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Assessment of the emissions of greenhouse gases in Barcelona City. Period 1987-1994

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Abstract

Emissions of greenhouse gases for Barcelona City are estimated for the period 1987-1994. Sources considered are: public and private transportation; industrial, commercial and domestic activities; and municipal solid waste disposal. Results show that the main source of CO_2 emissions in Barcelona is private vehicle transportation, which accounts for a 35% of the total. The second most important source is the municipal solid waste landfill facility of the city (28% of the total emissions). However, CO_2 emissions per inhabitant during the period studied is the lowest of all the values for other industrialized cities available for comparison.

1 Background

The campaign **Cities for the Protection of the Climate** emerged as a contribution of the local administrations to the UN Framework Convention on Climate Change (UNFCCC) established in the Conference on Environment and Development, that took place in Rio de Janeiro in June of 1992. Later on, the European Conference of Local Authorities was held in Amsterdam in March of 1993, where a statement was approved that proposed the **Campaign of the European Cities for the Protection of the Climate.** The city of Barcelona joined this campaign.

Within this process, in September 1994 took place in Heidelberg the international conference: "***How to Global Combat Warming at the Local Level***", co-organized by the OECD, EC, ICLEI and the city of Heidelberg, with the participation of the city of Barcelona. The mayors

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and local authorities that participated in the conference recognized, in the form of a statement (Heidelberg, 9 of September of 1994):

- that cities constitute an important part of the total energy consumption. This consumption is mainly used in air conditioning (heating/refrigeration), industrial and commercial activities and in transportation, all of them concentrated in the large urban agglomerations;

- that these trends cause local pollution and contribute to injure the environment at a global scale; and

- that the promotion of an environmental-friendly energetic management and the reduction of the negative impacts of the growing traffic is of first importance.

Considering the urgent need of taking actions at the local level, the signers of the statement were committed to reduce, by year 2005, the emissions of CO_2 in their responsibility areas in at least a 20% with respect to the levels in 1987.

The mechanism by which the carbon dioxide (CO_2) and other gases with similar properties, such as methane (CH_4), nitrous oxide (N_2O) and the chlorofluorcarbons (CFC), heat the Earth's atmosphere is called greenhouse effect. This effect, known since the end of last century, is based on the common property of certain gases present in the Earth's atmosphere of absorbing the infrared radiation. It is a similar phenomenon, but not identical, to the one that takes place in agricultural greenhouses and from which it takes its name. It results in a natural heating of the atmospheric lower layers that leads to the climatic conditions that we know today. As a consequence of this effect, the mean temperature of the planet is currently of 15°C, instead of the - 21°C that would be given in absence of these gases. This makes the Earth a more comfortable place to inhabit.

Scientifically, it can not be asserted without doubt that we are facing a climatic change induced by man activities, but the Intergovernmental Panel on the Climatic Change (IPCC), in 1995, has verified that it exists *a visible human influence on the climatic change*. As a consequence, a current opinion tendency has been formed in the sense that the potential threat that the climatic change represents to the planet is too serious to wait to have a better knowledge of what is happening to start to act. As a

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result, the application of the *Precautionary Principle* is imposed; that is to say, the need of taking correction measures from now. This is one of the objectives of the UNFCCC signed in Rio de Janeiro in 1992 which became effective in March 1994.

Obviously, to reduce the possibility of increasing the greenhouse effect, it is necessary to limit the emissions of the gases that produce it. It is here where other types of problems emerge: How much is being emitted? How much has to be reduced? When and for how long? How and where can the emissions be reduced? Who must reduce them?

According to the reports of the UNEP/WHO of 1992, there is a growing tendency towards the concentration of population in large urban centers. This process means that cities are becoming the main centers of generation of man-related emissions of greenhouse gases. As a consequence, many of the corrective measures to reduce emissions will have to be taken in the cities themselves.

In the Summit of Berlin (March 1995), parts that joined UNFCCC were expected to decide the percentage of reduction of the emissions of the greenhouse gases, but the difference of postures between the different delegations made the agreement impossible. The parallel summit of local authorities proposed a reduction of a 20% of the emissions of CO_2 by year 2005. Although such proposal was not assumed, the opening of a section in the States Conference so that cities can expose their criteria, means by itself a certain recognition of the important role they play in the solution of a global problem.

Delegates at the UNFCC at Kyoto (December 1997) reached an agreement to curb greenhouse gas emissions in the near future. Developed counties will, as an average, cut their emissions back to 5.8 percent below 1990 levels (7% reduction for the US; 8% EU; 6% Japan and Canada; but 8% increase for Australia). Many charged that the treaty did not go far enough and that emissions levels will no fall off fast enough to prevent global warming.

Humanity is facing, for the first time, a high complexity environmental problem at the global scale that affects the survival of the current human civilization more than the survival of the planet itself. The necessary actions to remedy this threat span through a set of measures of a very wide and different scope, both at the collective and the individual point of view.

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2 Global assessment of the emission of greenhouse gases in the city of Barcelona

Emissions of CO_2 and CH_4 have been estimated, using a bottom-up methodology, only from man-related activities, since biogenic emissions have not been considered. The considered sources have been: private and public traffic; industrial, commercial and domestic activities; and disposal of municipal solid waste (MSW). We have considered not only the final quantities of consumed fuels, but also the emissions produced during their life cycle; that is, emissions related to their extraction, processing, transportation and distribution. **Table 1** collects the estimated emissions for the period 1987 to 1994.

As we can see in the table, a percentage of the 10% has been added to the emissions of CO_2, which intends to account from the emissions that we could not estimate due to the lack of information. Under the denomination of "others" we include emissions derived from the use of solid fuels (coal, wood, etc.), flammable liquid for heating (gas oil), consumption in airports and harbors, etc.

The percentage distribution of these emissions is also shown in **Table 1**, where we can observe that annual variations are soft, with an almost-linear growing evolution between year 1987 and 1990. A small increase is observed until 1992, followed by a reduction in 1993 and 1994. This behavior can be accounted to the decrease of electrical consumption, despite the increasing emissions from traffic. The lower emissions from energy generation have to do with the reduction of the use of fossil fuels and to the increase of electricity from nuclear and hydraulic sources.

The emissions of equivalent tons of CO_2 per inhabitant in the city of Barcelona, that oscillate between 2.6 and 3.2 equivalent tons of CO_2 per person and year during the period 1987-1994, must be considered low if we compare them with the values from other cities of industrialized countries.

The low emission levels per inhabitant can be explained, among other reasons, if we take into account that:

- the economic structure of the city is mainly based on the tertiary sector (services), the less energy consumer sector.
- the electrical energy that Barcelona consumes proceeds, in a

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Table 1. Total emissions of greenhouse gases in Barcelona, expressed as equivalent tons of CO_2. Period 1987-1994.

SOURCE (tons/year)	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**
TRANSPORTATION	1.533.484	1.588.742	1.643.999	1.699.257	1.576.775	1.593.123	1.609.556	1.655.096
NATURAL GAS	501.204	492.453	515.225	526.538	607.477	631.684	626.043	607.654
LPG	207.513	195.009	182.598	178.835	183.545	188.255	230.582	228.276
ELECTRICITY	579.095	581.864	631.253	642.193	698.047	877.894	525.649	497.630
MSW INCINERATION	305.773	336.878	196.522	344.760	224.833	264.554	230.373	265.299
MSW LANDFILL	899.384	955.016	1.168.272	1.040.782	1.258.674	1.254.038	1.274.900	1.196.088
TOTAL =	4.026.453	4.149.962	4.337.869	4.432.365	4.549.351	4.809.550	4.497.103	4.450.043
OTHER (10% total)	402.645	414.996	433.787	443.236	454.935	480.955	449.710	445.004
TOTAL =	4.429.099	4.564.958	4.771.656	4.875.601	5.004.286	5.290.505	4.946.813	4.895.047
Population	1.714.355	1.712.350	1.707.286	1.696.795	1.643.542	1.630.635	1.635.067	1.630.867
(tons CO2/inhabitant)	2,6	2,7	2,8	2,9	3,0	3,2	3,0	3,0
SOURCE (%)	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**
TRANSPORTATION	34,6%	34,8%	34,5%	34,9%	31,5%	30,1%	32,5%	33,8%
NATURAL GAS	11,3%	10,8%	10,8%	10,8%	12,1%	11,9%	12,7%	12,4%
LPG	4,7%	4,3%	3,8%	3,7%	3,7%	3,6%	4,7%	4,7%
ELECTRICITY	13,1%	12,7%	13,2%	13,2%	13,9%	16,6%	10,6%	10,2%
MSW INCINERATION	6,9%	7,4%	4,1%	7,1%	4,5%	5,0%	4,7%	5,4%
MSW LANDFILL	20,3%	20,9%	24,5%	21,3%	25,2%	23,7%	25,8%	24,4%
OTHER (10% total)	9,1%	9,1%	9,1%	9,1%	9,1%	9,1%	9,1%	9,1%

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large percentage, of sources that don't emit greenhouse gases (nuclear and hydraulic energy represents a 90% of the total consumption).

- the city of Barcelona and its surrounding area, adopted the general use of natural gas back in the eighties .
- Barcelona is a Mediterranean city that enjoys a mild climate. Therefore, energy consumption for heating uses will be, in comparison to other cities (specially with respect north and center of Europe cities), lower.
- refrigeration systems is quite usual in offices and commercial buildings, but is not very common in particular houses.
- to its urban structure.

The distribution of the emissions by uses is shown in **Table 2** (for 1993).The principal source of greenhouse gases emissions in Barcelona is vehicle traffic. Following, we have emissions originated in the disposal of MSW, specially those generated in the Garraf landfill.

Transportation. Transportation is responsible of the 37,5% of the emissions of greenhouse gases, and shows a constant increase during the studied period. Only a 5,1% of these transportation emissions (1,9% of the total emissions) corresponds to emissions originating from public transportation. However, public transportation accounts for a 55% of the total number of trips.

Disposal of Municipal Solid Waste (MSW). Methane emissions generated in the Garraf landfill (28,7% of the equivalent emissions), positions the current management model for MSW in Barcelona as the second most important source of greenhouse gases. If that methane were burnt or recovered, the percentage of participation of the disposal of MSW in the global emissions would be considerably reduced.

The incineration of MSW has a high emission of CO_2 to produced GWh ratio, responsible for a 4,4% of the emissions of CO_2. This ratio is due to the calorific power of MSW and the efficiency of the actual facilities.

Other activities. The rest of the emissions, a 33,8%, are mainly distributed between the industrial sector, presently of little importance in the city of Barcelona and air conditioning of buildings (heating and refrigeration). A small percentage of the emissions are related to activities that use gas (such as the production of sanitary hot water, cooking stoves, etc.), and applications of electricity such as lighting.

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Table 2. Distribution of the emissions, by to uses and sectors (1993).

	Equivalent tones CO_2. 1993	
PÚBLIC TRANSPORTATION	100.670	1,9%
PRIVATE TRANSPORTATION	1.866.613	35.6%
HEATING	370.826	7.1%
REFRIGERATIÓN	68.757	1,3%
INDUSTRY	478.338	9,1%
OTHER USES OF GAS	179.661	3,4%
LIGHTING, SERVICES AND DOMESTIC	67.294	1,3%
OTHER USES ELECTRICITY	124.348	2,4%
MSW DISPOSAL	1.505.273	28,7%
OTHER	476.178	9,1%
TOTAL =	5.237.959	

3 Comparison with other cities, with Catalonia and with Spain.

A comparative analysis between Barcelona and other cities, from which information about their CO_2 emissions is available, takes us to the conclusion that Barcelona has a very low value of equivalent CO_2 emissions, having the lowest emission per inhabitant ratio among the cities studied (see **Table 3)**. In most of the cities studied, the analysis only considered emissions from energetic sources, ignoring emissions from the disposal of MSW. The following factors are believed to influence the low emission values for Barcelona:

- The climatic characteristics of the city (geographical location);
- The urban structure;
- The city's present economic activity (services rather than industry);
- The habits of the population (use of the car, etc.);
- Road and transportation structure.
- The sources of energy (natural gas, fuel oil, hydraulic energy, nuclear energy, etc.)and its cost;
- The model of municipal waste management urban (recycling, landfill, composting, incineration);

If we compare Barcelona with Catalonia and Spain, these strong differences are maintained (see **Table 4**).

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Table 3. Comparison of the CO_2 emissions in different cities.

	t CO_2/inhabitant/year
BARCELONA (E), 1993	3,2
ANKARA (TK), 1988 [1]	3,6
BOLOGNE (I), 1988 [1]	5,7
COPENHAGEN (DK), 1988 [1]	7,5
HEIDELBERG (D), 1987 [2]	7,9
HELSINKI (Fin), 1988 [1]	8,3
TURIN (I), 1990 [3]	8,6
SAN JOSÉ, CA (USA), 1988 [1]	8,8
PORTLAND, OR (USA), 1988 [1]	10,1
SAARBRUCKEN (D), 1988 [1]	10,4
HANOVER (D), 1988 [1]	10,6
DADE COUNTY, MIAMI, FL (USA), 1988 [1]	11,6
TORONTO METRO, ON (Can), 1988 [1]	13,5
TORONTO CITY, ON (Can), 1988 [1]	15,0
MINNEAPOLIS, MN (USA), 1988 [1]	17,5
DENVER, CO (USA), 1988 [1]	22,3

Table 4. Emissions of CO_2 per capita in Barcelona, Catalonia and Spain.

t/Inhabitant/year	1987	1988	1989	1990	1991	1992	1993	1994
BARCELONA	2,6	2,7	2,8	2,9	3,0	3,2	3,0	3,0
CATALONIA [4]				5,7	5,9	5,9	5,7	5,8
SPAIN [5],[6]				7,0			7,0	

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