as mentioned above, forest activities and agriculture are important components of the national geography and economy, but they are almost absent in the city of Sao Paulo, as it is the case in many other urban areas. Nonetheless even if these two categories were not included, RCF would still be smaller than 1 (i.e. the per capita carbon footprint of the city of Sao Paulo would be lower than the Brazilian one). Together, the emissions included in the categories *Land Use, Land-*

[7] The details of Sao Paulo's and Brazil's GHG emissions are in Appendix A. Except when specified otherwise, data on Brazil are from the national GHG inventory 2009, Brazilian Ministry of Science and Technology (MCT 2009)- data for the year 2003 are estimated using the historical data for 1990, 1994, 2000 and 2005. Data on Sao Paulo are from the city's GHG inventory <u>*Secretaria Municipal do Verde e do Meio Ambiente*</u> SVMA, 2005

Use Change and Forestry (LULUCF) and *Agriculture* are responsible for the 91.3 % of the difference: they represent an important but not sufficient explanation of why Sao Paulo has a per capita level of GHG emissions which is lower than Brazil. It is for this reason that we now turn toward other categories of the two GHG inventories, i.e. the categories of energy supply and the waste management.

The analysis of the difference in the energy supply category (tCO2e/capita 1.14 for Sao Paulo vs. 1.92 for Brazil) indicates that there are sectors whereby Sao Paulo presents a lower footprint and other where the footprint is higher. The generation of electricity, for instance, is a sector whereby Sao Paulo's per capita footprint is half as large as the Brazilian one (0.13 tCO2e vs. 0.27 tCO2e). This happens despite the higher electricity consumption at the city level, given a lower carbon intensity for the electricity production matrix of the region of Sao Paulo (33.46 tCO2e/GWH against the 74.73 tCO2e/GWH for Brazil) (SVMA, 2005, for Sao Paulo; and MME, 2003, for Brazil). Similarly, in the production of energy for the industrial sector, the city performs lower emissions than the country (0.07 vs. 0.63 tCO2e). While in economic terms the relative importance of the industrial sector is similar, this difference is due to the fact that industries in the city are less energy intensive than at the national level (i.e. a lower amount of energy is required to produce the same monetary value) (SVMA, 2005, for Sao Paulo; and MME, 2003, for Brazil). Finally the energy for agricultural activities accounts for 0.0003 tC02e in Sao Paulo s. 0.08 tCO2e at the national level. The difference, once again, is due to the fact that in Sao Paulo the sector is almost absent[8].

There are other sectors whereby Sao Paulo per capita carbon footprint is higher than the national one. These differences, yet, are not sufficient to balance the elements explained above. The building sector, for instance, accounts for 0.12 tCO2e/capita in Sao Paulo and for 0.10 in Brazil. In this case, the difference might be attributed to a different income level (higher in Sao Paulo), leading to higher energy consumption, or to a different average number of dwellers per residential unit (3.43 person/unit in Sao Paulo vs. 3.75 in Brazil in 2000) (IBGE, 2010). Also, the per capita emissions deriving from the transport-related energy

[8] As the 'fugitive emissions' were not calculated at the city level, an estimation has been done based on the national value. For this reason, the total value result to be different than the city GHG inventory. In this section, the comparison is carried on only for what concerns the 'fuel combustion' sub-category

consumption are higher in the city than in the country (0.79 and 0.73 tC02e respectively). This is probably due to the much higher car ownership rate in the city than in the country: in Sao Paulo it amounts to 520 passenger cars per 1000 people vis-à-vis a national rate of 131 cars (SVMA, 2005, for Sao Paulo; and databank.worldbank.org, 2012, for Brazil). Finally, emissions related to the waste disposal sector are 1.4 times higher in Sao Paulo than the national value (0.35 vs. 0.25 tCO2e/capita), probably because of the larger generation of waste (1.4 vs. 0.9 kg per day/capita) (UNEP 2003, for Sao Paulo; and stats.oecd.org, 2012, for Brazil). At the country level, moreover, it is estimated that 32.83% of the waste was recovered in 2000, as opposed to the city, where virtually all waste was sent to landfills (data from UNEP 2003, for Sao Paulo; and stats.oecd.org, 2012, for Brazil). Today the situation is likely to be different, as in January 2004 (*after* the GHG inventory was compiled) the *"Bandeirantes Landfill Gas to Energy Project"* was started, resulting in an average estimated reduction of GHG emissions of almost 30% per year (ICLEI, 2009). If this is the case, the per capita emissions of Sao Paulo's waste sector would be slightly lower than the national level.

2.3.3. Cape Town

Cape Town Metropolitan Municipality[9] lies at the core of the second most populated city-region in South Africa. The metropolitan municipality, which host 3.2 million inhabitants, covers 2,461 km2, with an estimated population density between 1300 and 1400 persons per squared kilometre. The end of apartheid in 1994 is the single most important event in the recent history of South Africa, as it has triggered a remarkable process of political democratisation and of economic development and stabilisation. Nonetheless, while the national economy has been growing steadily, its substantial reliance on natural resources as inhibited the translation of economic growth into creation of employment. The gap of life standards, due to the racist policies during the apartheid, has remained as a consequence of large income inequality. The reforms, for instance, have not achieved the necessary results in terms of education, with huge disparities persisting. This, in turn, has lead to an excess demand for skilled labour and a large surplus

[9] In this section , data on Cape Town, mainly draw on the OECD territorial review of the Cape Town (2008)

of low-skilled and non-skilled labour, generating growing wage differentials. Today South Africa presents an extremely high Gini coefficient (0.59), which is one of the major causes of most the country's social problems. These issues are reflected in Cape Town too. Even though the dynamics of development have began to change, the urban form still resents significantly from the apartheid period. The planning system exacerbated a low-density, sprawling form of expansion, leading to a fragmentation in numerous nodes of the urban economic activities, and to limited possibilities to develop a viable public transport system, liveable neighbourhoods and economies of scale in the delivery of public services.

The economy of the city is dominated by the service sector which today represents almost 70% of the total GDP and employment. While the South African pole for financial and business services remains Johannesburg, the contribution of the finance and insurance sector to Cape Town regional GDP has grown enormously in the decade from 1995 to 2005, thanks to the presence of HQ of a number large of firms, and it represents today the 16.6% of the regional economy. Other important activities include urban consumption (e.g. real estate development) and food processing. Finally, thanks to the geographical position of the city, the logistics cluster is particularly prosperous, making of Cape Town a major node for the regional and international transportation of agro-food, refined oil and steel. As opposed to the city's economy, the national economy shows a larger dependency upon natural resources such as such as gold and iron ore abundant in the country. The manufacturing sector is also responsible for a great share of the national production, with an important automotive and metal industry. In 2001, South Africa was the 19th producer of steel in the world, and the first in Africa, with almost 60% of the total production of the continent. Until 2007, moreover, the country was the leading producer of gold in the world. The tertiary sector, finally, accounts for about half of the national GDP.

2.3.4. The carbon footprint of Cape Town and South Africa[10]

Cape Town level of GHG emissions equals to 10.21 tons of CO2e per capita, which is equal to the 103%

[10] The details of Cape Town's and South Africa's GHG emissions are in Appendix B. Except when specified otherwise, the data on South Africa come from the national GHG inventory, DEAT, 2009. Data on Cape Town the city's GHG inventory presented in three papers by Kennedy et al. (2009a; 2009b; 2010)

of the national level (South Africa's level of emissions is 9.91 tCO2e/capita)[11]. A careful analysis of the data, however, reveals that the two inventories include slightly different categories, and interpreting this mismatch in different ways, might lead to different results. For this reason it is necessary to distinguish what are the sectors that are directly comparable, and what are those which are not. For instance, certain sectors[12] were not included in the inventory of Cape Town. This does not change the overall result (RFC>1), as if these values were counted for in the city's inventory, the difference between city and country level of GHG emissions would have been even greater. At the same time, the 'marine and aviation' category was calculated with different methodologies for the city's and the country's inventory[13]. Yet, this sector has been included in Cape Town's inventory, "in order to include impacts from the movement of people and goods to and from the city", which is a crucial component of the nature itself of the city (Kennedy et al., 2010). Considering the role of the city as a national and international transportation hub, moreover, it is likely that the per capita level of GHG emissions related to this sector would be in any case higher than the national level. It has to be noted, that even if none of these sectors was included in either one of the inventories, the per capita footprint of Cape Town would still be higher than the national one, i.e. 6.4 and 6.02 tCO2e/capita respectively.

Beside the presence of categories which are not directly comparable at the country and at the city level, there are few sectors that help identifying why Cape Town per capita level of emissions is higher than the national one. The category including buildings heating and energy for industries, for instance, accounts for 1.15 tCO2e/capita in Cape Town and 1.07 in the whole South Africa. This is due to a different level of

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[11] Comparing Cape Town's to South Africa's carbon footprint is a difficult task, as the GHG inventories report slightly different variables. It has been therefore necessary to calculate again the respective values and draw a new set of variables, by aggregating or disaggregating the data available.

[12] These include: Industrial processes and product use, Agriculture, forestry and land use, Petroleum extraction, Waste water handling, Fugitive emissions from fuels

[13] The IPCC 2006 guidelines, applied to compile the South African national inventory, recommend to include as a memo item GHG emissions from international aviation, including take-offs and landing and international water-borne navigation. At the same time, the Cape Town inventory has been calculated on the basis of the total fuel loaded locally into planes and ships "in order to include impacts from the movement of people and goods to and from the ten cities"(Kennedy et al. 2010)

energy consumption, 1.7 times higher in Cape Town than in South Africa, possibly due to a different per capita income level. The difference in energy consumption, yet, is partially outweighed by a less carbon intensive energy matrix in Cape Town. The higher income of Cape Town lifts up the GHG emissions in the transportation sector too, where it is related to a higher car ownership rate, twice as high as the national rate (City of Cape Town 2009, for Cape Town; and databank.worldbank.org 2012, for South Africa), and the gasoline consumption 1.8 times as high (Kennedy et al. 2009a, for Cape Town; and databank.worldbank.org, for South Africa). The level of emissions is 1.44 in Cape Town tC02e/capita and 0.9 in South Africa. Beside the income levels, this difference is likely to reflect also the fact that Cape Town suffers from a very low degree of connectivity, and private cars are by large the preferred mean of transportation (OECD, 2008). Finally, it is difficult to compare the waste-related GHG emissions, as the two inventories have used different methodologies[14]. However it is likely that the footprint is higher in Cape Town, provided that the city presents a level of per capita waste generation more than twice as high as the national amount, and there is to date no particular technology in the city to reduce the emissions from this source (Kennedy et al., 2010).

The estimation of GHG emissions related to the production and consumption of electricity represents the only sector where the city's footprint is lower than the national one. The per capita levels equal respectively 3.38 tC02e (for Cape Town) and 3.88 tC02e (for South Africa). The difference – i.e. Cape Town's levels only amounts to 87% of the South Africa level- is due to different levels of energy consumption, which is lower in Cape Town. The lower level of emissions might appear surprising, when looking at the per capita level of income, higher in Cape Town than at the national level. Nevertheless this might be explained by the fact that countrywide, 60% of the national electricity supply is consumed by the industrial sector (ABB Group, 2011), which in Cape Town is relatively small (17% of the GDP according to the OECD 2008), as opposed to other industrial cities such as Sedibeng where industries account for 40% of the local GDP (Van Vuren et al., 2008:13), or to the national level where the sector accounts for 30%. Another possible factor

[14] The national inventory has been calculated using a First Order Decay (FOD) model, as described by the IPCC 2006 guidelines. Conversely, Kennedy et al. used the Total Yield Gas approach (IPCC, 1996)

of the low per capita consumption might be the underinvestment in the electricity supply, which does not have kept the pace with demand. Even if the demand was higher, the final consumption could not rise because of supply shortage (OECD, 2008).

3. Discussion and Conclusion

3.1. Findings of the research

Sao Paulo and Cape Town represent respectively an example of a city where the per capita level of GHG emissions is lower than the national one (i.e. RCF < 1), and of a city where the emissions level is higher (i.e. RCF>1). There is not a single answer explaining the different value in the two cities, and the analysis of the difference between each of the components of the national and the local inventories sheds light on the multiple reasons why this happens. The most important dimensions to look at are the structure of the economy, the level of per capita income and what is directly dependent on that, and the carbon intensity of the energy matrix. Comparable indicators and detailed data on these sectors become crucial to explain with precision cities' Relative Carbon Footprint.

Structure of the Economy

The main driver of the gap between city and country per capita footprint is, in both cases, the different range of economic activities in the city and in the country. This is evident when considering, for instance, the impact of activities such as agriculture and forestry in explaining the gap between the Paulistan and the Brazilian carbon footprint. Also the emission levels related to energy consumption in the industry sector depend upon the different activities, which in Sao Paulo present a much lower energy intensity. On the other hand, the 'marine and aviation' sector produces similar results in explaining why the carbon footprint of Cape Town is higher than the South African one. Moreover, the low electricity consumption in Cape Town, which implies a lower level of energy-related GHG emissions in the city, is also due to the economic profile of the city where the high electricity-consuming industrial sector is relatively small. While it sounds like a truism, i.e. a city releases less greenhouse gases if the carbon intensive activities are conducted elsewhere, this result is crucial to show, for instance, that it is not urbanisation per se that determines the level of emissions (high or low), but polluting activities and whether they are carried on in a certain city or elsewhere.

Per Capita Income

The level of per capita income in the city also plays an important role, much in line with the arguments introduced in part 2.2. As already mentioned, both cities present a per capita income which is more than 3.5 times higher than the national average. In both cities, this is directly linked to higher emissions from the transportation sector, through higher car ownership rate; from the waste disposal sector, through higher per capita generation of waste; and from the heating sector, through higher levels of energy consumption. There is evidence, however, suggesting that the effect of the higher income can be magnified or neutralised by the way urban development is governed. For instance, the fact that Cape Town is highly fragmented and public transport is not adequate to connect the urban fabric, it is likely that GHG emissions from the transportation sector increase far beyond the level of cities with comparable per capita income. Conversely, the waste management project in the *Bandeirantes* landfill in Sao Paulo demonstrates that it is possible to reduce significantly the carbon footprint, despite the high level of waste generation.

Energy Matrix

Finally, an important dimension to be considered when looking at GHG inventories (both urban and national) is the way energy is produced. The different carbon intensity of the energy matrix already explains the absolute difference between Sao Paulo's and Cape Town's per capita footprints. Nevertheless, it also plays a role in determining the different RCF of the two cities. For instance, the fact that the energy supply to the Sao Paulo region is less carbon intensive than the national average contributes to decrease even further the city's RCF. In Cape Town the situation is different, as the city sources its energy in the national grid. Yet, the less carbon-intense energy mix for the 'heating and industry' sector (compared to South Africa's national average) contributes to lowering the city's footprint as opposed to the national one, even if it is not sufficient to reverse the value of the RCF.

3.2. Policy implications and Openings to further research

The findings of this research are relevant for purposes of urban policy making, both at the local and at the national level, as the identification of the critical sectors in terms of GHG emissions is fundamental to reducing anthropogenic pressure onto the climate. Determining what are the conditions under which cities represent a solution for reducing a country's total GHG emissions, is fundamental in this period characterised by an increasing importance of cities in determining the social, economic, demographic and cultural trends.

Establishing what economic activities in the city and in the country are the determinants of RCF, and how this happens, is useful to identify the priorities of action to reduce the emissions. Sao Paulo, for instance, might serve as an example of a city that is prosperous thanks to a relatively low-carbon economy, as opposed to Cape Town. This does not mean that we recommend shifting polluting economic activities outside the city boundaries to reduce the relative and absolute level of GHG emissions. Instead, we simply highlight that the economic development of cities does not need to be bound to high levels of emissions, and that certain carbon intensive economic activities (not necessarily all of them) could be limited or avoided with no damage to the urban economic performance. While this recommendation concerns the urban economic production, the following step is to look at the consumption of a city, e.g. the GHG emissions of the urban consumption basket[15], to identify once again the assets and the constraints of a certain urban economy.

The analysis of the level of income in both cities suggests similar conclusions. In both cities the per capita level of income is higher than in the country as a whole, as well as the level of GHG emissions from sources directly related to it, i.e. transportation, heating and waste. This indicates that the identification of a strategy for decoupling economic growth and people's wellbeing from resource depletion and environmental degradation (in this case through GHG emissions) has not been successful yet, and needs to be a paramount political priority. Life standard has to be decoupled from carbon intense consumption and

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[15] See for instance CGDD 2012

production, either by changing the patterns of consumption and production, or by reducing the emissions originating from the current ones. The aforementioned "*Bandeirantes Landfill Gas to Energy Project*" is an example in this sense. In both cases (i.e. looking at the economic structure and at the level of income) the analysis of RCF is useful to highlight an important difference between Sao Paulo and Cape Town. While both cities are economically successful vis-à-vis their respective country averages, the Brazilian city is also a virtuous case of environmental performance (at least for what concerns a production perspective). The mere analysis of the city characteristics in absolute value would have missed an important dimension: the economic and the environmental performance is a consequence of different dynamics (including, for instance, the stage of development). These indicators, when looked at in comparative terms (i.e. *relatively* to the country average), shed light on the potential of a specific urban reality.

Finally, the present research has shown how important the energy matrix is. Even in the cases when the issue lies outside the sphere of urban policy making, which is not always the case, it remains an important indicator to consider. For instance, if the energy matrix already presents a low carbon-intensity, investments and policies targeting energy efficiency are unlikely to have high returns in terms of GHG reduction and could probably have a different target. The focus on the RCF, once again, provides important insights as it indicates, for instance, to what extent energy intensive activities can be carried on in the city, as opposed to other locations in the country.

This study also opens the way to further research. Identifying important variables which contribute to explain the environmental impact of a city might be useful to prepare a comparison among cities on a larger scale. Once these variables are measured for different cities, quantitative analysis could be carried out to understand, in a more general perspective, what variables are more important in determining the RCF of cities. Furthermore, the approach that has been used here, i.e. the analysis of one indicator of environmental conditions of a city's carbon footprint *as opposed* to the average of the country in which it is located can be developed with regard to other indicators as well. In particular, whereas the level of GHG emissions is an important dimension to indicate one of the impacts of a city on the global environment, indicators measuring other flows of the urban metabolism could be useful to assess the performance of essential infrastructures. In fact, even though it has been at the centre of international debate, the emissions of greenhouse gases is far from being the only element of cities' environmental pressure. Similarly to RCF, the analysis of other indicators at the city level relatively to the national level contributes to identifying the potential of a specific urban form and, at the same time, allows ranking cities countrywide and worldwide.

Finally, the assumption stated at the beginning of the research needs to be further developed. Cities are the *locus* to understand important environmental issues, as well as issues of economic and human development. In this sense, the perspective taken in this study (i.e. looking at city/country values) could be used to look at the state of the life quality in a city alongside with its environmental performance. This would be useful to explore and compare what are the urban dynamics that are determining the city potential for granting high standards of life, while reducing resource use and environmental impact[16]. Also in this sense, the analysis of the performance of a city vis-à-vis the country it belongs to would allow to fully understand the specificity and the potential of a particular urban reality.

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[16] see UNEP 2011b

Bibliography

ABB Group 2011, South Africa, Energy Efficiency Report, Country reports | Trends in global energy efficiency 2011

BAI, X. 2002, Industrial relocation in Asia: A sound environmental management strategy? Environment 44(5): 8–21.

BROWN, M, F SOUTHWORTH AND A SARZYNSKI (2008), “Shrinking the carbon footprint of metropolitan America”, Brookings Institution, Washington DC, accessed 2 December 2008 at http://www.brookings.edu/papers/2008/05_carbon_footprint_sarzynski.aspx.

CGDD 2012, Commissariat Général au Développ ement Durable (Ministère de l'Écologie, du Développement durable, des Transports et du Logement), Le contenu carbone du panier de consommation courante, *Le Point sur* n°121 avril 2012, retrieved the 18.4.2012 at http://www.statistiques.developpement-durable.gouv.fr/fileadmin/documents/Produits_editoriaux/ Publications/Le_Point_Sur/2012/LPS%20121%20Panier%20carbone%20BDv2.pdf

City of Cape Town 2009, Integrated Transport Plan2006-2011

Clinton Climate Initiative (undated), William J Clinton Foundation, accessed on the 4.3.2012 at http://www.clintonfoundation.org/what-we-do/clinton-climate-initiative/cities

databank.worldbank.org, 2012, World Development Indicators, retrieved the 14.4.2012 at http://data.worldbank.org/data-catalog/world-development-indicators

DE FACCIO CARVALHO Paulo César, (2006) Brazil, FAO Country Pasture/Forage Resource Profiles, retrieved the 12.4.2012 at http://www.fao.org/ag/AGP/AGPC/doc/Counprof/Brazil/Brazil.htm

DEÁK, Csaba (2001) “Sao Paulo” in Carmona, Marisa & Burgess, Rod (orgs, 2001) Strategic planning & urban projects/ Responses to globalisation from 15 cities Delft University Press, Deft, pp:173-82 (text) & 282-88 (illustrations)

DEAT 2009, Department of Environmental Affair and tourism of the Republic of South Africa, Greenhousegas inventory South Africa 1990 to 2000, National Inventory Report, May 2009

DECKER, H.; ELLIOTT, S.; SMITH, F. A.; BLAKE, D. R.; SHERWOOD ROWLAND, F. Energy and material flow through the urban ecosystem. Annu. Rev. Energy Environ. 2000, 25, 685–740.

DODMAN David 2009a, “Blaming cities for climate change? An analysis of urban greenhouse gas emissions inventories”, Environment and Urbanization Vol 21, No 1, April, pages 185–201.

DODMAN David 2009b, Urban Density And Climate Change, United Nations Population Fund (UNFPA) Analytical Review of the Interaction between Urban Growth Trends and Environmental Changes

GLAESER Edward, The Triumph of the City 2011

GLAESER Edward L., KAHN Matthew E. 2010, The greenness of cities: Carbon dioxide emissions and urban development, Journal of Urban Economics 67 (2010) 404–418

HOORNWEG Daniel, SUGAR Lorraine and TREJOS GOMEZ Claudia Lorena (2011), Cities and greenhouse gas emissions: moving forward, Environment and Urbanization, published online 10 January 2011

IBGE, 2010, Censo Demográfico 2010, retrieved the 24.3.2012, at http://www.ibge.gov.br/home/estatistica/populacao/ (for national data) ; http://www.censo2010.ibge.gov.br/ (for local data)

ICLEI 2009, Sao Paulo, Brazil,Turning pollution into profit: the Bandeirantes Landfill Gas to Energy Project, ICLEI case studies

IEA/OECD (2008). World Energy Outlook 2008.

IPCC, 1996. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Vol. 1–3468–483.

IPCC,2001:Climate Change 2001:The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton,J.T.,Y. Ding,D.J. Griggs,M. Noguer,P.J. van der Linden,X. Dai,K. Maskell,and C.A. Johnson (eds.)]. Cambridge University Press,Cambridge,United Kingdom and New York,NY,USA,881pp, retrieved the 19.2.2012 at http://www.grida.no/publications/other/ipcc_tar/?src=/climate/ipcc_tar/wg1/index.htm

IPCC 2006, Intergovernmental Panel on Climate Change, Guidelines for National Greenhouse Gas Inventories, Cambridge University Press, Cambridge.

KAMAL-CHAOUI, Lamia and ROBERT Alexis (editors) (2009), “Competitive cities and climate change”, OECD Regional Development Working Paper No 2, OECD Publishing, page 12.

KATES, R, M MAYFIELD, R TORRIE AND B WITCHER (1998), “Methods for estimating greenhouse gases from local places”, Local Environment Vol 3, No 3, pages 279–298

KENNEDY, C., J. STEINBERGER, B. GASSON, T. Hillman, M. HAVRÁNEK, D. PATAKI, A. PHDUNGSILP, A. RAMASWAMI, G. VILLALBA MENDEZ, (2009b) Greenhouse Gas Emissions from Global Cities, Environmental Science & Technology VOL. 43, NO. 19, 2009

KENNEDY C. A., A. Ramaswami, S Carney and S Dhakal (2009). Greenhouse Gas Emission Baselines for Global Cities and Metropolitan Regions, paper presented at the 5th Urban Research Symposium: Cities and Climate Change – Responding to an Urgent Agenda, Marseille, June 28-30 2009

KENNEDY, C.; STEINBERGER, J.; GASSON, B.; HILLMAN, T.; HAVRANEK, M.; PATAKI, D.; PHDUNGSILP, A.; RAMASWAMI, A.; VILLALBA MENDEZ, G. Methodology for inventorying greenhouse gas emissions from global cities. Energy Policy 38 (2010) 4828–4837

McKinsey Global Institute 2011, Mapping the Economic Power of Cities”

MCT 2009- Ministério da Ciência e Tecnologia, Inventário Brasileiro Das Emissões E Remoções Antrópicas De Gases De Efeito Estufa, Informações Gerais E Valores Preliminares

MEHAFFY Michael, The real reason cities can be so much greener than other places, The Atlantic Cities, 22 February 2012, retrieved the 15.4.2012 at http://www.theatlanticcities.com/jobs-and-economy/2012/02/real-reason-cities-can-be-so-much-greener-other-places/1293/

MME 2003, Ministerio das Minas e Energia do Brasil, Balanços Energéticos Nacional, retrieved the 24.3.2011 at http://www.agg.ufba.br/ben2003/default.htm

Munich Re Group (2004), Megacities; Megarisks; Trends and Challenges for Insurance and Risk Management, Munich Reinsurance, Munich, page 25.

NEWMAN P, KENWORTHY J, 1989, ``Gasoline consumption and cities'' Journal of the American Planning Association 55 24 ^ 37

OECD (2010), Cities and Climate Change, OECD Publishing. http://dx.doi.org/10.1787/9789264091375-en

OECD (2008), OECD territorial reviews: Cape Town, South Africa

prefeitura.sp.gov.br 2012, Municipio em Dados, retrieved the 13.3.12 at http://www9.prefeitura.sp.gov.br/sempla/md/index.php?texto=introducao&ordem_tema=5&ordem_subtema=11

RAMASWAMI, Anu, HILLMAN, Tim, JANSON, Bruce, REINER, Mark, and THOMAS, Greg. 2008. "A demand-centered, hybrid life-cycle methodology for city-scale greenhouse gas inventories." Environmental Science and Technology. Vol. 42, No. 17, pp. 6455—6461.

REES E. William 1992 Ecological footprints and appropriated carrying capacity: what urban economics leaves out, Environment and Urbanization 4: 121

RICKWOOD, P.; GLAZEBROOK, G.; SEARLE, G. Urban Structure and Energys A Review. Urban Policy Res. 2008, 26 (1), 57–81.

SANTOS, Thereza Christina Carvalho; CÂMARA, João Batista Drummond. Geo Brasil 2002: perspectivas do meio ambiente no Brasil. Brasília: IBAMA, 2002. 447p.

SATTERTHWAITE David 2008, "Cities' contribution to global warming: notes on the allocation of greenhouse gas emissions", Environment and Urbanization Vol 20, No 2, October, pages 539–549

stats.oecd.org, 2012, OECD.Stat Extracts, retrieved the 14.4.2012 at http://stats.oecd.org/Index.aspx?datasetcode=METRO#

SVMA (2005)- Secretaria Municipal do Verde e do Meio Ambiente de Sao Paulo (2005), Inventário de Emissões de Efeito Estufa do Município de Sao Paulo, Centro de Estudos Integrados sobre Meio Ambiente e Mudanças Climáticas (Centro Clima) da Coordenação dos Programas de Pós-graduação de Engenharia (COPPE) da Universidade Federal do Rio de Janeiro (UFRJ).

UNITED NATIONS (2007), "City planning will determine pace of global warming", accessed 2 December 2008 at http://www.un.org/News/Press/docs/2007/gaef3190.doc.htm.

uncsd2012.org, 2011, Making the economic case for greening cities, Published 13 Oct 2011 on http://www.uncsd2012.org/rio20/index.php?page=view&nr=430&type=230&menu=39

UNDP & Stockholm Environment Institute 2002 - Making Green Development A Choice China Human Development Report

UNDP 2011, Human Development Report 2011

UNEP 2003, GEO Cidade de Sao Paulo

UNEP 2011a, Green Economy Report, Cities chapter accessed 28.10.2011 at http://www.unep.org/greeneconomy/Portals/88/documents/ger/GER_12_Cities.pdf

UNEP 2011b, Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel. Fischer-Kowalski, M., Swilling, M., von Weizsäcker, E.U., Ren, Y., Moriguchi, Y., Crane, W., Krausmann, F., Eisenmenger, N., Giljum, S., Hennicke, P., Romero Lankao, P., Siriban Manalang, A., Sewerin, S.

UNEP- World Bank – UN-Habitat, 2010 -International Standard for Determining Greenhouse Gas Emissions for Cities VERSION 2.1, 28 JUNE. 2010

UNFPA 2007, Linking Population, Poverty and Development - Urbanization: A Majority in Cities accessed the 28.10.2011 at http://www.unfpa.org/pds/urbanization.htm

UN-Habitat, 2010 Sao Paulo: A Tale of Two, Cities. Cities & Citizens Series: Bridging The Urban Divide

UN-Habitat, 2011 Cities And Climate Change: Global Report On Human Settlements

VAN VUREN Lennard, GROBLER Wynand and PELUPESSY Wim 2008, Globalization And Local Development: The Sedibeng Steel Industry In South Africa, African Studies Centre (ASC) – Leiden University (The Netherlands), Seminar on 17 April 2008

VANDEWEGHE Jared R. and KENNEDY Christopher 2007, A Spatial Analysis of Residential Greenhouse Gas Emissions in the Toronto Census Metropolitan Area, Journal of Industrial Ecology Volume 11, Number 2

VOM HOVE Tann,ed. by, undated, The world's largest cities and urban areas in 2006 and 2020, retrieved the 13.4.2012 at http://citymayors.com/statistics/urban_2006_1.html

WACKERNAGEL Mathis, KITZES Justin, MORAN Dan, GOLDFINGER Steven and THOMAS Mary (2006), The Ecological Footprint of cities and regions: comparing resource availability with resource demand, Environment and Urbanization 2006 18: 103

WHITAKER FERREIRA Joao 2010, Interview with author, in United Nations Human Settlements Programme (UN-HABITAT), 2010 Sao Paulo: A Tale of Two, Cities. Cities & Citizens Series: Bridging The Urban Divide

WIEDMANN, T. and MINX, J. (2008). A Definition of '□Carbon Footprint'□. In: C. C. Pertsova, Ecological Economics Research Trends: Chapter 1, pp. 1--11, Nova Science Publishers, Hauppauge NY, USA. https://www.novapublishers.com/catalog/product_info.php?products_id=5999.

Appendix A

Brazil and Sao Paulo GHG inventories (in tCO2e)

Brazil and Sao Paulo GHG inventories (in tCO2e)					
2003	Br Total	Br/capita	SP total	SP/capita	SP / Br
Energy	348,454,800	1.92	11,896,000[17]	1.12	0.584
Electricity	48,934,200	0.27	1,334,478	0.1300	0.47
Industries	113,799,800	0.63	769,070	0.0700	0.11
Transportation	132,642,600	0.73	8,422,810	0.7900	0.10
Residential Buildings	17,957,600	0.10	1,316,223	0.1200	0.12
Agriculture	14,900,400	0.08	2,779	0.0003	0.00
Other sector	3,934,800	0.02	213,739	0.0200	0.92
Fugitive Emissions	16,285,200	0.09	476,347	0.0400	0.5
Industrial Processes	36,121,000	0.20	-	-	-
Agriculture/Husbandry	447035400	2.46	780	0.0050	0.00
LULUCF	1259520600	6.93	52,000	0.005	0.001
Waste	45655000	0.25	3,703,000	0.35	1.387
Total	2,136,786,800	11.76	15,651,780	1.47	0.125

Data on Brazil are from the national GHG inventory 2009, Brazilian Ministry of Science and Technology (MCT 2009)- data for the year 2003 are estimated using the historical data for 1990, 1994, 2000 and 2005.

Data on Sao Paulo are from the city's GHG inventory Secretaria Municipal do Verde e do Meio Ambiente SVMA, 2005

[17] This is less than the total of the Energy sub-sectors to avoid double counting of emissions from electricity production.

Appendix B

South Africa and Cape Town GHG inventories (in tCO2e)					
Sector	SA total (2000)	SA per capita	CT total (2005)	CT per capita	CT/SA
Energy	268,452,528	6.10	34,207,938	9.78	1.603
Energy industries	170,716,300	3.88	11,826,518	3.38	0.872
Heating and Industries	46,532,424	1.06	4,021,662	1.15	1.087
Transportation - as per IPCC 2006 guidelines	39,445,315	0.90	5,035,820	1.44	1.606
Transportation - Aviation and marine	11,758,490	0.27	13,323,940	3.81	14.257
Solid Waste	8,085,000	0.18	1,484,881	0.42	2.311
Other Sectors	166,339,550	3.62	-	-	-
Industrial processes and product use	61,469,090	1.40	-	-	-
Agriculture, forestry and land use	20,493,510	0.43	-	-	-
Energy Industry - Petroleum extraction	42,658,510	0.90	-	-	-
Waste water handling	1,307,800	0.03	-	-	-
Fugitive emissions from fuels	40,410,640	0.86	-	-	-
Grand Total	442,877,078	9.91	35,692,819	10.21	1.030
Total of the comparable information (with aviation and Marine)	276,537,528	6.28	35,692,819	10.21	1.624
Total of the comparable information (without aviation and Marine)	264,779,038	6.02	22,368,880	6.40	1.063

Data on South Africa come from the national GHG inventory, DEAT, 2009.

Data on Cape Town the city's GHG inventory presented by Kennedy et al. (2009a; 2009b; 2010)