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doi:10.1016/j.cities.2007.01.012

Cities, Vol. 24, No. 5, p. 353–364, 2007

0264-2751/$ - see front matter

Local perspectives in the control of greenhouse gas emissions – The case of Rio de Janeiro

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Received 6 December 2005; received in revised form 19 December 2006; accepted 20 January 2007
Available online 29 May 2007

Municipalities in developing countries can contribute to mitigating climate change and thereby benefit from reductions in the emissions of conventional pollutants and traffic jams or from improvements in waste management systems, amongst other local benefits. These benefits result from measures taken to reduce greenhouse gases emissions (or carbon sequestration) by two means: either measures taken to mitigate greenhouse gases emissions themselves and/or from the income obtained in the international carbon market. The evaluation of the current status of emissions and the potential for mitigation measures are based on various planning techniques, such as inventories and scenario building, as suggested in the paper. A brief report of the experience in making an inventory from secondary data and building up scenarios that has been undertaken in Rio de Janeiro, Brazil, is presented as a case study. Mitigation measures that are beneficial to the quality of city environments and suited to municipal administrations are also presented.

Keywords: Climate change, municipalities, local benefits, evaluation techniques

Climate change and municipal management in the control of greenhouse gas emissions

In global terms, because of a historical trend of population concentration in major urban centers, cities consume most of the energy produced to meet the demands of transport, industrial and commercial activities, heating and cooling. Likewise, solid wastes and domestic, commercial and industrial effluents are mostly produced in urban agglomerations. These factors not only contribute to local pollution but also to enhancing the greenhouse effect.

From the point of view of integrating public policies, several local benefits were identified among policies to control local and regional atmospheric pollution, as well as policies directed at global environmental problems (global warming). For example, policies (or projects) that reduce fuel consumption have positive results for both air quality and climate issues. This is because fossil fuels are not only the main source of many local and regional pollutants but also of greenhouse gases (GHG).

The same combustion process that emits gases affecting human health, ecosystems, agricultural productivity and many materials – such as sulfur dioxide (SO_2), nitrous oxides (NOx), suspended particulate material, volatile organic compounds (VOC), carbon monoxide (CO) and ozone (O_3) – also causes the emission of gases that interfere in the climate of the planet – such as carbon dioxide (CO_2), methane (CH_4) and nitrogen oxide (N_2O). Thus, several measures aimed at reducing fossil fuel

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consumption in order to lower local atmospheric pollution levels, will, at the same time, reduce GHG emissions or vice versa.

Paradoxically, solid wastes and domestic, commercial and industrial effluents, when adequately managed, may produce CH_4. In the case of solid wastes, this occurs mainly when they are disposed of in sanitary landfills, one of the simplest and most environmentally sound forms of waste management. Nevertheless, the more efficient this operation is, the more CH_4 that is released into the atmosphere, since this gas is produced when organic matter is under anaerobic conditions not found at the same level in open air garbage dumps. The same occurs for domestic sewage and industrial effluents treated in anaerobic plants. As a result, and since methane is a very powerful greenhouse gas as well as a tropospheric ozone precursor,[2] these management options for urban wastes[3] need to be dealt within a context where both climate issues and local and regional pollution are envisaged jointly as co-benefits.[4]

There are some ways by which climate mitigation can help local administrations to promote better welfare levels for their citizens. Apart from the fact that lowering pollution levels increases general welfare, there are specific positive effects for public finances due to savings in health and on other damages caused by local pollutants that can be avoided by GHG mitigation strategies. Kousky and Schneider (2003) quote a number of authors who have identified these positive effects. They also list many local efficiency projects with a high potential for GHG mitigation that present a positive internal rate of return[5] representing an improvement in local finances. Another possibility for developing countries is the use of financial resources from the carbon market to upgrade management systems and implement good projects.

In Brazil, project opportunities are quite different from most of the cities of the rest of the world. The electrical energy matrix is very peculiar with over 76% of the generation capacity coming from hydro power and almost 6% from nuclear thermal plants and biomass (ANEEL, 2006). Only the remaining 17% of capacity is attributed to conventional sources (coal, gas and fuel oil and Diesel) where most GHG are produced. Therefore, there is little space to reduce emissions through local management of electricity consumption. The same applies to emissions from the industrial sector and from LULUCF (land use and land use changes), which have a low level of municipal regulation, in the former case, and enforcement capacity, in the latter. In this sense, Brazilian cities can contribute to climate mitigation mainly through activities related to the transport systems and waste management.

In respect to the carbon market, opportunities have emerged from the Kyoto Protocol which created the clean development mechanism (CDM), through which industrialized countries are able to buy certified emissions reductions (CERs) from projects that mitigate emissions in developing countries.[6] Generally called carbon credits, CERs can be used by industrialized countries to meet their own reduction targets at a lower cost. By doing this, these countries can also contribute to sustainable development worldwide by transferring both technology and financial resources.

This mechanism is already operating and provides a great opportunity for implementing emission reduction projects in developing countries and improving welfare. Cities may participate in the CDM with multiple goals other than just climate mitigation: the reduction of local pollutant emissions, the optimization of traffic and transport systems, the reduction of energy consumption costs and the improvement of solid waste and sewage management, etc, what represent enormous political gains.

CDM, therefore, can contribute to improving the quality of life of developing countries, similar to what happened in metropolises in industrialized countries, which today have air and water pollution levels far lower than in the 1950s and 1960, thanks to urban pollution control policies. More recently, European countries benefited from the indirect effects of climate policies resulting in a reduction of abatement costs by 50% to 70% for SO_2 and by around 50% for NOx (Van Harmelen et al., 2002).

Brazil has two successful experiences in CDM projects based on local initiatives.[7] Both involve landfill gas burning. One is in Nova Iguaçu, in Rio

[2] According to IIASA (2004), "the combined effect of increasing CH_4 and other precursor emissions of ozone (NOx, VOC and SO_2 in the presence of light) results in elevated tropospheric ozone levels. Recent epidemiological studies detect significant negative health impacts from ozone".

[3] According to Oliveira and Rosa (2003, p. 1482), "Using the 20 million tons a year of municipal solid wastes produced in Brazil to generate electricity... could boost electricity supplies ... to around 17% of the nation's consumption".

[4] Co-benefits are produced from policies that are developed to achieve both climatic and other environmental goals simultaneously (Metz et al., 2001). These are distinct in the literature from ancillary benefits, which are a beneficial side product, but not a goal of mitigation policies.

[5] The internal rate of return (IRR) is the maximum discount rate for which the project will generate positive net benefits.

[6] There is also a market for carbon sequestration.

[7] In total, considering not only local initiatives, 82 projects had been approved by the federal government to be submitted (some of which have actually been submitted) to UNFCCC by July 2006 (MCT, 2006).

Table 1 Main measures that may be directly adopted by Brazilian local governments to reduce greenhouse gas emissions under the clean development mechanism

Proposed application	Measures for reducing GHG emissions			
	Sewage treatment plants and sanitary landfills	Captive fleet (own or third party)	Streets and other public locations	Public buildings (oces, workshops, schools, hospitals, etc.)
1 – Capture and burning of methane (transforming into CO_2)	×			
2 – Replacement of fossil fuels by renewable energy sources				
• Use of biogas produced in sewage treatment plants or sanitary landfills		×		
• Use of biodiesel from virgin plant oils or used animal and plant oils (from restaurants and food industries)		×		
• Use of alcohol		×		
• Use of electricity from solar panels, wind generators, and biogas and biodiesel powered generators			×	×
3 – Increase of energy efficiency				
• Use of cleaner fossil fuels, such as natural gas		×		
• Use of light bulbs and equipment with greater energy efficiency			×	×
• Use of electrical material and equipment with energy efficiency criteria			×	×
• Use of more efficient refrigeration systems or natural refrigeration systems			×	×
4 – Carbon sequestration				
• Increase in the number of trees in streets and squares[a] or increase in urban parks and forests			×	

Source: Authors.[b]
[a]CDM rules for carbon sequestration through reforestation are very strict. Plantation of trees on streets and squares are not suitable for this mechanism. In this case a non compliance market to the CDM should be envisaged.
[b]Most of the options listed in the table were drawn out from Cadernos NAE # 3 (2005) and take into consideration the sphere of action of Brazilian local administrations.

de Janeiro state, and the other in Salvador, Bahia, and in both funds from carbon credits are used to improve the operation of sanitary landfills.

However, for a project to be eligible for CDM it must respect the concept of additionality and not be considered part of a country's natural development path. The rules stipulate that a CDM project activity is additional if its emissions are below those of its baseline, where ''the baseline for a CDM project activity . . . is the scenario that reasonably represents the anthropogenic emissions by sources of greenhouse gases that would occur in the absence of the proposed project activity'' (Paragraph 44 of CDM modalities and procedures, 2005). In other words, only projects that involve additional activities other that those that would be undertaken without the mechanism itself are eligible.

Table 1 shows the main measures for reducing emissions that can be undertaken directly by local governments in the major urban centers in Brazil in their facilities, vehicles, urban equipment, etc, which have the characteristics required[8] for CDM projects. Adoption of these measures will depend, obviously, on the baseline for proposed application as well as on the logistic possibilities.

In addition to the above measures, local governments are generally responsible for establishing standards and regulations for civil construction and in some cases for landscape management aiming at improving the quality of urban life. These rules can also contribute to mitigate climate changes through GHG emission reductions or carbon sequestration. This would be the case, for example, of rules requiring the adoption of bioclimatic building methods and techniques or a reduction in municipal taxes on energy efficient products.

Table 2 shows the measures with the greatest impacts on climate change mitigation that local governments can enforce and promote, the first through

[8] But not enough.

Table 2 Main measures suitable to the clean development mechanism that Brazilian local governments can implement through regulations or incentives

Proposed application	Measures for reducing GHG emissions		
	Industry	Trade and services	Households
1 – Capture and burning of methane (transformed into CO_2)	Installation of flares		
2 – Replacement of fossil fuels by renewable energy sources			
• Use of methane produced in effluent treatment plants or industrial landfills	Captive fleet, boilers, heaters, furnaces, electric generators	Captive fleets	Private cars
• Use of biodiesel from virgin plant oils or used animal and plant oils (from restaurants and food industries)	Captive fleet		
• Use of alcohol	Captive fleet		Private cars
• Installation of solar panels	Lighting, electrical equipment and heaters		
• Installation of wind generators	Lighting and electrical equipment		
3 – Increase of energy efficiency			
• Use of light bulbs and equipment with greater energy efficiency	×	×	×
• Use of more efficient refrigeration systems or natural refrigeration systems	×	×	×
• Use of electrical material and equipment with energy efficiency criteria	×	×	×
• Use of building methods and materials suitable to the local climate	×	×	×

Source: Authors.

regulation and the second through incentive mechanisms.

Municipal inventories and scenarios as planning instruments for mitigating GHG emissions

Two questions arise when a municipality decides to control GHG emissions: (1) how to identify the main sources of emissions and (2) what are the potential benefits. In this regard, inventories that show the current levels of GHG emissions and scenarios that simulate future emissions levels with and without controlling measures are two major planning instruments that help the identification of project opportunities.

Inventories allow the actual level of GHG emissions to be identified. Scenarios allow: (i) projection of the baseline, that is, how the future (GHG emissions) would unfold if no additional measures, other than those that would naturally occur or already conceived, were implemented and (ii) assessment of results of new climate mitigation strategies (plans of action to reduce GHG emissions) that could generate carbon credits. After estimating emissions in relation to the baseline and in the alternative scenarios (mitigation scenarios), it is possible to identify the local government management options with the greatest potential for becoming CDM projects.

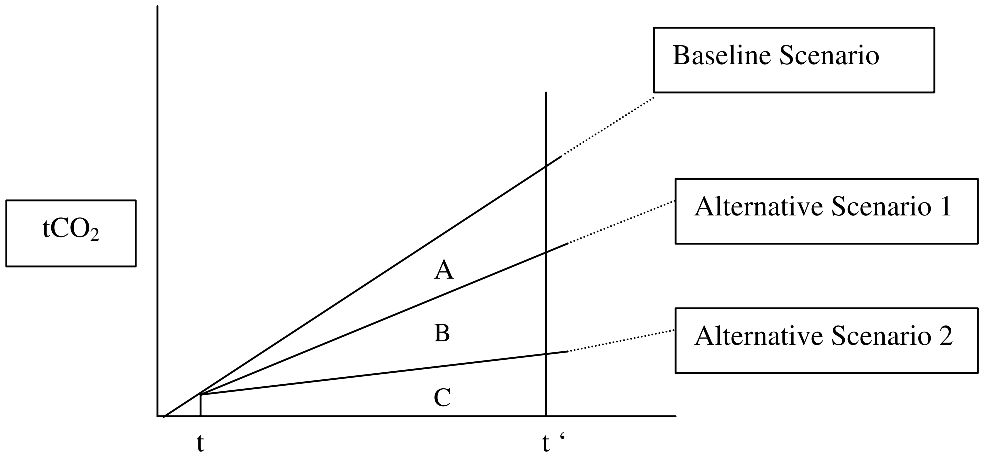
The available methodology for inventories, the preparation of which is a commitment of the signatories of the United Nations Framework Convention on Climate Change (UNFCCC), is the Intergovernmental Panel of Climate Change (IPCC).[9] This methodology, known as The Revised 1996 Guidelines for National Greenhouse Gas Inventories (hereinafter IPCC Guidelines, 1996), includes not only simple methods and default emissions factors for the major GHG sources and sinks but also far more elaborate ones, which require detailed databases.

There are no methodological guidelines for scenario building,[10] since countries are not committed to present them. However, the preparation of scenarios for planning purposes can use the methodology employed in Emissions Scenarios – A Special Report by IPCC (SRES, 2000), where global scenarios covering the major driving forces for emissions[11] are presented.

[9] A United Nations Panel consisting of more than 300 scientists from all over the world with the mission of disseminating consensual opinions from different areas related to the greenhouse effect.

[10] Scenarios must be interpreted as simple estimates of how the future may unfold under some circumstances and hypotheses and consequent emissions arising therefrom. They are possible paths to the future and a way of enhancing the understanding of the consequences of potential events, of long term policies and projects at a certain level.

[11] Future GHG emissions are the result of highly complex dynamic systems determined by driving forces such as demographic development, socioeconomic development and technological changes.



t = inventoried emissions in year t

t’ = any time in future

Total Baseline Emission Scenario in t’ time = A + B + C

Total Emission from t to t’ time by Alternative Scenario 1 = B + C

Total Emission from t to t’ time by Alternative Scenario 2 = C

Total Emission Reduction Reached in t’ time by Alternative Scenario 1 = A

Total Emission Reduction Reached in t’ time by Alternative Scenario 2 = A + B

Figure 1 Baseline emissions and emissions reductions with alternative scenarios.

The main stages in building a scenario are: (1) delimitation of the system being studied, (2) diagnosis of the behavior of the system and (3) analysis of how the system has evolved in the past. Based on this, the prospective analysis can begin. Econometric techniques can be used to relate prior levels of the main socioeconomic variables (e.g., GDP and population) with a certain amount of emissions and to project future emissions as these variables change in the time horizon of the scenario. Intuitive thinking encompassing the opinion of specialists about how the future may unfold is a technique also used as an input for scenario building.

The baseline scenario, the so-called business as usual scenario (BAU), should project the emissions that could occur in the future due to the expected socio-economic development path, disregarding emission reductions that will be achieved through mitigation projects or actions that are not an attractive.

In the case of alternative scenarios, they are built, deducting from the baseline emission reductions that can be obtained by measures and/or projects specially implement by local governments to mitigate climate change.

Figure 1 represents the amount of emissions estimated in the baseline scenarios and the respective reductions that can be obtained by adopting alternative scenarios (mitigation scenarios).

In building alternative scenarios, targets for future emission reductions can be set and then how the results of the most feasible actions and projects could contribute to reaching that target could be tested. Alternatively, these actions can be identified in the first place, and then their possible effects in terms of GHG mitigation achieved can be tested.

Note that these planning techniques can incorporate variables other than GHG emissions. For example, a joint target can be set for local and global pollutants, and alternative scenarios built to include both variables.

A GHG inventory and the building of scenarios were carried out for Rio de Janeiro as part of the International Council for Local Environmental Initiatives (ICLEI) in the Cities for Climate Protection (CCP) campaign.[12] In 2003, the local government

[12] According to ICLEI (2006) 650 local governments participate in CCP.

Table 3 Source categories for CO_2 and CH_4 emissions for local inventories

IPCC methodology adapted to the City of Rio de Janeiro 2003 inventory

1 – Energy (top-down approach[a])
Expressed in fuel consumption of the following large final consumer sectors: power generation, industry, individual transport, collective and cargo transport, air transport and households and commerce
• *Estimation of CO_2 emissions from energy use*
IPCC methodology adopted in the 2003 Inventory and simplest option for the Brazilian cities:

$$GgCO_2 = \sum(((FC_{ab} * EF) - SC) * UC) * 44/12$$

where
CO_2 = carbon dioxide emitted in current year
FC = fuel consumption (TJ)
EF = emission factor (tC/TJ)
SC = stored carbon
UC = unoxidazed carbon ratio
a = fuel type
b = activity sector
44/12 = conversion factor (from carbon to carbon dioxide)

• *Estimation of CH_4 emissions from natural gas activities*
IPCC methodology adopted in the 2003 Inventory and simplest option for the Brazilian cities:

$$GgCH_4 = CC * DV * EF$$

where
CH_4 = methane emitted in current year
CC = gas consumption (TJ)
DV = default values for gas release (%)
EF = emission factor

2 – Industrial processes
This category is considered of very low interference from the Brazilian municipal administration perspective and therefore emissions are not taken into account

3 – Agriculture
• *Estimation of CH_4 from livestock, manure management, rice fields and burning of savannas.*
In Rio de Janeiro there are no rice fields and burning of savannas. Therefore only enteric fermentation and manure management emissions were estimated. This category is considered to be of very low interference from the Brazilian municipal administration perspective and therefore emissions are not recommender to be taken into consideration, unless under specific conditions where the local administration foresee opportunities to undergo partnerships or if costs of estimating such emissions are marginal in the general assessment.
IPCC methodology for enteric fermentation used in the 2003 Inventory:

$$GgCH_4 = P \times EF$$

where
CH_4 = methane emitted in current year
P = livestock population
EF = emission factor

IPCC methodology for manure management used in the 2003 Inventory:

$$GgCH_4 = P \times MP \times EF$$

where
CH_4 = methane emitted in current year
P = livestock population
MP = per capita manure production
EF = emission factor

4 – Land use change and forestry
• *Estimation of CO_2 emissions from forest removals due to the expansion of the urban area*
The IPCC methodology accounts for the carbon released into the atmosphere due to plantation and cattle raising activities. However, the great majority of the Brazilian municipalities are focused only on the conservation of the remaining native forests where urbanization is taking place and being responsible for the deforestation, as it is the case of the Atlantic Forest. In these cases, deforestation is a creeping phenomena when the vegetation is removed and dumped in landfills or left to decay in inner parts of the forest. Because of that, the methodology used in the 2003 Inventory and that can be used in other localities only accounts for CO_2 emissions of the carbon content of the vegetation, since emissions from fire are marginal.
IPCC methodology for deforestation used in the 2003 Inventory and simplest option for the Brazilian cities:

Table 3 (*continued*)

$ktCO_2 = BC * BD * CC * 44/12$

where
CO_2 = carbon dioxide emitted in the current year
BC = biomass cleared (ha) in the year
BD = biomass density (dry matter/hectare – varies according to vegetation type)
CC = carbon content of dry biomass
44/12 = conversion factor (from carbon to carbon dioxide)

• *CO_2 removal from annual growth increment of biomass (reforestation).*
Likewise deforestation, carbon sequestration that takes place due to the municipalities initiatives is peculiar since it is related to forest recovery and not for economic purposes. In that sense, the IPCC methodology needs to be adjusted:

IPCC methodology : $ktCO_2 = ((ha * BG) - (TH * ER)) * CC * 44/12$

where
CO_2 = carbon dioxide uptake in the current year
ha = planted hectares
BG = average annual growth per hectare in biomass (dry matter/hectare – varies according to vegetation type)
TH = total harvest
ER = expansion ratio to treat slash
CC = carbon content in dry matter
44/12 = conversion factor (from carbon to carbon dioxide)
Adapted methodology used in the 2003 Inventory that could be adopted whenever the reforestation is for forest recovery:

$ktCO_2 = ha * BG * CC * 44/12$

where
CO_2 = carbon dioxide uptake in the current year
ha = planted hectares
BG = average annual growth per hectare in biomass (dry matter/hectare)
CC = carbon content in dry matter
44/12 = conversion factor (from carbon to carbon dioxide)

5 – Waste
• *CH_4 emissions from landfill*
IPCC methodology (default) adopted in the 2003 Inventory:

$GgCH_4 = (MSWT \times MSWF \times MCF \times DOC \times DOC_F \times F \times 16/12 - R) \times (1 - OX)$

where:
MSWT = total municipal solid waste generated (Gg/yr)
MSWF = fraction of MSW disposed to solid waste disposal sites
MCF = methane correction factor (depends on the anaerobic conditions of the waste disposal)
DOC = degradable organic carbon (depends on the type of the contents of the waste)
DOC_F = fraction DOC dissimilated (fraction of DOC that completely degrades – default value is 0.77)
F = fraction of CH_4 in landfill gas (default is 0.5)
R = recovered CH_4 (Gg/yr)
OX = oxidation factor of CH_4 (fraction – default is 0). There is a "lack of understanding of the effects of CH_4 oxidation in waste disposal sites"[b]
Due to new CDM rules regarding the requirements to estimate CH_4 formation in landfill for mitigation projects[c], it is highly recommended that new inventories use he IPCC First Order Decay methodology as they are compatible and allows to a better evaluation of the CDM potentials, as follows:
IPCC methodology (kinetic approach) recommended for cities:

$Q = Lo * R(e^{-kc} - e^{-kt})$

where:
Q = methane generated in current year (m^3/yr)
Lo = methane generation potential (m^3/Mg of refuse)
R = average annual waste acceptance rate during active life of the site (Mg/yr)
k = methane generation rate constant (1/yr)
c = time since SWDS closure (yr)
t = time since SWDS opened (yr)
• *CH_4 emissions from wastewater treatment.*

(*continued on next page*)

Table 3 (*continued*)

IPCC methodology used in the 2003 Inventory:

$$GgCH_4 = (OM \times Bo \times MCF \times EF) - MRi$$

where

CH_4 = methane emissions in current year

OM = organic matter produced (BOD – biochemical (biological) oxygen demand for domestic and commercial wastewater and sludge or COD – chemical oxygen demand for industry wastewater and sludge)

Maximum methane producing capacity (*Bo*): 25% (default value)

MCF = $0 \leqslant$ methane conversion factor $\geqslant 1$ (0.0 for a completely aerobic system, 1.0 for a completely anaerobic system)

MR*i* = total amount of methane recovered or flared from wastewater type *i* in kg CH_4.

Source: Authors, based on IPCC Guidelines 1996 and 2003 Inventory.

[a]Emissions estimates are based on the amount of fuel consumed times the respective average emission factors.

[b](IPCC Guidelines, 1996), Module 6, p. 6.10.

[c]According to the Executive Board of the Clean Development Mechanism – 23rd meeting report (CDM EB, 2006).

published the Inventory of Greenhouse Gas Emissions of Rio de Janeiro (Inventory, 2003), hereafter referred to as 2003 Inventory. To illustrate, an analysis of this experience is presented next, in Sections ‘‘Inventory of greenhouse gas emissions of Rio de Janeiro’’ and ‘‘Greenhouse gas emissions scenarios for Rio de Janeiro’’.

Inventory of greenhouse gas emissions of Rio de Janeiro[13]

The 2003 Inventory aimed to quantify annual CO_2 and CH_4 emissions for the period 1990–1998 that was extended to embrace future emissions scenarios. To the inventory purpose, the IPCC methodology (IPCC Guidelines, 1996) was adapted to local specificities and applied to the energy, land use change and forest, agriculture and waste sectors.[14]

Table 3 shows the emission source categories and methodological approaches used and proposed to be adopted by other urban localities in Brazil as a starting point for further developments in this area. The proposed approach is considered to be feasible from the point of view of Brazilian urban dynamics and the availability of data. The methodological approach is mentioned when there are options in the 1996 IPCC guidelines or when the original IPCC methodologies are adapted.

Figure 2 shows the emissions per energy source and per sector demand in Rio de Janeiro in 1998. Emissions from electricity are attributed only to the Power Generation Sector and not to the end use sectors to avoid double counting.

According to *Figure 2*, the energy consumption sector has the greatest responsibility for emission accounting for 60% of the total, with transport being the most important source in this sector. The solid wastes management sector is the second largest source of emissions with a significant 37% share. The other sectors are quite insignificant.

Greenhouse gas emissions scenarios for Rio de Janeiro

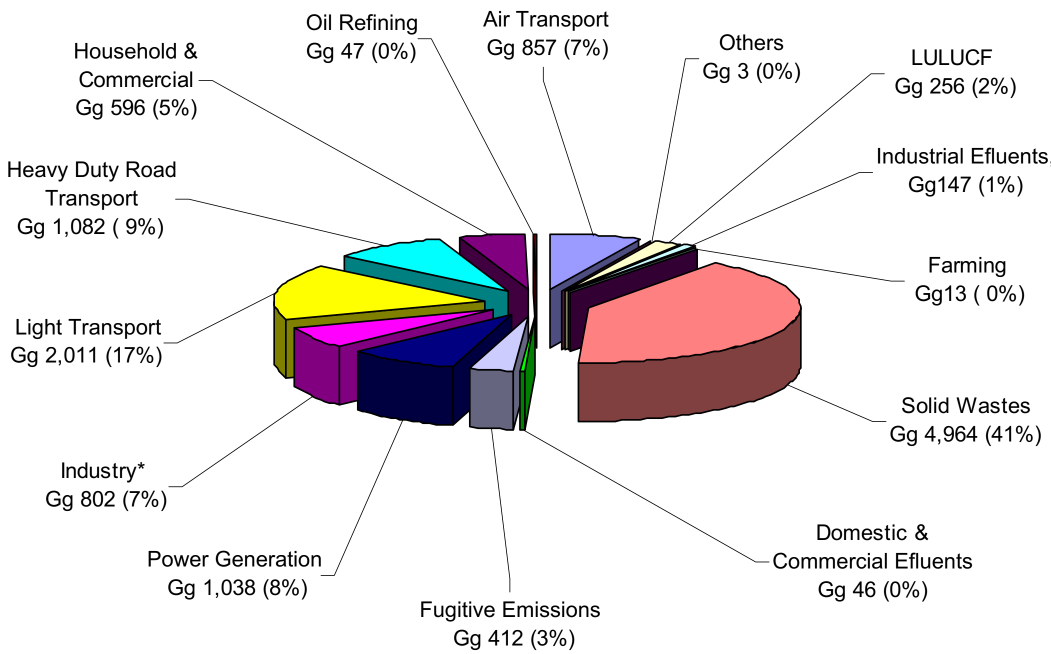
Scenarios were designed for the short, medium and long term (2000, 2010 and 2020), based on IPCC scenario building methodology. The process began with initial sector meetings with local government experts, followed by a large seminar with the purpose of framing possibilities for the future. Here, information was gathered and opportunities identified for projects with the greatest chance of participating in the CDM. Other future variables that could influence emission patterns were also estimated.

Three emission scenarios were built based on a socioeconomic development path (population growth and gross domestic product projections) produced by the relevant local public agency.

Scenario A is the baseline scenario and is, therefore, built on the premise that no special efforts would be made by the municipal government to reduce GHG emissions. Emissions would simply follow the current trends determined by the parameters of the socioeconomic scenario, taking into account projects already implemented or planned. Scenario B encompasses the improvements that the municipal government can implement based on a moderate effort involving new projects and activities that reduce GHG emissions. In Scenario C, several possible projects and alternatives that

[13] All the following data was obtained from the Inventory of Greenhouse Gases of Rio de Janeiro (2003).

[14] This study, although part of the ICLEI campaign, was carried out by the Centro Clima, a research institute of the Energy Planning Program of the Graduate Studies in Engineering Program, the Federal University of Rio de Janeiro – PPE/COPPE/UFRJ.



* Emissions from electricity consumption not included
Source: Based on Inventory (2003)

Figure 2 CO_2 and CH_4 emissions in 100-year GWP – Sectoral emissions – City of Rio de Janeiro, 1998. (Global warming potential: an index, describing the radioactive characteristics of GHG, that represents the combined effect of the differing times these gases remain in the atmosphere and their relative effectiveness in absorbing infrared radiation. This index approximates the time-integrated warming effect of a unit mass of a given greenhouse gas in today's atmosphere, relative to that of carbon dioxide (SRES- IPCC, 2000).)

could result from a major municipal government effort to reduce GHG emissions are included. *Table 4* presents the main measures included in scenarios B and C that were considered plausible for Rio de Janeiro and the local benefits that can be obtained from these measures when compared to scenario A.

According to the evolution of emissions in the above scenarios, it is estimated that there will be an increase of 115% in Scenario A (baseline), 93% in Scenario B and 69% in Scenario C in 2010 with in comparison to 1990 and an increase of 169% in Scenario A, 140% in Scenario B and 99% in Scenario C in 2020, also in comparison to 1990. Since the population projected for 2020 is only 8.5% bigger than in 1990, it is assumed that even in Scenario C, in which public administration would concentrate efforts to reduce GHG emissions, there will be a fairly substantial increase of per capita emissions for this period. *Table 5* shows the average annual increase of emissions in each scenario, relative to the emissions inventoried in 1990.

Municipal inventories and scenarios – Rio de Janeiro in the global context

In order to evaluate the scale of its contribution to climate deterioration, the studies carried out by the time of the 2003 Inventory compared emissions from Rio de Janeiro and from other cities worldwide as shown in *Table 6*.

The data shows a great disparity among these cities. This is mainly a reflection of differences in vehicle fuels (greater or lesser consumption of oil products), sources of electricity (greater or lesser share of hydropower, nuclear energy, etc.), urban spatial distribution (greater or lesser concentration of population and demand for transport) and types of waste management (greater or lesser use of anaerobic treatment and/or energy production with waste), as well as income levels, which determine overall consumption levels.

Possible emission reductions in Rio de Janeiro (obtained from Scenarios B and C in respect to scenario A) are not expected to be very significant when compared to the possibilities of cities from industrialized countries that are much more carbon intensive. This is due to the fact that current emissions in Rio de Janeiro are already low, which leaves little room for mitigating projects. For example, the reductions that can be achieved in Rio de Janeiro add 3,910 t CO_2/year considering all sectors analyzed (energy consuming sectors, forest and land use change and waste management), while those

Table 4 GHG emission reduction measures in scenario B (moderate local government effort) and scenario C (major local government effort) and potential local benefits – Rio de Janeiro

Sector	Scenario B		Scenario C	
	GHG emissions reduction measures	Main local benefits	GHG emissions reduction measures	Main local benefits
Energy				
Transports	Replacement of diesel or gasoline vehicles owned or hired by the local government by alcohol or CNG powered vehicles	Reduction of local atmospheric pollutants	Same as in scenario B plus replacement of diesel oil by CNG in the municipality's bus fleet	Expanded benefits of scenario B
	Rationalization of routes and modernization of the bus fleet (Rio Bus Project)	Reduction of local atmospheric pollutants and of transport costs incurred by the population	Same as scenario B	Same as scenario B
	Capacity building in transport companies to improve management measures and to increase efficiency in the use of diesel in heavy duty fleet. (Economizar Project)	Reduction of local atmospheric pollutants	Same as scenario B	Same as scenario B
Electricity	Energy efficiency in public lighting (Rioluz/Procel Project)	Improvement of public lighting with reduction of public expenditure on electricity	Same as scenario B plus energy efficiency in public buildings	Expanded benefits of scenario B
Gas	Replacement of liquefied petroleum gas by natural gas in the domestic and commercial markets	Reduction of local atmospheric pollution	Reproduces Scenario B (no actions were identified to add to Scenario C)	Same as scenario B
Solid wastes	Recovery of up to 42% of the methane production in sanitary landfills by flaring	Future possibility for replacing more polluting vehicle fuels or for generating less polluting electricity, decreasing public expenditure on energy	Recovery of up to 85% of the methane production in sanitary landfills by flaring	Expanded benefits of scenario B
Land use and forest	Carbon sequestration through reforestation of small cleared areas.	Improvement of urban landscape, better support of hills and less silting of rivers and lakes	Carbon sequestration by reforestation of large cleared areas; increase in the number of trees in urban areas	Expanded benefits of scenario B plus increase in shadow areas, reducing urban heat
Domestic and comm. sewage	Reproduces Scenario A (no actions were identified to add to Scenario B)	–	Flaring methane generated in sewage treatment stations	Future possibility for replacing more polluting vehicle fuels or for generating less polluting electricity, decreasing public expenditure on energy[a]
Industrial effluents	Reproduces Scenario A (no actions were identified to add to Scenario B)	–	Reuse of biogas by industry to substitute natural gas	Reduction in business expenditures on energy

Source: Authors based on the scenario studies developed for Rio de Janeiro.

[a]This benefit will be appropriated at the municipal or at the state level, depending on the regulatory framework of the basic sanitation sector currently under discussion in Brazil.

Table 5 Variation of GDP and emissions with respect to 1990

	2000	2010	2020
Population (number of inhabitants)	5,608,983	5,756,535	5,907,968
	Average annual growth with respect to 1990 (%)		
Population	0.30	0.29	0.28
GDP	0.80	0.90	0.93
Emissions scenario A	4.00	3.90	3.35
Emissions scenario B	3.57	3.34	2.96
Emissions scenario C	2.97	2.66	2.32

Source: Authors based on 2003 Inventory data.
Note: Scenario A = baseline.

Table 6 Magnitude of Rio de Janeiro emissions in comparison with other cities[a]

City	Base year[i]	CO_2 emissions ($GgCO_2$ eq)[ii]	Population (# inhabitants)	*Per capita* emission (t CO_2 eq/inhab)
Rio de Janeiro[(1)]	1990	10,972	5,435,942	2.0
Rio de Janeiro[(1)]	1998	12,798	5,633,407	2.3
Ten medium sized American cities (mean of the values from Atlanta, Austin, Albuquerque, Denver, Miami, Minneapolis, Portland, Oakland, San Jose, Tucson)[(1)].	1990	9,953	443,612	22.4
Los Angeles, USA[(1)]	1990	32,133	3,485,398	9.2
Chicago, USA[(1)]	1990	22,848	2,783,726	8.2
Seven Medium Sized Canadian Cities (mean of the values from Toronto, Edmonton, Hamilton, Regina, Sudbury, Vancouver, Ottawa)[(1)]	1990	5,050	375,505	13.4
Toronto (metropolitan area), Canada[(1)]	1988	28,300	3,898,933	7.3
Fourteen Medium Sized European Cities (mean of the values from Copenhagen, Helsinki, Graz, Linz, Dusseldorf, Hannover, Saarbrücken, Bolonha, Amsterdam, Gdansk, Stocolmo, Göteborg, Zurich, Lviv)[(1)]	Several years	4,520	468,531	9.6
Prague, Czech Republic[(1)]	1990	9,123	1,215,771	7.5
Berlin, Germany[(1)]	1990	30,926	3,471,418	8.9
Rome, Italy[(1)]	1993	13,923	2,693,383	5.2
Barcelona, Spain[(2)]	1996	5,139	1,511,470	3.4

Sources: (1) ICLEI 1997 *apub* 2003 Inventory and (2) Baldasano et al. (1996).
[a]Information about sectors and gases are not available.
[i]Baseline year for the greenhouse gas inventory for the municipality in question.
[ii]1 Gg CO_2 = 1000 tonnes CO_2.

envisaged for Leicester, England result in 23,157 t CO_2/year just from energy saving (Fleming and Webber, 2004).[15]

Nevertheless, it must be stressed that there are some sectors that could benefit from the additional resources CDM projects could attract and therefore contribute to enhancing the quality of life in developing countries in accordance with UNFCCC principles.

[15] The periods in which these emissions would be achieved are 1998–2010 for Rio de Janeiro and 1996–1999 for Leicester making the comparison just illustrative.

Conclusion

Planning activities at the municipal level can incorporate the greenhouse effect problem in their variables, like the activities that took place in Rio de Janeiro. This new attitude can contribute to the climate issue and also raise resources under the clean development mechanism. This additional income from GHG emissions reduction projects can help control local pollution and achieve other types of benefits such as lower public expenditure, traffic improvement, reductions in atmospheric pollution, among other aspects important to the quality and everyday life of communities.

For this reason, an inventory of current emissions could be a useful first step indicating the main sources of the problem. Alternative scenarios encompassing the consequences of the various options for policies, plans and projects to be adopted in the near and the distant future could be a second valuable step. This would allow locally made decisions to incorporate the climate issue and improve quality of life using resources available in the global carbon market.

Acknowledgments

This work is based on the studies of evaluation methodologies for GHG emissions in Brazilian municipalities being carried out by Centro Clima, with the support of the Ministry of the Environment. The case study illustrating this article was funded by the Municipal Government of Rio de Janeiro.

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