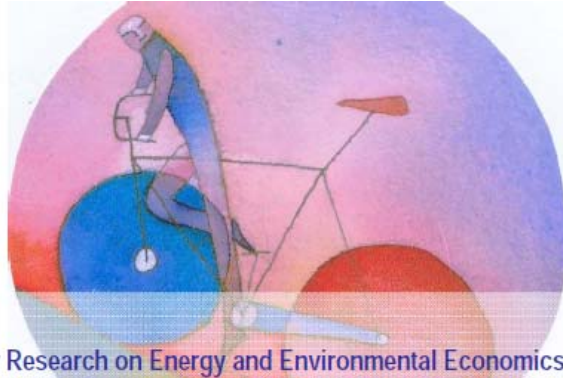


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**A Comparative Analysis of Global City Policies in
Climate Change Mitigation:
London, New York, Milan, Mexico City and Bangkok**

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**A COMPARATIVE ANALYSIS OF GLOBAL CITY POLICIES IN
CLIMATE CHANGE MITIGATION: LONDON, NEW YORK,
MILAN, MEXICO CITY AND BANGKOK**

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Abstract: Global cities have emerged as major players on climate change issues. The paper considers five case studies (London, New York, Milan, Mexico City, Bangkok), with the aim of identifying main emission drivers at urban level and verify the coherence of urban mitigation strategies with local emission contexts. At this purpose, local emission inventories and mitigation plans of the five cities are compared through a set of city indicators. In all cases GHG emissions derive primarily from local energy uses. Transportation and energy uses in buildings are the most emitting sectors in all cities, with different weights in analyzed cases depending on specific conditions. City mitigation strategies and measures, though characterized by different time horizons, are coherent with local emission contexts. The need of standardized indicators and methodologies constitutes an area of future development and investigation.

Key Words: climate change, global cities, mitigation plans, local emission inventories

JEL classification codes: Q49; Q54; R00

A COMPARATIVE ANALYSIS OF GLOBAL CITY POLICIES IN CLIMATE CHANGE MITIGATION: LONDON, NEW YORK, MILAN, MEXICO CITY AND BANGKOK

I. INTRODUCTION

Major cities contribute significantly to global greenhouse gas (GHG) emissions, in particular of carbon dioxide (CO₂)¹. Urban areas concentrate people and businesses that are responsible for high levels of energy consumption to satisfy residential, production and mobility needs.

Urban features like high population density and compactness have usually been associated with congestion, pollution and pressure on public service provision, but recent works have highlighted they may also generate agglomeration benefits that are environmentally effective (GLA, 2008b). If we consider per capita GHG emissions, cities turn out to be more efficient than nations. A survey on selected cities from Europe, North America, South America and Asia shows that city per capita CO₂ equivalent emissions (CO₂e) are substantially smaller than their countries (Dodman, 2009). Beijing and Shanghai are an exception to this statement², suggesting that differences in the relationship between urban structure and emissions should be further explored especially among cities in developing countries.

An increasing number of city mayors is recognizing the potential to reduce emissions in their territories and is committing to voluntary reduction targets. Mitigation commitments can take the form of both individual or collective self-commitments (such as the U.S. Conference of Mayors Climate Protection Agreement) or formal agreements with international institutions (such as the European Covenant of Mayors)³. Worldwide, local commitments on climate change are often spread by international associations and city networks, playing a major role in sharing best practices on mitigation (i.e. guidelines to build emission inventories, tools and software to calculate local emissions, guidelines to define and implement mitigation plans)⁴. Moreover, they

¹Estimates account urban activities responsible for 80% of global carbon dioxide (UNEP, UNHabitat, 2005). Emission levels of a global city as New York may be compared with national emissions of a country like Ireland: respectively, 63,1 MtCO₂e (Bloomberg, 2008b) and 69,7 MtCO₂e (UNFCCC, 2008).

²Beijing and Shanghai per capita emissions, expressed as percentage of national per capita emissions, are 205,4% (Beijing) and 241,1% (Shanghai) (ibid.).

³The “U.S. Conference of Mayors Climate Protection Agreement” sets the American Kyoto target at city level and is currently endorsed by 900 municipalities (<http://www.usmayors.org/climateprotection/agreement.htm>); the European Covenant of Mayors involves almost 500 municipalities and commits them in adopting a Sustainable Energy Action plan, with a target going beyond the 20% reduction of GHG emissions by 2020 (<http://www.eumayors.eu/>). In June 2008, delegates from ten Asian cities signed the “Bangkok Declaration on Climate Change” during the “ASEAN+6 City Forum on Climate Change”, organized by the Bangkok Metropolitan Authority and UNEP (<http://www.roap.unep.org/press/NR08-08.html>).

⁴Within its “Cities for Climate Protection” campaign, ICLEI has defined a “five milestones” process to guide local governments in the development of a local plan; an “International Local Government GHG Emissions Analysis Protocol” to set criteria that may guide in the collection of data and conceptual organization of local emission inventories; a software tool called “Clean Air and Climate Protection software” to estimate and monitor emissions. CCP is currently engaging 700 municipalities worldwide (<http://www.iclei.org/co2>). In February 2009, ICLEI published a “City Climate Catalogue” web tool, in collaboration with the City of Copenhagen, that gathers local reduction targets and provides information on the implementation of the “five milestones process” in several cities

provide reports on cities from different countries, as they track periodically the progress of participating cities in the implementation of local policies⁵.

In the last 20 years, many cities in industrialized countries have developed climate change plans. More recently, climate change plans have been defined by cities in developing countries, especially by mega-cities such as Mexico City and Bangkok.

The aim of this paper is to identify the main emission drivers and the most relevant mitigation measures planned by a set of global cities⁶ through a comparative analysis of their emission inventories and climate change plans. The focus is on global cities, which have emerged as major players in setting global agendas and acting on climate change related issues. For limited availability of adaptation strategies⁷, the analysis regards only urban mitigation strategies.

Five cities have been chosen (London, New York, Milan, Mexico City and Bangkok) from both industrialized and developing countries in order to represent a variety of characteristics⁸. Data availability regarding city statistics, emission inventories and climate change plans has strongly conditioned the choice.

The main indicator to compare city emissions is emissions per capita, which depend on carbon intensity, energy intensity and production per person⁹. Carbon intensity is determined by emission factors of fuel consumptions, energy intensity depends on morphological and territorial features on one side and on socio-economic and behavioural characteristics of population and city users on the other side. Production per person is the usual indicator of economic development. In the paper we identify relevant drivers influencing these indicators.

Insufficient data coverage in climate-relevant dimensions led us to choose a qualitative approach. Main biases in the analysis are due to:

- *differences in territorial units data refer to*. The selection of territorial units of analysis is a common problem in urban comparative studies, as definitions of urban areas may differ among

(<http://www.iclei.org/climate-commitments>). A specific network has been created in 2005 by representatives of 18 global cities, that now gathers more than 40 participants: the “C40 Climate Leadership Group”. C40 promotes the definition of common procurement policies and alliances to accelerate the uptake of low-carbon technologies and influence the market (<http://www.c40cities.org/>).

⁵Recently, Climate Alliance and IFEU have developed a specific tool to compare mitigation performances in cities from U.S.A., Germany and Japan within the “Local Governments Climate Partnership” initiative. The LGCP benchmark system is structured in four parts: 1) a city fact sheet with general and energy data of the city; 2) an activity profile that illustrates present state and implementation of a city's climate protection activities in four categories (“climate policy”, “energy”, “traffic” and “waste”); 3) a CO₂-emission display detailed diagram showing the development of the final energy use and the CO₂ emissions of the city according to energy source and sector; 4) a set of indicators to overview the effects of previous climate protection activities and identify areas with room for improvement (<http://www.localclimateprotection.eu/455.html>)

⁶Sassen (2001) defines global cities as major cities that have gained a new strategic role for the combination of spatial dispersal and global integration, and now “function in four new ways; first, as highly concentrated command points in the organization of world economy; second, as key locations for finance and for specialized service firms, which have replaced manufacturing as the leading economic sectors; third, as sites of production, including the production of innovations, in these leading industries, and fourth, as markets for the products and innovations produced”.

⁷New York’s “PlaNYC” is one of a few examples of comprehensive strategies on mitigation and adaptation.

⁸Foreign Policy, A.T. Kearney and The Chicago Council on Global Affairs have recently published a “Global Cities Index”, a comprehensive ranking of metro areas developed according to metrics identified in five dimensions (business activity, human capital, information exchange, cultural experience, political engagement). Crossing all dimensions, our case studies rank as follows: New York (1), London (2), Bangkok (22), Mexico City (25), Milan (39) (Foreign Policy, 2008).

⁹The Kaya identity expresses global GHG emission levels as the product of the following inputs: [CO₂ emissions per capita = Carbon content of energy * Energy intensity of economy * Production per person] (Kaya and Yokobori, 1997). As this analysis is developed on cities, it is more significant to use data on energy consumption rather than energy production in calculating energy intensity.

countries and accordingly to criteria used. Administrative boundaries of a city are not always representative of the limits of the urban agglomeration¹⁰ and not all global cities have a metropolitan body or a unique local authority managing the wide-urban area. In reviewing local mitigation plans we tried to uniform data on territorial features, transportation, energy consumption and waste, in order to make them comparable.

- *differences in methodologies applied to estimate emissions at the local level.* As a unique international framework is not yet available, emission inventories differ in sectors and sources comprised in estimates. We tried to specify these differences when possible.

The analysis is structured in four main sections: in the first one, inventories are compared according to criteria applied to collect and organize data; in the second one, the emissive context of each city is depicted through a set of indicators; in the third one, plans are compared according to their main components and mitigation measures. In the last section we draw our conclusions with regard to coherence, effectiveness and efficiency of city mitigation plans.

II. COMPARATIVE ANALYSIS OF LOCAL EMISSION INVENTORIES

1. City emissions measurement

In recent years more and more urban authorities are elaborating city emissions inventories according to their mitigation targets. In the absence of official international standards and guidelines providing methodological guidance for cities inventories, many urban authorities use, as a base, the IPCC methodology¹¹, which however has been conceived for national emissions inventories. The main ambiguity in compiling urban emission inventories is to identify the spatial area and the activities that should be included or not, namely to quantify direct and indirect emissions, choosing criteria to assign them to a local context. Direct emissions can be associated with emission sources (point, linear, diffused) located inside city boundaries. Indirect emissions are emissions from sources that are not controlled by a city government or comprised within its jurisdiction, but which occur wholly or in part as a result of the city activities (e.g. purchased electricity, emissions embedded in the consumption of goods and services)¹².

ICLEI's protocol (ICLEI, 2008) suggests classifying emissions at community level in three scopes according to their being direct (emissions from direct sources located within the city boundary), indirect (emissions from direct sources located outside city boundaries, that result as

¹⁰Several boundaries can be identified within large cities: the core city, the contiguous built-up area, the metropolitan area and an extended planning region (Satterwhite, 2008).

¹¹Intergovernmental Panel on Climate Change (IPCC, 2006), "Guidance for National GHG Inventories".

¹²The definition has been adapted from Hakes (1999). Other classifications are possible. In a recent review of urban GHG inventories (i.e. Barcelona, Glasgow, London, District of Columbia, New York City, Toronto, Rio de Janeiro, Sao Paulo, Beijing, Seoul, Shanghai, Tokyo) (Dodman, 2009), the author distinguishes between a production-based approach, taking into account GHGs produced within the area under consideration, and a consumption-based approach. This last approach follows a quantification methodology comparable with the ecological footprint. According to the author, this approach may have higher degrees of uncertainty, as more elements should be incorporated in final calculations, but it would be more suitable to identify the responsibilities and where climate interventions and policies are really necessary (ivi). ADEME's "Bilan Carbone" (ADEME, MIES, 2007) is an example of methodology based on a consumption approach. Emissions are calculated on the lifecycle of each product/service consumed and are then allocated to consumers. The City of Paris used the "Bilan Carbone" methodology to provide the informative basis for its climate plan. Initially we considered Paris as case study, but we had to exclude it as its emission values are hardly comparable with values obtained with a production-based methodology.

a consequence of activities carried out within the boundary) and all other indirect/embodied emissions (emissions that can be useful to depict local climate impact, but are not conventionally included in GHG accounting). Scopes should enable to categorize emissions and avoid double-counting.

2. GHGs accounting methods

There are two main approaches that can be followed in estimating emissions: a “top-down” and a “bottom-up” approach. The top-down approach considers emissions estimates derived from national or regional data and, subsequently, the emissions are scaled to the area covered by the inventory, using some measures of activities directly or indirectly related to the emissions in the area of study (Hutchinson, 2002). Population figures, energy consumption and mobility demand are usually used to scale emissions at the local level. In a bottom-up approach, estimates are made from local data, from single sources when possible. At urban level, the bottom-up approach is to be preferred if the emission inventory elaboration aims to be the basis of a mitigation plan, as it provides detailed information that can be used in the definition of specific reduction measures and projects.

In all the inventories considered in the case studies, a bottom up methodology is followed to define the local emission context, with differences in relation to greenhouse gases and sectors included in the analysis. We defined a checklist to review the following elements in each inventory (Table 1):

- what types of GHG are included in emissions inventory;
- which activities are included;
- what types of indirect emissions are considered.

Table 1: Comparison of emission inventories

	London	NYC	Milan	Mex.City	Bangk.
The inventory quantifies emissions related to the following gases:					
CO ₂	X	X	X	X	X
CH ₄		X		X	X
N ₂ O		X	Q*	X	
HFC		X			
PFC		X			
SF ₆		X			
The inventory quantifies direct emissions in the following sectors:					
domestic heating	X	X	X	X	n.a.
commercial/tertiary heating	X	X	X	X	n.a.
<i>[road transport]</i>	X	X	X	X	X
public transport	X	X	X	n.s.	n.s.
private transport	X	X	X	n.s.	n.s.
aviation	Q	Q			
shipping	Q	Q	n.a.	n.a.	
waste management		X	Q*	X	X
wastewater management		X			X
<i>[industry]</i>	X	X	X	X	
energy use in industrial buildings	X	X	X	X	
energy use for industrial processes (combustion)	X				
emissions from industrial processes (non-combustion)					
agriculture			Q*	X	X
sinks				X	X
energy supply plants within the city boundaries	X	X	X	X	n.s.
The inventory quantifies indirect emissions in the following sectors:					
domestic (electricity)	X	X		X	
commercial/tertiary (electricity)	X	X		X	
transport (electricity)	X		X	n.s.	X
industrial (electricity)	X	X		X	
waste management (plants outside city boundaries)					
wastewater management (plants outside city boundaries)					

Source: authors on different source data

Mayor of London (2006b), Bloomberg (2007b), Bloomberg (2008b), IEFÉ (2009), Pardo and Martínez (2006), Lapeyre et al. (2008), BMA (2008), BMA, GLF, UNEP (2009).

Inventories were available for the following base years: 1990-2000, 2003, 2004-2005 (London); 2005, 2006, 2007 (New York); 2005 (Milan); 2000, 2004 (Mexico City); 2005 (Bangkok). The inventory considered in the checklist is highlighted in italics.

For Greater London, the checklist was filled with reference to the 2003 inventory (called LECl, London Energy and CO₂ emissions Inventory), which focuses on CO₂ emissions. The 2004-05 inventory, (called LEGGI, London Energy and GHG Inventory), comprises also estimates of CH₄, N₂O, HFC, PFC, SF₆. Estimates for Greater London Authority's operations and buildings are included in the Climate Change Action Plan.

n.a.: not applicable

n.s.: not specified

Q: quantified but not included in the emission values of the plan base year

Q* non-CO₂ gases had been quantified in a previous inventory (AMA, 2007), but these emissions have not been comprised in the Climate Plan of Milan, as they added a negligible quantity to total emissions.

All inventories report at least emissions from carbon dioxide and methane. Present guidelines and recommendations¹³ on the compilation of inventories underline that collecting detailed local

¹³e.g. ICLEI (2008), Denny (2008).

data on all Kyoto GHGs may be onerous for a city government. They thus suggest focusing on the estimation of carbon dioxide and methane, as they are the most relevant gases in city contexts.

Heating sector emissions are considered in all cities inventories, except Bangkok, which has not emissions by heating sector for meteorological reasons.

For road transport, two main approaches can be identified: Bangkok and Mexico City estimate emissions from fuels consumed within city boundaries, while emission estimates for London, New York and Milan are derived from kilometres travelled by different categories of public and private vehicles and characterized by specific emission factors¹⁴. Only New York City and London choose to quantify emissions from aviation and shipping¹⁵.

For the waste management sector, all the cities considered GHG emissions from waste, except London which considered only CO₂ emissions sources¹⁶, but each city applied different methodologies to quantify waste emissions¹⁷. Methane from wastewater plants is quantified only in the inventories of New York¹⁸ and Bangkok.

Emissions from industry have been reported in all inventories, except for Bangkok, in relation to energy use within industrial processes, to the operations of industrial buildings or to both emission categories.

Agriculture has no relevance in the urban contexts of Greater London and New York City and a limited relevance in the other cities. CO₂ and CH₄ have been estimated in relation to fuel consumptions and emissions from agricultural operations in the inventories of Mexico City and Bangkok. Both inventories also evaluate the offsetting potential of sinks - urban forestry and green areas within administrative boundaries.

Energy generated by supply plants within city boundaries is generally quantified by all the cities. As far as “indirect” emissions are concerned, all inventories include only emissions related to imported electricity and make no attempts to estimate emissions embedded in goods and services consumed within the city. New York, London and Mexico City, in particular, detail electricity consumptions in each end-use sector¹⁹.

¹⁴New York and London consider kilometres travelled within city boundaries, Milan includes also kilometres travelled by vehicles crossing city borders, namely entering or going out the city. Furthermore, London includes emissions from taxiing aircraft and during take-off and landing in ground-based transport emissions.

¹⁵Both London and New York quantify CO₂ emissions from aviation and shipping, though not including them in reduction targets. Methodologies for aviation differ substantially: emissions associated with Heathrow and City airports are allocated to London on a share of UK passenger kilometres basis. Estimates for New York are derived from quantities of fuels loaded on planes departing from J.F.K. and La Guardia airports. For shipping, London inventory elaborates data on vessels movements to estimate energy consumptions and emissions; New York adopts a down-scaling method: fuel state-use is apportioned to counties based on each counties’ water freight shipping tonnage.

¹⁶Emissions from waste and wastewater plants are not quantified in the LECI inventory neither comprised in the Climate Change Action Plan of Greater London. The Mayor has published specific strategies for these themes. The prevailing waste management mode in London is landfilling in areas out of Greater London’s boundaries (method applied to 72% of municipal waste in 2000/01, 57% in 2006/07)(Mayor of London, 2007c).

¹⁷NYC quantifies CH₄ emissions from previously disposed solid waste in in-city landfills each year over the life of the gas. The waste coefficient was revised to exclude the sequestration of carbon for waste disposed of in out-of-city landfills. Mexico City and Bangkok quantify CH₄ emissions from landfills but do not specify the location of landfills. Milan quantifies emission from waste only in relation to combustion in waste-to-energy.

¹⁸i.e.fugitive methane emissions from incomplete combustion of digester gas flare of wastewater plants. CO₂e emissions from energy use of water and sewer facility are also quantified.

¹⁹Bangkok does not provide details on uses of electricity within different sectors. Indirect emissions from electricity consumptions have been estimated for Milan in a recent updating of the inventory published by AMA in 2007 (IEFE, 2009).

Inventories are based on international references. New York City uses ICLEI's Protocol for the inventory structure and software to convert all data about energy use, transportation patterns, waste disposal and other inputs into GHG emissions. London and Milan refer to CORINAIR methodology for the choice of main sector-based sources and emission factors (even if both refer, in some cases, to their own emission factors). Mexico City refers to IPCC methodology for calculation methods and emissions factors.

A comprehensive analysis of inventories should also address issues related to data quality, coverage and approaches in emission estimates. As our focus is mitigation strategy rather than technical aspects of local GHGs accounting, data and estimates quality falls outside the purview of this analysis. Cities that have the longest time series of inventories (London, New York) have already started to address the issue of data quality, to verify and update methodologies.

3. Emissions by source

The analysis of emission inventories shows that energy consumptions are determinant in characterizing GHG emissions attributable to cities. Direct emission sources such as industrial processes, power stations and agricultural activities are usually located outside city boundaries or in peri-urban areas. As "urban" power supply covers a limited part of local consumptions, cities have traditionally adopted an estimation approach that relies on end uses. All inventories we considered assign to their respective cities emissions due to energy uses of individuals and urban activities, notwithstanding the location of energy production.

Table 2: Emission values and main emission indicators

	London	NewYork	Milan	Mex.City	Bangkok
Base year of emission values	2006	2005	2005	2000	2005
Total emissions (MtCO ₂ e) (a)	44,2	63,1	7,0	33,5	42,8
Emissions per capita (tCO ₂ e per capita) (a)	5,9	7,7	5,4	3,9	7,1
Emissions from the transport sector per capita (tCO ₂ e per capita) (a)	1,28	1,69	1,10	1,68	3,53
Emissions from the building sector per capita (tCO ₂ e per capita) (a)	4,19	5,94	4,22	0,93	2,48
Energy consumption per capita (MWh per capita) (b)	20,7	24,6	21,7	10,9	20,0 ²⁰
Electricity consumption per capita (MWh per capita) (c)	5,2	6,7	5,3	1,7	4,8
Carbon intensity of energy consumption (tCO ₂ e/GWh) (d)	284	310	250	317	300
Energy intensity of GDP (kWh/\$) (b) (e)	0,45	0,47	0,61	0,76	2,55
GDP_ppp (purchasing power parity) (\$ per capita) (e)	46.200	52.800	35.600	14.300	7.845

²⁰Bangkok seems to have an energy consumption index comparable to those of European cities, but this value may be affected by a significant error according with an underestimation of Bangkok population. A specific research of the National Institute of Development Administration estimated that Bangkok not registered population could be around 3,2 millions on a total registered population of about 6 millions (NIDA, 2000 in BMA, UNEP, 2002).

Source: authors on different source data

(a) Mayor of London (2007a), Bloomberg (2008b), IEFE (2009), Pardo et al. (2006), BMA (2008). For London and Milan, emission values refer to CO₂ only.

(b) Mayor of London (2007b), Kennedy et al (2009), AMA (2007), Pardo et al. (2006), BMA (2008). For Bangkok energy consumption value refers only to sectors for which GHG emissions were calculated .

(c) Mayor of London (2007b), Bloomberg (2008a), AMA (2007), IEFE (2009), Pardo et al. (2006), BMA (2008).

(d) Mayor of London (2007a), Mayor of London (2007b), Kennedy et al (2009), AMA (2007), IEFE (2009), Pardo et al. (2006), BMA (2008).

(e) OECD (2006), except for Bangkok (Yusuf, Nabeshima, 2006). OECD indicators refer to metro-regions defined through three criteria (thresholds of urban density and population size; area with a self-contained labour market): New York corresponds to an area including New York county, other 9 counties of New York State and 12 counties of New Jersey State; Milan to the province of Milan and 7 adjacent provinces; Mexico City to the federal district of Mexico City and 53 adjacent districts, London to the Greater London and 10 adjacent counties.

Per capita values have been calculated by authors (sources for population values: GLA (2008b), U.S. Census Bureau, Comune di Milano, DF (2007), BMA Data center).

Table 2 shows a consistent gap between absolute emission values of Milan and the other cities, according with the different area size and population. New York City and Bangkok have the highest per capita emissions (7,7 and 7,1 tCO₂ per capita) but with substantial differences in energy consumption (24,6 and 20,0 MWh per capita), and in electricity consumption (6,7 and 4,8 MWh per capita respectively). Milan and London have similar per capita emissions, energy and electricity consumption (5,4 and 5,9 tCO₂ per capita; 21,7 and 20,7 MWh per capita; 5,3 and 5,2 MWh per capita respectively). Mexico City produces the least emissions per capita and shows the lowest energy and electricity consumption value per capita (3,9 tCO₂ per capita; 10,9 MWh per capita; 1,7 MWh per capita)²¹.

Different factors concur in determining per capita emissions: carbon intensity of energy consumption, energy intensity of production and production per capita²².

Carbon intensity depends on the share of renewable energies in the satisfaction of urban energy consumptions and on the carbon content of fuels that are consumed within the city. The comparison of energy consumption patterns of London and Milan shows that Milan has a higher share of electricity consumption than London (Figure 1). The difference between average carbon intensity of energy for the two cities may be due to a relevant difference between carbon intensity of electricity²³. Bangkok and Mexico City show different energy consumptions values but similar fuel consumption pattern and similar carbon intensities. Bangkok's lower carbon intensity value may be explained by a lower emission factor used to estimate emissions from electricity²⁴ for this city.

Comparing emission indicators for the selected cities (Table 2), GDP per capita also seems to have relevance in explaining different emission levels, except for Bangkok. For this city, a

²¹While New York, Milan, London and Mexico City result to have lower emissions per capita than their respective countries, Bangkok produces much higher emissions per capita than Thailand. Per capita emissions in year 2002: 20 t, United States; 9,8 t, United Kingdom; 4,2 t, Mexico; 3,2 t, Thailand (UNEP/GRID, 2005). 9,7 t, Italy (UNFCCC, 2003).

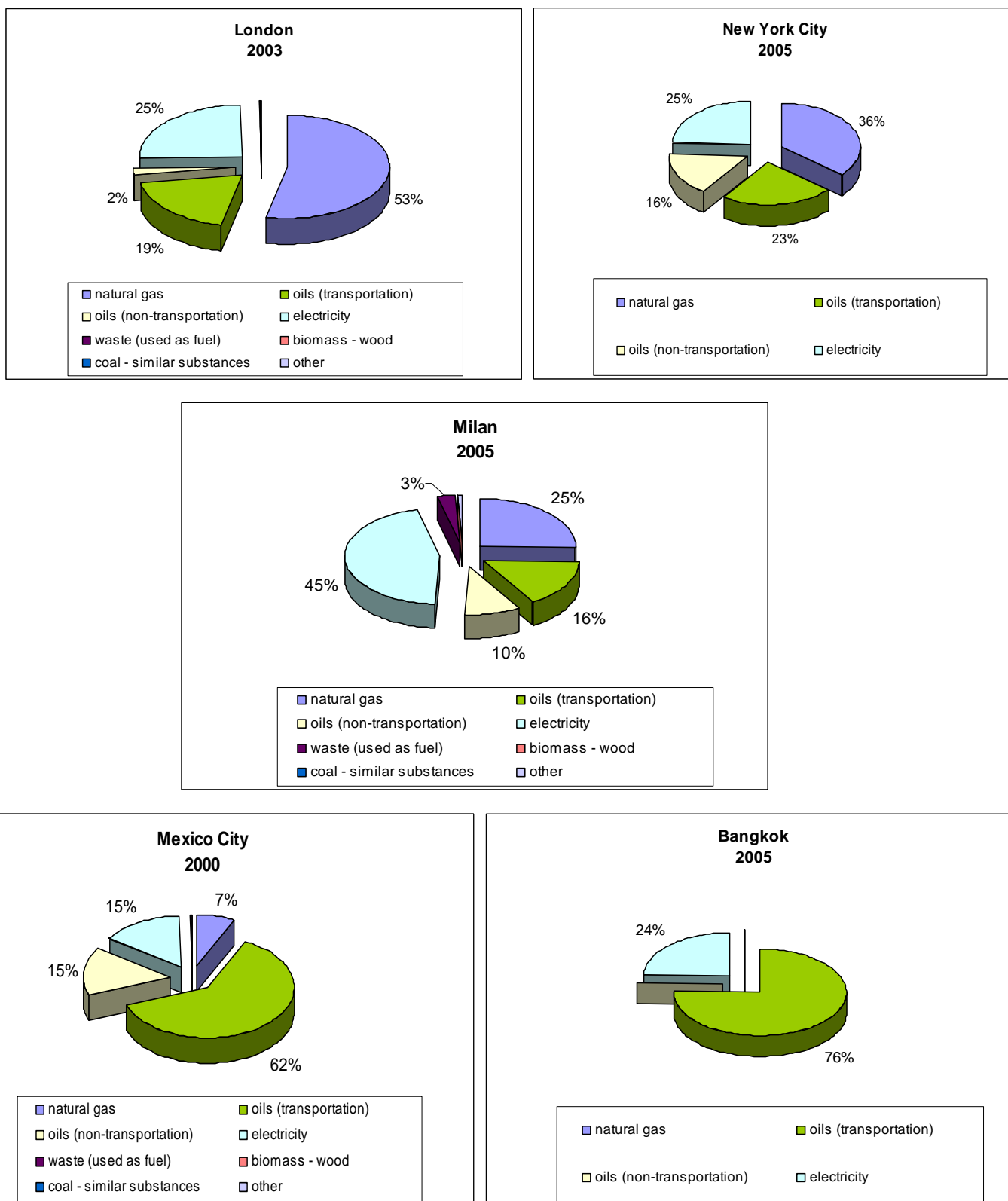
²² See note 9.

²³The average carbon intensity of electricity consumed in Milan is 311 gCO₂/KWh (IEFE, 2009); carbon intensity of electricity supplied to London from the National Grid is 520 gCO₂/KWh. The carbon intensity of grid electricity for London is higher than the one of the gas heating network (Mayor of London, 2007a).

²⁴509 gCO₂/KWh for Bangkok (BMA, 2008); 683 gCO₂/KWh for Mexico City, as elaborated on data from Pardo et al. (2006).

greater relevance in determining high emissions should be attributed to energy intensity of production.

Figure 1: Energy consumption by fuels



Source: authors on different source data

Mayor of London (2007b), Kennedy et al (2009), AMA (2007), Pardo et al. (2006), BMA, 2008. Oils for transportation include gasoline and diesel; non-transportation oils include fuel oils, LPG, kerosene.

Considering urban emissions by sectors, we retrieve that buildings and transportation are the most emissive sources, with different relevance. In cities belonging to industrialized countries (London, New York, Milan), emissions from energy use in buildings (residential, commercial, tertiary and public) cover a majority of urban emissions, amounting approximately to 70% of the total. In cities belonging to developing countries, emissions from buildings are the second most relevant source and amount to 24% and 35% (Mexico City, Bangkok, respectively).

Transportation is a relevant emission source throughout all selected cities, covering almost half of total emissions in cities from developing countries (42% Mexico City, 49% Bangkok). In cities from industrialized countries, transportation results the second most emissive sector (22% New York, 22% London, 20% Milan).

The industrial sector shows a limited contribution to total emissions, as economic activities in global cities are marked by tertiary functions. This sector accounts for 2% of Milan total emissions, 7% of London and 22% of Mexico City²⁵.

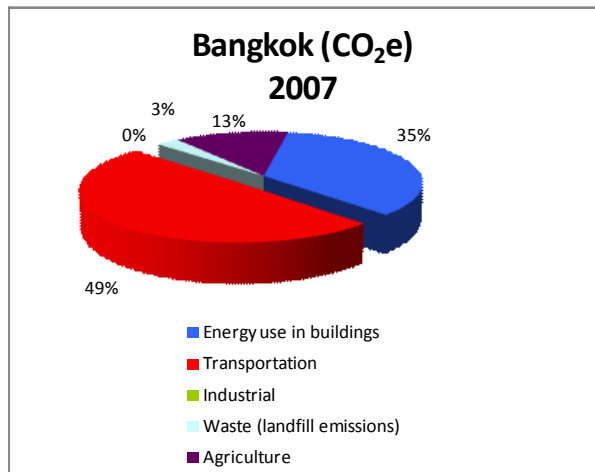
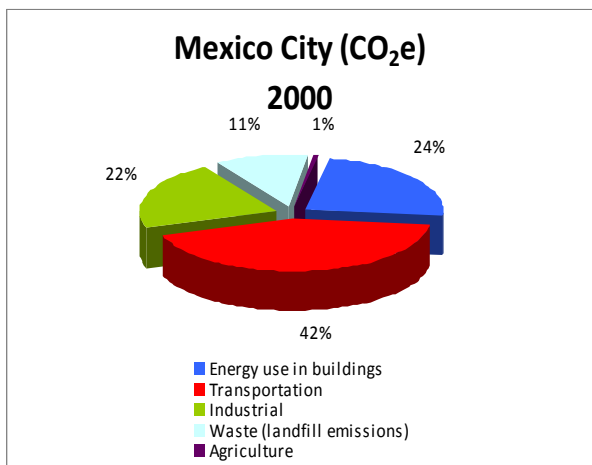
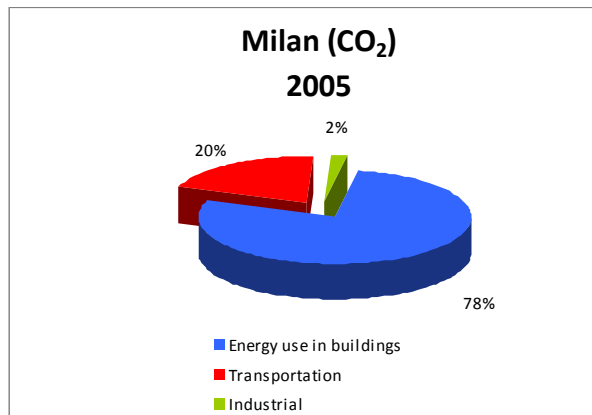
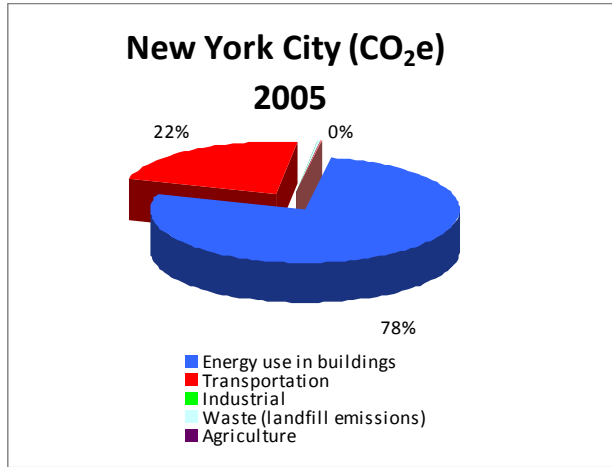
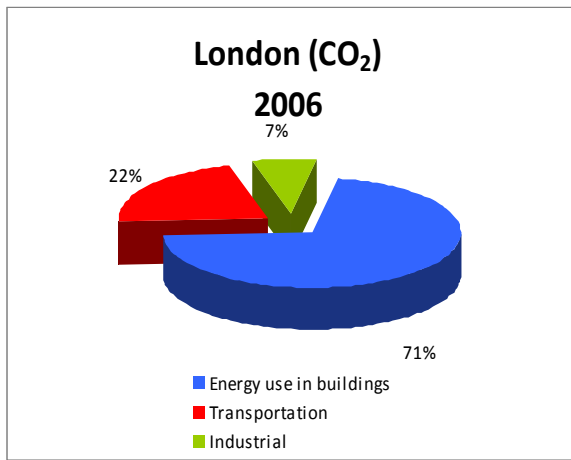
Solid waste stored in landfills contributes scarcely to urban emissions (less than 1% for New York, approximately 3% for Bangkok), except for Mexico City, whose landfill emissions account for 11% of the total²⁶. For Bangkok, agriculture accounts for 13%, but this sector contains also not specified emissions.

A strong correlation among emissions and energy consumptions can be highlighted. Furthermore, emissions are deeply influenced by the combined effect of energy intensity and production, expressed by GDP. As these indicators are influenced by local conditions and lifestyles, in the following section we take into account urban features that may characterize each local context and provide elements to explain differences in the emission levels of cities.

²⁵According to Mexico City climate plan, sector-based classification should be interpreted with caution as far as energy consumptions in the industry sector is concerned, as data from energy providers classify as “industrial” many small commercial activities (Lapeyre et al., 2008).

²⁶For Milan the emissions from waste are only in relation to combustion in waste-to-energy and they are included in energy use in buildings sector for electricity and heat production.

Figure 2: Emissions by sectors



Source: authors on different source data
 Mayor of London (2007a), Bloomberg (2008b), IEFE (2009), Pardo et al. (2006), BMA (2008).

III. COMPARATIVE ANALYSIS OF LOCAL EMISSION CONTEXTS

1. A selection of drivers for the characterization of local emissions contexts

Almost all anthropogenic GHG emissions come from the consumption of material goods and energy and the production of waste, which depend on living standards and behaviors. As cities tend to concentrate population, high living standards and economic activities, they are responsible for consuming large amounts of goods, services and, indirectly, energy (Dhakal, 2004). Energy use, in particular, is strongly influenced in its extent and nature by specific urban features, namely the spatial structure of the city, its infrastructures and the characteristics of urban population and activities. Such key factors have been identified as follows (ivi):

- compactness of the urban settlement;
- urban zoning and functions;
- nature of the transportation system;
- income level and lifestyle;
- energy efficiency of key technologies;
- nature of economic activities;
- building technologies and building floor space use;
- waste management;
- climate factors.

Analyses on energy consumption and GHG emissions have been developed mainly for the national level. Studies at city scale are limited. Main difficulties in analyses at city scale consist in getting data at urban level and linking decisions on energy issues, concerning primarily the national level, to urban contexts (ivi). Furthermore, there is a lack of comprehensive analyses of macro driving factors crossing all major sectors of energy uses and GHG emissions in cities, and in particular a lack of international comparisons (ivi).

This section aims at contributing to this gap. We analyze a set of city indicators, which can characterize the population living standards and be interpreted as drivers of energy consumptions, energy intensity, production and consequently emissions at urban level.

Indicators are subdivided into 5 sections: socio-economic features, urban territorial features, urban transportation system, waste production and management (Table 3 and 4, Figure 3).

Socio-economic characteristics are described by the elder-young ratio²⁷ and the activity rate²⁸.

Territorial features are expressed by population density, which is considered a significant measure of urban form and has been found to influence energy demand and GHG emissions for urban transportation (Kenworthy, 2003) and dwelling density, to provide information on the compactness of the residential built stock. A third indicator, the availability of green spaces, has been included to characterize urban land use. Furthermore, Heating and Cooling Degree Days have been considered to characterize local conditions affecting energy needs.

Urban mobility has been depicted through the modal share on daily trips; in order to deepen the role of private motorized transport within our case studies, car ownership²⁹ has been put in relation to emissions from transport.

²⁷The index expresses the quotient of the inhabitants' number over 60 years to inhabitants' number under 19.

²⁸The index expresses the percentage of population aged from 15 to 65 years, that represents the labour force.

²⁹The index states the ratio of the number of registered cars per 1.000 inhabitants.

For the waste sector, two indicators have been selected: the solid waste amount collected per capita and the percentage of waste collected yearly for recycling.

Table 3: Data on selected drivers

	London	NYC	Milan	Mex. City	Bangkok
Socio-economic features					
Elder/young ratio (a)	65,5	64,0	190,0	31,0	30,55
Activity rate (%) (b)	48,5	46,7	48,0	39,2	77,4
Territorial features					
Population density (residents per km ²) (c)	4.780	10.470	6.990	5.810	3.610
Dwelling density (dwellings per km ²) (d)	1.990	4.080	3.250	1.420	1.330
Public green space per capita (m ² per capita) (e)	25,5	16,6	15,9	5,4 ³⁰	1,8
Heating and Cooling Degree Days (°C)	Table 4				
Urban transportation					
Car ownership rate (f)	310,8	228,1 ³¹	623,5	164,0	271,0
Waste production and management					
amount of solid waste collected (tonnes per capita per annum) (g)	0,59	0,81	0,57	0,55	0,54
% waste collected for recycling (h)	18,1 %	37,8%	30,6%	n.a. ³²	8,04%

Source: authors on different source data

(a) GLA (2008c), U.S. Census Bureau, Comune di Milano, SEDECO, UNESCAP.

(b) OECD (2006), except for Bangkok (UNESCAP).

(c) GLA (2008a), U.S. Census Bureau, EUROSTAT Urban Audit, DF (2007), BMA data center.

(d) GLA (2007), U.S. Census Bureau, IEFE (2009), Pardo et al. (2006), BMA data center.

(e) GLA (2008b), GLA (2008b), Comune di Milano (2007), DF (Plan Verde), Thaiutsa et al. (2008).

(f) EUROSTAT Urban Audit, NYS Department of Motor Vehicles, EUROSTAT Urban Audit, APERC (Asia Pacific Energy Research Centre) in Shrestha (2008), APERC in Shrestha (2008).

(g) EUROSTAT Urban Audit, NYC Department of Sanitation and HDR (2004),) EUROSTAT Urban Audit, DF (2006), Phdungsilp (2006). All data refer to domestic and commercial solid waste. For Mexico City index, it is not specified.

(h) Mayor of London (2007b), NYC Department of Sanitation and HDR (2004), Pitea (2008), BMA, UNEP (2003). All data refer to domestic and commercial waste.

³⁰Other sources (INEGI, 2005) estimate availability of green spaces per capita in the Federal District as 15,1 m²; this value includes private green spaces, ecological reserves and other areas with limited accessibility.

³¹Trucks, motorcycle and commercial vehicles are not included.

³²Data on selective collection of waste for Mexico City are not comparable with the other values.

Table 4: Heating Degree Days and Cooling Degree Days (base temperature: 18°C) for the selected cities

	HDD
London	2679
New York	2641
Milan	2157
Mexico City	584
Bangkok	0

	CDD
Bangkok	3884
Milan	867
New York	639
Mexico City	245
London	84

Source: Sivak (2009), except for Milan (Degreedays)

1.1 Emissions from energy use in buildings

Emissions from buildings encompass three broad categories, namely electricity use (for lighting, refrigeration, appliance use, air conditioning and, less frequently, space heating), direct fuel combustion (mainly for space heating) and district heating, each having different burdens in emissions of the domestic and non-domestic built stock (Gupta, 2009). A main determinant of energy needs and a majority of emissions are local climate conditions: values of Heating and Cooling Degree Days explain quite well different emission values in the built sector among our case studies, highlighting higher emissions for cities with significant needs for heating (London, New York, Milan) or cooling (Bangkok).

Density of the built stock may have a role in influencing emissions, as detached housing units require on average more energy than flats to be heated or cooled, but data we collected do not show significant relations with emission values in this sector; this may be due to the fact that density is more representative of the urban design when calculated on urbanized areas rather than the administrative land area (Bertaud, 2003), but in the paper we considered administrative boundaries as data on land uses are collected with different approaches. Furthermore, the indicator of dwelling density refers only to a fraction of total built volumes in a city. Data on green public spaces had been collected to give further insight on the issue of urban density, but different values of availability of green spaces per inhabitant seem to reveal the effects of specific policies to protect green spaces within the administrative boundaries of the city (e.g. *suelo de conservacion*, in Mexico City; Green Belt and Metropolitan Open Land policies in London), rather than features of urban density.

A complete overview on emissions of the built sector should take into account differences in the built stock and characterize the typologies of dwellings and commercial units within the city, the technological mix related to heating-cooling systems and the efficiency of appliances and policies or legislative frameworks (local, national) influencing them. Furthermore, a behavioural component may be also identified.

1.2 Emissions from transportation

In a recent comparative analysis of urban carbon emissions, private cars have been found as the primary source of emissions in the transport sector within a sample of 12 metropolitan areas worldwide (Sovacool, Brown, 2009), even in those cities having developed an extensive mass transit infrastructure.

Considering our case studies, cities with high car ownership rate seem not responsible for the highest transport emissions, consistently with previous studies on the relationship between urban features and CO₂ finding that car usage is strongly conditioned by factors other than ownership, related to the urban form, functions and supply of alternative modes of transport (Kenworthy, 2003). A compact urban form, in particular, and the mix of functions have been found as effective in discouraging the use of private motorized modes in favour of public transport and reducing the average length of trips (Jabareen, 2006). Taking into account the caveats on density data highlighted in the previous paragraph, the least dense among cities we considered shows quite high transport emissions (Bangkok), but for the other case studies no significant relations can be identified.

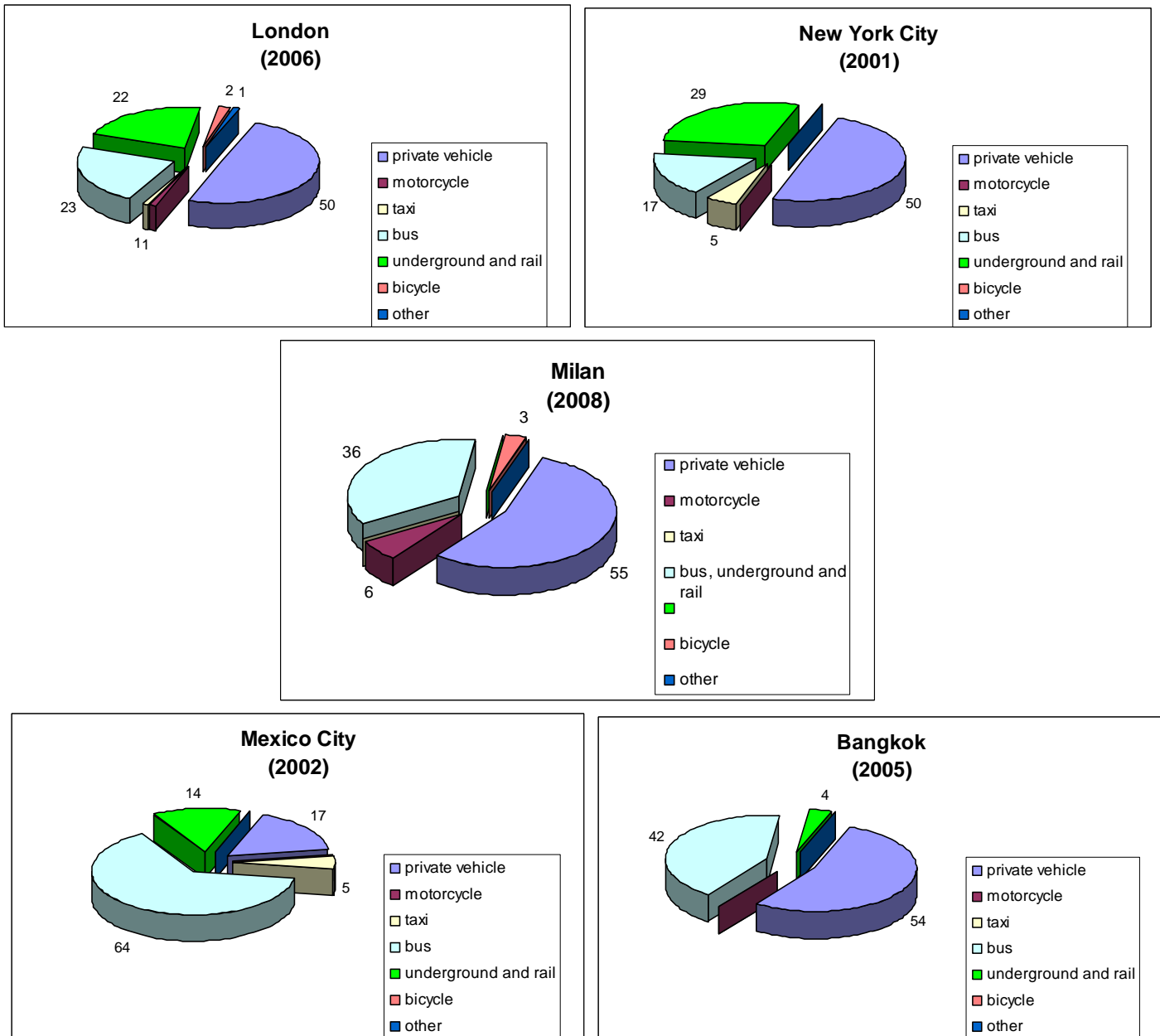
A representative insight on urban mobility may be drawn from the modal share of daily trips: within our case studies, car usage covers approximately half of mechanized trips, except for Mexico City (17%). Public transport thus covers significant percentages of trips within all the cities we considered (40-50%, almost 80% in Mexico City), with relevant differences in the role of the underground and rail accordingly to the existing supply. Recent data from UITP³³ (Allen, 2009) show that cities with a modal share of public transport and non-motorised modes higher than 55% are able to limit CO₂ emission from transport below 1 tCO₂ per capita. Values for New York, London and Milan (Table 2) show that these cities are actually benefitting from their mass transit systems in containing their transport emissions, whereas values for Bangkok and Mexico City suggest that more insights may derive from further information on the composition of public and private vehicle stock. As a matter of fact, the majority of trips by motorised transit modes in Mexico City are made by gasoline powered mini-buses, which have proved to be highly inefficient in terms of vehicular emissions (Quadri de la Torre, 2003).

1.3 Emissions from waste

As different accounting methods have been applied in these five inventories, emissions from waste in our case studies cannot be directly compared. As the main source of GHG connected to waste are landfills, further consideration of these five cities shall consider quantities of waste that are stored and managed through this system. General data we collected show that waste production is similar in quantities among these cities, except New York having the highest per capita production. Still, management methods show quite different patterns, with Bangkok and, notably, London, having low recycling rates.

³³International Association of Public Transport, <http://www UITP.org/>.

Figure 3: Modal share on daily trips



Source: authors on different source data

TfL (2007), Bloomberg (2007c), IEFE (2009), Lapeyre et al. (2008), World Bank (2007).

2. Correlation between drivers and emissions

As we are considering a limited number of case studies, data on the selected drivers can hardly be correlated with emission values estimated for the five cities. Socio-economic indicators reveal

only different characteristics as far as the age structure of urban population and its labour market are concerned. If availability of data on energy and GHG emissions at city level keeps increasing, thanks to a broader awareness on local climate change policies and their diffusion, and cities already having an inventory keep track of their emission performances, a broader database will be gradually available and these variables may be further considered on a wider and also temporal basis.

Looking at emissions by sector, several hints can already be drawn. A negative correlation between urban density and emissions from transport is well established in literature, but further consideration may be given to the spatial organization of trips within the city and to the characteristics of the vehicle stock, in terms of emission efficiency. Similarly, for the built sector a more detailed look at urban design and, in general, at the emission efficiency of built volumes could clarify different emission performances. In this context, policies that are already being implemented within these sectors shall be taken into account, as innovative measures and strong regulations promoted by city governments may already have induced significant changes in emission performances.

IV. COMPARATIVE ANALYSIS OF CITY PLANS

1. Main components of the local climate plans

According to ICLEI, building a local emission inventory is the first step for local governments wishing to implement a mitigation strategy through a climate action plan³⁴. The inventory provides an informative basis that is necessary to identify mitigation options and actions. Besides, it provides a basis to elaborate a Business As Usual projection of future GHGs levels, against which reduction targets may be set and the effectiveness of mitigation measures be assessed.

We compare mitigation strategies in the five cities, reviewing contents of each plan and taking into account:

- *the local BAU scenario*: which assumptions and drivers have been considered in projecting local emissions in the future?
- *the choice of the base year and of reduction targets*: which criteria has the local government followed in choosing and defining its reduction commitment?
- *mitigation measures*: how relevant is each measure and which roles does the local government play in each sector?
- *implementation and monitoring*: does the plan identify who will be responsible of the plan implementation and of the monitoring system that will assess the plan effectiveness?
- *financing*: does the plan address the funding of measures?

³⁴ICLEI's "five milestone process" defines the basic elements of a local climate strategy: 1) building a local emission inventory and 2) a Business as Usual Scenario as a base to identify mitigation actions; 3) setting a reduction target; 4) sharing the plan with stakeholders; 5) monitoring the implementation of the plan.

Table 7: Reduction targets, base years and target years in the case studies

	London ³⁵	NYC ³⁶	Milan ³⁷	Mex.City ³⁸	Bangkok ³⁹
Targeted GHGs	CO ₂	CO ₂ , CH ₄ , N ₂ O	CO ₂	CO ₂ , CH ₄ , N ₂ O	CO ₂ , CH ₄
Reduction target and target year	- 20% (2016) - 60 % (2025)	- 30% (2030)	- 20% (2020)	7 MtCO ₂ e to be reduced in the period 2008-2012	- 15% (2012)
Base year GHG level	1990: 45,1 MtCO ₂	2005: 63,1 MtCO ₂ e	2005: 7,19 MtCO ₂	2000: 33,5 MtCO ₂ e 2006: 36,2 MtCO ₂ e	2005 ⁴⁰ : 42,65 MtCO ₂ e ⁴¹
Estimated GHG level for target year (BAU scenario)	2025 BAU: 51 MtCO ₂ (+15% ⁴²)	2030 BAU: 80,1 MtCO ₂ e (+27%)	2020 BAU: 7,78 MtCO ₂ (+8%)	2012 BAU: 35 – 49 MtCO ₂ e (+11% low) (+ 25% medium) (+ 35% high)	2012 BAU: 48,69 MtCO ₂ e (~ + 14%)
Emission reductions to be achieved, calculated for the target year	33 MtCO ₂	36 MtCO ₂ e	2 MtCO ₂	7 MtCO ₂ e to be reduced in the period 2008-2012	7 MtCO ₂ e
Annual reductions over the plan time frame (as % of the base year)	2,1 %	2,3 %	1,8 %	4,1 %	2,13 %

Source: authors on different source data

Mayor of London (2007a), Bloomberg (2007a), IEFE (2009), Lapeyre et al. (2008), BMA (2008).

³⁵“Action Today to Protect Tomorrow -The Mayor's Climate Change Action Plan” was endorsed in 2007 by the former Mayor Ken Livingstone. Mayor Boris Johnson, elected in 2008, is proceeding with the implementation of the local climate change strategy. Tackling climate change at city level is a legal requirement under a Greater London Authority Act (http://www.opsi.gov.uk/acts/acts2007/pdf/ukpga_20070024_en.pdf).

³⁶“PlaNYC 2030” was developed by the Office of Long-term Planning and Sustainability with public involvement and endorsed in 2007 by Mayor Michael Bloomberg. The plan focuses on five key dimensions of the city (land, water, transportation, energy, climate change).

³⁷The “Sustainable Energy and Climate Action Plan” of Milan has been elaborated to comply with commitments proposed by the European Covenant of Mayors, endorsed by Mayor Letizia Moratti in December 2008, and its main contents have been recently published (December 2009).

³⁸The “Climate Action Plan of Mexico City” was endorsed in 2008 by the present Federal District Governor Marcelo Ebrard Casaubon.

³⁹The “Action Plan on Global Warming Mitigation” was promoted in 2008 by Apirak Kosayodhin, Governor of Bangkok Metropolitan Administration. The present Governor, M.R. Sukhumbhand Paripatra, has been elected in January 2009 and has expressed the will to proceed with the implementation of the plan (personal communication).

⁴⁰2005 is the base year for the emission inventory. Bangkok Metropolitan Administration fixes a reduction target of – 15% below 2012 BAU emission levels.

⁴¹Net emissions: parks and trees absorb 0,1 MtCO₂e/year.

⁴²+30% including aviation

1.1 Business As Usual Scenarios

BAU scenarios are estimates on how future GHG emissions would unfold if no additional measures, other than those that would naturally occur or already conceived, were implemented. (Dubeux, La Rovere, 2007). They provide a basis for the assessment of results of new climate mitigation actions (ibid). According to the IPCC, the main driving forces of future GHG trajectories are demographic trends, socioeconomic developments and the rate and direction of technological change (Nakicenovic, Swart, 2000). The elaboration of BAU emission scenarios for urban contexts borrows driving forces either from specific local projections and/or from projections for the regional and national scale.

BAU emission projections are available in all plans of selected cities. We briefly review scenarios for London, New York, Milan and Mexico City, as they provide details on emission drivers.

1.1.1. Emission drivers

Emission projections in BAU scenarios are based on the estimation of future energy consumptions, namely heating for buildings, electricity use and fuel consumption from transportation. London includes also emissions from industrial sector, New York City and Mexico City emissions generated from solid waste. Forecasts on the main drivers are derived either from the expected evolution of socio-economic conditions in the city (London, Mexico City, Milan) or from historical emissions growth rate (New York)⁴³, assuming that city growth will continue steadily in the BAU scenario.

1.1.2 Emission projections

Population and economy are projected to grow in all BAU scenarios, thus foreseeing a growing demand for energy, transport provision and housing needs⁴⁴. Assumptions underlying these projections concern either the attraction these global cities will continue to exercise towards people, for opportunities linked to jobs and study (London, New York, Mexico City), or to local specific policies aimed at attracting people and increase the density of the city (Milan).

⁴³i.e. for New York, a total BAU Compound Annual Growth Rate for emissions was calculated from individual growth rates in the period 2000-2005 for emissions in the following sectors: electricity use, buildings heating fuels and on-road combustion vehicles (Bloomberg, 2008b).

⁴⁴London population is projected to increase 7-9% by 2016 and 11-16% by 2026 from 2005 level (Mayor of London, 2006). New York population is projected to increase 2% by 2010 and 9% by 2030 from 2006 level (Bloomberg, 2007a). Forecasts for Mexico City differentiate among the densest part of the agglomeration (Federal District) whose population is projected to remain steady, and the wider urban zone (Zona Metropolitana del Valle de México), whose population is projected to increase 7,6% (low scenario), 13,5% (medium) and 18% (high) by 2012 from 2000 levels (Pardo, Martínez, 2006). Demographic projections for Milan involve assumptions concerning the attraction the city will exercise in the next years, thanks to a series of important residential and tertiary projects that are being realized in brownfield sites within the city boundaries. Milan population is projected to increase 16% by 2020 from 2005 levels (IEFE, 2009).

Economic growth projections have been defined before the beginning of the current global crisis and do not account for the restraining effect that the crisis may have on energy demand and emissions⁴⁵.

1.2 Base year and reduction targets

Guidelines on local GHGs accounting suggest choosing the base year to calculate reduction targets according to the completeness of data in the local emission inventory, as data for the Kyoto reference year (1990) are usually difficult to obtain at local level. Furthermore, a detailed and documented base year provides a good basis for planning (ICLEI, 2008). The EU Covenant of Mayors suggests local authorities that have not developed yet an emission inventory to collect data for 2005 and set it as base year, in order to maintain homogeneity with the EU energy and climate targets.

As in most of the case-studies inventories are available for a unique year (Milan, Mexico City, Bangkok), the choice of the base year is made accordingly. For New York City, inventories with reliable data were available also for 1995 and 2000, but 2005 has been set as base year to grant coherence among the climate change mitigation strategy and the larger sustainability framework of PlaNYC (Bloomberg, 2007b). London adopts 1990 as base year in order to align with national and international targets.

As reduction targets are voluntary, they are not set with homogenous criteria by city governments. London adopts a long term reduction target with intermediate steps, New York and Milan choose a medium term target. Milan, in particular, refers to 2020 for coherence with the EU energy and climate policies time frame. Bangkok and Mexico City adopt a shorter-term target (2012), that may be linked to operative conditions of the local administration that has endorsed the climate plan⁴⁶. We can calculate the average yearly emission reduction that needs to be achieved, in order to comply with the target (Table 7). From the comparison of values, it turns out that both cities with a shorter-term horizon strategy and cities with a longer-term horizon show similar values of yearly reductions, expressed as percentage of base year emissions. Nonetheless, a long-term view should be preferred in local climate strategies, as many mitigation measures require long-term investments.

It is not our aim to analyze the effort the city has committed itself, but rather the mitigation potential that each local government evaluates as feasible. Mitigation potential is influenced by roles the local government can play within each emissive sector and the degree of control the local government can exercise on emissions.

1.3 City government's roles and degree of control over local GHG emissions

The definition of global cities refers to capacities and competences that identify and distinguish cities at international scale, but each city government is placed in a specific national context and has connections with multiple administrative levels. National, state and regional policies on climate and energy may affect city policies defining and implementing legislation and instruments that overlap with local mitigation strategies. This issue is addressed in particular in

⁴⁵e.g. For Mexico City, historical GDPs were used for economic sectors and industrial subsectors: for 2001, 2002, 2003, a 1,5% annual increase in GDP was considered; for the other years, the following assumptions were used in the three scenarios: in the low scenario, GDP increased by 1,5% till 2012; in the medium scenario, GDP increases gradually reaching a growth rate of 4,5% in 2012; in the high scenario, GDP growth increases from 3,5% in 2004 to 7,5% in 2012 (Pardo et al., 2006).

⁴⁶The time frame of Mexico City's plan coincides with the mandate of the present administration (2006-2012).

the climate plan of London, that provides an assessment of the achievable reductions at city level under present circumstances and highlights the roles of the national government and the EU level in enabling the achievement of further reductions, through legislative reforms that could influence technological and behavioral change.

The analysis provided by the Greater London Authority suggests that main interactions of London climate policies with national and international policies concern the following sectors:

- *energy supply*: as the city import most of the consumed electricity from the national grid, national policies on energy supply influence directly carbon emissions associated with citizens' consumptions. Furthermore, national legislation can directly enable or hurdle the penetration of decentralized or renewable supply systems in cities (e.g. in London statutory barriers hurdle the penetration of Combined Cooling Heat and Power - CCHP - plants).

- *energy efficiency and savings in the building sector*: the national government defines through legislation a framework, providing standards for new buildings. Furthermore, the national government is responsible of the implementation of directives on energy efficiency in appliances and buildings (i.e. EU Performance of Buildings Directive, EU Energy end Use and Efficiency Directive) and may concede grants, incentives or advice to support the realization of energy efficiency measures;

- *transport sector*: in addition to funds for transport infrastructure, the national level may influence circulating vehicles with taxes on the most polluting vehicles.

Besides, the active implementation of a global carbon pricing system would strongly influence prices of goods and services, thus orientating consumers towards lower-carbon consumptions. (Mayor of London, 2007a).

Although the urban mitigation potential is influenced by national factors, climate protection at municipal level has developed worldwide as city governments have identified a feasible potential to reduce emissions through their competences in climate-relevant dimensions. A city government can act as a consumer, intervening directly on municipal energy and transport consumptions; as planner and regulator, orientating urban development and using authoritative powers to set mandatory conditions related to energy efficiency; as provider and supplier, investing in infrastructures in the transport, waste and energy supply sector, either directly or owning companies providing the public service; as enabler and advisor, influencing other actors through information campaigns on sustainable behaviors or supporting them directly with incentives and counseling, aimed at enhancing measures that can contribute to climate change mitigation⁴⁷.

Alber and Kern (2008) classify these roles according to governing mode that each role implies.

- *self-governing* is the capacity of the local authority to govern its activities through reorganization, institutional innovation and investments. It is associated with the role of the local government as consumer;

- *governing by authority* refers to regulations and sanctions the city government can set. It is based on the authoritative powers of the local government;

- *governing by provision* consists in delivering resources and services and it is thus connected with the "provider and supplier" role;

- *governing by enabling* refers to the capacities of the local government to coordinate actors and encourage community engagement, as in the "advisor and enabler" role.

⁴⁷Climate Alliance provides a review of mitigation measures that can be implemented by city governments in climate-relevant sectors, highlighting the different roles of the local authority (<http://www.local-climate-protection.eu>).

Although different governing modes may characterize the same action, this classification provides a conceptual framework to analyze local mitigation strategies.

1.4 Reduction measures

Grounding on governing modes, we classify emission reduction measures included in the climate plans in the sectors of energy, transport, waste and urban planning. To weigh mitigation measures in each local strategy, we analyze the expected impacts of measures included in plans⁴⁸. The weight of each measure is expressed as a percentage of the total emission reductions that should derive from the implementation of the plan. Emission reductions that are achievable through each measure are usually expressed in the plans as annual reductions.

Table 8: Mitigation measures of the plans classified in sectors and governing modes

Governing modes	Energy	London	NYC	Milan	Mexico City	Bangkok
Self governing	Energy efficiency schemes and use of CHP within municipal buildings	< 1		1	2	< 1
	Procurement of energy-efficient appliances					
	Purchasing of green energy					
	Eco-house and renewable energy demonstration projects				< 1	
Enabling	Campaigns for energy efficiency	37		9	7	28
	Advice on energy efficiency to businesses and citizens					
	Promotion of the use of renewable energy					
Provision	Minor carbon intensity in the main energy supplier	17		22	< 1	
	Decentralized energy supply (CHP, waste-to-energy)	19		7		
	Network upgrading to improve energy savings				< 1	
	Energy service companies					
	Provision of incentives and grants for energy-efficiency measures			11	< 1	
	Provision of incentives and grants for renewable energy in private buildings			1		
Authority	Strategic energy planning to enhance energy conservation					
	Mandatory use of renewable energy in the new build sector				< 1	
	Energy efficiency standards in the new build sector	4		6		
Subtotal – Energy		78		57	14	29

Governing modes	Transport	London	NYC	Milan	Mexico City	Bangkok
Self governing	Mobility management for employees	< 1				
	Green fleet				2	
Enabling	Education campaigns	6				
	Green travel plans					
	Quality partnerships with public transport providers					
Provision	Public transport service provision	11		6	37	39
	Provision of infrastructure for alternative forms of transport	4		5	< 1	
	Upgrading of road network to increase traffic efficiency					17
	Logistic centres for goods transport and freight management			4	2	
	Incentives to purchase low-emission cars			25		
Authority	Transport planning to limit car use and provide walking and cycling infrastructure			2		
	Workplace levies and road-user charging					study
Subtotal – Transport sector		22		42	42	56

⁴⁸The plan of New York does not include estimates on emission reductions that should derive from each measure.

Governing modes	Waste	London	NYC	Milan	Mexico City	Bangkok
Self governing	Waste prevention, recycling, and reuse within the local authority					
	Procurement of recycled goods					
Enabling	Campaigns for reducing, reusing and recycling waste					3
	Promotion of the use of recycled products					
Provision	Waste service/wastewater treatment provision				9	< 1
	Installations for recycling, composting and 'waste to energy' facilities				4	study
	Recycling, composting and reuse schemes					1
	Methane capturing from landfills (energy production)				31	
Authority	Regulations on methane combustion from landfill sites					
Subtotal – Waste sector (if applicable)					44	5

Governing Modes	Urban Planning and land use	London	NYC	Milan	Mexico City	Bangkok
Self governing	High energy-efficiency standards and use of CHP in new public buildings					
	Demonstration projects – house or neighbourhood scale.					
Enabling	Guidance for architects and developers on energy efficiency and renewables					
	Promotion of tree planting					3
Authority	Strategic land use planning to enhance en. efficiency and renewables					
	Planning of sites for renewable installations					
	Strategic land-use planning to enhance public transport					
	Urban forestation			< 1		7
Subtotal – Urban forestry and land use sector (if applicable)				1		10

Source: authors on different sources, based on Alber, Kern (2008)

Mayor of London (2007a), Bloomberg (2007a), IEF (2009), Lapeyre et al. (2008), BMA (2008)

Numbers refer to the weight of specific measures on annual total emission reductions expected from the implementation of the plan.

Table 8 shows that the plans of New York, London and Milan assign a great relevance to policies concerning energy supply, energy efficiency and savings, throughout all governing modes. Policies combine relying on advice and counseling to citizens with incentives to support both energy efficiency measures in existing buildings and installation of renewable energy micro-plants.⁴⁹ More than a half of expected emission reductions for London and Milan comes from measures in these fields. These cities assign a relevant role for mitigation to their main energy supplier, on whom they are able to exercise a certain degree of influence⁵⁰. New York City authorities schedule a set of energy measures, with the collaboration of its main energy supplier, in order to secure a cleaner energy supply to the city⁵¹.

In the plans of Mexico City and Bangkok, the highest local mitigation potential is identified within the transport sector, enhanced by investments in infrastructures to provide a sustainable use of public transport: this sector contributes for nearly half of expected emission reductions.

⁴⁹In particular, New York has foreseen in its plan a property tax abatement for solar panel installations. Milan will deliver incentives to enhance thermal plant substitutions in residential buildings.

⁵⁰Decentralized production (CHP, waste-to-energy projects) accounts respectively for 19% (London) and 22% (Milan) of total emission reductions. The reduction of carbon intensity of the main energy supplier accounts for 17% (London) and 22% of total emission reductions (Milan). For London, influence on carbon intensity is limited as it is related with the policies of the national government concerning a lower carbon intensity in the national grid and with Great Britain's targets within European directives on renewable sources (Mayor of London, 2007a). Milan has more power in influencing strategic investments of its main energy supplier, A2A, as the Municipality is a majority shareholder in the company.

⁵¹ The New York plan foresees to 1) facilitate repowering and construction of cleaner power plants and dedicated transmission lines; 2) expand Clean Distributed Generation connected to the city grid; 3) foster the market for renewable energy; 4) support expansion of city's natural gas infrastructure (Bloomberg, 2007a).

Reductions from the transport sector contribute significantly also in the plans of London and Milan. For Milan, relevant reductions are expected from local policies aimed at reducing the use of private cars and lowering the average carbon emission factor in circulating vehicles, including a pollution charge. These policies are complemented by incentives to consumers for the purchase of low-emitting vehicles, provided by regional and national authorities.

Measures concerning urban planning can hardly be associated with quantified emission reductions. Planning policies usually set a framework that indirectly influences the building and transport sector. Within land use, only Milan and Bangkok evaluate a potential increase in urban forestry and assign to tree planting a role in the comprehensive mitigation strategy (respectively, 4% and 7% of all expected reductions).

In the waste sector, Mexico City identifies a relevant mitigation potential in a project concerning energy production from landfill methane (30% of expected reductions). London, New York and Milan address issues related to waste service in specific plans and do not include measures concerning this sector in their local climate strategies.

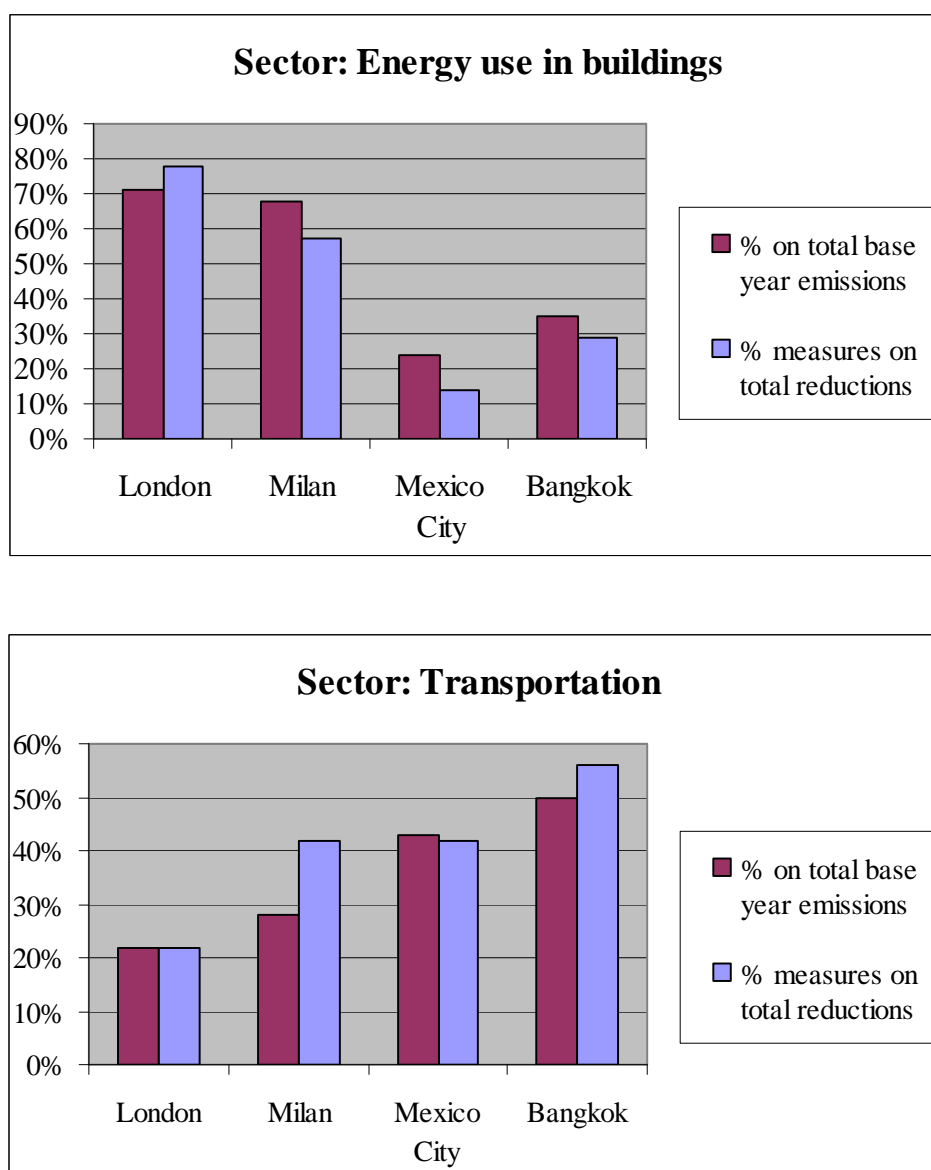
Weights assigned to mitigation measures reveal that climate plans in these global cities are coherent with the emission contexts defined through the respective local inventories. We can verify this aspect comparing the emission contribution of the two most relevant sectors (i.e. buildings, transportation), expressed as percentages on total emissions⁵², with the weights of measures belonging to these sectors within each plan. The plans of London, Milan, Mexico City and Bangkok identify a reduction potential for emissions from energy use in buildings and transportation, that is very similar to the share these sectors cover within total emissions (Figure 4). The plan of Mexico City shows a gap in defining measures targeting energy consumptions in buildings. It assigns a significant weight to measures concerning waste (44%), despite a more limited contribution of this sector to total emissions (11%). The plan does not include measures for the industrial sector, which contributes considerably to total emissions (22%). This aspect may be due to difficulties in identifying local measures to target the industrial sector⁵³.

We cannot derive any conclusions regarding the efficiency of plans, as marginal costs of emission abatements are not available for specific measures. In fact, the efficiency of plans would require the equalization of marginal abatement costs of included measures.

⁵²As in Figure 2, pag. 12.

⁵³ Furthermore, many activities classified as industrial may actually belong to the commercial sector (note 26).

Figure 4: coherence among emission sectors (inventories) and reduction measures (local mitigation plans)



Source: authors on different sources

Mayor of London (2007a), IEFE (2009), Lapeyre et al. (2008), BMA (2008)

1.5 Implementation and monitoring

Two alternative approaches can usually be retrieved in the implementation of urban mitigation plans: 1) a unit in charge of climate policy is created in each department whose competences are relevant for mitigation measures; 2) a group with climate change competences (climate steering group, coordination office, overarching unit) is established in the local government (Alber, Kern,

2008). The climate group needs to be combined with task forces coordinating activities on specific issues and across relevant local policy areas.

The second approach seems more promising, if the climate group can act within a general framework (strategic plans with sector-based targets, policies and measures) and if a project-based approach is adopted, as it prevents departmental segregation (ivi). Competences for climate change policy are often concentrated in environmental departments and this feature may lead to coordination and integration problems if such skills are not completed by competences to implement comprehensive concepts (ivi).

London and New York have chosen the second approach. New York has created an office charged with competences of coordination and implementation concerning the sustainability vision of the city, including climate change issues (Mayor's Office of Long-Term Planning and Sustainability). The office cooperates with the City Agencies and the Mayor's Advisory Board. A specific agency, NYC Energy Planning Board, will be created to coordinate all energy supply and demand initiatives of the city.

London has assigned to a pre-existent institution, the London Climate Change Agency (LCCA)⁵⁴, the task to implement mitigation measures of the plan concerning advice and counseling. Furthermore, LCCA directly manages CO₂ reduction and energy efficiency projects⁵⁵.

Mexico City has assigned to the environmental secretariat the coordination of measures⁵⁶, identifying for each measure internal sectors and outer actors that are responsible and co-responsible for implementation. Bangkok and Milan have not defined yet issues concerning implementation. The plan of Milan has been developed by the environmental department, with the support of a municipal agency with competences on mobility, environment and territorial issues (AMAT)⁵⁷.

Efficacy of the coordination role of specific units or environmental units within climate change strategy should be investigated in future research.

Inventory updating is identified as a key tool to assess progress toward targets (London, New York, Milan). Monitoring reports are assigned to units charged with plan implementation (New York) or to an "ad hoc" monitoring and evaluating committee (Mexico City). London, besides periodical reporting by the Mayor, includes CO₂ reduction reporting in assessments provided by agencies and departments linked to climate-relevant sectors⁵⁸. This feature may be considered as a sign of high integration of climate strategy in the local government and its institutionalization⁵⁹.

⁵⁴London Climate Change Agency (LCCA). The LCCA was already in place when the Plan was published; it is a commercial company wholly owned, controlled by and housed in the London Development Agency (<http://www.lcca.co.uk/server.php?show=nav.005001>).

⁵⁵LCCA Ltd has formed in 2006 the "London ESCO", a joint venture company with EDF Energy.

⁵⁶Secretaría del Medio Ambiente.

⁵⁷Agency for Mobility, Environment and Territory.

⁵⁸Progress in implementing actions of the plans and delivering CO₂ reductions will be reported in sector-based publications and reports (Annual review of progress against Mayor's Energy Strategy, Mayor's State of the Environment Report, London Sustainability Development Commission annual performance indicators, TfL annual Environment Report, monitoring performance against Transport for London's environmental performance indicators, LFEPA Environment Update and Monitoring Annual Report monitoring performance against LFEPA's Environmental Action Plan, Metropolitan Police Environment Report).

⁵⁹Institutionalization of climate protection policy is defined as the location of the policy within the local authority and the extent to which formal strategies, action plans and reduction goals have been developed and implemented (Bulkeley, Kern, 2004).

1.6 Financing

Financial aspects of mitigation measures in the plans are addressed providing an estimation of the costs for each measure (Mexico City) and foreseeing a budget allocation, for measures whose allocation is feasible (London, New York).

According to Mexico City's local government, CDM credits and revenues from the Kyoto market will be fundamental to acquire resources to finance mitigation measures. These resources may be included in the Public Environmental Fund of the Federal District.

The use of Kyoto credits as means for emission offsetting can be retrieved only in the plan of Milan, which focuses on CDM projects to compensate indirect emissions from purchased electricity⁶⁰.

V. CONCLUSION

The analysis of emission inventories shows that local emissions strongly depend on energy uses, in particular referred to building use and transports. Considering main indicators of emissions, GDP seems to have relevance in explaining emission levels of the selected cities except for Bangkok, whose emissions are more characterized by energy intensity of production.

GHG emissions have then been put in relationship with sectorial urban drivers, but no evidence of correlation has been found. Further analyses of the characteristics of the built stock, dwelling density, the motor vehicle stock and transport network may explain specificities of each city determining similar emission levels, but due to different contributions of the transport and building sectors (e.g. New York, Bangkok).

In depth analysis of emission values and mitigation strategies reveals that cities from industrialized countries, namely London, New York and Milan, share similar local emissive contexts and mitigation strategies. For these cities, the highest contribution to urban emissions is related to energy consumptions in buildings (i.e. residential, commercial, institutional). The review of mitigation measures provided in climate plans points out that these cities identify the greatest potential within the energy sector and adopt coherent measures. Their policies share the following essential features:

- stimulating energy efficiency and savings from individual action, both of citizens and businesses, leveraging on combined instruments (i.e. direct incentives or tax breaks, integrated by advice and technical counselling);
- promoting high energy efficiency and renewable energy in the newly built sector, mainly through standards, regulation and incentives;
- supporting decentralized supply and CHP;
- relying on a lower carbon intensity in the energy supply of the main provider (London, Milan).

This latter point is characterized by different degrees of influence of each city government on its main energy supplier.

The transport sector is the second highest contributor to urban emissions for these cities and it is targeted by policies aiming at enhancing the existing public transport infrastructure and its use. As we remarked in the analysis of city indicators, daily modal share of public transport is already high in London, New York and Milan, but private motorized travels show potential for further

⁶⁰Up to now, the Municipality has defined preliminary agreements with cities in developing countries to implement CDM projects with the support of the World Bank, within a project portfolio that will compensate emissions from the 2015 World Exposition Event (personal communication).

reductions. Investments planned by the municipality of Milan to extend the underground network, combined with incentives to support the renovation of circulating cars, are highly coherent with the markedly high car ownership that is typical of this city.

Bangkok and Mexico City share an emissive context and mitigation strategies strongly influenced by transportation. Their climate strategies identify the most relevant mitigation potential within the transport sector and strongly rely on public transport provision.

All cities considered in the paper have thus defined a strategy that is coherent with their local emission contexts, as they focus mitigation measures on sectors identified as most relevant in determining their urban emissions.

Main limits of this paper are due to the low number of case studies, determined by the scarce availability of inventories, data on GHG emissions and energy at the local level. Furthermore, differences in methodologies to estimate emissions and energy consumption at city level affect GHG emission figures.

Future research

As local mitigation policies and city planning instruments for climate change keep spreading worldwide, a wider range of case studies will be gradually available for comparison. Further development of research may also benefit from a greater availability of comparable city-level data on energy, GHG emissions and territorial features⁶¹. Emission values in particular can be standardized through the establishment of a common and accepted methodology to build local GHG emission inventories. A research area that still needs to be covered regards the costs of mitigation measures at local level and – more broadly – the costs for the implementation of local climate plans.

As global cities start publishing data and progress reports on their climate strategies, three main research areas may be specifically targeted. As far as implementation is concerned, the effectiveness and efficiency of each mitigation strategy may be assessed and compared, to identify the most cost-effective measures and those instruments and governing modes proving to be the most successful in pursuing reduction targets.

Secondly, each mitigation strategy may be reviewed with regard to other plans defined at city level, in order to explore synergies, co-benefits and linkages. Finally the integration between mitigation and adaptation strategies should be further explored.

⁶¹The Government of Japan has recently funded the development of an international program to standardize, collect and organize data in collaboration with the World Bank (“Global City Indicators”, <http://www.cityindicators.org>)

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