Commercial and Informal Atmospheric Emissions in the Mexico City Metropolitan Area: Scenario Analysis and Policy Proposals

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Submitted to the Engineering Systems Division
in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Technology and Policy

at the
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September 2003

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ABSTRACT

The commercial and informal sectors contribute with significant amounts of emissions to the atmospheric pollution problem of the Mexico City Metropolitan Area (MCMA). It is more the case for some pollutants than for others, but, in any case, policies tackling the emissions of these sectors have been very few, and of very limited effect. Even the measurement of the emissions is believed to be underestimated, especially for the informal sector, which is mostly unaccounted for in the recent emissions inventories developed in the MCMA. This thesis intends to improve the estimation of commercial and informal emissions in MCMA, through a qualitative assessment of the range of emission sources in these sectors, and an emissions model based on the integrated scenario analysis methodology implemented in the Mexico City Program at MIT. The ultimate goal of this research is to propose and evaluate new policies to reduce commercial emissions, both formal and informal, in MCMA.

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ACKNOWLEDGEMENTS

My first thank you goes to Steve Connors, for his enthusiastic and knowledgeable guidance of my work in the scenario analysis team of the Mexico City Program, and for his supervision of my writing of this thesis, in which I summarize and present the results of this work.

Thanks also to the people in Mexico who gave me very useful information and comments for the completion of this research project: Julia Martínez, Hilda Martínez Salgado, Teresita Gutiérrez Rivera, Mauricio Coronado, Ubaldo Inclán, Luis Mario Reyes Craft, Víctor Hugo Páramo Figueroa, Jorge Sarmiento, Rocío Reyes, Cuihtláhuc Cruz, Luis Miguel Galindo, Martha Schteingart, and María Eugenia Ibarrarán.

Thanks to my friends and fellow students in the Mexico City Program, for their support and inputs: Dan Amano, Chiz Aoki, Alejandro Bracamontes, Rebecca Dodder, Michael Gilat, Dong Young Kim, Ali Mostashari, Kelly Roth, and Samudra Vijay.

All my appreciation goes to the Integrated Program on Urban, Regional and Global Air Pollution: Mexico City Case Study (better known as The Mexico City Program), for their financial support, and for providing all the necessary conditions for the completion of my research project. Thanks as well to Mexico City's Metropolitan Environmental Commission, who are the main sponsors of the Program.

Thanks are also due to the Mexican National Council for Science and Technology (CONACYT), for their additional financial support.

My deepest gratitude to Mario and Luisa Molina, and to Adrián Fernández Bremauntz, for their extraordinary support and encouragement. It is to them that I owe the great experience of being at MIT.

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1. INTRODUCTION

The purpose of this thesis is to analyze the contribution of the commercial formal and informal sectors to air pollution in the Mexico City Metropolitan Area (MCMA), with the intention of developing policy proposals that may help reduce it. One of the main reasons driving this analysis is the concern over what I believe could be significant contributors to air pollution, that have so far remained almost totally unaccounted for, and not tackled by policies. I intend to not only assess the impacts of these sectors on emissions in the MCMA, but also to propose some policies to reduce those impacts.

The motivation behind this project is, in good part, to attempt find some answers to the following, among many other questions:

- What is, in the context of atmospheric pollution emissions in the MCMA, the real measure and relevance of the commercial and informal sectors?

- Why have air quality policies tackling these sectors in the MCMA been so few and of so limited scope?

- What barriers exist for the design and implementation of policies tackling the commercial and informal sectors?

- How could we achieve a more comprehensive set of policies and strategies to reduce the emissions of the commercial and informal sectors in the MCMA?

- Is there a way to improve the implementation of these policies?

The information and considerations presented in this study derive mostly from literature review, data analysis, interviews, empirical observations, and previous experience of the author, who worked for the Mexican Ministry of Environment for more than seven years.

The narrative in this thesis more or less follows the course of action taken in the analysis that supports the results presented on it. There are, in all, seven chapters in this thesis, including this introduction, and a chapter for conclusions and recommendations.

Immediately after the introductory chapter, in Chapter 2, I define the methodology followed in the analysis of formal and informal commercial emissions, and describe the broader framework of the scenario analysis followed in the Mexico City Program, of which this thesis is only a small component. I also discuss, in this chapter, the tradeoff analysis tool, which was used for the assessment of proposed policy strategies. After that, there is some general discussion of the emissions model that I used for analyzing the commercial and informal sectors, even though a more detailed description of the model comes in a later chapter.

What follows, in Chapter 3, is a discussion of the air pollution problem faced in the MCMA. This analysis of the problem to whose solution this thesis attempts to contribute, is very important for understanding the relevance of this study, and also to get a sense of direction for where to look at in the analysis. As part of the analysis of the air pollution problem in the MCMA, there are sections discussing its political component, its institutional component, and also its policy component, looking at the air quality process and at the programs put in place in there up to this moment. At the end of this chapter, there is also some background information about the Mexico City Program, to try to convey the whole picture in which this analysis fits.

Then comes Chapter 4, which gives a first look at the formal and informal commercial sectors in the MCMA, with the intention of defining the scope of the analysis. There are four sections in this chapter. One looks at the formal commercial sector, trying to define its magnitude and relevance in the context of the MCMA. The following one, with the same intention, looks at the informal sector, though, by necessity, devoting more space to try to understand, to begin with, what should be understood by "the informal sector", to then develop, in a separate section, some estimation of its size. The last section of the chapter compares and contrasts the formal vs. the informal sector.

After analyzing the formal and informal commercial sectors in general, I proceed, in Chapter 5, to look at them in light of their contribution to atmospheric emissions in the MCMA. In this chapter, I first analyze what the current and past emissions inventories in the MCMA have done to account for the emissions of these sectors. After that, in another section, I look at the most recent air quality programs that environmental authorities have put together for the MCMA, to see what measures affecting the formal and informal commercial sectors they have included, and what these measures have aimed at. In the following section, I define what the driving factors of commercial and informal emissions are, to close the chapter with a section in which I present the baseline emissions of these sectors, which I estimated for the year 2000.

Chapter 6 presents the assumptions, definition and results of the commercial and informal emission models, both under three future stories, and under three scenarios. This analysis is followed by additional policy proposals, and their assessment, for which I used the tradeoff analysis methodology, and identified the key sensitivities. The chapter is divided into five sections. First, I discuss the modeling assumptions used in the analysis, and how the model is conceived, to then proceed to present the emissions trends observed under these assumptions, which are included in the following section. After that, I discuss, in a separate section, the policy proposals that I have considered, to then proceed to evaluate them, looking at the tradeoffs between potential emission abatement and cost, which occupies the next section. Finally, I look at the key sensitivities that are relevant for the implementation of the selected policy strategies. It is relevant to mention that the analysis of the factors that influence the design and performance of current and future environmental policies in Mexico remained far from exhaustive, but hopefully it may anyhow be of use for policy design.

The last chapter in this thesis, Chapter 7, presents the conclusions of the analysis. It summarizes the main findings of the study, looks at its limitations, and presents recommendations for policy and for further research.

It is relevant to mention that, although both the commercial and the informal sector, as analyzed in this thesis, include in strict sense activities that are not commercial, like brick production, or street paving, they are mostly commercial. Throughout this thesis, the two sectors analyzed are indistinctly referred to as "the formal and informal commercial sectors" or as "the commercial and informal sectors". In both cases I refer to the exact same categories, which are defined and analyzed in depth in later sections of this study.

2. METHODOLOGY

In this chapter, I present a brief discussion of the methodology followed in this thesis. I first introduce some concepts about the integrated scenario analysis, which is the framework used in the Mexico City Program, of which the work presented here is part of. I will give more details about both the Mexico City Program, and also about how this thesis fits into it, in the first section of this chapter. In the following section, I present a brief description of the model that I have used for the analysis of commercial, formal and informal, emissions, of which I present a deeper discussion in Chapter 6. The third section of this chapter, takes us from the discussion of the methodology used to estimate emissions, to that followed in the analysis of policies.

2.1 Integrated Scenario Analysis

This thesis is but a small part of a much larger effort to assess in an integrated manner the air pollution problem of the MCMA, from emissions of atmospheric pollutants and their causes, all the way to human exposure and health consequences. This effort has been carried out by MIT's Integrated Program on Urban, Regional and Global Air Pollution: Mexico City Case Study (known simply as "The Mexico City Program"), and it is intended as both an applied research exercise of very large scale and complexity, but also as a practical way of supporting air quality policy design and implementation in the MCMA, particularly for the development of the new MCMA air quality program, which came into effect in 2002.

The design of this strategy, according to the postulates of the Mexico City Program, includes the following aspects (MIT, 2000):

- The evaluation of air quality trends, and their impacts on human health.
- The definition of quantitative goals and objectives for abating emissions and improving air quality.

- The application of tools such as emissions inventories, air quality modeling, and the assessment of patterns of population exposure to pollution.
- The identification and characterization of atmospheric pollution prevention and control strategies and measures, in light of the national and international experience on the subject.
- The design of public participation mechanisms, effective in the preparation, implementation, following-up, and evaluation of the air quality program.
- The development of an effective communication strategy.

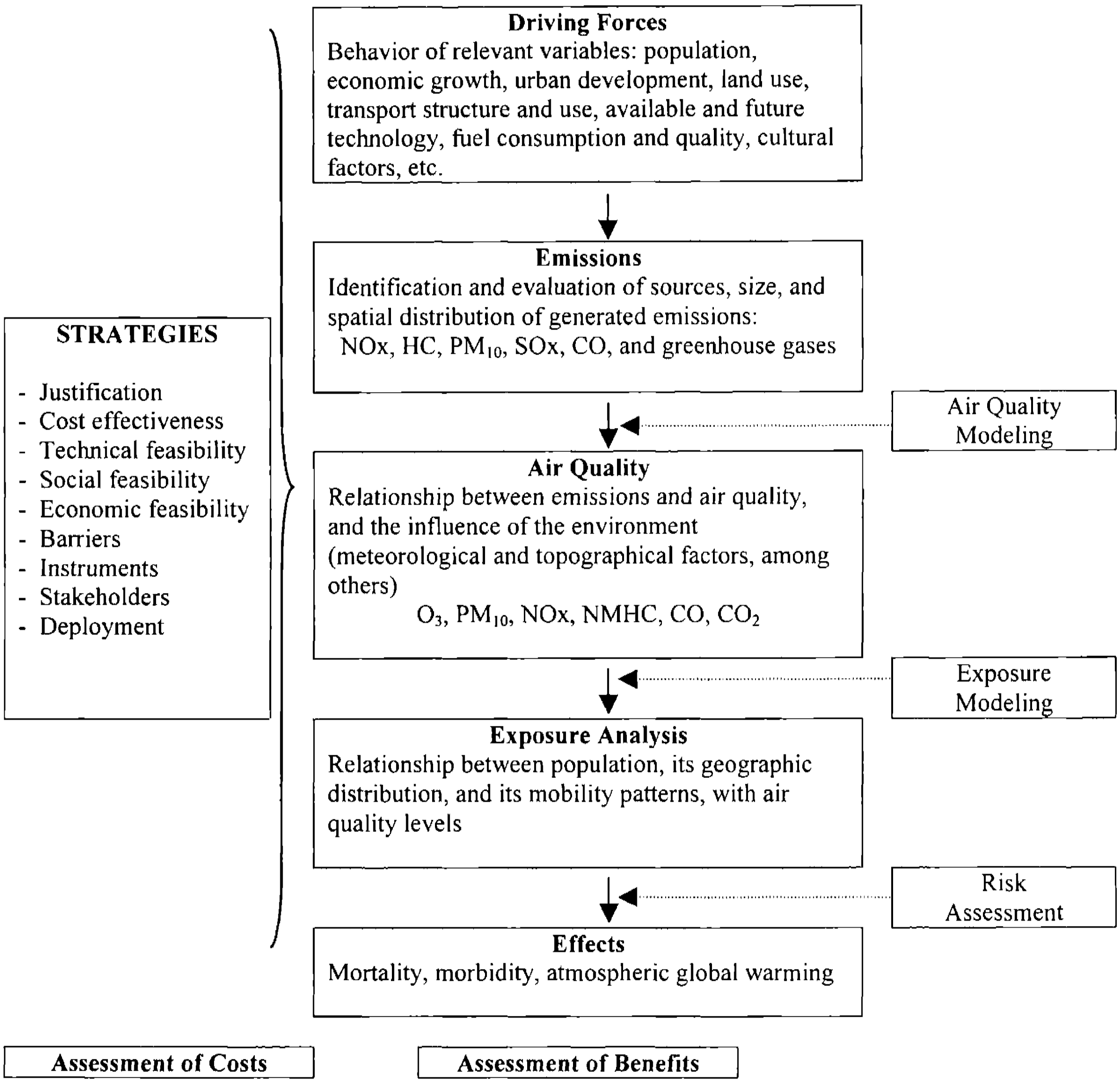
The integrated assessment methodology followed up by MIT's Mexico City Program departs from the recognition that there are multiple factors interlinked in a problem as complex and large-scaled as the MCMA pollution problem. The Program recognizes the need of including several social, political, and economic aspects related to the air pollution problem of MCMA, together with its technical components.

The evaluation and analysis process proposed by the Mexico City Program (See Figure 2.1) was closely followed-up in the development of the Program for Improving Air Quality in the Mexico City Valley Metropolitan Zone 2002-2010 (Proaire III), which is the new air quality program referred to earlier, and of which there is a broader explanation and more details in Chapters 3 and 5 of this thesis.

This thesis is one component of the emission analysis stage of the integrated assessment framework, though it also touches on the driving forces, and also attempts to produce and assess strategies, evaluating their costs, and somehow also their benefits, not measured in the traditional way of cost-benefit analyses, but in terms of emission reductions.

The estimation of emissions in the integrated scenario analysis of the Mexico City Program is divided into two broad categories: transportation, and non-transportation. The commercial and informal sectors are part of the non-transportation category, together with the residential sector, industry, and power generation.

FIGURE 2.1
ANALYSIS AND EVALUATION PROCESS FOLLOWED IN PROAIRE III



Source: MIT, 2000 (Reference translated and adapted from SEMARNAT-GEM-GDF- SS, 2002).

The estimation of emissions, to sustain policy suggestions and their assessment, has been carried out using an emissions model that links emissions of criteria pollutants and greenhouse gases, to socio-economic indicators, which evolve in the future according to three different future stories, and depending also on what policies are implemented, and their deployment schedules.

The development of the future stories, which are common to the whole emissions modeling team within the Mexico City Program, is based on the Royal Dutch/Shell approach to scenario analysis (Schwartz, 1991). Several quantitative indicators were developed to reflect the characteristics of three distinct future stories, named "divided city", "changing climates", and "growth unbound" (See Table 2.1). The purpose of the scenario approach, within which these three future stories were developed, is to develop an understanding of the different forces that "drive" the activities that generate emissions, to envision possible paths in the evolution of the MCMA, and to avoid relying on a single forecast of the many drivers of emissions (Dodder, 2003).

TABLE 2.1
GENERAL CHARACTERISTICS OF FUTURE STORIES

FUTURE STORY	MAIN CHARACTERISTICS
Divided City	- Rising income inequalities, a growing informal economy, urban instability and crime, and segregated (rich vs. poor) urban development. - High level of political disagreement and lack of cooperation between the State of Mexico and the Federal District, due to divisive party politics.
Changing Climates	- Growing evidence of local impacts of global climate change. - Mexico engaged actively in the international climate agenda, with strong support from the public and the media. - Rapid development and acquisition of new, cleaner technologies.
Growth Unbound	- High levels of private and public investments propel growth, led by the financial and commercial services sectors. - Moderate population growth, but an increasingly decentralized city, highly dependant on the automobile.

Source: Dodder, 2003

The specifics of each one of the three future stories used as the basis of the emission models developed for all relevant activities in the MCMA, are presented in Table 2.2. In this table, we can see how a variety of driving forces change with each one of the three future stories conceived by the Mexico City Program Scenario Analysis Team. The main driving forces, which vary, depending on future story, refer to the economy, society, urban form, technology, politics, and the environment.

TABLE 2.2
DRIVING FORCES UNDER EACH FUTURE STORY

DRIVING FORCES	FUTURE SORIES		
	Divided City	**Changing Climates**	**Growth Unbound**
Economics	3% national growth Heavy on manufacturing	4% national growth Balanced sectoral growth	5% national growth Finance and services –led Sustained high investments
Society	Income inequality worsened Large informal sector Urban instability Civic participation vocal	Shrinking income inequality Convergence between SoM and DF Growing civic participation	Security remains problematic Civic participation low Income inequalities persist
Urban Form	Expansion High population growth Large portion of irregular households	Consolidation / densification Shrinking household and family size Moderate population growth in both the DF and SoM	Sprawl and automobile dependence Expansion & densification "Planned" suburban development in SoM Low population growth
Technology	Long lag time with US technologies Sensitivity of equity issues	Convergence with US technologies High investment in science and technology Rapid learning curve and diffusion of "best practices"	Rapid turnover of technologies, but... Lagging behind US standards on efficiency and emission control equipment
Politics	Further fragmentation of parties Dynamic and unstable Inter-jurisdictional conflict Corruption high	Government intervention high in investment and enforcement Better accountability Metropolitan governance successful	Government intervention low Institutional reforms slow
Environment	Social problems overshadow environmental issues Water becomes the critical environmental issue	Heat island impacts shift local environmental attitudes International actions both top-down (Kyoto) and bottom-up with local NGOs	Environmental issues not addressed Public apathy and resignation

DF: Distrito Federal; SoM: State of Mexico (Metropolitan)
Source: Dodder, 2003.

Future stories are intended as coherent, credible stories about alternatives futures (Schwartz, 2001). They are not forecasts of the future, but are intended to cover a wide spectrum of possible futures, so that the estimation of emissions and the assessment of polices, are evaluated and "tested" under different conditions.

We can clearly see that the three future stories on which the analysis of emissions lies, could not by any means be categorized as an optimistic, an average, and a pessimistic "scenario". These future stories combine, each one, several positive and negative characteristics, which make them in most cases closer to what any probable real future is going to be like.

2.2 Model Description

It is important to first define, for the purposes of this analysis, what activities are comprised in the commercial formal and informal sectors, which may be relatively significant contributors to air pollution emissions in the MCMA. After that, we must determine what is the size of the informal sector, in relation to the better-known formal one. Finally, we have to assess the impacts of both the commercial formal and informal sectors on emissions, analyzing their activities and technologies. All these things are done with limited access to data, especially for informal activities, because data is very scarce for the informal sector in Mexico, and even more so when it comes to its impacts on pollution. The effort has to be done, in any case, to get to at least rough estimates that can serve to design policies.

The following are some of the most important questions that this research attempts to find answers to:

- What activities are comprised within the commercial activities, both formal and informal?
- What drives emissions on these sectors?

- What is the informal sector?
- Where do we draw the line between informal and formal economic activities?
- How much is informal activity a consequence of poverty?
- Is the informal sector less productive than the formal one?
- Does the informal sector have less access to technology?
- Are informal sector activities more pollution-intensive than the equivalent formal ones?
- How much do commercial formal and informal activities contribute to atmospheric pollution in MCMA?
- What has been done to tackle those sources of emissions?
- At what extent have policies succeeded?
- What other policies could be implemented to abate pollution generated by these sectors?
- What obstacles are there for those policies to succeed?
- How can we overcome those obstacles?

Once we set the basis for the analysis of the commercial formal and informal sectors, through the review of the most important and relevant characteristics of the air pollution problem in the MCMA, the analysis of the commercial and informal sectors in Mexico, and the preliminary assessment of their baseline emissions, we then move to the specific emission models developed for these two sectors.

The emission models are in the form of a 3X4 matrix. On one axis we have the three future stories developed by the Mexico City Project Scenario Analysis Team, which were briefly described earlier, and on the other axis, the four reference cases that the team developed for the analysis of emissions. The four cases are: 1) The Base Case, which assumes the implementation of the measures in the MCMA Air Quality Program 1995-2000 (Proaire II), and the continuation of current trends in emissions; 2) The Ideal Case, in which we assume the implementation of all Proaire III measures in the sector, as described and with the deployment schedules indicated in the 2002-2010 Air Quality Program; 3) The MIT Case, in which we assess whether the Proaire III measures are realistic, and, if not, we make changes to their scope or deployment schedule; and 4) Alternative Policies, in which a new set of technically feasible options are assessed, and their emissions modeled.

The emission models are spreadsheets that link emissions of a series of pollutants to their driving factors, which may be population, inflation, economic growth, mix of formal and informal activity, urban sprawl, etc. The emission factors are initially the same ones used in the MCMA emissions inventory (described in chapter 5 and 6 of this thesis), although they are altered whenever we assume a change in technology. More detail on the assumptions of the model, and its actual results, are in chapter 6.

2.3 Tradeoff Analysis Framework

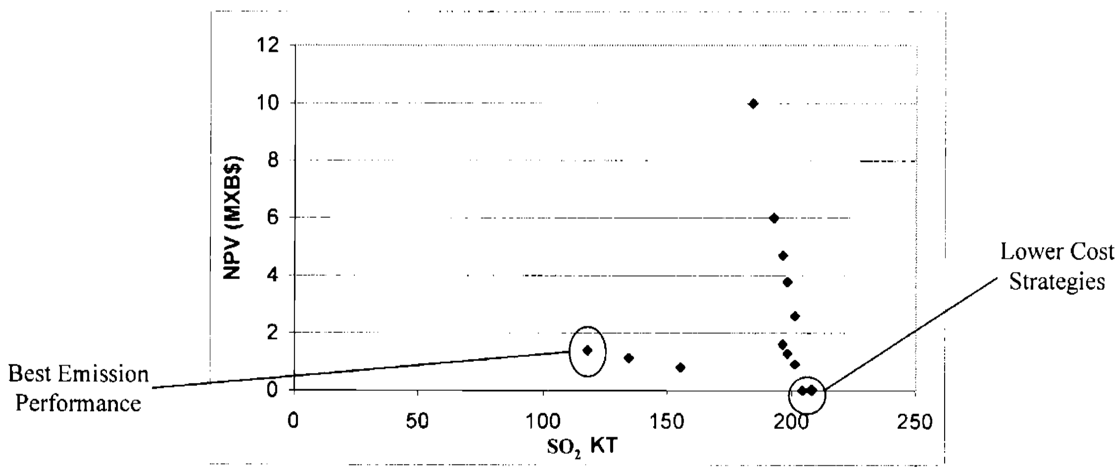
The tradeoff analysis is a specific tool used for the assessment of existing and proposed policy strategies. The fourth one of the reference cases listed above requires that proposed policies are assessed in terms of their emission abatement potential, but for really assessing whether they are feasible in reality, we should first know not only the impact they may have on emissions, but their costs as well.

The tradeoff analysis compares, in a two-dimensional way, costs and emissions, indicating, in a tradeoff plot, what are the most cost-effective strategies, which in the tradeoff plot are the points closer to the either one of the two axis (See example of a trade-off plot in Figure 2.2).

The most important components of the cost variable, in the case of the formal commercial sector policies assessed, are the costs of technology, fuel costs (including price differentials among fuel types, and distribution and installation costs), labor costs, and administrative costs (particularly for enforcement). In some cases, savings in the use of inputs are the result of a given policy, and they are also accounted as cost components accordingly.

In the case of informal activities, the most important components of the costs of new policies are, besides the ones already mentioned for the commercial formal activities, some of the social costs that are specific to this sector, and the administrative costs resulting from data gathering and analysis, and from enforcement, which may be significantly higher than for formal activities.

FIGURE 2.2
ILLUSTRATION OF A TRADEOFF PLOT



After the tradeoff analysis, what remains is to define and analyze the key sensitivities of the proposed policy measures that appear to be more attractive. Key sensitivities may refer to political feasibility, technical feasibility, or the availability of inputs in the times and places where they are required. They often refer to the assumptions made in the analysis. For the commercial sector, the key sensitivities refer to technology availability and deployment, fuel prices, energy availability, and effectiveness in enforcement. For informal activities, there are also key sensitivities for the implementation of new policies, deriving from a better understanding of the sector, the availability of inputs, access to technology, effective enforcement, and from social and political concerns, which may be crucial.

3. BACKGROUND

After having explored the basic ideas about the main methodological tools used in this thesis, this chapter presents a necessary step in the analysis of formal and informal commercial emissions in the MCMA, which is the analysis of the problem: air pollution, its causes, and its consequences. This chapter also serves the purpose of putting in context the analysis to follow in this thesis. In the first sections of the chapter, I present the general information that may help understand the complexity of the urban system of which we are analyzing but one component. I first give some information about the MCMA, and then move to its air pollution problem. After that, I analyze the institutional and legal issues that are relevant for this thesis, to then discuss the air quality policies that have been put in place, with particular attention to the air quality programs. To close this chapter, I include a section in which I describe, as part of the context of this analysis, the Mexico City Program.

3.1 Putting Mexico City in Context

Air pollution problems, of some sort or another, are present in practically all major urban areas and industrial clusters in Mexico (INE-SEMARNAP-CENICA-JICA, 1999). In most cases, they are the product of uncontrolled urban growth, with a consequent increase in human activity. Often, there are other contributing factors that aggravate air pollution, like the lack of access to technology, and the public sector's inability to enforce stricter regulations (INE, 2000). Figure 3.1 shows a map of Mexico, in which we can see some of the most important cities in the country. For several of them, there have been efforts in place to monitor air pollutant concentrations, followed by specific policies to control them or to minimize their consequences. In a few cases (7 cities), more comprehensive air quality programs have been put in place. These have tended to focus on a few cities in the Northern border, in some heavily industrialized urban areas in the center of the country, and in the three biggest metropolitan areas in Mexico: Guadalajara, Monterrey, and, of course, Mexico City.

Even though the problem of increasing emissions and consequently high concentrations of criteria pollutants is present in practically every major urban area in the country, it is particularly serious in the MCMA (INE-SEMARNAP-CENICA, 1997). The MCMA is the second most populated urban area in the world (SEMARNAT - GEM - GDF - SS, 2002), and for years has had what is considered one of the worst recorded air pollution problems of any city in the Western Hemisphere. The MCMA population has grown from less than 3 million in the middle of the 20th century, to 17.8 million in 2000 (See Table 3.1), and is projected to reach 20 million by the year 2010 (SEDESOL-INE, 1995).

FIGURE 3.1
MAP OF MEXICO

Source: CIA – The World Fact Book, 2002.

The MCMA extends over an area of roughly 4,925 km^2 (of which 1,547 km^2 are in the DF), located at the southern end of the Valley of Mexico, at an average altitude of 2,240 m. It has about one sixth of the national population, and roughly one third of its gross national product (OECD, 1998). It also consumes about 17% of domestic energy production (INEGI, 2003). From 1995 to 2000, the MCMA population grew at an annual rate of 1.4%, compared to the national annual population growth rate of 1.6% (INEGI, 2001). It seems that population is tending to stabilize in this metropolitan area, which has been losing residents in its core, as they have moved to the periphery, and as immigrants from rural areas have also settled down in the most sub-urban areas of the city (Molina and Molina, 2002).

The MCMA spreads over two political jurisdictions: the Federal District (DF), which is divided into 16 municipalities (called "delegaciones"), and the neighboring State of Mexico (SoM), of which, according to the Metropolitan Environmental Commission, 27 municipalities are currently part of the MCMA (See Figures 3.2 and 3.3). Presently, about half of the population of the MCMA lives in each jurisdiction, though this distribution is likely to change in a few years, with current population growth rates being significantly higher in the SoM than in the DF. The difference between the population growth rates of the two MCMA jurisdictions, although getting narrower, is still significant, with the DF losing relative weight. From 1990 to 2000, the MCMA's annual population growth rate was 1.7 % (See Table 3.1), but, during that same decade, the DF grew at an annual rate of 0.42%, and the metropolitan SoM at an annual rate of 3.14% (Molina and Molina, 2002). Between 1995 and 2000, six metropolitan municipalities in the SoM grew at a rate higher than 5% per year, with one of them growing at more than 11% (INEGI, 2001). In contrast, the 4 most central delegaciones in the DF lost population between 1990 and 2000 (Molina and Molina, 2002). The MCMA is becoming more suburbanized, and the central parts of the city have switched from residential to commercial activities.

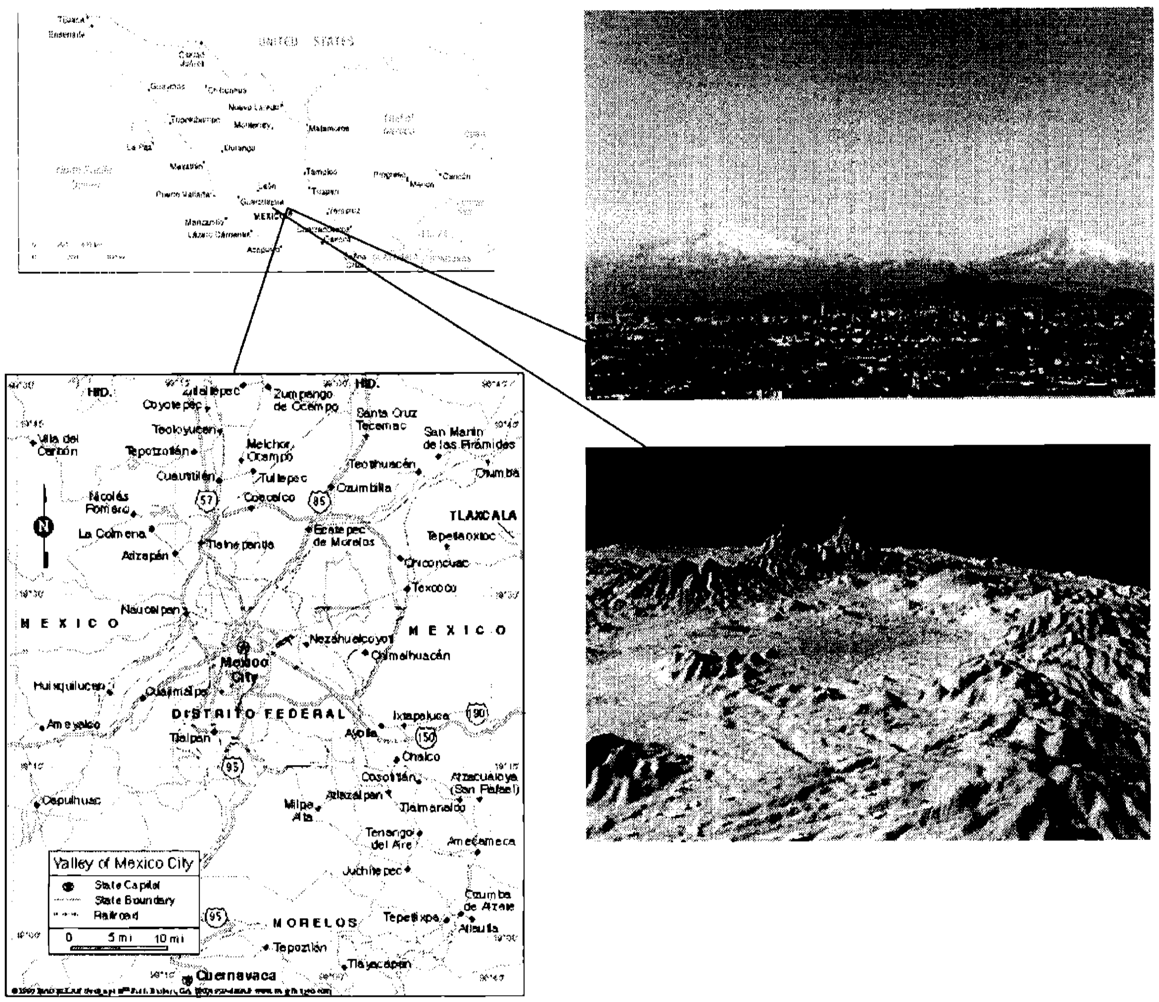
TABLE 3.1
POPULATION OF THE MCMA 1950-2000

Year	Population (thousands)	Annual Growth Rate (preceding decade)
1950	2,953	5.17
1960	5,125	5.64
1970	8,816	5.30
1980	12,333	4.73
1990	15,047	0.92
2000	17,787	1.73

Source: CAM, 2002; INEGI, 2001.

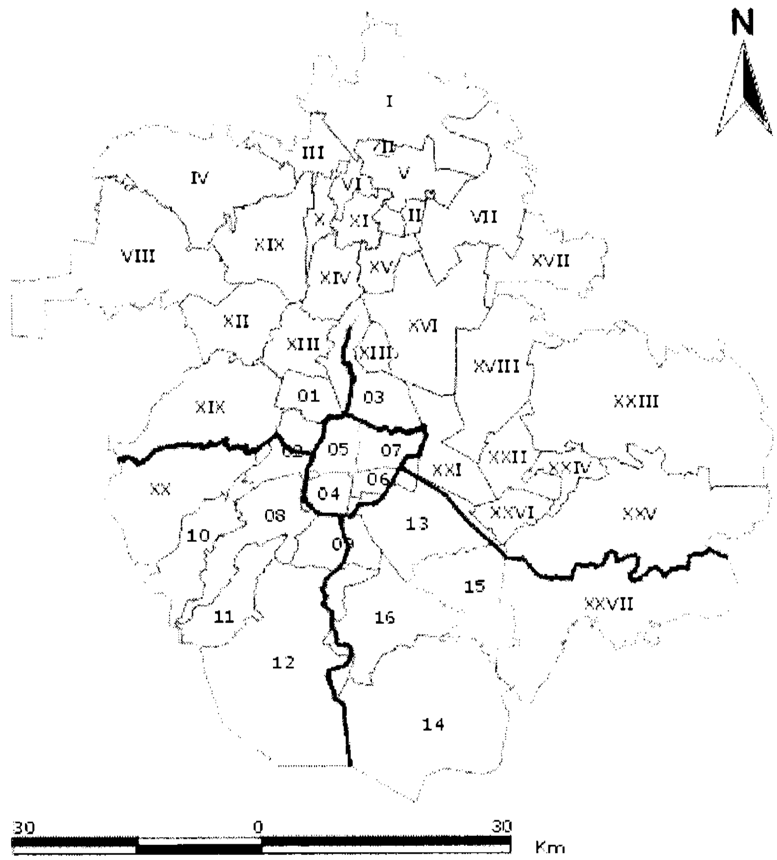
Having two state-level governments ruling over different portions of the MCMA means a shared responsibility over city affairs. Traditionally, this division of responsibilities for the MCMA affairs between the DF and the SoM governments, has made it difficult to create any joint projects on planning or infrastructure development. However, the establishment of a Metropolitan Transit Council and the creation of the Metropolitan Environmental Commission (CAM), which I will describe in more detail in a later section of this chapter, have improved integration between jurisdictions, and, although at a much lesser extent, between different sectors (CESPEDES-CANACINTRA, 1998).

FIGURE 3.2
THE MEXICO CITY METROPOLITAN AREA IN IMAGES



Source: CIA-The World Fact Book, 2002; INE-SEMARNAT, 2003; Mexicochannel.net, 2003.

FIGURE 3.3
POLITICAL DIVISION OF THE MCMA



Source: CAM, 2003
Note: The gross line indicates the division between air quality monitoring districts: Center, Northeast, Northwest, Southeast, and Southwest

TABLE 3.2
DF DELEGACIONES AND SoM MUNICIPALITIES IN THE MCMA

FEDERAL DISTRICT (DF)	STATE OF MEXICO (SoM)	
01 Azcapozalco	I Zumpango	XVII Acolman
02 Miguel Hidalgo	II Jaltenco	XVIII Atenco
03 Gustavo A. Madero	III Teoloyucan	XIX Naucalpan
04 Benito Juárez	IV Tepotzotlán	XX Huixquilucan
05 Cuauhtémoc	V Nextlalpan	XXI Nezahualcoyotl
06 Iztacalco	VI Melchor Ocampo	XXII Chimalhuacan
07 Venustiano Carranza	VII Tecamac	XXIII Texcoco
08 Alvaro Obregón	VIII Nicolas Romero	XXIV Chicoloapan
09Coyoacan	IX Cuautitl1án Izcalli	XXV Ixtapaluca
10 Cuajimalpa	X Cuautitlán	XXVI La Paz
11 Magdalena Contreras	XI Tultepec	XXVII Chalco
12 Tlalpan	XII Atizapan de Zaragoza	
13 Iztapalapa	XIII Tlalnepantla	
14 Milpa Alta	XIV Tultitlan	
15 Tláhuac	XV Coacalco	
16 Xochimilco	XVI Ecatepec	

In practical terms, the separation of two clearly defined and in many ways independent political entities, one a federal state, the other, the federal capital of the country, has created a border within the city, often perceptible at simple sight. I think this is explainable, at a great extent, because of the marked difference in resource distribution among these two entities. The DF, though slightly less populated than the metropolitan municipalities in the SoM, got, in 2000, more than 7 times the amount of federal funds that these municipalities received (GDF-INEGI-GEM, 2002).

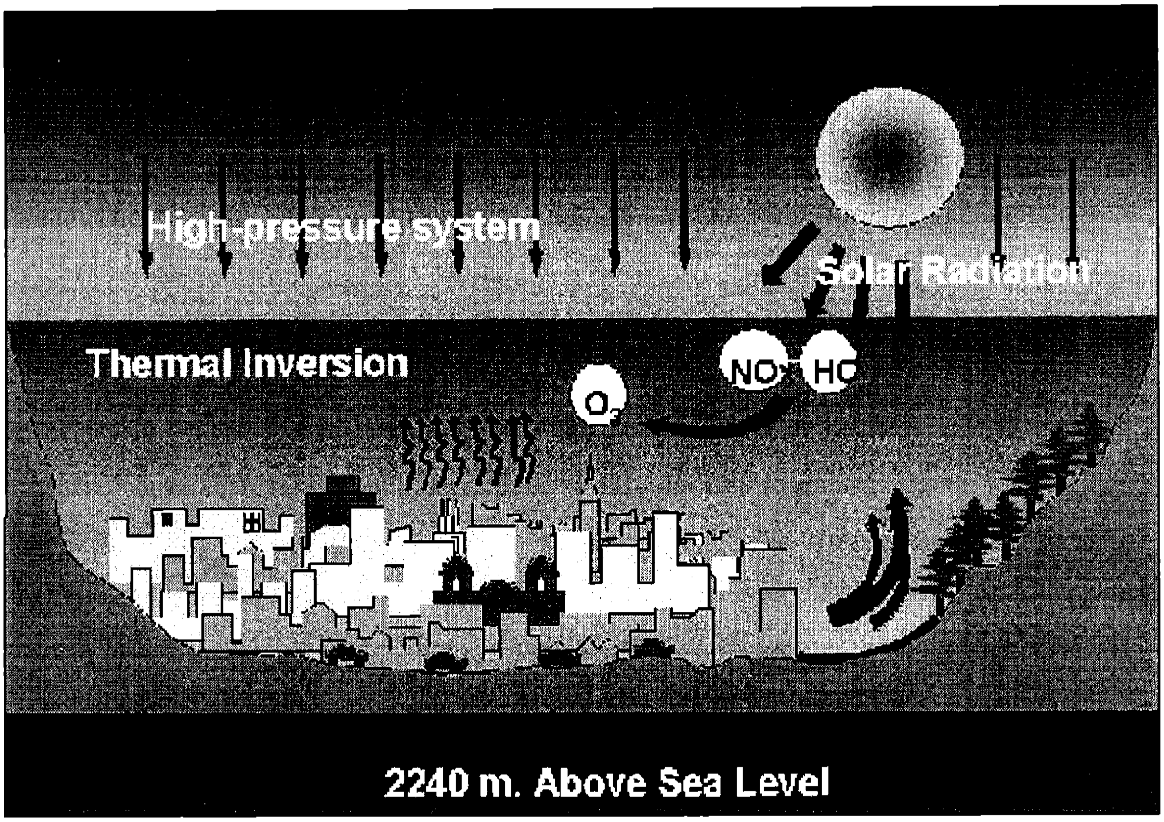
Even when there have been attempts to put in place some homogeneous policies in several sectors (clearly it is the case in regard to the environment, as I will discuss in a later section), the division of responsibilities among bodies with so different capacities as the SoM and the DF have, make it difficult in reality to implement and enforce policies evenly throughout the MCMA. If we go to a smaller level of government, which is that of delegaciones and municipalities, differences are even greater.

3.2 Air Pollution in the MCMA

The air pollutants of greatest concern in the MCMA are ozone (O_3) and fine particulate matter, followed by carbon monoxide (CO) and, at a less extent, lead. Due to sharp cuts in the lead content of gasoline since 1991, ambient lead levels have been greatly reduced, and are now only rarely in excess of concentration limits. Toxic and carcinogenic air contaminants such as benzene and formaldehyde are also of concern, but there is still not enough quantitative information about their concentrations.

The effects of air pollution in the MCMA are aggravated by geography, since the mountains surrounding the city tend to trap pollutants, with resulting higher concentrations. The valley in which Mexico City rests is also subject to thermal inversions, especially during winter (See Figure 3.4).

FIGURE 3.4
PHYSICAL AND METEOROLOGICAL CONDITIONS IN THE MCMA



Source: Instituto Nacional de Ecología, SEMARNAT, 2003.

Ozone is a secondary pollutant, generated in the atmosphere from the transformation of nitrogen oxides (NOx) and non-methane hydrocarbons (NMHC), together with other substances, and in the presence of solar radiation and particular meteorological conditions (See Figure 3.4). To abate concentrations of ozone in the lower atmosphere, which are the cause of respiratory diseases, other health problems, and damage to material structures, among other impacts, we should reduce emissions of the two primary pollutants that cause ozone formation. As I mentioned already, they are NOx and NMHC, two pollutants that besides their reactivity potential (to form secondary pollutants), are also directly harmful to human health. The reduction of their concentrations is, for both reasons, desirable. NOx emissions come mainly from mobile sources (See Table 3.3, Table 3.4, and Figure 3.5).

If we look at the specific sources of NOx emissions, we can see that the main generators are private automobiles. NMHC also come from mobile sources (See Table 3.3), though the single most important source of emissions is the use of solvents in industry, the commercial sector, and households (CAM, 2001b).

In the case of particles, presently only particulate matter higher than 10 micrometers in diameter (PM_{10}) is monitored in the MCMA. The main source of this pollutant is soil erosion and dust stirred by vehicles circulating in unpaved roads (CAM, 2001b). If we consider particulate matter of 2.5 micrometers in diameter or less ($PM_{2.5}$), which is a much smaller fraction, generated mainly by combustion, we would probably have freight as a major source, basically because of the bad state of the truck fleet in the MCMA and the poor quality of the fuels they use (MIT, 2000). There is still some uncertainty about the health effects of both, but they are believed to be the cause of increased mortality and respiratory disease (Molina and Molina, 2002).

Major sources of pollutant emissions in the MCMA are road transport, industry, commercial and service sector activities, waste disposal, and natural sources (INE-SEMARNAP-CENICA-JICA, 1998). Road transport is the most important single source, accounting for more than 75% of the total mass of pollutant emission. Together with non-road transport, it adds up to about 80% of emissions. Entrained dust stirred up by vehicles accounts for roughly another 5% of total emissions. These add up to a contribution of almost 85% of the total mass of emissions, done by mobile sources (See Table 3.3).

The high level of transport emissions is mainly attributed to the large number (more than 3 million) of road vehicles in use, rapid urbanization (resulting in increased demand for road transport), and traffic congestion, among other less important causes (OECD, 1998). The total number of vehicles in the MCMA has grown at a much higher rate than the population (DDF-GEM-SEMARNAP-SS, 1996). This implies an accelerated process of growth in the density of vehicles, with a negative impact on air quality. In 1940, there was one vehicle per 49 inhabitants in Mexico City. Today, there is roughly one vehicle per 6 inhabitants. This change has provoked a tremendous increase in the consumption of fuels, traffic congestion, higher demand for parking spaces, and more air pollution (CESPEDES-CANACINTRA, 1998).

TABLE 3.3
EMISSIONS IN THE MEXICO CITY METROPOLITAN AREA - 1998
(TONNES/YEAR)

SECTOR	TONNES/YEAR						
	PM_{10}	SO_2	CO	NOx	NMHC	TOTAL	%
Point Sources	3,093	12,442	9,213	26,988	23,980	72,623	2.94
Area Sources	1,678	5,354	25,960	9,866	247,599	288,779	11.68
Soils and Vegetation	7,985	N/A	N/A	3,193	15,669	18,862	0.76
Mobile Sources	7,133	4,670	1,733,663	165,838	187,773	2,091,944	84.62
Total	**19,889**	**22,466**	**1,768,836**	**205,885**	**475,021**	**2,472,208**	**100**

Source: CAM, 2001b.
N/A: Not applicable

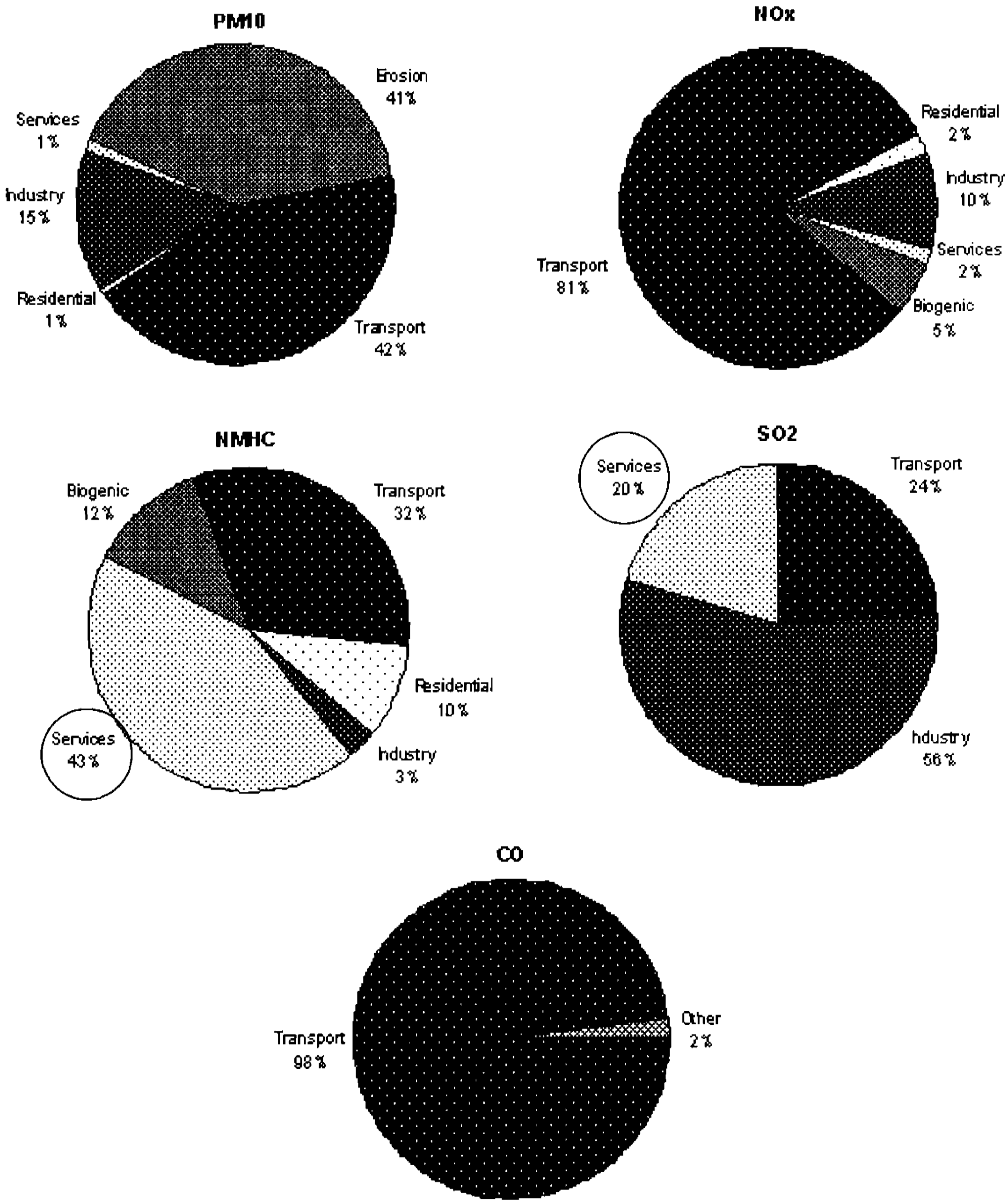
TABLE 3.4
EMISSIONS IN THE MEXICO CITY METROPOLITAN AREA - 1998
(PERCENTAGES)

SECTOR	PERCENTAGE				
	PM_{10}	SO_2	CO	NOx	NMHC
Point Sources	15.55	55.38	0.52	13.11	5.05
Area Sources	8.44	23.83	1.47	4.79	52.12
Soils and Vegetation	40.15	N/A	N/A	1.55	3.30
Mobile Sources	35.86	20.79	98.01	80.55	39.53
Total	100	100	100	100	100

Source: CAM, 2001b.
N/A: Not applicable

Non-transportation sources of criteria pollutant emissions are mainly due to combustion processes in industry, commerce and households, and to the use of solvents for diverse purposes in the commercial and residential sectors (CAM, 2001b).

FIGURE 3. 5
RELATIVE CONTRIBUTION TO CRITERIA POLLUTANTS BY EMISSION SOURCE - 1998



Source: CAM, 2001b.

To measure pollution in a way that may be transmitted more easily to the public, the authorities in charge of atmospheric monitoring "translate" the emissions of several criteria pollutants into an index that converts them into a more easily readable scale, which relates pollution levels with human health (See Table 3.5 and Table 3.6). This index is called Metropolitan Index on Air Quality, or IMECA, by its initials in Spanish.

TABLE 3.5
WHAT THE IMECA INDEX MEANS IN TERMS OF AIR QUALITY AND HEALTH EFFECTS

IMECA Level	Air Quality	Health Effects
0 - 100	Satisfactory	Favorable conditions for developing all sorts of physical activities.
101 - 200	Not Satisfactory	Minor effects, felt mainly among sensitive individuals.
201 - 300	Bad	Increased effects, particularly among people with respiratory conditions.
301 - 500	Very Bad	Symptoms felt among healthy people. Less resistance to exercise.

Source: SEDESOL-INE, 1995

TABLE 3.6
IMECA INDICATORS FOR OZONE AND PM_{10}

IMECA Level	100	200	300
PM_{10} $\mu g/m^3$ (daily average)	150	350	420
Ozone parts per million (daily 1-hr maximum)	0.110	0.232	0.355

Source: DDF, GEM, SEMARNAP, SS (1996)

Some improvements in air quality have been recorded in recent years, being particularly significant in the reduction of ambient concentrations of lead, and also in reductions in ozone peak concentrations, although not in days of standard non-compliance (INE, 2000; CAM, 2001a; Molina and Molina, 2002) (See Table 3.7). These improvements are in good part the result of improved fuel composition, fuel switching and stack controls in industry, and new vehicle technologies, in part promoted by environmental policy makers. The air pollution problem is slowly ceding, but there is still a long way to go to declare it solved.

Local air quality still poses significant risks to human health. Air pollution in major urban areas has been correlated to increased incidence of respiratory disease (Margulis, 1992; MIT, 2000; Molina and Molina, 2002). Peak ozone concentrations in Mexico City, though generally flatter nowadays, are still among the highest of any city in the world, being more than three times the accepted national and international standards (INE-SEMARNAP-CENICA-JICA, 1999).

TABLE 3.7
DAYS EXCEEDING THRESHOLD IMECA LEVELS PER YEAR 1988-2002

Year	Number of Days with IMECA...		
	> = 100	> = 200	> = 300
1988	330	69	1
1989	332	15	0
1990	341	94	4
1991	351	162	7
1992	335	125	12
1993	324	85	1
1994	346	101	0
1995	325	94	0
1996	333	71	0
1997	337	55	0
1998	320	58	0
1999	300	30	0
2000	323	19	0
2001	273	6	0
2002(1)	242	6	0

Source: CESPEDES-CANACINTRA, 1998; GDF-INEGI-GEM, 2002; INE, web-page.
(1) Data shown is for the violations to ozone IMECA in the Pedregal monitoring station, where the highest ozone levels are recorded in MCMA.

3.3 Institutions and Laws

As I mentioned earlier, both the federal government and the local governments of DF and the SoM have jurisdiction over MCMA affairs. Together, they have formed an environmental coordination body, that I alluded to earlier on, which is called the Metropolitan Environmental Commission (CAM). This Commission was put in place in 1996, with the general objective of "systematically and periodically defining, coordinating, and following-up the policies, programs, projects and actions related to environmental protection and ecological preservation and restoration in the DF and the metropolitan area territory" (SMA-GDF, web-page). Permanent members of CAM are the Federal Minister of Environment and Natural Resources, the Head of the DF Government, and the Governor of the SoM. CAM's technical secretariat is in charge of the actual design and execution of the work-program of the Commission. CAM also has an advisory board, of which several representatives of industry, academia, the society, and the federal and local congresses are members. Within CAM, there are several working groups, and the most active of them, by far, is the Air Quality Group. CAM is responsible for designing and publishing the MCMA Air Quality Program.

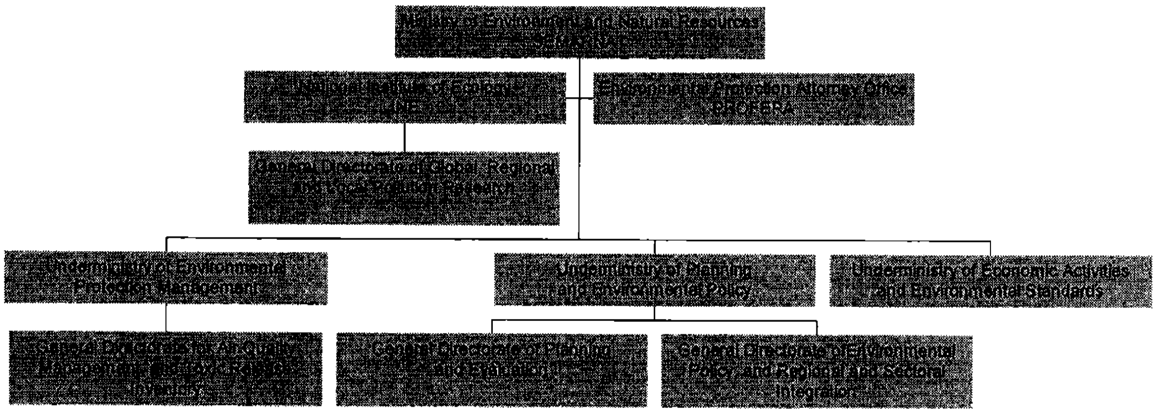
In reality, CAM has no legal status within the public administration structure, no physical location, and no budget. Although CAM is in charge of designing the air quality management plan for the MCMA, it has very little control over policy implementation, so it tends to collect in this program the particular policies that each relevant sector and level of government is set to put in place anyway, provided that they have some environmental benefit. Even with all its shortcomings, CAM has shown several positive results, at least by favoring a more technical discussion of issues among parties whose political dissimilarities would otherwise not allow them to interact in a collaborative way.

Environmental policy making and implementation remain in most part divided among the relevant federal and local public organizations. At the federal level, environmental concerns, though part of the public interest since the early 1970s, did not translate into high-level offices until the mid-1980's, when an Under-Ministry of Ecology was created within the Ministry of Urban Development and Ecology (SEDUE). This office suffered a few changes throughout the following years, the most important at the beginning of the 1990s, when it was divided it into two offices, one in charge of policy, called the National Institute of Ecology (INE), and the other in charge of enforcement, called the Environmental Protection Attorney Office (PROFEPA), both within the new Ministry of Social Development (SEDESOL), which replaced SEDUE.

Later on, in December 1994, the Federal Congress approved the creation of the Ministry of Environment, Natural Resources and Fisheries (SEMARNAP), concentrating most of the offices in charge of environmental affairs within the Federal Government, including INE and PROFEPA. The structure of the Ministry brought together the policies, programs, and administrative resources for forests and fisheries, soil conservation and restoration, environmental management of federal laws, and environmental policy (SEMARNAP, 1997). This Ministry suffered some changes at the beginning of the current federal administration, and on December 2000, it lost its "Fisheries" part, and became the Ministry of Environment and Natural Resources (SEMARNAT), and INE was transformed into the research arm of the ministry, and stopped being a policy-making organization (See Figure 3.6). Within SEMARNAT, there are now several offices with responsibility over MCMA air quality affairs. INE does the research, but now it is the General Directorate for Air Quality Management and Toxic Release Inventory the one in charge of representing the Ministry in the Technical Secretariat of CAM, and also the one in charge of standard setting and most federal air quality policy design. PROFEPA is still in charge of enforcement, and a few other offices within SEMARNAT have some say when it comes to air quality policies that affect their sphere of responsibility.

According to the dictates of the public administration regulations, environmental offices must ideally work in combination with other agencies within the government in the making and execution of policies, in a multi-sector task. They have also the responsibility of taking into consideration other members of the society, who traditionally play an important role in the implementation of environmental policies.

FIGURE 3.6
OFFICES DEALING WITH AIR QUALITY WITHIN THE FEDERAL MINISTRY OF ENVIRONMENT AND NATURAL RESOURCES



In reality, there are many reasons why this collaboration among agencies is not fully implemented. In some cases, institutional changes may be needed, in addition to specific policies. The case is that, even with the concentration, within SEMARNAT, of formerly disseminated offices, the need persists to create strong and permanent connections with other areas within the government, as well as with the private and social sectors, whose intervention is often necessary for the implementation of environmental policies.

There are also several other ministries at the federal level in the country that have some interests or responsibilities regarding the environment. The question is how much these separate entities work together for designing and implementing environmental policies in general, or air quality policies in particular. In reality the level of inter-institutional co-operation varies a lot. It sometimes depends on finding common ground for action as well as a common interest to design integrated solutions.

There are, nevertheless, working groups, commissions and councils that bring together representatives from different ministries and different levels of government, in pursuit of common objectives, or in circumstances in which responsibilities are not clearly defined by the law, or when they may fall in the sphere of competence of different entities. For the case of air pollution control policy in the MCMA, for instance, there is CAM, in charge of designing strategies for pollution control and environmental improvement. In fact, the commission has managed to put together a more or less comprehensive program for abating pollution, which has been renewed two times already, coinciding with the change of federal administration. Transferring the program into actions has been, nevertheless, done in most cases by some sort of division of tasks, and not necessarily via integrated efforts.

Despite the efforts to develop the metropolitan level of government, local environmental authorities still carry a lot of the responsibilities related to air quality policy design and implementation in the MCMA. The Secretariat of the Environment of DF, and the Secretariat of Ecology of the SoM, which are both representatives of their governments in the Technical Secretariat of CAM, carry, on their own, several air quality policy implementation and enforcement tasks within their respective jurisdictions. Among them, air quality monitoring, and vehicle inspection and maintenance. Recently, the Secretariat of Environment of DF got also in charge of managing transportation infrastructure development projects of great impact and visibility in the MCMA. The justification that the DF government gave for that, was the supposed environmental benefits of these projects, particularly those that have to do with the development of the road network, even when several environmentalists and academics did not agree with this idea.

In general, environmental regulations in Mexico rest largely on environmental impact assessment, land use planning, and environmental standards. The Mexican environmental law (called General Law for Ecological Balance and Environmental Protection), which took effect in March 1988, and was substantially amended in 1996, is the most important environmental statute in the country. It regulates matters concerning the protection and restoration of ecological balance, as well as the protection of the environment (SEMARNAP, 1997). The environmental legislation in Mexico stipulates that any measure considered "ideal" to prevent and control pollution and to assure the more efficient use of natural resources must be executed.

Several regulations derive from the General Law for Ecological Balance and Environmental Protection, being among them one for prevention and control of atmospheric pollution, which establishes dispositions for stationary and mobile sources of atmospheric emissions.

Besides the federal one, state governments have enacted their own environmental legislations. The Federal Constitution sets the basis for the separation of powers between the Federal Government and the states. It also provides the foundation on which federal and state governments enact, implement and enforce environmental protection laws. In 1987, the Constitution was reformed to give the states power to implement actions to conserve and restore the "ecological balance", even in private properties (SEDESOL - INE, 1995).

According to the law, implementation of the policies to attain air quality management objectives falls both on the federal and local governments. The General Law for Ecological Balance and Environmental Protection, points out that the states and municipalities, according to the attributions marked by local laws, should take responsibility for the prevention and control of atmospheric pollution.

A good proportion of air quality policies in Mexico have relied on standard setting. Presently, Mexico has 55 standards related to atmospheric pollution. Among them, there are 22 Mexican Official Standards (legally enforceable), for matters such as monitoring, stationary and mobile sources emissions, and atmospheric concentrations of pollutants (INE, web page). The maximum levels set in each standard are those below which there is no hazard to human health, animals, plants, the cultural heritage and material goods. They are intended to avoid any possible contamination of other media (water or soil) as a consequence of air pollution. Standards mark the threshold above which control measures are necessary.

The assignment of responsibilities across different levels of government dictated by the law, has important implications for the implementation of environmental technologies and policies in the MCMA. These responsibilities include choosing policy targets, controlling instruments, and developing and implementing strategies for air quality monitoring and regulation enforcement (PEF, 1996).

3.4 Politics

In general, Mexico has a progressive approach regarding the assignment of environmental responsibilities. The law and the institutions are designed to allow co-operation between governmental and non-governmental entities, and responsibilities are divided among different institutions and different levels of government. In reality, nevertheless, there are some co-ordination problems and lack of a clear definition about the roles of different institutions. The difficulty in integrating policies in Mexico seems to derive from the fact that each public organism defines its own lines of action, that in most cases address only the necessities of the sector they work for.

Institutional and legal changes may be needed in order to promote a real integration of policies. Conditions must be created to motivate co-operation between public institutions. Specific actions that need to be taken include the decentralization of environmental planning, the creation of technical autonomous organisms, the promotion of effective enforcement and control systems, and the encouragement of multi-sector and multi-disciplinary participation. Attention must be given to create effective information channels, and to promote the participation of all sectors of society.

Co-ordination is an important step to reach integrated policy design and implementation. In Mexico, this principle of co-ordination is stressed in the legislation, but implementation falls short. Co-ordination agreements can be entered between the Federal Authority, the states, and municipalities. State laws include rules establishing forms of co-ordination and exchange of information between state and municipal authorities (SEDESOL-INE, 1995). The General Law for Ecological Balance and Environmental Protection, for instance, assigns an important role to what is called the National Ecology Commission, as a permanent body for inter-ministerial co-ordination and to promote collaboration between public authorities and society (SEMARNAP, 1997). In reality, again, co-ordination efforts seem to be more the product of individual initiatives, and not the consequence of a policy principle or a systematic practice.

At the local level, co-ordination between the various agencies often takes place in an informal fashion. I think that, although informal co-operation should be encouraged, formal mechanisms are also needed to avoid inaction or duplication, and to facilitate integration.

Not long ago, practically all levels of government with jurisdiction over MCMA affairs were occupied by members of the former official party, the Revolutionary Institutional Party (PRI), which ruled the country for 71 years. In consequence, there was not much debate over policy strategies. With democratization, public management in the city got a little bit more complicated. Since 1998, there is an elected major of the Federal District. So far, the two that have been elected there came from the leftist Party of the Democratic Revolution (PRD). Since 2001, local authorities are also democratically elected within the DF's 16 delegaciones. Presently, 11 delegaciones are ruled by PRD, and the rest by the right-wing Party of National Action (PAN). The SoM governor is and has always been from PRI, although the majors of the richest, more industrialized, and middle-class SoM municipalities in the northern areas of the MCMA are from PAN, and the ones in the poorer, mostly residential SoM municipalities at the East of the MCMA are from the leftist PRD, with a few in that poorer areas also from PRI, though mainly in the more rural municipalities. The federal government, which also has some jurisdiction over MCMA affairs, is currently from PAN.

All this explanation about politics in the MCMA is relevant, I think, because politics plays a fundamental role in public policy in Mexico, and particularly in environmental management in the MCMA. Matters related to the environment in the MCMA are pretty visible nationally, and since the three major political parties in the country have jurisdiction over those matters, they tend to "politicize" discussions, trying to gain political power by defending their views, and often by fiercely opposing the other's. It is clear that the major of the DF, and often also the governor of the SoM, are at any given time feasible candidates for the presidency of the country, given the power and visibility that those positions give them within their political parties and in the public opinion.

Institutions dealing with environmental problems suffer the effects of the political battles, and, for that and several other reasons, seem to be limited in their capacity for responding to the needs of the society. They sometimes get entangled in the search and interpretation of "scientific" evidence that supports the political views of their heads, and tend to give too much weight to the interests of the stakeholders they favor or want to "seduce", in most cases, of course, for political reasons and party interests.

3.5 Air Quality Policy

It is extremely difficult to predict how political decisions may influence the success of proposed environmental policies in Mexico. It depends very much on a series of conditions that may not even be evident to policy-designers. For instance, it is known that taxes, in general, but particularly in times of elections, are not very popular among politicians. Any measure that affects influential groups or sectors of the society is at risk of not being implemented at all. It is important for policy designers to be sensitive when working on any proposal that goes beyond the acceptable for a certain interest group. "Political feasibility" is a very important condition to consider when evaluating policies (OECD, 1991), and this may be particularly true in Mexico, where democracy is still developing.

It is worth noting that political pressure can also work in a positive way. The effort that NGOs put in "persuading" the government to take action in a certain direction is a clear example. Sometimes political pressure derives from international obligations. In Mexico there are several examples of this. The signing of the North American Free Trade Agreement (NAFTA), for instance, implied for Mexico a commitment to improve its environment via certain specific policies.

It is to be noted that there is, especially among industrialists, the perception that policies are not always focusing on the real cause of the problems (CESPEDES-CANACINTRA, 1998). In the MCMA, many of the policies implemented have responded to the urgency of putting some remedy to a problem, atmospheric pollution, which grew almost out of control. Measures like prohibiting circulation of vehicles one day per week (whose ineffectiveness in the long term became evident as people bought second cars, often older and more polluting than the first one), or restricting economic and even social activities when high levels of pollution are detected, only contribute to reduce the effects of the problem, but do not tackle its causes.

Industry also complains about how little response they get from the government when they comply with regulations. They perceive that the industrial sector is really making an effort to improve environmental quality, whereas other sectors, like agriculture, or car drivers in the case of most major urban areas, not to mention the informal sector, have done so little, and are not as regulated as they are (CESPEDES-CANACINTRA, 1998).

Politics has some influence over the fact that integrated efforts among different sectors of the government and the society are so few. These efforts may be important, because they can open channels of communication and make future co-operation possible, but remain, as I mentioned earlier, the product of someone's initiative, and not of a systematic pursuit.

The division of administrative responsibilities between the DF and the neighboring municipalities in the SoM, all of which form the MCMA, and the political implications of this division, make it also sometimes difficult to agree on integrated solutions. The electric transportation (Metro) system, for instance, is almost exclusive to the DF, and despite several efforts to extend it beyond, to the suburban areas where roughly half of the city's population live, agreements between the competent authorities have been very limited. Consequently, the Metro system is underused. In the case of buses, the situation is similar. Concessions are given either by the DF Government, or by the SoM, and in no case can a bus route cross the line between them.

With all, CAM still manages to design policy. As I mentioned earlier, they put together a comprehensive air quality management program for MCMA. The current one is actually the third, and this time it came with the intention to go beyond the end of the current federal administration, to mark a change from the previous programs, which had a six-year span.

3.6 Proaire III

The new Program for Improving Air Quality in the Mexico City Valley Metropolitan Zone 2002-2010 (Proaire III), proposes 89 measures to improve air quality, grouped in the following categories: 38 for transportation, 7 for industry, 9 for services, 15 for natural resource conservation, 8 for health protection, 4 for environmental education, and 8 for institutional strengthening (SEMARNAT-GEM-GDF-SS, 2002). Some of these measures are very specific, very concrete, and of easier implementation, while numerous others are very vague, expressing more what I believe is an intention than a real idea of how to put it into practice. Some measures could be actually categorized as policies, but others refer more to favoring certain policy instruments, even though they are listed under the same category of "actions" in the Proaire III. I will go back to analyze the Proaire III in more detail, particularly in the sectors that are relevant for this thesis, in the following chapters.

There are also several policies that transcend whatever is included in the Proaires (current and previous). A very visible policy that has outlasted air quality programs and the administrations that put it in place, for instance, is the "Hoy No Circula", or one day without a car program, that I briefly mentioned earlier. There is also continuous monitoring of air quality in the MCMA, giving especial attention to ozone and PM_{10} levels. In cases when pollutants reach unacceptable levels, to give another example, a contingency plan goes into action, banning, on its first phase, some industrial activity, and forcing cars to be kept out of circulation for an additional day per week. When concentrations of pollutants are very high, the second phase of the plan is put into action, closing schools, public offices and more industries. The contingency plan is an effective mechanism for responding to emergency situations, although it is arguable whether it solves the pollution problem of MCMA at all (CESPEDES, CANACINTRA, 1998). Vehicle and industry inspection is another one of those almost permanent policies in place in MCMA.

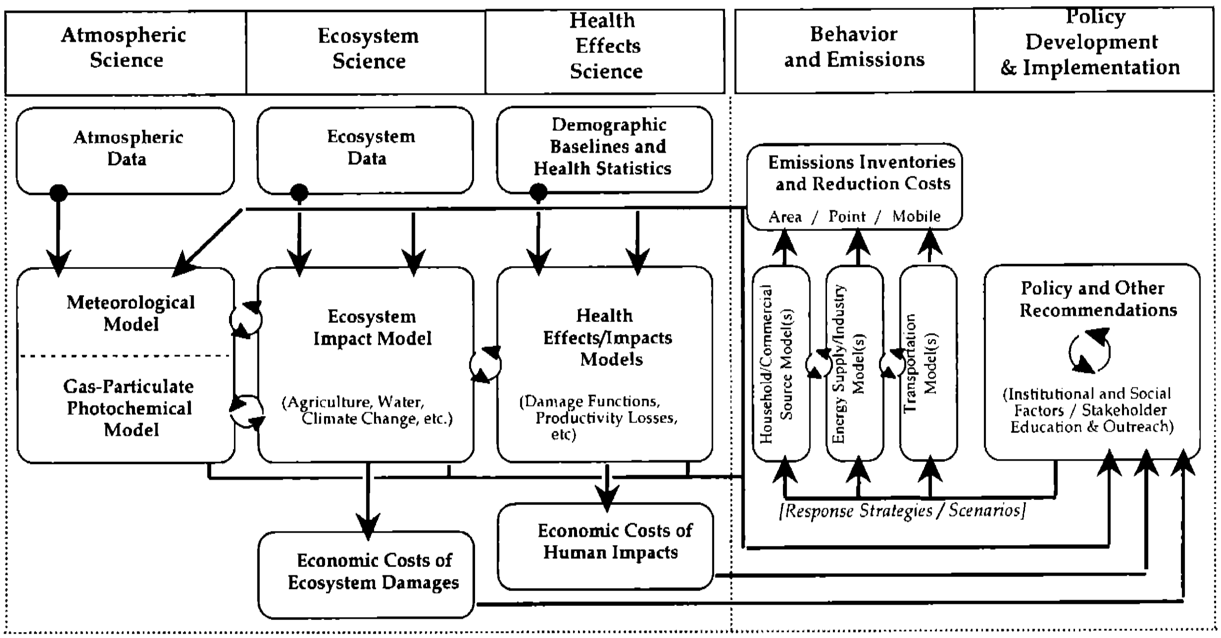
In my opinion, the analysis of the factors contributing to air pollutant emissions in the MCMA that supports policy making, has failed, in general, to look at the overall picture, and policies, consequently, have only tackled the most obvious contributors to air pollution, which are vehicles and industry. I will further refer to this topic later on. This idea is very relevant for this thesis.

3.7 The MIT Mexico City Program

To improve air quality management, CAM, and its members separately, have looked for the collaboration of external advisors, especially among academia. In recent years, they have received several inputs from the Massachusetts Institute of Technology's Integrated Program on Urban, Regional and Global Air Pollution: Mexico City Case Study (known as The Mexico City Program). The Mexico City Program brings together experts from several fields and several institutions mainly from the U.S. and Mexico, to study the many sides of the atmospheric pollution problem of the MCMA: from the causes of emissions, to the chemistry of pollutants in the atmosphere, to the impacts on human health; from technology assessment, to policy implementation (See Figure 3.7).

The Integrated Program on Urban, Regional and Global Air Pollution proposes to follow the framework shown in broad terms in Figure 3.7, to perform an integrated assessment of air pollution, in which all scientific, technological, political, institutional and administrative aspects of the issue are analyze, not only separately, but also in their relationships (CAM, 2000). This framework has been put in place to analyze the MCMA case, which serves not only for the purposes of designing and promoting air quality policies with a very good analytic basis, but also to test a methodology that could be put in place in other urban areas.

FIGURE 3. 7
MIT INTEGRATED ASSESSMENT FRAMEWORK



Source: MIT – Integrated Program on Urban, Regional and Global Air Pollution, 2000.

An important part of this integrated assessment is the analysis of emission sources, both to improve the understanding of the causes of pollution, but also, most importantly, to support the design of policies to tackle them. As explained in Chapter 2 of this thesis, the team in charge of analyzing the "behavior and emissions" component of the integrated assessment, followed a scenario analysis methodology, combined with a trade-off analysis, to design and propose robust and cost-effective strategies for each specific sector. The analysis that I present in this thesis fits in that part of the overall picture, and its main result will be in the form of policy proposals to tackle commercial and informal sources of emissions in the MCMA.

The collaboration between MIT and the MCMA authorities, has resulted already in several recommendations that have influenced policies in the new Proaire III (SEMARNAT-GEM-GDF-SS, 2002). Among them, the improvement of emissions inventories, the assessment of personal exposure to pollution, the renewal of the vehicle fleet, and the improvement of fuels, which are all measures in the Proaire III, that were analyzed and supported by the Mexico City Program. Most recently, the monitoring of $PM_{2.5}$, which had been also proposed by the Mexico City Program, started in the MCMA, In general, the Program also receives a lot of public and media attention in Mexico, and has established very strong links with environmental decision makers there, so it is likely that its future outcomes will continue supporting policy making in the MCMA and the whole of the country.

4. THE FORMAL AND INFORMAL COMMERCIAL SECTORS IN THE MCMA

The distinction between formal and informal commercial emission sources has many reasons. Access to technology, energy intensity, pollution intensity, and several other characteristics of the sources of emissions in each category are very different. More importantly, information availability is also unequal among these two sectors. Even though commercial emissions are not fully analyzed for the purposes of assessing emissions and designing air quality policies in MCMA, at least they are considered, but the fact is that informal emissions are mostly unaccounted, and specific policies to tackle them are practically nonexistent. More so, implementation of policies would probably require a far greater effort for the informal sector, which by nature tends to avoid public regulations, and this makes a difference for policy design that should be acknowledged by decision makers.

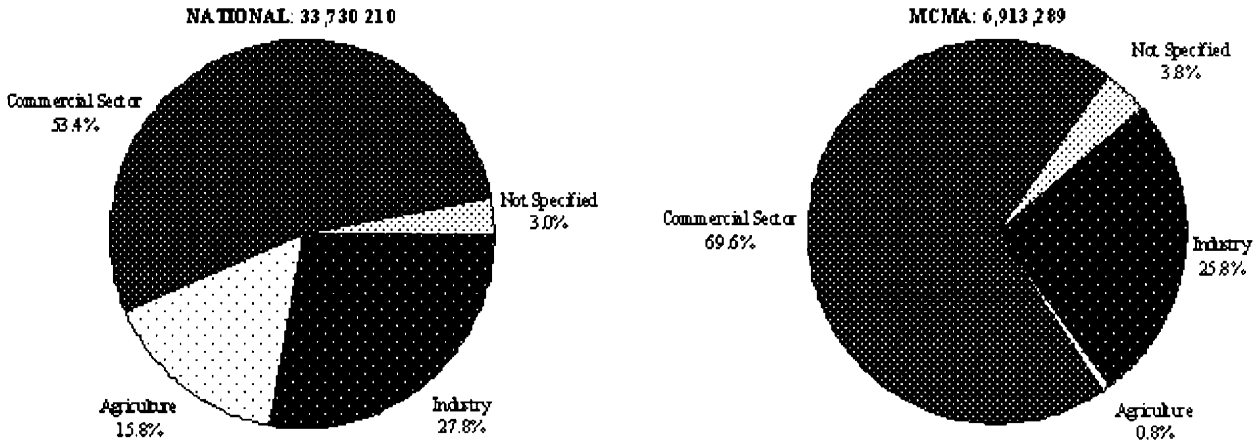
In this chapter, I present a brief discussion about the commercial and informal sectors of the economy in MCMA. The discussion is necessarily larger for the informal sector, paradoxically, because less is known about it, so it is more relevant for the analysis to follow to try to set the basis for better understanding this sector.

4.1 The Commercial Sector

The commercial sector, also known as the tertiary sector in economic analysis, contributes with nearly 53% of the total employment in Mexico, and almost 70% in the MCMA (See Figure 4.1). This difference is due, in part, to the fact that there is relatively less agricultural activity in the MCMA than in the country as a whole, and also to the fact that the MCMA has the highest concentration of government offices in the country, and a relatively high concentration of administrative offices and headquarters of the largest companies in the country. Coming from a tradition of high centralization, Mexico City still provides several services to the whole country, both in the private and public sectors.

It is true that, in general, urban areas tend to have relatively higher participation of the tertiary sector in their economies, but in the case of the MCMA, it is more the case, considering also the de-industrialization policies that have been put in place in recent years, for reasons that include, in a preeminent position, the environmental ones.

FIGURE 4.1
OCCUPATION BY ECONOMIC SECTOR IN MEXICO AND THE MCMA - 2000
PERCENT DISTRIBUTION

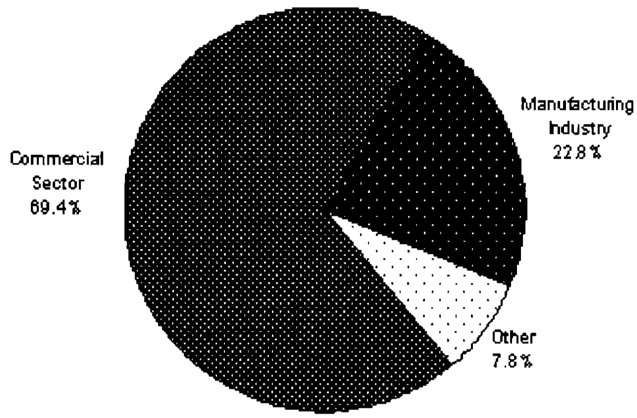


Source: INEGI, 2001.
Note: Data as of February 14, 2000.

Looking at the value added per activity sector in the MCMA, we have that 70% of it comes from commerce and services, followed by the manufacturing industry, which produces about 22% of total value added in the MCMA (See Figure 4.2). The largest activity in terms of its contribution to the value added of the commercial sector is the financial and insurance sub-sector, with more than 23% of the total value added produced by the commercial sector. It is followed by wholesale, with roughly 17%, mass media information (including newspaper distributors), which accounts for another 16%, and retail, which contributes with roughly 12% of the value added of the commercial sector (GDF-INEGI-GEM, 2002). Together, these 4 sub-sectors concentrate more than 68% of the value added of the whole commercial sector.

The figures for value added result from subtracting total inputs from the total value of the production of a sector or sub-sector. It is expressed in gross terms, which means, in this case, without computing equipment depreciation.

FIGURE 4.2
VALUE ADDED PER SECTOR IN THE MCMA - 1998
PERCENT DISTRIBUTION



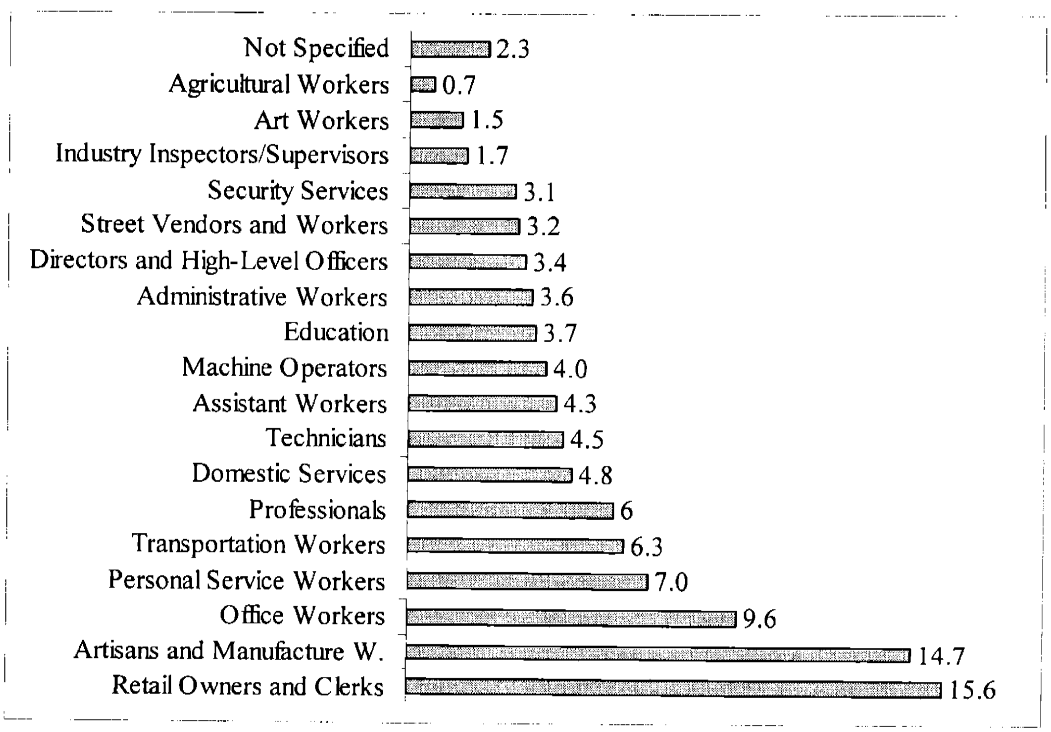
Source: GDF-INEGI-GEM, 2002.

If we compare the number of employees instead of the value added or production, we have a whole different picture, in which there is more atomization of the commercial sector, in several categories of occupation. Out of the almost 7 million people employed in the MCMA (See Figure 4.1), roughly 16% work in retail, as owners or clerks, almost another 10% perform office work, an additional 7% perform work offering personal services, and another 6% are professionals (meaning employees qualified with a university degree), although this last category is not fully commercial (See Figure 4.3). As we saw earlier, the commercial sector employs about 70% of the total number of employees in the MCMA (See Figure 4.1), and, out of that, we have that, together, these 4 major categories of employment concentrate a little bit more than 57% of the total commercial employment. Nine other of the activities in which employment has been categorized by INEGI in the 2000 General Population Census, contribute, each, between 3 and 5 % of the total employment in the MCMA (See Figure 4.3). Some of these activities are clearly fully in the commercial sector, but others, like directors and high-level officers, administrative workers, or machine operators, even when it is very likely that, at least in the MCMA, they fall mostly in the commercial sector, they may also include employees in the manufacturing sector. The figures include workers both in the formal and the informal portions of the economy.

By comparing value added to employment in the commercial sector, we see that value added is more concentrated in a few sub-sectors, while employment is more scattered. It is relevant to mention that transportation workers, though in strict sense are providers of a service, are not included in this thesis as part of the commercial sector, since transportation has been analyzed as a separate component of the analysis in the Mexico City Program.

FIGURE 4.3

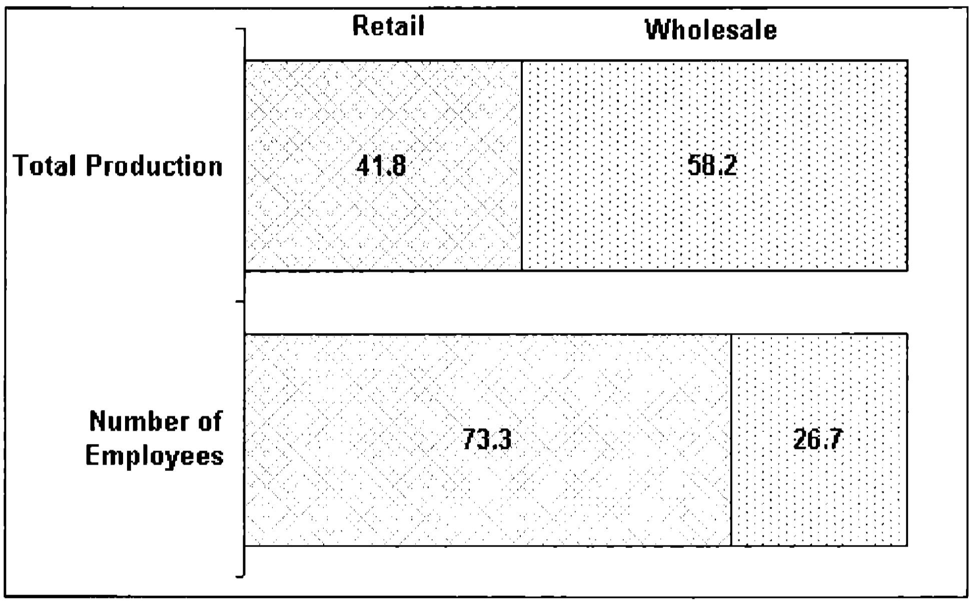
EMPLOYMENT BY MAJOR OCCUPATION IN THE MCMA - 2000
PERCENT DISTRIBUTION



Source: INEGI, 2001.
Note: Data as of February 14, 2000.

If we do the same type of comparison, between employment and production, for retail and wholesale, we see the same type of distribution as for the whole commercial sector. Retail contributes with nearly 75% of the total employment in the merchandise commercialization sub-sector, while it only concentrates about 42% of the total production of the sector.

FIGURE 4.4
RETAIL AND WHOLESALE EMPLOYMENT AND PRODUCTION IN THE MCMA (PERCENT DISTRIBUTION)



Source: GDF-INEGI-GEM, 2002.

Most of the commercial sector seems to be highly dispersed around the MCMA, with relatively small establishments everywhere throughout. In some specific sub-sectors, like wholesale, there may be a little bit more concentration of production, but the sector remains highly scattered, which may pose a challenge to be faced at the moment of designing and implementing policy.

Commercial activities are both formal and informal, although, because of the lack of data about informality, the tendency is to underestimate it in official statistics, when it is considered at all. Most of the data that I presented in this section, unless specified, referred to formal activities exclusively. The following section presents an attempt to set the basis for analyzing the informal sector. As we sill see, that may not be an easy task.

4.2 The Informal Sector

The term "informal sector" is used so often, that one would expect a clear and common understanding of what this concept involves. The truth is that there are multiple definitions of informality, and often there is no certainty of what exactly people are considering when they refer to it. The source of this lack of agreement may be due to the heterogeneity of the informal sector itself. It may encompass industrial and commercial units that have limited access to technology, or those that do not pay taxes, or those that do not provide benefits to employees, or the ones that perform illegal activities. To complicate matters, there are degrees of informality even in what would be usually considered as formal establishments. Some, for instance, pay taxes, but have poor working conditions. Only rarely does informality mean breaking all the laws, mostly it means living within a gray area, which has a long frontier with the formal world (de Soto, 1989).

There are several, often conflicting definitions of the informal sector, but, even with these discrepancies, opinions coincide about its growing role in the economy, especially in developing countries (Cross, 1998). According to the International Labor Organization (ILO Dilemma 1991, in Mhone, 1996), the term "informal sector" refers to:

> Very small-scale units producing and distributing goods and services, and consisting largely of independent, self-employed producers in urban areas of developing countries, some of whom also employ family labor and/or a few hired workers or apprentices; which operate with very little capital, or none at all; which utilize a low level of technology and skills; which therefore operate at a low level of productivity; and which generally provide very low irregular incomes and highly unstable employment to those who work in it. They are informal in the sense that they are for the most part unregulated and unrecorded in official statistics; they tend to have little or no access to organized markets, to formal credit institutions, to formal education and

> training institutions or to many public services and amenities; they are not recognized, supported or regulated by the government; they are often compelled by circumstances to operate outside the framework of the law, and even where they are registered and respect certain aspects of the law, they are almost invariably beyond the pale of social protection, labor legislation and protective measures at the work place. Informal sector producers and workers are generally unorganized, and in most cases beyond the scope of action of trade unions and employers' organizations. They generally live and work in appalling, often dangerous and unhealthy conditions, even without basic sanitary facilities, in the shantytowns of urban areas.

The term informal sector describes economic activities that take place outside the formal norms of economic transactions established by the state and formal business practices, but which are, in most cases, not clearly illegal in themselves (Cross, 1998). As such, the term is conceptually, methodologically and theoretically difficult to define in terms of its precise nature, size and significance, leading some authors to criticize it for lack of clarity (Peattie 1989; Bromley, 1990).

In 1993, an international definition of the informal sector was adopted by ILO, to include small unregistered enterprises, paid and unpaid workers in them and casual workers without fixed employers (WIEGO, Web-page).

According to the Mexican National Institute of Statistics, Geography and Informatics (INEGI), "the informal sector can be described as a set of units dedicated to the production of goods and services, with the main purpose of generating employment and income. These units work with a low level of organization, with very basic or no division between labor and capital as production factors, and mostly at a small scale. Labor relations within the informal sector are commonly based on occasional hiring, and on family or personal relationships, without a contract setting any formal guarantees" (INEGI, 2000). This definition is very similar to one published by the ILO, which states that "the urban informal sector can be characterized as a range of economic units in the urban areas, which are mainly owned and operated by individuals either alone or in partnership with members of the same household, and which employ one or more employees on a continuous basis in addition to the unpaid family worker and/or casual employee. Typically these units operate on a small-scale, with a low level of organization and little or no division between labor and capital. They are engaged in the production and distribution of goods and services with the main objective of generating employment and a basic income to the persons concerned" (ILO, 1993).

This is only one of several definitions used by ILO, which has been studying the informal sector and its implications on labor conditions for years. It seems to me that they tend to "adapt" their definition of the informal sector in each study, according to its purposes. Often, the definition of the informal sector can go beyond considerations of employment conditions, in others, it does not include any productivity criteria. Access to technology, or the lack of it to be precise, could be another indication of informality in the economy. Illegality and corruption are certainly other indicators that may be used to assess the level of informality of an economic activity.

In any case, even when the lack of agreement to define the informal sector creates confusion, it is even worse when looking for a methodology for measuring it. To that, we have to add the lack of accurate data on the sector, which, even in the rare cases when it does exists, must be taken with caution. Official sources, for instance, may tend to underestimate the importance of this sector, while international organizations, depending on their agenda, would in some cases probably do the opposite.

The existence and scale of the informal sector are quite often thought of in function of the degree of poverty of a region (de Soto, 1989). It is not necessarily clear, in any case, which one is the cause and which one the consequence. What is clear is that not everybody in the informal sector is, or was at any given time, poor, and, on the other hand, it is also not the case either that everybody who are poor belong to the informal sector. To poverty, we should maybe add other factors, like a heavy burden of taxes, corruption, and bureaucratic difficulties that force many producers to operate in the informal sector (de Soto, 1989). According to OECD (1999), the informal sector in Mexico expands in times of economic recession, because it becomes then the last resource for individuals who lose their jobs.

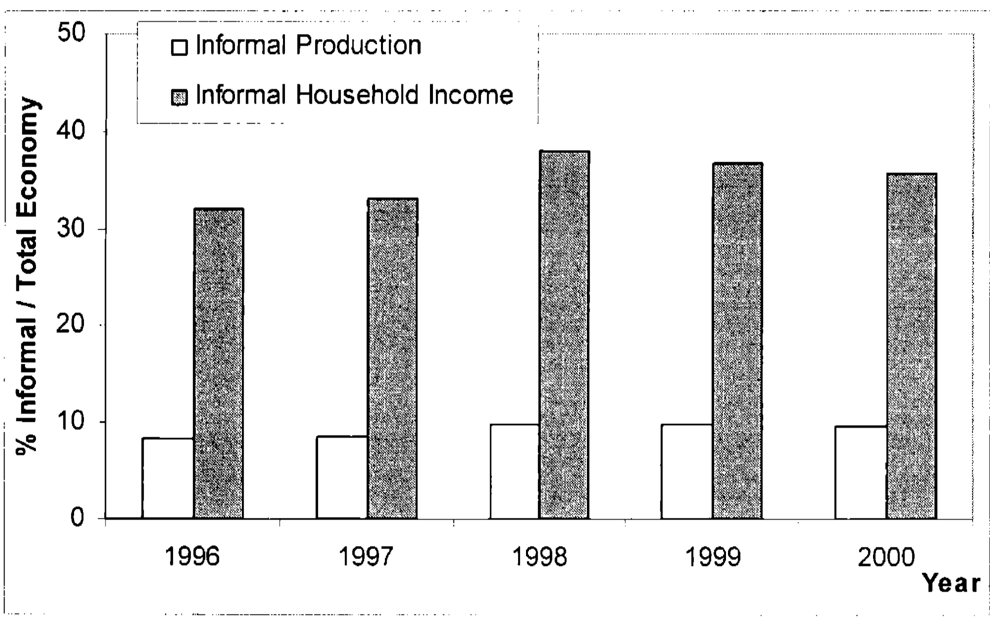
Official statistics indicate that the share of the informal sector in the non-agricultural workforce ranges from over 55 percent in Latin America, to 45-85 percent in different parts of Asia, to nearly 80 percent in Africa (ILO, web-page). The contribution of the informal sector to the economy, and not only its size, is quite large. The contribution of informal sector income to total household income is significant in many regions: for example, in several African countries, informal sector income accounts for nearly 30 percent of total household income and over 40 percent of total urban income (ILO, web-page). The contribution of the informal sector to GDP is probably also significant. For those developing countries where estimates exist, the share of the informal sector in non-agricultural GDP is between 45 and 60 percent (WIEGO, web-page).

4.3 Estimating the Size of the Informal Sector of the MCMA

There are several approaches to measure the size of the informal sector in an economy. The most common one seems to be by measuring its relative contribution to employment, which seems to be a good indicator for assessing the social implications (and benefits) of informality. If the focus is more on its economic weight, it makes more sense to measure the relative contribution of the informal sector to the total GDP, evaluated for the whole of the economy, or for a particular activity, depending on whether or not we want to focus on a specific sub-sector. The issue is that, by being more labor intensive than the formal economy is, the outcomes of measuring one way or the other are different. Comparing the contribution of the informal sector to net production of the whole economy in Mexico, to its contribution to household income (See Figure 4.5), we can see that choosing a given indicator or another to determine the size of the informal sector may produce different outcomes.

By some estimations, the informal sector accounts for roughly one third of the national GDP of Mexico, producing an estimated US$ 146 billion in 1998 (OECD, 1999), though the Mexican Ministry of Finance estimated the contribution of the informal sector to be only 10% of GDP. It contributes around 44% of the total urban employment (OECD, 1999), and as much as 57% of the labor force working in other than agricultural activities in Mexico (ILO, web-page). Figures for this last category are, again, a little different in other sources. According to UN estimates, only roughly 38 % of people working in other than agriculture activities in the country are in the informal sector. The U.N. statistics indicate that in Mexico, 41% of women, and 35% of men working in other than agricultural activities are in the informal sector (U.N., web-page).

FIGURE 4.5
RELATIVE CONTRIBUTION OF THE INFORMAL SECTOR TO PRODUCTION AND HOUSEHOLD INCOME IN MEXICO 1996-2000



Source: INEGI, 2002.

According to INEGI, the informal sector contributes, in 2000, with almost 10 % of the national GDP, although its contribution varies according to the economic sector we refer to (See Table 4.1). For commerce, restaurants and hotels, almost 20% of the national production comes from the informal sector, even though this figure has been decreasing over the last five recorded years. For construction, which is another relevant sub-sector for the purposes of this thesis, the informal sector contributes with about 5% of the national production in 2000, having increased significantly between 1996 and 1998, and having stabilized from there on until 2000, which is the last year for which there is data available.

TABLE 4.1
INFORMAL SECTOR PRODUCTION BY ECONOMIC ACTIVITY IN MEXICO (PERCENT CONTRIBUTION TO TOTAL NATIONAL PRODUCTION)

ACTIVITY	1996	1997	1998	1999	2000
Manufacturing Industry	5.5	5.3	5.5	5.5	5.3
Construction	3.3	6.5	11.2	11.0	10.9
Commerce, restaurants and hotels	24.6	21.4	20.7	20.5	19.5
Transportation, storage and communications	4.0	6.5	10.3	9.8	10.0
Communal, social and personal services	12.0	14.2	18.4	17.8	16.4
TOTAL	**8.4**	**8.6**	**9.8**	**9.9**	**9.6**

Source: INEGI, 2002.

Besides the impact on air pollution that these activities have, which is the main focus of this thesis, they are also politically and socially relevant, due to their socio-economic positive and negative impacts. They often represent unfair competition for the formal activities they tend to replace, and are the cause of several social problems. On the other hand, it is also the case that the informal sector provides employment opportunities to women and young people, that they otherwise would not have, and much of that is not even accounted in official statistics.

4.4 Formal vs. Informal

The fundamental problem with the definition of the informal sector seems greatly to lie in the nature of the concept itself. By using the term informal, we necessarily imply that the activities in that sector are defined by contrasting them to activities in another sector (the formal one), which is seen as external and opposed. Because of this, the two sectors are treated as separate from the start, as if they were two self-contained units, even though the dynamics between informality and formality are not always oppositional, but often benign, and even dependent (TWN, 1999). Another point is that what is referred to as the informal sector has a very diffuse frontier connecting with the formal economy, and it is often difficult to draw the line among them.

There are, between these two extremes, all sorts of "semi-formal" or "semi-informal" activities in the economy, which are subject to a certain level of regulation, but still receive a certain degree of benefits of informality from state officials, for whatever reason, often even because of political negotiation. Examples of this sort of activities are: garbage collection and treatment, house maintenance and repair done by hired workers, and even street vending.

Despite any agreement on its definition, collecting accurate statistics on the informal sector remains exceedingly difficult, because of its diversity and the wide range of activities it encompasses. The informal sector seems to be as heterogeneous as the economy as a whole is.

As mentioned earlier, the informal sector represents a wide proportion of the economic activity in many countries, especially in the less developed ones, Mexico not being the exception. But while its role in economic development may be debatable, it must be recognized that it is an important sector in terms of correcting, at least partially, some of the injustices inherent to developing economies. It is widely accepted that this sector is especially important for providing opportunities of employment to the urban poor, and among them especially to women.

Various analysts and policy makers approach the study of the informal sector with different expectations, and thus draw different, and many times contradicting conclusions. Some see it as providing jobs, absorbing labor that cannot find employment in the formal sector, and playing a useful complementary role in the provision of goods and services. Others see the sector as an incentive to independent economic development, and seek to promote it as a basis for industrialization. For still others, the informal sector is the last resort for untrained labor, especially during periods of severe economic crisis (TWN, 1999). It is also true that many tend to focus more on the negative side of the informal sector, seeing it as a seed of social problems, as an unfair competitor against formal establishments that pay taxes and comply with regulations, as a contributor to the exploitation of cheap labor, including children, and as a nonproductive consumer of inputs.

From the economic perspective, it is true that informal businesses can derive several advantages from their informality. The fact that they are not at all, or only partially regulated, constitutes in fact a subsidy. The point is how much of it is transferred to the formal sector, via inputs or outsourcing, and how much is really socially justifiable. On the other hand, a relevant question relates to whether the costs of being "formal" are, in simple words, so high, that they may make it impossible or at least difficult for small businesses to pay them, and at the end of the day favor large firms and constitute a barrier to entry.

For the economy as a whole, nevertheless, it is generally believed that the informal sector may have negative consequences. Is has been found that an increase in the size of the informal sector hurts growth by reducing the availability for public services for everyone in the economy and by increasing the number of activities that use some existing public services less efficiently or not at all (Loayza, 1997). In general, formal firms are optimized as they become more capital intensive and can grow to achieve economies of scale. Informal sector businesses, on the other hand, must evade regulatory costs on labor while their capital is subject to much greater risk (due to lack of legal protection), so they are then optimized by becoming (or staying) labor intensive, and by remaining small enough to capture economies of flexibility (Cross, 1998). The approach to technology of each one of them, formal as opposed to informal, is, then, dictated by their willingness to achieve, or not, economies of scale or economies of flexibility.

Understanding conceptually the formal and informal sectors of commercial activity in MCMA, trying to assess, even if very broadly, their size and relevance for the economy and the society, and defining some of their dynamics, have been necessary steps to proceed to the analysis of their impacts on emissions, and then to the definition and assessment of policies to reduce those emissions.

5. FORMAL AND INFORMAL COMMERCIAL EMISSION SOURCES

In this chapter, I move from the more general analysis of the commercial formal and informal sectors within the context of the economy of MCMA, to now look at these activities, more specifically, as sources of air pollution in the context of the city's air pollution problem and policies. After a brief definition of what commercial, formal and informal, activities may be relevant sources of atmospheric emissions in the MCMA, I present a discussion about the MCMA emissions inventories, and their analysis of these sectors. From that, I move to discuss what policies tackling these sectors have been put in place in the city's air quality programs, to then analyze the drivers of commercial, formal and informal, emissions, and to finally present an estimation of these sector's baseline emissions.

The commercial sector includes the following activities or sub-sectors: auto shops, bakeries, construction, dry cleaners, gas stations, hospitals, hotels, offices and commercial buildings, print shops, public baths, restaurants, retail stores and street maintenance. For the commercial sector, the most relevant emissions to target are NMHC, mainly due to the consumption of solvents, and SO_2, which is produced mostly by combustion in boilers.

The informal sector includes the informal portion of some commercial activities, plus other sub-sectors that are mostly in the "underground economy". In all, the following sub-sectors are analyzed: informal auto shops, brick kilns, informal print shops, informal house repair and painting, and street vendors (particularly of food). For the informal sector, even though emissions are very uncertain, the main concerns are PM_{10}, derived mostly from combustion, and NMHC, due mainly to the use of solvents.

As we will see, the emissions inventories carried out in MCMA, as well as the policies to tackle commercial activities, most of which are included in the MCMA air quality programs, often aggregate some of the activities mentioned above, and treat them in block, according to the type of activity that is common to them, and which is the cause of emissions. For instance, the inventory treats all commercial combustion as a single issue, and does the same for solvent use for the purposes of cleaning or de-greasing, regardless of what sub-sectors do these things. This is one of several issues to be discussed in the following sections.

5.1 The MCMA Emissions Inventory

CAM has been in charge of estimating and publishing the amount of annual emissions emitted in the MCMA, adding up the contribution to emissions of all identified sources. From 1994 to 1998, emissions inventories were produced every two years, although each one became publicly available only two to three years after the year of reference. By August 2003, an emissions inventory for 2000 has not yet been published, although, CAM members have a first draft of it.

Emissions inventories, in general, are thought of as a necessary step for air quality policy design and implementation. The emissions inventories carried out in the MCMA, have improved significantly over the last years. At the beginning, they almost exclusively relied on emission factors that were taken from other cities in the world, mostly from the US, but, more and more with each new inventory, these emission factors have been adapted to local conditions.

The MCMA Emissions Inventory is divided in four categories: point sources, area sources, soils and vegetation, and mobile sources. Five criteria pollutants are estimated and reported in the inventory: Particulate matter of a diameter equal or less than 10 microns (PM_{10}), sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen oxides (NOx), and non-methane hydrocarbons (NMHC).

The 1998 emissions inventory, which is the last one published in the MCMA, covers an area of roughly 3,540 km^2, including the whole DF, but only 18 municipalities in the SoM, and not the 27 municipalities that CAM itself defined as part of the Metropolitan

Area of MCMA, and that would make its whole extension reach 4,925 km^2. For the analysis I present here, I considered the 27 municipalities that CAM uses.

Emissions are estimated mostly using emission factors produced by the U.S. Environmental Protection Agency (EPA), most of which have been adapted to MCMA characteristics. Several of the emission factors used for estimating commercial activities link particular emissions for a specific activity or sub-sector to the size and density of the population; the type and amount of raw materials used; the number of employees in a sub-sector; or the amount and mix of fuels consumed, in the case of combustion (CAM, 2001b).

Commercial sector activities are treated as area sources in the 1998 MCMA Emissions Inventory (CAM, 2001b). The reason for considering commercial sources of emissions as area sources, as explained in the inventory, is that they are too small, and too disperse throughout the territory of the MCMA. As discussed in Chapter 3, in the 1998 MCMA Emissions Inventory, area sources are relatively important contributors of NMHC and SO_2.

Area sources are categorized in 5 groups in the inventory (See Table 5.1): (a) The first category is almost exclusively devoted to transportation, though it also includes fuel storage, which in any case will not be treated as a commercial activity, except for gasoline distribution stations. (b) The second category is solvent evaporation, which includes some activities that are clearly recognizable as commercial, such as graphic arts (printing), dry cleaning, auto painting, and hospital sterilizations. Other activities in this category belong to other sectors, but there are also some that do not make any distinction between industrial, residential, transportation-related, or commercial use, such as one called "consumption of solvents", and another one named "cleaning of surfaces and de-greasing". (c) The third category, evaporative sources and hydrocarbons, includes one activity that is commercial, which is bakeries. (d) The next category is exclusively for mobile sources. (e) The last category within the area sources, which is combustion sources, includes something called "commercial and institutional combustion", and hospital combustion as well.

TABLE 5.1
CLASSIFICATION OF AREA SOURCES IN THE MCMA EMISSIONS INVENTORY

CATEGORY	ACTIVITY OR SUB-SECTOR
(a) Evaporative losses in transportation and fuel storage	- Gasoline distribution and storage - Airplane filling - Fuel storage
(b) Solvent evaporation by area sources	- Dry-cleaning - Cleaning of surfaces and de-greasing - Graphic arts - Commercial consumption of solvents - Industrial coatings - Architectural coatings - Auto painting - Street painting - Hospital sterilization - Hospital waste incineration
(c) Hydrocarbon evaporative sources	- Sanitary landfills - Waste dumps - Liquified petroleum gas (LPG) distribution - Asphalt use - Bakeries - Waste water treatment plants
(d) Non-road mobile sources	- Railroad locomotives - Airport operation equipment
(e) Combustion sources	- Residential combustion - Commercial-institutional combustion

Source: CAM, 2001b.

As briefly mentioned earlier, the MCMA Emissions Inventory treats a few specific commercial sub-sectors separately (for instance bakeries, dry cleaners, or graphic arts), but in the most part makes the estimation of emissions on the basis of the type of activity that provokes the relevant emissions (for instance combustion, or solvent consumption) regardless of the sub-sector where that activity takes place.

A more detailed categorization of emission sources within the broader category of area sources is presented in the emissions inventory. According to the sub-sectors and activities included in the emissions inventory, then, the following commercial ones are identified, and used for the analysis carried out in this thesis:

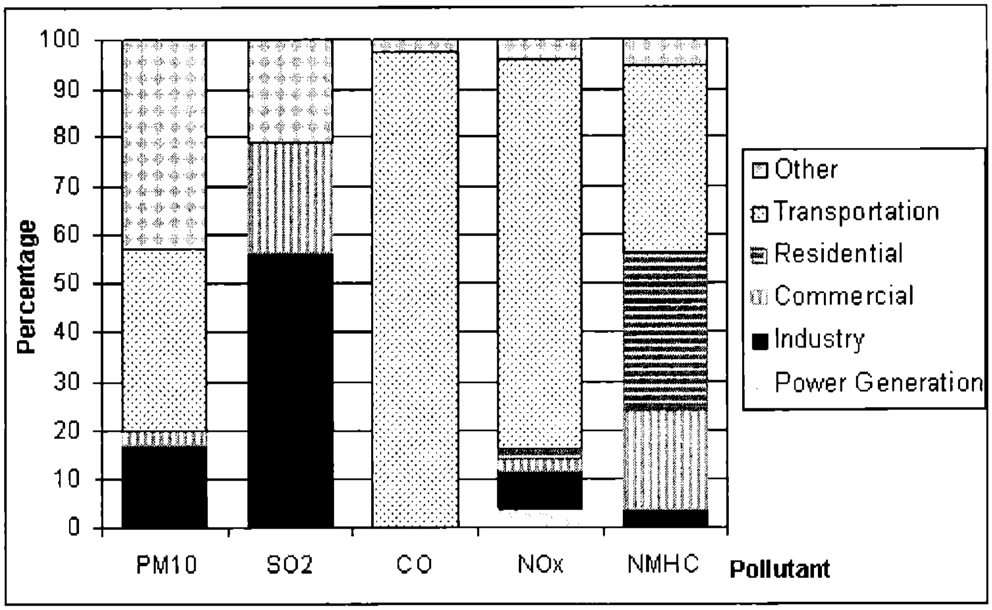
Commercial consumption of solvents
Cleaning of surfaces and de-greasing
Dry cleaning
Graphic arts
Bakeries
Painting (transit related)
Auto painting
Hospital sterilization
Hospital combustion
Commercial-institutional combustion
Gasoline distribution and storage
Asphalt paving

Besides these categories, other commercial activities not included explicitly in the emissions inventory will be included in this thesis, or disaggregated, whenever possible, to make the assessment of policy impacts easier. In the inventory, for instance, there is no explicit mention of hotels, restaurants, offices, public baths, retail, etc.

From the estimations presented in the 1998 Emissions Inventory, if we see the relative contribution of emissions by sector of economic activity, and not by type of emission (as in the four broad categories mentioned earlier), we can corroborate that commercial emissions are relatively high contributors of SO_2 and NMHC (See Figure 5.1).

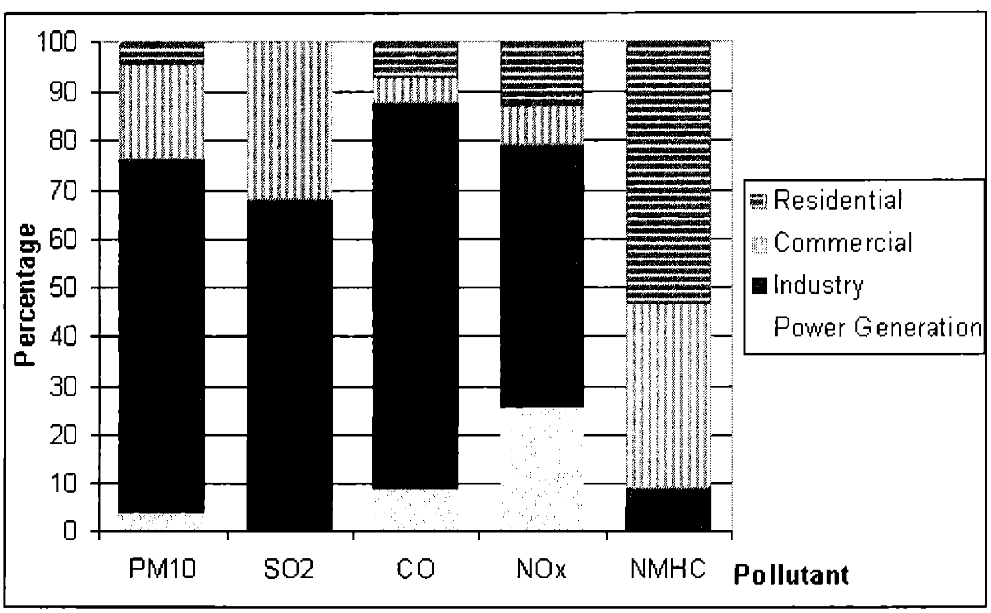
If we look only at non-transportation sources of emissions (Figure 5.2), we have that, besides those two pollutants, the commercial sector is also an important non-transport non-natural factor contributing to PM_{10} emissions.

FIGURE 5.1
THE MCMA EMISSION SOURCES- 1998



Source: CAM, 2001b: 1998 MCMA Emissions Inventory.

FIGURE 5.2
NON-TRANSPORTATION EMISSION SOURCES IN THE MCMA - 1998



Source: CAM, 2001b: 1998 MCMA Emissions Inventory.

The Emissions Inventory does not make any distinction between formal and informal activities. It is not clear whether or not the emission factors used compute any emissions from the informal activities within the commercial or industrial sectors, which may be significant in some particular sub-sectors.

The 1996 Emissions Inventory had a brief addendum in which emissions from brick kilns, an important sub-sector within the informal sector, were preliminarily calculated. The methodology followed for that estimation linked fuel types and amounts of them consumed, to emissions. The emission factors used were also from EPA (AP-42-95). This has been the closest environmental authorities have been of acknowledging and even attempting the estimation of informal emissions. There is no systematic analysis of the emissions from the sector, and, even if it were the case that they are implicitly included within the estimation of other commercial activities (which does not seem to be the case, anyway), it is likely that they would be under-estimated, since their emission intensity per unit of input (fuels, for instance) would be in most cases probably larger than that of equivalent formal activities.

5.2 The Commercial and Informal Sectors in Proaire III

The Program for Improving Air Quality in the Mexico City Valley Metropolitan Area 2002-2010 (Proaire III) describes two broad sources of pollution in the MCMA: transportation, and use of energy, which derives mainly from the use of fossil fuels in all economic sectors. It does not make any explicit mention of the informal sector when describing the sectors using energy. Other sectors are mentioned in the Proaire III, including transportation, industry, services, and the domestic sector.

The previous air quality program, the Proaire 1995-2000 (Proaire II), included only one specific measure for the commercial sector, which was the installation of vapor recovery systems in gas stations, and no measure at all to tackle informal emissions. Other than that, there were a couple of measures that had some effect in the emissions of both these sectors. One was the reformulation of paints, which reduced NMHC emissions from auto and road painting. The other was the implementation of stricter standards for fuels, which reduced the reactivity of LPG, and lowered sulfur levels in other fuels (DDF-GEM-SEMARNAP-SS, 1996). The deployment of the vapor recovery systems in gas stations was completed by the end of the Proaire II. The reformulation of paints is in progress beyond the end of Proaire II, as the use of reformulated paints would increase through time. The reformulation of fuels derived from the Proaire II was achieved by the end of the program, with a caveat, which was the lowering in the sulfur content of gasoline, which was not achieved in the Proaire II, and was set again as a policy objective in the Proaire III.

In the Proaire III, there is, again, only one concrete measure for the commercial sector, which aims at modernizing 388 of the city's dry cleaners, via the installation of closed-loop equipment that reduces the use and emission of cleaning solvents (specifically perchloroethilene). For the informal sector, there is also one particular measure (though not as concrete), which refers to the design of regulations for fuel combustion and for the use of handcrafted ovens for brick production. Other than these two measures, there is another that may affect both sectors, as it refers to educating employees in sectors where combustion is frequent, on more efficient ways of operating their combustion processes. Besides, there are a couple of measures also included in the section of the program that refers to services, but they are not concrete measures at all. The Proaire III does not include a deployment schedule for any of these measures.

The focus of the Proaire III is to reduce primary pollutant emissions, and it is expressed through four goals (SEMARNAT-GEM-GDF-SS, 2002):

1) To reduce ozone concentrations in the MCMA, to avoid any concentrations above 200 IMECAS. To reduce the number of days with ozone IMECA levels between 100 and 200 points, and to increase the number of days of compliance with standards.

2) To reduce the particles produced by gasoline and diesel vehicles, street and road dust, industry, combustion processes in services and commerce, and forest fires, among other sources. The goal set is to increase the number of days of compliance with PM_{10} standards, and to reduce the annual average concentrations of this pollutant. Regarding $PM_{2.5}$, which are the ultra-fine fraction particles, Proaire III established the need of setting a standard and to begin monitoring their concentrations by 2003, according to which CAM should set concrete abatement goals.

3) To reduce current concentrations of CO, mainly generated by vehicles and by the combustion processes in industry, and to totally avoid concentrations above 9 ppm (average in an 8-hour period).

4) To reduce sulfur dioxide concentrations, generated mainly by the combustion processes in industry and services, and by vehicles. To totally avoid extraordinary peaks in SO_2 concentrations due to the use of fuels with high sulfur content.

The Program has 89 particular policy measures, but in a wide spectrum of concreteness and specificity. There is, for instance, one measure that aims at the reduction of the sulfur content of gasoline to 50 ppm, and, at the same level, another measure that aims at increasing the use of economic instruments for environmental protection. In between, there are technology options, management options, enforcement options, policy analysis options, etc., and they are all called "measures".

As briefly mentioned in Chapter 3, the measures included in the Proaire III are divided in 7 categories (See Table 5.2). Most measures, which also tend to be the more concrete ones, relate to the transportation sector. For what the Program calls the services sector, there are 9 measures included, but, as mentioned earlier, only one could be considered as a concrete policy for the commercial sector. The rest are somehow vague, or, if not, at least much more general, and difficult to assess, if implemented.

These measures were designed by nine working groups within CAM, in which there was some involvement of stakeholders, including academia. Proaire III explicitly recognizes the inputs received from MIT's Mexico City Program, especially for providing data on the atmospheric chemistry within the MCMA, and on the size and nature of the health exposure to air pollution and its effects, which drives several of the measures designed.

TABLE 5.2
NUMBER OF PROAIRE III MEASURES BY CATEGORY

CATEGORY	NUMBER OF MEASURES
Vehicles and Transportation	38
Industry	7
Services	9
Natural Resource Conservation	15
Health Protection	8
Environmental Education	4
Institutional Strengthening	8
TOTAL	**89**

Source: SEMARNAT-GEM-GDF-SS, 2002.

The following are the 9 measures that the Proaire III includes in the services category, as defined by the program:

- Reduction of hydrocarbon emissions in dry-cleaning establishments
- Mechanisms for self-regulation and the improvement of environmental management in small and medium establishments.
- Training in efficient combustion practices for commercial and service establishments that operate with steam boilers.
- Reduction of LPG leakages in domestic installations in the MCMA.
- Inspection of vapor recovery systems installed in gas stations.
- Regulations for extraction activities of mineral materials.
- Guidelines for the use of fuels and the operation of ovens for brick production.
- Promotion of solar energy to substitute fossil fuels.
- Promotion and development of economic instruments for environmental improvement for industrial and service establishments in the MCMA.

As mentioned earlier, there is only one concrete measure, which refers to the reduction of NMHC emissions from dry-cleaners. One other measure listed above, the reduction of LPG leakages, is also concrete, but it falls within the residential sector, which is analyzed separately within the Mexico City Program.

5.3 Drivers of Commercial and Informal Emissions

By drivers of the emissions we shall understand those factors that determine the size of the emissions of a specific sub-sector or activity within it.

The drivers of the emissions in the commercial sector are the growth of the Gross Domestic Product (GDP), including in some cases the sector GDP and the regional GDP (GRP); population growth; technology availability; regulations and enforcement; environmental awareness; prices of energy/labor/capital; employment levels; infrastructure availability; and socio-cultural elements.

Even within formal activities, survey evidence has shown that emissions among different establishments within the same sub-sector vary tremendously in Mexico, with some having adopted significant pollution control measures, while others have made little or no effort to improve their environmental performance (Dasgupta, 1999). There are several reasons to explain this variability, going from business ethics, to scale, access to technology, and availability of financial resources. We would expect the environmental performance of the informal sector to be at the lower end of the spectrum. The establishments in the informal sector tend to be smaller and to have less resources to control emissions, so we can expect them to be, in general, more pollution-intensive (Beckerman, 1995).

The main drivers of informal emissions are the GDP growth and distribution; population growth; urban sprawl; social factors, like employment; enforcement of regulations; and cultural elements.

Besides the direct impacts on emissions from the informal sector, we should also consider its indirect impacts on the rest of the economy, whose access to environmental technology may be affected by the unfair competition that similar informal activities represent. The existence of a growing informal sector reduces the availability of public services for everyone in the economy (Loayza, 1997). The atmosphere could, in strict sense, be considered one of those public services that become scarcer and are used less efficiently because of the implicit subsidy given to the informal sector.

Informal activities are very difficult to regulate, due to several political and technical reasons. As mentioned earlier, the informal sector may have negative consequences on the economy and on the environment, but it also represents a valve of escape for several social pressures.

From my perspective, fighting the informal sector with the sole purpose of abating emissions, is not a feasible solution to the air pollution problems in MCMA, not at least while there are no equivalent employment opportunities in the formal sector. Solving environmental problems causing social injustices just does not make any sense. Policies, then, have to focus on the causes of the atmospheric problem, but with attention to not creating or deepening other, maybe even more preeminent problems.

In any case, the informal sector in Mexico, though more in certain sub-sectors than in others, is organized and exercises political pressure. Its members are often linked to political parties, in a mutually beneficial relationship. People in the informal sector, though in strict sense are at a certain extent affected by the general institutional and legal framework, develop their own laws and institutions, to make up for the shortcomings of the official legal system (De Soto, 1989). It is important to keep this in mind when designing and assessing policies that may affect this sector.

Pollution can be thought of as a cost that industry or consumers transfer to society without compensating them for it. In one word, an "externality" deriving from economic activity, that is not internalized by those producing it, because of market failures and the inefficiency of public authorities to correct those failures. Pollution can be also though of as an expression of underdevelopment, in a certain sense a consequence of it, but at a larger extent also a cause, as it affects quality of life so much, impacting human health and the natural environment, diminishing well-being, and sometimes even reducing life expectancy. We can argue that, at the end of the day, pollution is also an effect of technology, or the lack of it, and technology in turn can and is often driven by public policy. So, when public policy fails to influence, on any of the possible fronts, the causes of pollution, the problem persists or aggravates.

5.4 Estimating Baseline Commercial and Informal Emissions

Using a scenario approach, it was analyzed, sub-sector by sub-sector, the contribution of the informal sector to pollutant emissions in the MCMA. The detailed results of this analysis are presented in the following chapter. A preliminary step for that was to set the baseline commercial and informal emissions for the sectors we are analyzing, for the baseline year established in the scenario analysis group of the Mexico City Program, which is the year 2000.

Many of the estimations of the baseline emissions were achieved by extrapolating the data from the 1998 Emissions Inventory, using the same emission factors, but updating the estimation to 2000 data on population, fuel consumption, GDP, or whatever indicator was relevant for the specific sub-sector and pollutant being estimated.

For the informal sector, baseline emissions were calculated assuming an emissions factor that varies depending on the sub-sector, but which is generally higher by unit of input or on a per capita or per unit of income -basis, whatever the case may be. Knowing the data on the size of the informal fraction of the most relevant commercial activities, it was possible to make the estimation of baseline emissions. When there was not sufficient data to accurately assess the size of a given informal activity, as compared to the corresponding formal one, it was assumed that it was proportional to the its relative employment, or to some other available indicator, like aggregate production.

Although it has a history of over 30 years, the analysis of the informal sector in Mexico has concentrated on the impacts of informality on the economy, employment, and the society. Even though the study of this phenomenon has focused mainly on urban areas, little is known about its contribution to air pollution.

As mentioned earlier, the first problem when approaching the informal sector activities and contribution to air pollution in Mexico City is the definition of what the informal sector is and what activities it should include. To complicate things, on top of all factors used to select what sub-sectors or activities are included in the category of "informal sector", we should include a specific criterion to assess its relevance in terms of atmospheric emissions. In this way, it is possible to narrow down all the activities included in this so wide sector to only those that are relevant from the perspective of air pollution, for which we looked for environmental management options.

After worrying about the definition of informal sector activities in MCMA, it is more important, for the purposes of this thesis, to determine the relative contributions of those sub-sectors to atmospheric pollution, to then try to tackle those that are relatively important emitters, via policies and control options.

Criteria for choosing relevant informal sub-sectors:

- Size of plants (or activities) measured in GDP or employment
- Scale of the operation
- Type of activity (and type of ownership)
- "Amount" of regulation (and/or enforcement)
- Relative access to technology (and ease of entry)
- Existence of traditional activities (and reliance on indigenous resources)
- Emissions of pollutants (relatively more pollution-intensive activities)

The most important element to consider, then, is the emission of pollutants, which would make an informal sub-sector relevant and "interesting' for this analysis. Applying these criteria, the selected informal sub-sectors analyzed are:

- Informal graphic arts
- Informal auto-repair shops
- Brick manufacture
- Informal home repairs and paintings (proxi for architectural surface covering)
- Informal combustion

One particular sub-sector, street vending, is probably the most visible of all informal sector activities in urban areas. Certainly it is one of the first to come to mind when thinking about the informal economy in the MCMA. This sector is included within informal combustion, but given its relevance, specific policies for it are treated separately in the analysis.

From all products commercialized in the streets in MCMA, it is probably the preparation and sale of food the one that has the most adverse consequences on health, both directly to consumers, but also indirectly, via pollution, to the general population. More detail on this activity, and the others included in this analysis, comes in Chapter 6 of this thesis.

To sum up this chapter, the estimation of the actual baseline emissions for the year 2000 is presented in Table 5.3.

Besides the criteria emissions considered in the emissions inventory, the emission model developed for this analysis includes carbon dioxide (CO_2), which is a greenhouse gas. Baseline emissions for this pollutant are presented, together with the trends by future story and scenario, in the following chapter, where there is more detail about the emissions model assumptions and results, necessary to then proceed to analyze policies.

TABLE 5.3
COMMERCIAL AND INFORMAL BASELINE EMISSIONS - 2000

SUB-SECTOR	TONNES/YEAR				
	PM10	**SO2**	**CO**	**NOx**	**NMHC**
COMMERCIAL					
Solvent consumption					86,533
Surface cleaning and de-greasing					34,044
Dry-cleaning					11,349
Graphic arts					7,557
Bakeries					2,693
Transit-related painting					3,363
Auto painting					2,456
Hospitals (sterilization and combustion)	10	26	23	87	28
Commercial-institutional combustion	787	5,714	569	3,019	420
Gasoline distribution and storage					6,302
Asphalt paving					107
Construction [1]	1,295	N.A.	N.A.	N.A.	N.A.
INFORMAL					
Informal graphic arts [1]					1,430
Informal auto-repair shops [1]					6,536
Brick manufacture [1]	947	22	6,591	77	3,385
Informal house repair/painting [1]					9,437
Informal combustion [1]	80	605	61	356	54

Source: Commercial and Informal Emissions Model (Estimations for 2000, based on categories in CAM, 2001b).
N.A.: Not available
Blank cells reflect where estimation is not applicable.
[1] Not a category in the Emissions Inventory

In the next chapter, I present the results of the emissions model on which the analysis of the commercial sector, both formal and informal, relies. I present both the assumptions and results of the model, to then move to the analysis of proposed additional policies and strategies.

6. EMISSION MODEL OVERVIEW AND OUTPUTS

In this chapter, I move to the analysis of the commercial and informal sectors emission model, and, from there, to the definition and assessment of proposed strategies to tackle these sectors. To begin the chapter, I present a more detailed description of the emission model that I have designed for the analysis of the formal and informal commercial sectors. I present a description of the model assumptions that the analysis relies upon, and make some observations about the structure and logic of the model. Then, I analyze the results of running the emissions model, both for the different reference cases and the future stories that the model considers. After that, I propose the policies that could be thought of to abate commercial and informal emissions. I also describe the purpose and scope of these policies, which are defined according to technical feasibility. Then, I analyze the potential emission abatement and costs of the policies, and bundle those that make sense as components of a particular strategy, to then compare, within a tradeoff analysis framework, the different strategies designed. Finally, I assess some political feasibility issues, and test the model results for key sensitivities.

6.1 Model Components and Assumptions

As mentioned in Chapter 2, the emission model for the commercial and informal sectors analyzes three future stories, and three reference cases, so it is basically a 3X3 model. The three reference cases are: the Base Case, the Ideal Case, and the MIT Case. The three future stories are named: Divided City, Changing Climates, and Growth Unbound. In Chapter 2, I gave a general description of what each reference case and future story implies. In this section, I make a more detailed analysis of these elements of the model, and of other relevant assumptions, particularly in reference to the commercial and informal sectors. In Chapter 2, I also mentioned that the model could be thought of as a 3X4 matrix, and this is because there is what we could call a fourth reference case, which would be that in which I analyze the impact in emissions of the additional policy strategies proposed in this thesis (See Figure 6.1).

FIGURE 6.1
EMISSION MODEL MATRIX

		FUTURE STORIES		
		Divided City	Changing Climates	Growth Unbound
REFERENCE CASES	Base Case (Proaire II measures and current emission trends)			
	Ideal Case (Proaire III measures implemented as planned)			
	MIT Reference Case (Realistic Implementation of Proaire III)			
ADDITIONAL CASE	Proposed New Strategies for the Commercial and Informal sectors			

What fills each of the squares in the matrix is the estimations of emissions of six pollutants, for each particular combination of future story and reference case, and, in a further step, the estimation of costs, which are necessary not for the emission model itself, but for the tradeoff analysis. The commercial and informal model is sub-divided into several models, with the same matrix structure, for each one of the categories that each sector is divided upon, whether they are sub-sectors, or specific types of activity, as mentioned in Table 5.3 in Chapter 5.

For the formal and informal commercial sectors, the base reference case would imply the implementation of the Proaire II measures that refer to these sectors, and the continuation of current trends in emissions. This reference case includes, then, the measures referred to in Table 6.1, which are the only measures in Proaire II affecting directly the commercial and informal sectors.

TABLE 6.1
BASE CASE MEASURES AND THEIR IMPACT ON EMISSIONS

Proaire II Measure	Implication in Emissions
Reformulation of Paintings	• It affects both the formal and informal commercial sectors • It affects NMHC emissions in auto painting and road painting • Measure impacts the NMHC emission factor for painting activities • Costs are spread among consumers
Vapor Recovery Systems in Gas Stations	• Reduction in NMHC evaporative emissions in gas stations • At the end of Proaire II, systems had been installed in 306 (out of a total of 466) stations in MCMA • According to environmental authorities (CAM, 2001a), 10,000 tonnes of pollutants (which I assume is all NMHC) were reduced from 1994 to 1996 • Emissions (NMHC) from gasoline distribution were reduced by 80% • Gasoline distribution and storage represents about 0.12% of total NMHC emissions in MCMA after implementation • Costs are absorbed by gas stations, but financed by a public revolving fund (Fideicomiso Ambiental)
Stricter Standards for Fuels	• Affects both the formal and informal commercial sectors • Impact in production of less reactive LPG, which would affect the emission factors for this fuel • Impact in lowering the sulfur content of diesel, which would affect the emission factors for this fuel • Costs are spread among consumers
Inspection and Enforcement Program for Industry and Services	• Inspection visits of federal level authorities would impact compliance with emission standards • Local government inspections would often derive in requests to establishments for improvements in emission performance, and for control equipment installation • Difficult to assess quantitative impact on emissions

The ideal reference case is based on the implementation, as planned, of the measures in the Proaire III, which would directly affect the commercial and informal sector emissions. These measures, and their main implication in the emission model, are presented in Table 6.2.

TABLE 6.2
IDEAL CASE MEASURES AND THEIR IMPACT ON EMISSIONS

Proaire III Measure	Implication in Emissions
Reduction of Hydrocarbon (HC) Emissions from Dry-Cleaning Facilities	• Reduction of NMHC emissions from dry-cleaners • Affects 388 establishments, all formal • The goal set by the Proaire III is to reduce HC emissions by 6,000 tonnes annually • Measure impacts NMHC emission factor for dry-cleaners • Costs are absorbed by establishments, though they expect governmental support • Savings in input consumption are possible
Verification of the Vapor Recovery Systems in Gas Stations	• Reduction of NMHC evaporative emissions in gas stations • Costs of verification are absorbed by local governments
Capacity Building on Efficient Ways of Combustion for Commercial and Service Establishments that Use Boilers	• Affects the formal sector • Measure would impact combustion emission factors • Difficult to assess the impact on emissions quantitatively • Cost for training courses absorbed by the government
Regulations for Fuel Combustion and Use of Handcrafted Ovens for Brick Production	• Affects the informal sector • Measure would impact sub-sector emission factors • Difficult to assess how the measure translates to concrete actions and its impact on emissions
Promotion of the Use of Solar Energy to Substitute Fossil Fuels	• Focus on water heating • Of variable technical feasibility, due to limitation in roof-area • Concrete actions not defined yet • Cost would be absorbed by establishments
Self-regulatory Mechanisms and Improvement of Environmental Management	• Very vague measure in terms of scope and objective • Difficult to assess its impact on emissions quantitatively • Cost would be small, and mostly administrative

For the MIT Reference Case, the same measures included in the Ideal Case are considered, but assuming a different, more realistic deployment schedule than the one set in the Proaire III.

The same three reference cases that this study looks at, are being used in similar analyses of the emissions of other relevant sectors, which are being conducted by other members of the Mexico City Program. For the sectors for which Proaire III includes several measures, like road transportation, there may be a significant difference between the Ideal Case and the MIT Reference Case. For my analysis, the difference is minimal, because Proaire III includes very few measures to tackle the commercial and informal sectors, and, of them, even fewer that are specific enough, so that they include a deployment schedule and the targeted reduction in emissions that they aim to achieve. In any case, the inclusion of the MIT Reference Case is done for consistency purposes, since the analyses of all sectors, including the ones we are dealing with in this thesis, add up to a comprehensive scenario analysis of the whole MCMA.

The emission model has a time span of 26 years, from 2000 through 2025, and considers, as mentioned earlier, three future stories. In the case of the commercial and informal sectors emission model, several of the assumptions used in the model derive from the assumptions developed for the future stories. Again, as for the reference cases, these future stories are common to the analyses of emissions of all the economic sectors considered in the Scenario Analysis of the Mexico City Program.

As mentioned earlier, the most important factors driving commercial and informal emissions are population growth and economic performance, in that order. Technology is a third driver to consider, but how much it may impact emissions depends on the deployment of relevant policies. For the informal sector, emissions from some activities would be expected to increase if the economy deteriorates, as a larger proportion of the economy would end up in the informal sector. The enforcement of regulations, the prices of production factors, employment levels, and environmental awareness are other drivers of commercial and informal emissions, considered as relevant for making policy proposals, even though their impacts may not be fully accounted in the emissions model. All these factors reflect in the model inputs, and also in the emission trends resulting from the model.

Population growth, which is one of the main drivers of emissions in the commercial and informal sectors, depends on the characteristics of each future story, and so does economic growth, both in general, and for each particular sector (See Table 6.3). Some of the variables used in the model, like GDP change, are constant throughout a certain given future, and only change from one future to another. Other variables change both from future to future, but also within the 26-year period that each one of those futures considers. Population growth, for instance, in the Changing Climates future story, evolves from 1.5% per year in 2000, to 0.9% per year in 2025; and from 1.5% to 0.1% in the Growth Unbound future story.

TABLE 6.3
MAIN MODEL VARIABLES BY FUTURE STORY 2000-2025

VARIABLE	FUTURE STORIES		
	Divided City	**Changing Climates**	**Growth Unbound**
Annual MCMA Population Change (%)	1.5	1.5 down to 0.9	1.5 down to 0.1
Annual MCMA GDP Change (%)	2.3	4.0	4.8
SECTOR CONTRIBUTION TO GDP			
Domestic Trade, Restaurants and Hotels GDP (% of National GDP)	21.4 up to 22.0	21.4 up to 24.0	21.4 down to 19.0
Construction GDP (% of National GDP)	5.1 up to 5.5	5.1 down to 5.0	5.1 up to 7.0
Financial Services GDP (% of National GDP)	12.2 down to 10.0	12.2 up to 14.0	12.2 up to 14.0
Other Services (% of National GDP)	24.4 up to 27.0	24.4 down to 21.0	24.4 down to 21.0

The four economic sub-sectors for which I looked at for analyzing their relative contribution to national GDP (See Table 6.3), are the most significant ones for the commercial and informal sector analysis. "Domestic trade, restaurants and hotels", together with "other services", are, together, possibly the closest to representing the whole formal and informal commercial activities included in the emission model. We can see that, in a Divided City future story, the relative contribution of these sectors to the whole of the economy would be increasing, particularly for "other services", which include most of the informal sector. In the Changing Climates future story, the commercial and informal sectors' contribution to the economy would remain relatively stable, with one category (domestic trade, restaurants and hotels) increasing, but the other (other services) decreasing by almost the same ratio. In the Growth Unbound future story, the main activities in the commercial and informal sector would lose relative importance in the national GDP, although financial services and construction would be growing.

The future story framework developed for the scenario analysis does not include specific growth figures for informal activities, but it gives, nevertheless, clear indications about the trend that the informal sector would follow under each future story. Knowing also, as we do, the contribution (especially by sub-sector) of the informal sector to whole of the economy, which I discussed in Chapter 4, and knowing the characteristics and assumptions of each future story, several of which directly or indirectly affect the informal sector, it was possible to sustain and support several of the assumptions related to how the informal sector would evolve, under each future story, over the 26-year period considered in the model.

The general characteristics of the future stories discussed in Chapter 2, make me reinforce the assumption that, under the Divided City future story, the informal economy would be relatively bigger, with high population growth, and with the whole of the economy not growing significantly. In contrast, in the Growth Unbound future story, the formal commercial sector would be growing, as the economy grows significantly, and population in MCMA grows moderately, but the informal sector would be relatively smaller.

Construction is an interesting sector to look at, because, although in Mexico it commonly reflects the state of the economy, in the assumptions of the future stories it does not do so in all cases. In the Divided City future story, for instance, in which the economy is slow, construction grows, while in Changing Climates, to a higher economic growth, follows a relatively smaller construction sector. The reason for that has to do with urban expansion, which is much greater in the Divided City. For the particular analysis of the commercial and informal sectors, the category of "construction" will help us reflect the emission trends in a few particular sub-sectors, which lie a little in the margin, if not outside, traditional commercial activities. One of them is construction, itself a category in the model, and the others are paving of roads, and brick production, which in the MCMA is mostly informal.

Besides the four sectors included in Table 6.3, the other sectors in which the economy is divided in the future story and scenario analysis, are: agriculture, cattle raising and fishery; mining and extraction activities; manufacturing industry; electricity, gas and water; and transport and communication (Dodder, 2003). None of these sectors is very relevant for the analysis carried out in this thesis.

In the commercial and informal emission model, each particular sub-sector that forms part of these two sectors is analyzed separately, and the addition of the emissions of all sub-sectors is then integrated into two 3X3 emission matrices, one for the commercial sector, and one for the informal one. The model assumptions described earlier in this chapter, are assumed to affect, in concrete and different ways, the emissions modeled for each sub-sector (See Tables 6.4 and 6.5).

The estimated emissions of each particular sub-sector, derive from the application of emission factors, most of which are specific for the MCMA, to the relevant variables that drive emissions under each particular case, which evolve differently under each future story. The resulting emission estimations are presented and discussed in the following section of this chapter.

TABLE 6.4
MAIN MODEL ASSUMPTIONS BY COMMERCIAL SUB-SECTOR

SUB-SECTOR	MAIN ASSUMPTIONS
- Commercial solvent consumption - Surface cleaning - Surface covering - Graphic arts - Bakeries - Auto painting	Emissions develop according to population and GDP per capita growth by future story Emission trajectories affected by relative change of the "other services" economic sub-sector Emission factor assumed to change in some reference cases with management improvement
- Dry-cleaning	Emissions develop according to population and GDP per capita growth by future story Emission trajectories affected by relative change of the "other services" economic sub-sector Emission factor assumed to change in some reference cases with solvent capture policy
- Transit-related painting - Construction	Emissions develop according to population and GDP per capita growth by future story Emission trajectories affected by relative change of the "construction" economic sub-sector Emission factor assumed to change in some reference cases with management improvement
- Hospitals (sterilization and combustion)	Emissions develop according to population and GDP per capita growth by future story Emission trajectories affected by relative change of the "construction" economic sub-sector For solvent emissions from sterilization and combustion, assuming kg/hospital-bed is directly proportional to kg/inhabitant, and that the relationship is constant (from 1998 values). For other combustion emissions, assuming constant rate per capita as in 1998 No emission factor changes due to technology changes were assumed
- Commercial-institutional combustion	Emission factor links fuel consumption to emissions Fuel consumption varies according to population and GDP growth, and on sector (domestic trade, restaurants and hotels) contribution to GDP Some change in emission factors through time in some reference cases, due to capacity building impact
- Gasoline distribution and storage	Emission factors relate emissions to gasoline sales Gasoline sales assumed to grow in proportion to average annual growth in population, MCMA GDP per capita, and sector (other services) contribution to GDP Emission factor includes delivery, spillages, refueling, and storage tanks leakages Small change in emission factor, due to vapor recovery systems verification, assumed over time in some reference cases
- Asphalt paving	Emissions develop according to population and GDP per capita growth by future story Emission trajectories affected by relative change of the "construction" economic sub-sector No emission factor changes were assumed
- Office buildings	Emissions develop according to electricity consumption, which varies according to population and per capita growth by future story. And to relative change in the financial services sector Emission of concern is CO_2

TABLE 6.5
MAIN MODEL ASSUMPTIONS BY INFORMAL SUB-SECTOR

SUB-SECTOR	MAIN ASSUMPTIONS
INFORMAL	
Informal graphic arts	Emissions develop according to population and GDP growth by future story Percentage of informal activity in the sub-sector assumed to change over time according to future story Emission factors assumed 10% higher than formal, multiplied by proportion of informal activity in the sub-sector
Informal auto-repair shops	Emissions develop according to population and GDP growth by future story Percentage of informal activity in the sub-sector assumed to change over time according to future story Emission factor used was that for surface cleaning
Brick manufacture	Emission factors relate emissions to brick production Brick production grows in proportion to average annual growth in population, MCMA GDP per capita, and sector (construction) contribution to GDP Emission factors vary according to types of fuels used: wood, used oil, tires.
Informal house repair/painting	Emissions develop according to population and GDP growth by future story Percentage of informal activity in the sub-sector assumed to change over time according to future story Emission factor used was that for architectonic and industrial surface covering
Informal combustion	Emission factor links fuel consumption to emissions Fuel consumption varies according to population and GDP growth, and on sector (domestic trade, restaurants and hotels) contribution to GDP Fuel consumption assumed to represent a proportion of formal combustion, which varies depending on type of fuel and on future story Some change in emission factors through time were assumed, in some reference cases, due to capacity building impact

6.2 Emission Trends

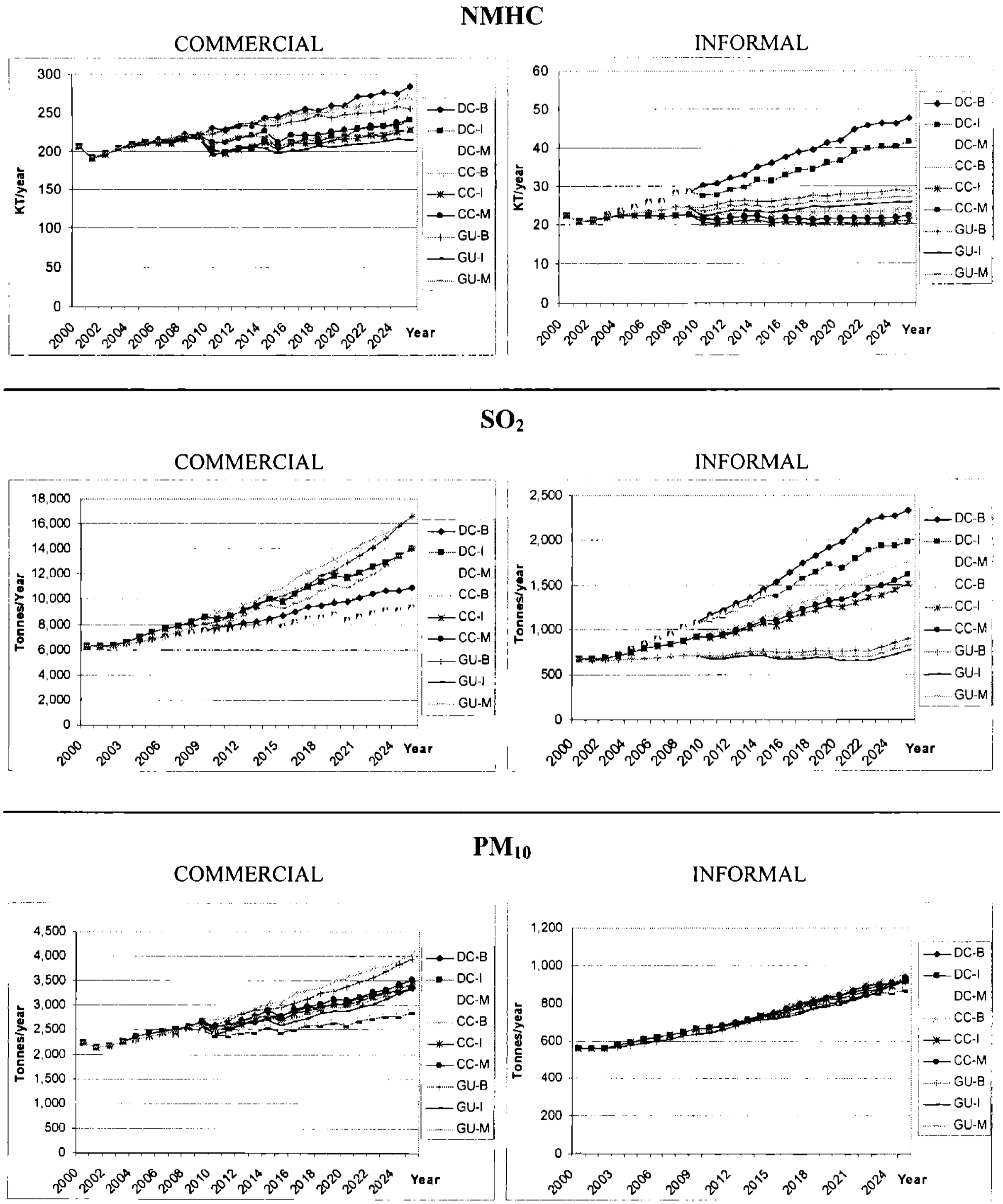
Emissions in the commercial and informal model are influenced more by future stories, than by the reference air quality programs. This probably derives from the fact that emissions in these sectors are highly dependant on population and economic dynamics, which vary according to future story, and also to the fact that, in the three reference cases, there are so few Proaire measures targeting these sectors. The trends that emissions would follow, according to the model, vary by pollutant (See Figure 6.2). In general, it can be observed that, in the short term, the most relevant emissions would increase, almost in parallel, for the three reference cases, no matter what the future story is. Then, in the medium and long term, the trends followed by the emissions under different reference cases and future stories, would diverge, in some cases significantly. The complete results from the 3X3 analysis, in annual total emissions, pollutant by pollutant, are presented in Tables III.1 through III.12 in Appendix III.

For NMHC emissions, which are very relevant, especially for the commercial sector, we have that the emission trajectories that correspond to the Divided City future story, in the base reference case, are the highest of all, both for the commercial and the informal sector. NMHC emissions are clearly dependent on future story, although some impact is perceived, also, in the case of the commercial sector, deriving from the one policy measure included in the Proaire III to control solvent evaporative emissions in dry-cleaners. This impact can be seen, in Figure 6.2, on the first plot, which is the one for commercial NMHC. There, we can see how the trajectories of the emissions under the three future stories vary little, mostly depending on the reference case each one corresponds to. The three trajectories with the highest increase correspond to the base case, and the three with the lowest to the ideal case. For informal NMHC emissions, the slope of the Divided City emission trends is bigger than for the other future stories. This may be the consequence of both a more rapid growth in population, but also of a relatively larger "other services" economic sub-sector, which are conditions assumed for this future story.

For SO_2, emissions, of which the commercial sector is a significant contributor in MCMA, we have, under certain future stories, the steepest emission growth trajectories, in some cases more than two-times, and even three-times the 2000 emissions by year 2025. These emissions are driven predominantly by the changes in population and economic output across the three future stories. In the case of the Divided City future story, informal emissions would increase significantly, due also to the relatively larger size of the informal sector, and to high population growth. In the case of Growth Unbound, annual SO_2 emissions from the informal sector would be expected to remain stable, but the ones from formal commercial activities would increase significantly.

FIGURE 6.2

3X3 EMISSION TRENDS FOR SELECTED POLLUTANTS



DC: Divided City; CC: Changing Climates; GU: Growth Unbound;
B: Base Case; I: Ideal Case; M: MIT Case
Note: Only trends are comparable among all graphs. Scales for pollutant emissions are different.

The model assumes some fuel improvements and improved emission controls for SO_2, and that may explain, even in the absence of any major Proaire policy affecting emissions of this pollutant in the informal and commercial sectors, the difference in the emission trajectories among different reference cases.

For the emissions of PM_{10}, which are believed relevant for the informal sector, even though they are currently underestimated, we can expect some annual growth in emissions for both the formal commercial and the informal sectors, ranging from about 40 to 80%, by the year 2025, depending on future story. This growth trends derive from a combination of economic and population dynamics.

In all, the current trends in annual emissions of the main pollutants of concern for the informal and commercial sectors, show, in most cases, a tendency to increase. To revert that tendency, additional policies should be implemented. The effectiveness of those policies over time, is measured in reference to the 3X3 emission trends that have resulted from the emissions model.

6.3 Additional Policies

The strategy to design policies for the commercial and informal sectors has been to look at "best practice", looking at solutions that have been implemented in other places, and at the ones that have already been mentioned or proposed for the MCMA, but never fully put in place, and in most cases not even analyzed. I recognize that there are almost no new ideas here, but only an attempt to look at technically feasible solutions in a comprehensive manner, finding a basis of comparison for them all, so that a decision can be made on the basis of their potential for reducing emissions as well as on their economic cost, and political feasibility. The tradeoffs between emission abatement and costs of different policies are assessed, in order to inform the decision making process on the pros and cons of different policy alternatives. Ultimately, there are no direct recommendations for policy implementation here, but only some proposals that decision makers may look at, and consider for implementation, depending on what tradeoffs they would be willing to accept..

In practical terms, I started the definition of additional policies by distinguishing options at a broad level, identifying first the categories of policy actions that could be relevant for tackling commercial and informal atmospheric emissions in the MCMA (See Table 6.6). After that, I identified, under each category, the possible, more specific, policy instruments that could be applied to reduce the emissions of concern. From that step, I moved to look at each particular sub-sector, or each particular activity from which emissions of pollutants are a product, to find where each of the possible policy options would make sense. This definition, on a more case by case approach, derived in a long list of policies, upon which I made a first, very preliminary assessment, to leave in the list of policies to be assessed only those that were technically feasible (See Tables 6.7 and 6.8). The last step in the definition of additional policies, was to combine identified policies, to integrate comprehensive strategies (See Table 6.9), by which I mean bundles of policies which make sense in conjunction. These strategies are the ones whose tradeoffs are to be assessed.

TABLE 6.6
CHOICE OF POLICY ACTIONS AND POLICY INSTRUMENTS

Policy Action	**Policy Instrument**
- Emissions Controls - Change of Technology - Relocation (or Closing) of Facilities or Activities - Energy Efficiency - Improved Production, Distribution and Consumption Practices - Fuel Switching - Fuel Improvements - Input Substitution - Improvement of inputs - Banning of inputs	- Regulations - Incentives - Improved Enforcement - Technological Innovations - Improved Management - Changes in Technology or Processes - Demand Side Management - Training, Education and Awareness

In any of these categories, there a several alternate measures that could achieve substantial reductions in the key pollutants of concern in the commercial and informal sectors. Fuel switching, or fuel substitution, for instance, could have an impact in SO_2 emissions. Phasing out or substituting solvents may reduce NMHC emissions. If the focus is PM_{10}, we could tackle construction activities, or brick kilns. There may be, in fact, several ways to approach the problem of defining specific policies. I chose to do it not by pollutant, but by sector, although at the end of the day, in any case, the policies and strategies that I have selected are assessed according to their impacts in the emissions of the pollutants of concern for the sectors analyzed. Tables 6.7 and 6.8 present a list of the policies that I have considered in the analysis. A more detailed description of these policies is included in Appendix I.

TABLE 6.7
COMMERCIAL POLICY AND TECHNOLOGY OPTIONS

ACTIVITY	OPTION	#	PACE
Solvent Use (several activities)	Reformulation paint products	11	M, F
	Reformulation/substitution of surface cleaners	12	S, M
	Phasing-out of perchloroethylene	13	S, M
	Occupational and personal exposure monitoring	14	
	Environmental education	15	
	Enclosure of facilities (closed-loop)	16	
Combustion (several activities)	Stricter standards for fuels (fuel composition Diesel 200)	21	
	Fuel Improvements (Diesel 30)	22	
	Fuel switching for boilers (to NG)	23	S, M,F
	Fuel switching for boilers (to LPG)	24	S, M,F
	Fuel switching for boilers (to Solar)	25	S, M
	Fuel switching for burners (to NG)	26	S, M,F
	Fuel switching for burners (to LPG)	27	S, M,F
	Emission control equipments	28	
Dry-Cleaners	Closed-loop new machinery	31	M, F
	Upgrading of existing equipment	32	
	Material substitution (to petroleum-based)	33	
	Partial change of process (to wet-cleaning)	34	
Gas Stations	Remaining vapor recovery systems	41	
	Training	42	
Graphic Arts	Increase use of low-solvent inks	51	S, M
Retail/Office Space	Efficient lighting	61	S, M, F
	Building codes	62	
	Efficient equipment	63	S, M, F
Construction	Substitute oil-based by water-based coatings	71	S, M
	Maintenance (emission control) of off-road equipment	72	

S: Slow; M: Moderate; F: Fast.

TABLE 6.8
INFORMAL POLICY AND TECHNOLOGY OPTIONS

ACTIVITY	OPTION	#	PACE
Solvent Use (several activities)	Reformulation of paintings	11	M, F
	Reformulation/substitution of surface cleaners	12	S, M
	Occupational and personal exposure monitoring	14	
	Environmental education	15	
	Enclosure of facilities	16	
Combustion (several activities)	Stricter standards for fuels (fuel composition Diesel 200)	21	
	Fuel Improvements (Diesel 30)	22	
	Fuel switching for boilers (to NG)	23	S, M
	Fuel switching for boilers (to LPG)	24	S, M
	Fuel switching for boilers (to Solar)	25	S, M
	Fuel switching for burners (to NG)	26	S, M
	Fuel switching for burners (to LPG)	27	S, M
	Emission control equipments	28	
	Regulations for combustion and operation	29	
Graphic Arts	Increase use of low-solvent inks	51	S, M
Brick Kilns	Brick kilns – banning of used oils	81	
	Brick kilns – fuel substitution by NG	82	S, M

S: Slow; M: Moderate; F: Fast.

Several of the policies listed in Tables 6.7 and 6.8 are subdivided into two or three policies, depending on the pace at which the policy is implemented. Slow, moderate and fast paces are considered. Some of these policies would impact both the commercial and the informal sectors, and in those cases, the strategy that includes them considers the impact on both. Reformulation of painting, to give one example, if implemented, would impact both the commercial and the informal sectors. Other policies, like fuel switching for boilers, though included in the list of policy options for both sectors, could be limited, in certain policies, to the sources of emissions in only one of those sectors. In any case, when combining options into strategies, I will clarify what options the strategy includes, and for what sector.

The evaluation of the emission reduction potential of each policy and strategy includes their impact on the annual emissions of the six pollutants included in this analysis. More attention, nevertheless, is put on the abatement of the pollutants for which the informal and commercial sectors are significant contributors, which are NMHC, SO_2, and PM_{10}.

Several policies mentioned in Tables 6.7 and 6.8 were not evaluated in the model, since they are more policy instruments than concrete policy measures. Examples of this are education, training, or monitoring, which should be considered as useful tools for abating emissions in the commercial formal and informal sectors, which is the reason why they are mentioned in those tables, but for which the definition of a scope, and even less the assessment of possible impacts in terms of emission reductions, would be almost impossible. Those are very case-specific policies, so, by any means, suggesting a general education program, or a monitoring analysis, would be pointless.

For the assessment of the costs of each policy, the key cost components being considered are technology costs, fuel price differentials, input price differentials, labor (particularly in the cases where training is required), and administrative costs, especially for enforcement. For some policies, some savings may also occur, particularly due to the reduction in input needs, as improved technologies, for instance, are put in place.

Each strategy adds both the emission reduction potential and the cost attached to each of the particular policies that they include. The analysis assumes that both are additive, not recognizing possible synergies, or even perverse effects among policies.

6.4 Emission Impacts of Policies

The estimation of the emission reduction potential of each one of the policies analyzed, for the six pollutants considered in this study, and under each one of the three future stories, is presented in Appendix IV (Tables IV.1 and IV.2). At this point, I will only discuss some of the observed effects of a few policies that may achieve the most substantial and sustained reductions of the most important emissions of concern for the commercial and informal sectors in the MCMA.

For reducing NMHC emissions, for instance, the installation of vapor capture (and solvent recovery) systems in dry-cleaners, printing shops, auto-painting shops, and bakeries, seems to be effective for reducing as much as 30% NMHC emissions from these activities, with a potential to achieve reductions of as much as 75% in NMHC emissions from particular processes, as it also lowers some costs due to reduced solvent consumption. For dry-cleaners, for example, it is a measure already proposed in the Proaire III, but at a limited scale. With this policy, as set by Proaire III, 388 new closed-loop facilities would be considered for the installation of new equipment, out of a possible 2,500 to 3,000 in operation in the MCMA.

The reformulation of products containing solvents appears to be another effective measure to reduce NMHC emissions, since most commercial emissions are due to solvent use. The potential that this policy has to abate NMHC emissions would vary depending on the scope of the policy, and on its pace. The assessment of this policy remains a little uncertain, since some assumptions had to be made to estimate current consumption, mix of inputs and products consumed, their composition, and also, in consequence, the abatement potential of reformulation options, and even their assessment of their technical and economic feasibility.

For the abatement of SO_2 emissions, the most effective policy seems to be the substitution of fuels, both for boilers and burners, in both commercial and informal activities. The switching from gas-oil to LPG seems to be the most cost-effective way of abating SO_2 emissions, although it would imply an increase in NOx and NMHC emissions, whereas, by switching to natural gas, for instance, and even though it is currently considerably more expensive per caloric unit than LPG in the MCMA, we could achieve roughly the same level of reduction of SO_2, reducing the emissions of NOx, though increasing NMHC emissions by even more than when the switch is made to LPG, and also at a significantly higher cost. Again, the decision on what policy to implement would depend on more than the mere comparison of the cost-effectiveness estimates of alternative policies.

If the focus is PM_{10}, some significant reductions in emissions could be achieved at the sub-sector level, for instance for construction and brick production, through the enclosing of facilities, although these reductions in emissions seem of little significance when seen within the whole, formal and informal, commercial sector emissions of PM_{10}, and even less when considering that the sector is a relatively small contributor to the total MCMA emissions of this pollutant. Fuel switching from gas-oil to natural gas or LPG, though intended to reduce SO_2 emissions, may work well at reducing PM_{10} emissions from combustion, achieving in some cases, depending on future story, close to a 30% reduction in aggregated total commercial PM_{10}.

For the reduction of greenhouse gases, and particularly of CO_2, the most effective policies, from those analyzed, are the switching to solar boilers, and the improvements to energy efficiency for buildings and equipment. The switch to solar energy for heating has positive impacts in all pollutants, but really insignificant in any other but CO_2, for which emissions of the commercial sector could be reduced by as much as 18 to 40%, depending on how fast and ambitious a policy to develop solar energy is, and also on future story assumptions. The impact of this policy in the local atmosphere is relatively small, and if what matters is its global impact, then it should probably be compared to other greenhouse gas abating policies.

For the informal sector, besides the options already discussed, an additional particular measure would be fuel switching in brick manufacture, substituting lower quality fuels such as used oils, wood and garbage by cleaner fuels, such as diesel or LPG. The current composition of fuels used is largely unknown, but it was estimated that at least half the amount of PM_{10} emissions from the entire informal sector could be reduced by having brick kilns switch to propane. Besides, even though the emissions from this sub-sector seem relatively small within the overall emissions in the MCMA, they may be very relevant if considering their effect on human exposure.

Several other policies tackling commercial and informal activities, in all, seem to have a very limited potential to achieve reductions in emissions. There is no point of comparison between them and the ones with a larger scope, like those mentioned earlier. The effective, "large" ones should be preferred, of course, but there is still room for the small policies, given the nature of the commercial and informal sectors, largely composed of small units, developing very diverse activities, and scattered all around the MCMA.

6.5 Tradeoff Analysis of Strategies

To begin this section, a clarification may be relevant. As I implied earlier, regardless of how effective a certain policy may look in terms of its potential to abate emissions, but even in terms of its cost, policy makers are the ones who would decide what policies to pursue, depending on the tradeoffs that they would be willing or compelled to take, and taking into account several other factors that would influence policy making at a given time. They should be informed, in any case, on the potential impacts and costs of technically feasible policy options. That is one of the objectives of this study, to process and present information that may serve policy making.

The tradeoff analysis seems to be a useful tool to comply with this task. With it, a lot of information is "translated" into visual stories that can help policy makers perform their jobs. It also serves, at least in this thesis, to summarize the main results of the quantitative analysis of policies.

In the case of the commercial and informal sector analysis, the policies selected were grouped into strategies, as listed in Table 6.9. It is these strategies whose tradeoffs between emission abatement potential and cost are analyzed.

The selection of policies within each strategy follows the logic of combining options that would make sense together. In any case, there is a far larger possible combination of policies, but I believe the ones that I have chosen pretty much compile the most relevant policies analyzed. In any case, in Appendix IV, I present the list of all policies, with their costs and emission reduction achievements, under each future story. If it is preferred, the comparison can also be made at the level of policies.

TABLE 6.9
POLICY AND TECHNOLOGY STRATEGIES

NAME OF STRATEGY	POLICY OPTIONS INCLUDED[1]
INCOM-(FS)-SOLVENT1	11 M
INCOM -(FS)-SOLVENT2	11 F
INCOM -(FS)-SOLVENT3	11F, 12S, 41, 51S
INCOM R-(FS)-SOLVENT4	13S, 41, 51S, 71M
INCOM -(FS)-SOLVENT5	12M, 13S, 31M, 41, 51M
INCOM -(FS)-SOLVENT6	12M, 13M, 31F, 41, 51M, 71S
INCOM -(FS)- COMBUST1	21, 24S, 27S
INCOM -(FS)-COMBUST2	21, 24M, 27M
INCOM -(FS)-COMBUST3	22, 24F, 27F
INCOM -(FS)-COMBUST4	21, 23S, 26S
INCOM -(FS)- COMBUST5	21, 23M, 26M
INCOM -(FS)- COMBUST6	22, 23F, 26F
INCOM -(FS)- COMBUST7	21, 25S, 26M
INCOM -(FS)- COMBUST8	22, 25M, 26F
INFOR-(FS)-COMBUST1	21, 81
INFOR-(FS)-COMBUST2	26S, 82
INFOR-(FS)-COMBUST3	26M, 83
COMER-(FS)-EFFICIE1	61, 62
COMER-(FS)-EFFICIE2	62, 72

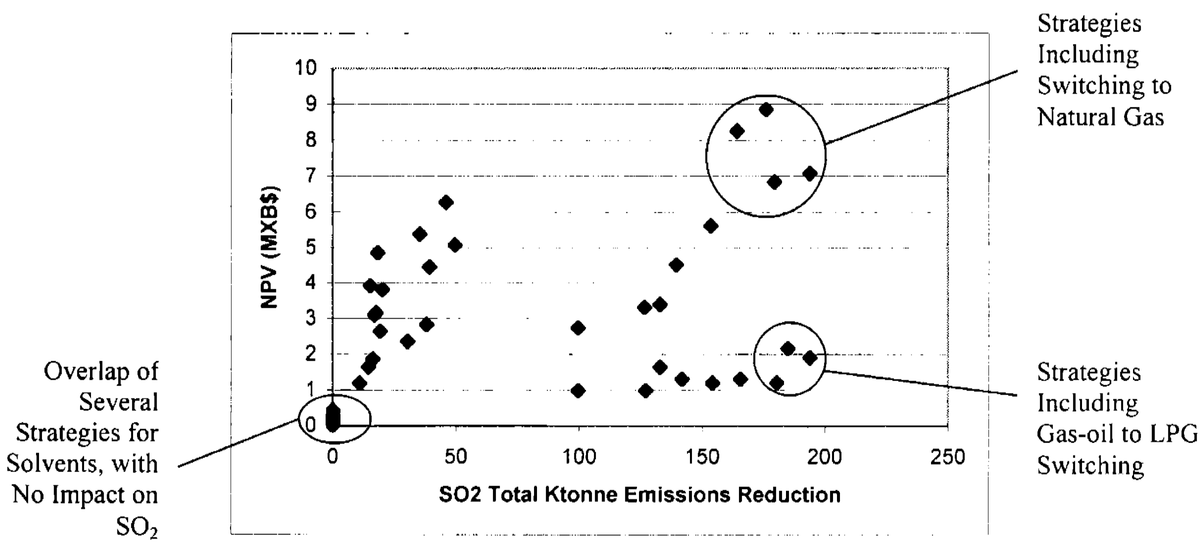
[1] Policy option numbers correspond to list in Tables 6.7 and 6.8

I present tradeoff plots for the three most relevant pollutants for the informal and commercial sectors, which are NMHC, SO_2, and PM_{10} (See Figures 6.3 through 6.6). Each point in these tradeoff plots represents a strategy, and combines its potential reduction of total emission of a given pollutant, over 26 years, with its total cost.

Several policies seem to perform well within specific sub-sectors, achieving significant reductions in emissions. The problem is that, in the tradeoff plots, when seen in the context of the whole sector, or, even worse, in the context of all sources of emissions in MCMA, their overall impact seems small. We should keep in mind that the comparison of policies should not be constrained to the overall analysis of their cost-effectiveness. Other factors are relevant to favor one over the others.

In the tradeoff analysis of SO_2 emissions, the most cost-effective strategies are dominated by a single policy, which is the switching to LPG, especially for boilers that currently use gas-oil. This policy is very effective for reducing SO_2 emissions, although it may produce a small increase in NMHC and NO_X emissions. The cost-effectiveness of this policy, as compared to other fuel switching strategies, is explainable in part by the current relative prices of fuels in the MCMA. Among other reasons to explain this difference, there is also the fact that comparable policies, like the switching from "dirtier" fuels to natural gas, or even more so the switching to solar energy, would require significantly higher capital investments than the switching to LPG. Often, some of these investments should be made even before the change to a new source of energy is implemented, and this turns out to be a further reason in favor of a strategy like the switching to LPG, or any other with small capital requirements. The estimation of NPV tends to value higher those costs or revenues occurring in the first years of a project, and (although it depends on the discount rate used and the life span of a project), to almost nullify in the computation those occurring far in the future.

FIGURE 6.3
TRADEOFFS BETWEEN SO_2 ABATEMENT AND NPV OF STRATEGIES
(ALL STRATEGIES ASSESSED FOR 3 FUTURE STORIES)



Note: Strategies and their performance can be seen in Appendix V.

A reduction of 180 kilotonnes of cumulative emissions of SO_2, which is roughly the maximum achievable with the best strategies analyzed, under the Changing Climates and Growth Unbound future stories, would mean an abatement of approximately 60% over the total 2000-2025 cumulative commercial and informal emissions (See Tables III.2 and III.8, in Appendix III).

As mentioned earlier, and just to summarize, the most effective way to reduce SO_2 emissions seems to be via the substitution of gas-oil used in boilers by a cleaner fuel. If it were substituted by diesel, SO_2 emissions from the commercial sector would be reduced by as much as 65% (3.5 kilotonnes) annually, with an annual cost, due to price differentials, of roughly MX$ 388 million, which would imply more than doubling the fuel cost for those activities using gas-oil, not considering distribution infrastructure costs, and assuming negligible technology costs for adapting to a new fuel. By substituting LPG with solar thermal energy for commercial water heating in hospitals, hotels and public baths, which is another possible measure, NOx and CO emissions from the commercial sector could be reduced by as much as 20%, with a cost of roughly MX$ 265 million.

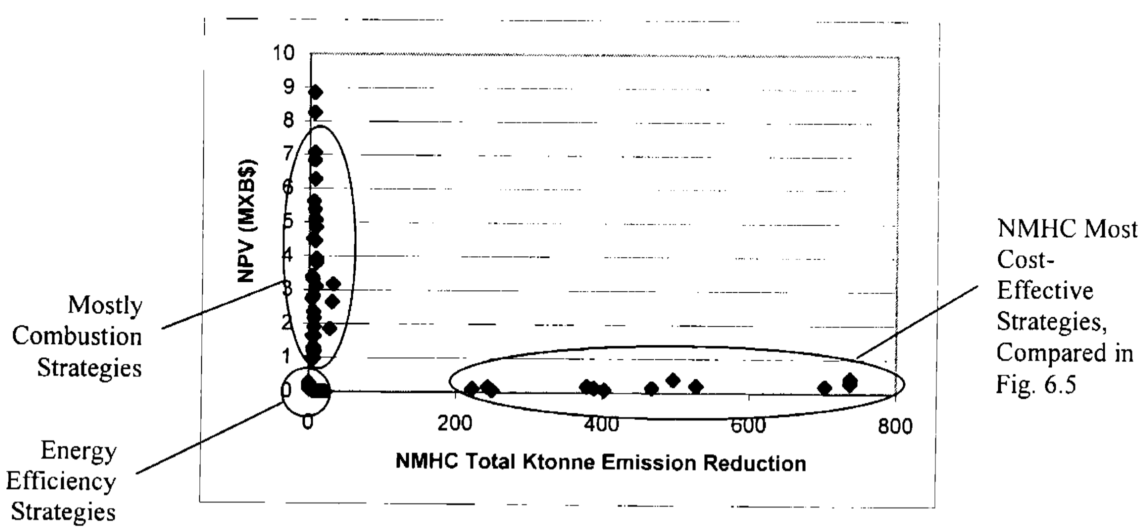
In general, I observed that some policies looked well in regard to the reduction of a certain key pollutant within their own specific sub-sector, and may have even been relatively cost-effective, although being relatively small in terms of their absolute emission abatement potential. Because of that, they do seem to be not as relevant when assessed in the context of the whole commercial sector emissions, not to mention the context of total MCMA emissions. It is the case, for instance, for the policy to reformulate paintings, or for the one to substitute inputs, like perchloroethylene, in some particular activities.

There is also the case of policies that would have other purposes than the reduction of commercial and informal emissions, and whose assessment would perhaps be much more positive if done in the context of the whole MCMA. That is, for instance, the case of fuel reformulation, to reduce the sulfur content of diesel. This measure is probably as important for the transportation sector as it is for industry and commercial activities. The analysis that I present here limits the scope of proposed policies to their effect and cost for the commercial and informal sectors, although recognizing that several of the policies proposed would have effects in other sectors.

On the issue of how the performance of a strategy is affected by future story, we can see in Appendix V, with more detail than in the tradeoff graphs, how variable is the emission reduction achieved by any policy depending on future story. In general, it is observed that strategies that perform well for NMHC, tend to have their best performance under the Divided City future story, and their worst in the case of Growth Unbound. On the other hand, combustion strategies, which would reduce both SO_2 and PM_{10} emissions, would perform better, although not significantly, under Changing Climates conditions.

Going back to the issue of the specific tradeoffs for policy strategies, looking at Figures 6.4 and 6.5 we can see, in the first one, how all strategies would perform in terms of their costs and abatement potential for NMHC, having the second one, in which only the best strategies are included, a clearer comparison of the most cost effective strategies.

FIGURE 6.4
TRADEOFFS BETWEEN NMHC ABATEMENT AND NPV OF STRATEGIES (ALL STRATEGIES ASSESSED FOR 3 FUTURE STORIES)

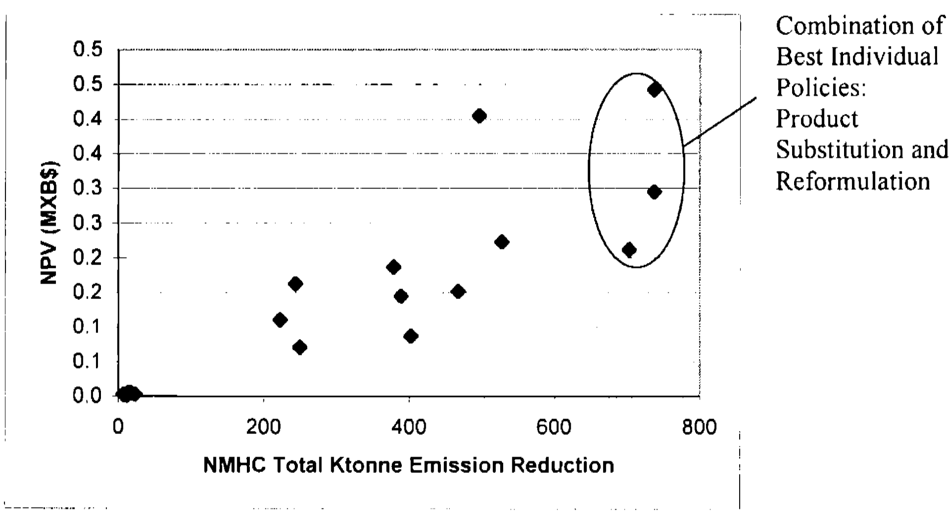


Note: Strategies and their performance can be seen in Appendix V.

We can see, in Figure 6.4, how the NPV of the cost of the most effective strategies to reduce NMHC, is relatively much smaller than that that of most combustion strategies. We can also see there, and in Figure 6.5, that the NPV of the costs of the most effective strategies for NMHC abatement, is also not significantly different among strategies, although their potential for reducing emissions, on the other hand, is.

The most cost-effective strategies for NMHC are not dominated by a single policy, but result from a combination of the "best" ones. In general, the substitution of inputs containing solvents, by others without them, seems to be the most effective way of reducing the emissions of this pollutant. It is the case for paint, and also for cleaners and de-greasers. The installation of new machinery, capable of "capturing" and even reusing some solvents, may be another effective measure, although some implementation issues may arise, as the costs of this policy, though not high overall, would probably be borne by the owners of the relatively small establishments where those emissions occur.

FIGURE 6.5
TRADEOFFS BETWEEN NMHC ABATEMENT AND NPV OF STRATEGIES (BEST STRATEGIES ASSESSED FOR 3 FUTURE STORIES)



Note: Strategies and their performance can be seen in Appendix V

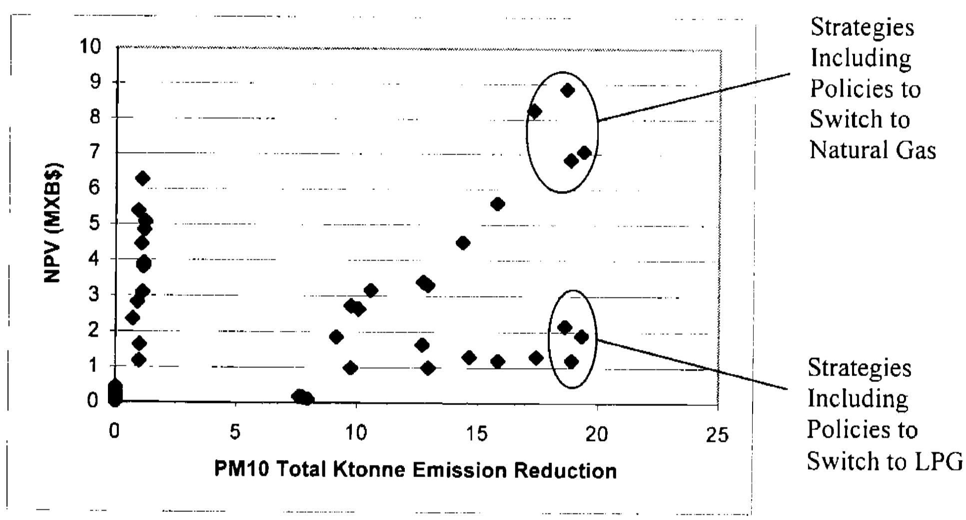
With the implementation of the most cost-effective strategies for NMHC, total cumulative emissions could be reduced by as much as nearly 750 kilotonnes, which would represent roughly about 15 % of total emissions from the formal and informal sectors (See Tables III.1 and III.7 in Appendix III). This estimation of potential abatement is very conservative, in part because of the uncertainty about the mix of solvents in use in the MCMA, and about their composition and polluting potential. Besides, in this case, policies were analyzed on a sub-sector basis, and would in fact be effective in substantially reducing the emissions of those sub-sectors they are applied to. The problem is that the estimation of total NMHC emissions, based on the MCMA emissions inventory methodology and emission factors, is largely driven by a category in the estimation of emissions called "solvent consumption", without much clarity about what activities or products it comprises.

One issue that should be addressed in more depth within the framework of the tradeoff analysis is that of who would be paying the costs of what seem to be the most cost-effective policies. Regarding costs, in all the modeled reference cases, there are only two measures that had a significant cost for the involved parties: one was the installation of vapor recovery systems in gas stations, and the other the proposed modernization of dry-cleaners, which falls under the category discussed earlier. The first one was funded with resources from the Environmental Trust-fund, through a revolving fund, that made it easy for the owners of gas stations to pay back the cost of implementation. This gives a lesson on how important it is to create funding schemes that help the implementation of a measure, no matter how much it costs or who has to pay for it. For the second measure, it is not clear yet how it will be financed, if at all, and the owners of dry-cleaners do not appear willing to assume its whole cost, at least not without the application of favorable funding schemes and incentives. For the additional policies proposed here, a scheme of revolving funds would be appropriate to begin the implementation of several strategies, being also applicable to the many cases of policies in which, additionally, some savings in the use of inputs and resources would result from policy implementation, besides the obvious environmental benefits.

Policies like energy efficiency, or others with a positive global impact, could also benefit from some funding mechanisms already in place in MCMA, that were created with international resources, and which are available to private and public parties.

The last pollutant to look at, before closing this section of the analysis, is PM_{10}. It is a pollutant of relatively little importance for the commercial sector, but believed to be relevant for the informal one. In Figure 6.6, we can see the tradeoff for all analyzed strategies, looking at their potential to reduce PM_{10} emissions.

FIGURE 6.6
TRADEOFFS BETWEEN PM_{10} ABATEMENT AND NPV OF STRATEGIES (ALL STRATEGIES ASSESSED FOR 3 FUTURE STORIES)



Note: Strategies and their performance can be seen in Appendix V.

From the analyzed strategies, the most effective ones in term of their potential PM_{10} abatement are those that include a policy to switch, for combustion activities, from gas-oil to gaseous fuels, either LPG or NG. The differential in prices of these two, as well as the difference in infrastructure development needs, already discussed, currently make the move to LPG more cost-effective.

In all, even the greatest reductions in PM_{10} in the commercial and informal emissions would probably look insignificant in the context of the whole MCMA, where they are relatively small contributors of this pollutant. In any case, a reduction of roughly 20 ktonnes of PM_{10} total cumulative emissions, which appears feasible in the context of the analysis, would mean a reduction of approximately 25% in total emissions (see Tables III.3 and III. 9, in Appendix III).

All these estimations, and the analysis that I have done of them, are constrained by a series of assumptions, in which the whole scenario analysis within the Mexico City Program, in general, and this specific piece of it, in particular, rely. I have, throughout this thesis, mentioned several of these assumptions, and many of the conditions that the model is sensitive to. I will close this chapter making a summary of those key sensitivities.

6.6 Key Sensitivities

For each relevant sub-sector, depending on a series of conditions and uncertainties, there are a series of external considerations to make for assessing the likelihood of success of a given strategy. The model is very sensitive to implementation issues, and, although it includes mostly policies that I am convinced are feasible, several of the factors that may affect their real implementation are unknown, or difficult to predict. In any case, more than looking at what is applicable in the current context, we should perhaps try to improve it. I believe that the policy process should not only adapt policies to the current circumstances of the MCMA, but, if possible, improve those circumstances, so that policies, and the well-being of the society, which, for that matter, is their ultimate goal, are attainable.

It has been once and again discussed within the Mexico City Program, how the lack of coordination and collaboration among different actors, that affect or are affected by environmental policy, is adverse for finding successful integrated solutions.

Environmental authorities, nevertheless, have the mandate to look for those solutions, and have to do whatever they can to implement them. Many of the proposals that I have analyzed would require certain integration among different sectors, as those sectors would be crucial for their implementation. It is mainly the case for the energy and the transportation sectors. The implementation of policies is sensitive to stakeholder collaboration, and, in general, the political feasibility of policies is a factor that would influence the viability of proposed strategies.

Another sensitivity related to implementation lies on assuring funding mechanisms for it. Currently, the cost of some technology replacements seem relatively high for individual establishments, so a challenge lies in designing feasible financing mechanisms.

In more concrete matters, the model is sensitive to its underlying assumptions. The costs and emission reductions attached to each policy, for instance, are assumed to be additive. In reality, there may be some synergies, not only among the sub-sectors included in the commercial and informal model, but also with other sectors within the MCMA. In some particular cases, there may be also some perverse effects of combining options. For example, by reducing the sulfur content of fuels, the effectiveness of a control equipment, measured in tonnes of sulfur "trapped", may be reduced. In any case, the effect of combining policies, in one way or another, was not taken into account in the model.

The costs of inputs, capital investments, and the administrative costs related to each policy are an important factor in the estimation of policy cost-effectiveness. If they, or the assumptions used to estimate them, change, the model estimations may change as well.

7. CONCLUSION

There are several lessons derived from analyzing and modeling the commercial and informal emissions. The first one relates to the importance of understanding the composition and relative importance of the sectors being analyzed, and, on a related note, of not getting "paralyzed" by lack of complete information. It has not always been easy to get data, especially for the informal sector, so qualitative information, the review of literature, and even some sense of how these sector works, have been fundamental for building what seem to be realistic assumptions. The lesson has been, then, to use whatever information is available to ultimately accomplish the goal of analyzing and proposing policies.

Given the complexity of the atmospheric pollution problem in MCMA, it requires a combination of many policies to be tackled. It is important to create the conditions for these policies to succeed: develop the institutions, adapt the legislation, involve all interested parties, educate environmental officials, and ultimately, and most importantly, have the determination to find permanent solutions. Only then technological improvements would be applicable with any expectation of success.

All those changes would make us move towards a better situation. Some of them are in the process, but they require a long time to be completed. In the meanwhile, anyway, policies have to be developed. The atmospheric pollution problem in the MCMA requires immediate solutions. Regulations, direct public and private expenditure, standards, they are all still much needed, but so are alternative policy measures, like improved technologies, management options, market-based instruments, together with education, and capacity development.

To the complexity of the issue at hand, we should add several political and social factors. It was the case that some policies that have been suggested, especially for the informal sector, were discarded, not because of their technical infeasibility, but because they seem, at this particular moment, impossible in the political context of the MCMA. Besides, their impact in emissions, if measurable, would be very difficult to predict. The idea, for instance, of extending governmental regulation, to improve law enforcement and to "legalize" the informal sector, is one that comes to mind almost immediately when discussing the negative impacts of the informal sector in the economy and society. That would be the perfect solution to put an end to all the negative consequences of the informal economy. To totally finish it, formalizing the activities within the informal economy that could resist "formalization", and still survive; and to "disappear" the rest.

Sounds simple, but there are, nevertheless, several factors to consider, some of which have been mentioned already. The social and political elements of the problem are important in the discussion. Certainly, even extending the scope of regulation could also have negative consequences, if it is not accompanied by improvements in enforcement. In any case, the complexity of the informal sector in Mexico City makes it almost impossible nowadays to even think about "terminating" it. It is an important source of employment, a contributor to economic growth, and an instrument of social justice.

Being more realistic, anyway, it makes more sense, throughout this analysis, to try to find small solutions applicable to certain specific sub-sectors within the informal sector, which may be contributing relatively more to atmospheric pollution. It was the same case for formal commercial activities. In general, it is the sum of several policies that achieves the most substantial and sustained reductions in pollution.

The model and the analysis it relies upon, which were presented in this thesis, have several limitations, many of which I mentioned when it was considered relevant. A general limitation of the tradeoff analysis, as performed in this thesis, is that it makes it possible to compare the costs of policies to their emission reduction potential, but for only one pollutant at a time. It is always possible, of course, to look simultaneously at different tradeoff plots and tables, but the analysis gets complicated when we have, as we did here, almost twenty strategies, composed of combinations among more than fifty policies, multiplied by three future stories, and for six different pollutants.

That is but one of the challenges of a study like this, in order to represent its inherent complexities. As a final remark, I would just say that the emission model, the design of policies and strategies, and the estimation of their costs, could be forever refined. The fact is that, even with their inherent uncertainties, these estimations can help improve policy decisions, and that is what this type of analysis should aim at. This one, at least, did.

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APPENDIX I
DESCRIPTION OF MODELED POLICIES

11. Reformulation of Paintings

This policy applies to both the commercial and informal sectors. Emission reductions and costs are assessed for two formal commercial activities, auto painting and transit-related painting, and for one informal activity, which is informal house-painting. The moderate policy assumes a 20% reduction in the solvent content of paints, achieved by 2010, and the fast one a reduction of 30%, by the same year.

12. Reformulation/substitution of surface cleaners

This policy applies to both the commercial and informal sectors. Emission reductions and costs are assessed for formal commercial surface cleaning, and for one informal activity, which is informal auto-repairs. The moderate policy assumes a 20% reduction in the solvent content of paints, achieved by 2010, and the moderate one a reduction of 30%, by the same year.

13. Phasing-out of perchloroethylene

It affects only the formal commercial sector, as it is assumed to affect only dry-cleaner emissions . For slow implementation, it is assumed that the phasing-out occurs gradually from 2010 to 2015. For fast implementation, it is assumed that phasing-out occurs in 2010, at once.

21. Fuel reformulation – Diesel 200

It affects both the formal and informal commercial sectors. It is assumed to reflect only in SO_2 emissions, in the same proportion of the reduction in sulfur content, which currently is about 500 ppm. It is assumed that it would have full implementation from 2006 on.

22. Fuel reformulation – Diesel 30

It affects both the formal and informal commercial sectors. It is assumed to reflect only in SO_2 emissions, in the same proportion of the reduction in sulfur content, which currently is about 500 ppm. It is assumed that it would have full implementation from 2010 on.

23. Fuel switching for boilers (GO to NG)

It affects both the formal and informal commercial sectors, though for the formal sector it could occur at a slow, moderate, and fast pace, whereas for the informal sector it is modeled only for slow and moderate implementation. Slow implementation implies a shift between 1 and 2% per year, moderate implementation, 3 to 4%, and fast implementation, 5 to 6%, varying according to future story.

24. Fuel switching for boilers (GO to LPG)

Same as 23

25. Fuel switching for boilers (LPG to Solar)

It affects both the formal and informal commercial sectors, in both cases considering a slow and a moderate implementation. Slow implementation implies a shift between 1 and 2% from LPG to solar per year, and moderate implementation, 3 to 4%, varying according to future story.

26. Fuel switching for burners (Diesel to NG)
Same as 23

27. Fuel switching for burners (Diesel to LPG)
Same as 23

31. Closed-loop new machinery for dry cleaners
It affects only formal emissions, as it applies, in the model, to dry-cleaners only. For the modeling, it was assumed that the modernization of dry-cleaners would be made, in the moderate case, in 20% more establishments than in the Ideal Proaire case, and for the fast implementation option, in 40% more.

41. Remaining vapor recovery systems for gas stations
It applies to the formal sector exclusively. It implies an additional 20% reduction in vapor recovery from gas stations, as new recovery systems are implemented, and existing ones are maintained.

51. Increased use of low-solvent inks
It applies for both formal and informal print-shops. The model assumes a 20% substitution of inks in the slow implementation pace, and 40% in the moderate one.

61. Efficient lighting
It affects the formal sector only. Gradual implementation from 2010, would imply reductions in electricity consumption of as much as 20%. The only pollutant modeled was CO_2.

62. Efficient equipment
It affects the formal sector only. Gradual implementation from 2010, would imply reductions in electricity consumption of as much as 30%. The only pollutant modeled was CO_2.

71. Substitute oil-based by water-based coatings
It affects only the formal sector, as it applies exclusively to architectural and industrial surface coatings. Slow implementation assumes a 20% substitution by 2010, and moderate implementation a substitution of 30%, by the same year.

72. Maintenance of off-road construction equipment
It affects only the formal sector, as it applies exclusively to the construction sub-sector. Gradual implementation from 2010, would imply reductions in PM_{10} emissions of as much as 20%.

81. Brick kilns – banning used oils
This measure affects only the informal sector. It is assumed in the model that no used oil consumption would occur by 2005, and that it would be substituted by wood.

82. Brick kilns – fuel substitution by NG

This measure affects only the informal sector It is assumed in the model that natural gas consumption in the sub-sector would satisfy 10% of the demand for fuels from brick production.

83. Brick kilns – fuel substitution by LPG

This measure affects only the informal sector. It is assumed in the model that LPG consumption in the sub-sector would satisfy 10% of the demand for fuels from brick production.

APPENDIX II
SUMMARY OF EMISSION FACTORS

TABLE II.1
BASELINE EMISSION FACTORS USED IN THE ANALISIS OF THE COMMERCIAL SECTOR

SUB-SECTOR	PM10	SO_2	CO	NOx	NMHC	CO_2
Solvent consumption	-	-	-	-	4.580 kg/hab/yr	-
Surface cleaning	-	-	-	-	1.802 kg/hab/yr	-
Surface covering	-	-	-	-	2.640 kg/hab/yr	-
Dry-cleaning	-	-	-	-	0.601 kg/hab/yr	-
Graphic arts	-	-	-	-	0.400 kg/hab/yr	-
Bakeries	-	-	-	-	0.151 kg/hab/yr	-
Transit-related painting	-	-	-	-	0.048 kg/hab/yr	-
Auto painting	-	-	-	-	0.130 kg/hab/yr	-
Hospitals (sterilization and combustion)	0.005 kg/hab/yr	0.001 kg/hab/yr	0.001 kg/hab/yr	0.005 kg/hab/yr	0.002 kg/hab/yr	
Combustion						
LPG	0.054 kg/m^3	0.003 kg/m^3	0.240 kg/m^3	1.740 kg/m^3	0.064 kg/m^3	1530.000 kg/m^3
NG	0.072 kg/m^3	0.010 kg/m^3	0.330 kg/m^3	1.600 kg/m^3	0.128 kg/m^3	1.851 kg/m^3
Gas-oil	4.880 kg/m^3	36.000 kg/m^3	0.600 kg/m^3	2.400 kg/m^3	0.067 kg/m^3	2.830 kg/m^3
Diesel	0.120 kg/m^3	8.520 kg/m^3	0.600 kg/m^3	2.400 kg/m^3	3.240 kg/m^3	3090.000 kg/m^3
Gasoline distribution and storage	-	-	-	-	0.009 kg/lt/yr	-
Asphalt paving	-	-	-	-	0.006 kg/hab/yr	-
Construction	0.071 kg/hab/yr	-	-	-	-	-
Office buildings	-	-	-	-	-	0.953 kg/kwh

Source: EPA AP42. Manual de Inventarios de Emisiones para Mexico. IPCC.

Note: In several cases, due to technology change assumptions, emission factors were assumed to change over time.

TABLE II.2
BASELINE EMISSION FACTORS USED IN THE ANALISIS OF THE INFORMAL SECTOR

SUB-SECTOR	PM10	SO_2	CO	NOx	NMHC	CO_2
Informal graphic arts	-	-	-	-	0.088 kg/hab/yr	-
Informal auto-repair shops	-	-	-	-	0.396 kg/hab/yr	-
Brick manufacture						
Wood	1.425 kg/t brick	0.335 kg/t brick	8.900 kg/t brick	0.090 kg/t brick	0.900 kg/t brick	245.000 kg/t brick
Used oils	0.170 kg/t brick	0.005 kg/t brick	2.200 kg/t brick	0.040 kg/t brick	4.800 kg/t brick	7.531 kg/t brick
Informal house repair/painting	-	-	-	-	0.581 kg/hab/yr	-
Informal combustion						
LPG	0.054 kg/m^3	0.003 kg/m^3	0.240 kg/m^3	1.740 kg/m^3	0.064 kg/m^3	1530.000 kg/m^3
NG	0.072 kg/m^3	0.010 kg/m^3	0.330 kg/m^3	1.600 kg/m^3	0.128 kg/m^3	1.851 kg/m^3
Gas-oil	4.880 kg/m^3	36.000 kg/m^3	0.600 kg/m^3	2.400 kg/m^3	0.067 kg/m^3	2.830 kg/m^3
Diesel	0.120 kg/m^3	8.520 kg/m^3	0.600 kg/m^3	2.400 kg/m^3	3.240 kg/m^3	3090.000 kg/m^3

Sources: EPA AP42. Manual de Inventarios de Emisiones para Mexico. IPCC.

Note: In several cases, due to technology change assumptions, emission factors were assumed to change over time.

APPENDIX III
3X3 EMISSION TABLES 2000-2025

TABLE III.1
3X3 COMMERCIAL NMHC EMISSIONS
2000-2025

	Ktonnes / Year								
	DC-B	DC-I	DC-M	CC-B	CC-I	CC-M	GU-B	GU-I	GU-M
2000	207	207	207	207	207	207	207	207	207
2001	193	193	193	191	191	191	192	192	192
2002	198	198	198	196	196	196	197	197	197
2003	204	204	204	204	204	204	204	204	204
2004	206	205	206	210	209	210	208	207	207
2005	210	209	209	213	212	212	211	210	210
2006	215	213	214	213	211	212	214	212	213
2007	212	209	210	214	211	212	217	214	215
2008	223	219	220	219	216	217	222	219	220
2009	220	216	217	224	220	221	221	217	218
2010	230	202	216	225	197	211	222	195	208
2011	227	199	213	226	197	212	228	200	214
2012	233	204	219	231	203	217	235	206	220
2013	234	205	218	236	207	221	236	207	221
2014	243	213	227	242	212	226	233	204	218
2015	245	206	217	239	202	212	234	197	207
2016	250	211	222	249	210	221	239	201	211
2017	255	216	227	249	210	221	241	203	214
2018	253	214	225	249	210	221	247	208	219
2019	259	219	231	254	214	225	244	205	216
2020	259	218	230	256	216	227	247	208	219
2021	271	229	241	258	217	229	249	209	221
2022	272	230	242	262	221	233	250	210	221
2023	276	233	246	260	219	231	253	213	224
2024	275	232	245	266	225	237	257	216	228
2025	285	241	254	270	228	241	256	215	227
TOTAL	**6,156**	**5,545**	**5,751**	**6,066**	**5,466**	**5,668**	**5,967**	**5,376**	**5,573**

DC: Divided City; CC: Changing Climates; GU: Growth Unbound;
B: Base Case; I: Ideal Case; M: MIT Case

TABLE III.2
3X3 COMMERCIAL SO_2 EMISSIONS
2000-2025

	Tonnes / year								
Year	DC-B	DC-I	DC-M	CC-B	CC-I	CC-M	GU-B	GU-I	GU-M
2000	6,278	6,278	6,278	6,278	6,278	6,278	6,278	6,278	6,278
2001	6,261	6,261	6,261	6,286	6,286	6,286	6,226	6,226	6,226
2002	6,319	6,319	6,319	6,370	6,370	6,370	6,249	6,249	6,249
2003	6,475	6,475	6,475	6,627	6,627	6,627	6,413	6,413	6,413
2004	6,608	6,608	6,608	6,986	6,985	6,985	6,621	6,620	6,620
2005	6,793	6,793	6,793	7,383	7,382	7,382	6,857	6,856	6,856
2006	7,036	7,036	7,036	7,682	7,682	7,682	7,123	7,123	7,123
2007	7,073	7,074	7,074	7,890	7,889	7,889	7,398	7,397	7,397
2008	7,367	7,366	7,366	8,206	8,205	8,205	7,777	7,776	7,776
2009	7,465	7,465	7,465	8,602	8,602	8,602	8,038	8,037	8,037
2010	7,786	7,398	7,398	8,913	8,468	8,468	8,230	7,819	7,819
2011	7,888	7,495	7,495	9,150	8,694	8,694	8,595	8,166	8,166
2012	8,091	7,688	7,688	9,517	9,043	9,043	9,137	8,680	8,680
2013	8,180	7,772	7,772	9,972	9,474	9,474	9,669	9,185	9,185
2014	8,480	8,057	8,057	10,568	10,040	10,040	9,996	9,497	9,497
2015	8,710	7,842	7,842	10,921	9,831	9,831	10,282	9,256	9,256
2016	9,017	8,118	8,118	11,621	10,461	10,461	10,695	9,628	9,628
2017	9,368	8,434	8,434	12,197	10,980	10,980	11,151	10,038	10,038
2018	9,504	8,556	8,556	12,618	11,359	11,359	11,835	10,653	10,653
2019	9,724	8,754	8,754	13,178	11,863	11,863	12,297	11,069	11,069
2020	9,775	8,314	8,314	13,728	11,673	11,673	12,866	10,940	10,940
2021	10,139	8,623	8,623	14,222	12,093	12,093	13,474	11,456	11,456
2022	10,400	8,844	8,844	14,841	12,619	12,619	14,084	11,975	11,975
2023	10,635	9,045	9,045	15,220	12,942	12,942	14,830	12,609	12,609
2024	10,683	9,086	9,086	15,824	13,455	13,455	15,783	13,419	13,419
2025	10,935	9,300	9,300	16,529	14,054	14,054	16,605	14,117	14,117
TOTAL	**216,992**	**201,000**	**201,000**	**271,331**	**249,356**	**249,356**	**258,509**	**237,483**	**237,483**

DC: Divided City; CC: Changing Climates; GU: Growth Unbound;
B: Base Case; I: Ideal Case; M: MIT Case

TABLE III.3
3X3 COMMERCIAL PM_{10} EMISSIONS
2000-2025

	Tonnes / year								
Year	DC-B	DC-I	DC-M	CC-B	CC-I	CC-M	GU-B	GU-I	GU-M
2000	2,233	2,233	2,233	2,233	2,233	2,233	2,233	2,233	2,233
2001	2,133	2,133	2,133	2,132	2,132	2,132	2,143	2,143	2,143
2002	2,176	2,176	2,176	2,178	2,178	2,178	2,180	2,180	2,180
2003	2,236	2,236	2,236	2,267	2,267	2,267	2,251	2,251	2,251
2004	2,269	2,269	2,269	2,354	2,354	2,354	2,306	2,306	2,306
2005	2,325	2,324	2,324	2,432	2,432	2,432	2,360	2,360	2,360
2006	2,389	2,389	2,389	2,471	2,471	2,471	2,419	2,418	2,418
2007	2,373	2,373	2,373	2,500	2,500	2,500	2,472	2,472	2,472
2008	2,485	2,484	2,484	2,581	2,581	2,581	2,559	2,558	2,558
2009	2,480	2,480	2,480	2,667	2,667	2,667	2,585	2,585	2,585
2010	2,588	2,383	2,459	2,712	2,503	2,577	2,612	2,408	2,482
2011	2,580	2,377	2,452	2,749	2,538	2,612	2,706	2,495	2,571
2012	2,649	2,441	2,517	2,839	2,621	2,697	2,822	2,603	2,681
2013	2,661	2,452	2,529	2,932	2,708	2,785	2,901	2,677	2,756
2014	2,765	2,548	2,627	3,050	2,819	2,898	2,921	2,699	2,776
2015	2,805	2,446	2,526	3,078	2,693	2,771	2,964	2,591	2,668
2016	2,885	2,515	2,597	3,240	2,835	2,916	3,048	2,666	2,744
2017	2,963	2,585	2,668	3,315	2,903	2,984	3,125	2,734	2,813
2018	2,967	2,589	2,671	3,367	2,950	3,031	3,256	2,850	2,931
2019	3,036	2,649	2,734	3,477	3,047	3,130	3,293	2,885	2,964
2020	3,039	2,585	2,669	3,565	3,032	3,115	3,389	2,882	2,963
2021	3,169	2,696	2,784	3,641	3,096	3,180	3,480	2,960	3,040
2022	3,212	2,732	2,821	3,755	3,193	3,278	3,567	3,033	3,114
2023	3,266	2,778	2,868	3,793	3,226	3,311	3,685	3,134	3,215
2024	3,268	2,780	2,869	3,915	3,330	3,416	3,837	3,263	3,345
2025	3,365	2,862	2,955	4,036	3,432	3,520	3,933	3,344	3,426
TOTAL	**70,317**	**64,514**	**65,841**	**77,279**	**70,739**	**72,036**	**75,046**	**68,728**	**69,995**

DC: Divided City; CC: Changing Climates; GU: Growth Unbound;
B: Base Case; I: Ideal Case; M: MIT Case

TABLE III.4
3X3 COMMERCIAL NOx EMISSIONS
2000-2025

	Tonnes / year								
Year	DC-B	DC-I	DC-M	CC-B	CC-I	CC-M	GU-B	GU-I	GU-M
2000	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387
2001	3,379	3,379	3,379	3,392	3,392	3,392	3,360	3,360	3,360
2002	3,411	3,411	3,411	3,438	3,438	3,438	3,374	3,374	3,374
2003	3,494	3,494	3,494	3,574	3,574	3,574	3,461	3,461	3,461
2004	3,566	3,565	4,065	3,767	3,765	3,765	3,573	3,572	3,572
2005	3,666	3,664	4,659	3,978	3,976	3,976	3,699	3,697	3,697
2006	3,796	3,794	5,279	4,137	4,135	4,135	3,841	3,839	3,839
2007	3,814	3,815	5,785	4,246	4,246	4,246	3,987	3,985	3,985
2008	3,973	3,971	6,421	4,415	4,414	4,414	4,190	4,186	4,186
2009	4,024	4,024	6,950	4,626	4,624	4,624	4,327	4,325	4,325
2010	4,198	3,990	7,386	4,791	4,555	4,555	4,428	4,210	4,210
2011	4,250	4,042	7,905	4,916	4,675	4,675	4,624	4,394	4,394
2012	4,360	4,145	8,470	5,112	4,860	4,860	4,912	4,667	4,667
2013	4,406	4,191	8,972	5,354	5,089	5,089	5,193	4,934	4,934
2014	4,569	4,343	9,576	5,671	5,389	5,389	5,365	5,099	5,099
2015	4,690	4,230	9,911	5,856	5,280	5,280	5,517	4,973	4,973
2016	4,855	4,378	9,945	6,230	5,614	5,614	5,736	5,169	5,169
2017	5,042	4,546	10,002	6,534	5,889	5,889	5,978	5,387	5,387
2018	5,113	4,612	9,959	6,757	6,090	6,090	6,341	5,712	5,712
2019	5,231	4,718	9,958	7,054	6,357	6,357	6,584	5,932	5,932
2020	5,258	4,486	9,621	7,346	6,258	6,258	6,886	5,864	5,864
2021	5,455	4,651	9,683	7,607	6,481	6,481	7,207	6,137	6,137
2022	5,593	4,770	9,701	7,936	6,759	6,759	7,530	6,412	6,412
2023	5,718	4,877	9,710	8,135	6,931	6,931	7,925	6,747	6,747
2024	5,743	4,900	9,637	8,457	7,203	7,203	8,430	7,175	7,175
2025	5,880	5,015	9,656	8,830	7,520	7,520	8,863	7,544	7,544
TOTAL	**116,872**	**108,398**	**196,922**	**145,547**	**133,898**	**133,898**	**138,719**	**127,544**	**127,544**

DC: Divided City; CC: Changing Climates; GU: Growth Unbound;
B: Base Case; I: Ideal Case; M: MIT Case

TABLE III.5
3X3 COMMERCIAL CO EMISSIONS
2000-2025

	Tonnes / year								
Year	DC-B	DC-I	DC-M	CC-B	CC-I	CC-M	GU-B	GU-I	GU-M
2000	644	644	644	644	644	644	644	644	644
2001	643	643	643	646	646	646	640	640	640
2002	649	649	649	654	654	654	642	642	642
2003	665	665	665	680	680	680	659	659	659
2004	679	678	678	717	716	716	680	680	680
2005	698	697	697	757	756	756	704	703	703
2006	722	722	722	786	786	786	731	730	730
2007	726	726	726	807	807	807	758	758	758
2008	756	755	755	839	839	839	797	796	796
2009	766	765	765	879	879	879	823	822	822
2010	798	759	759	910	866	866	842	800	800
2011	808	769	769	934	888	888	879	835	835
2012	829	789	789	971	923	923	933	887	887
2013	838	797	797	1,017	967	967	986	937	937
2014	869	826	826	1,077	1,023	1,023	1,019	968	968
2015	892	805	805	1,111	1,003	1,003	1,047	944	944
2016	923	833	833	1,182	1,066	1,066	1,089	982	982
2017	958	865	865	1,239	1,118	1,118	1,134	1,023	1,023
2018	972	877	877	1,281	1,156	1,156	1,203	1,084	1,084
2019	994	897	897	1,338	1,206	1,206	1,249	1,125	1,125
2020	999	854	854	1,393	1,187	1,187	1,306	1,113	1,113
2021	1,037	885	885	1,442	1,229	1,229	1,366	1,164	1,164
2022	1,063	907	907	1,504	1,282	1,282	1,427	1,216	1,216
2023	1,086	928	928	1,541	1,314	1,314	1,502	1,279	1,279
2024	1,091	932	932	1,602	1,366	1,366	1,597	1,360	1,360
2025	1,117	954	954	1,673	1,426	1,426	1,678	1,429	1,429
TOTAL	**22,223**	**20,624**	**20,624**	**27,624**	**25,425**	**25,425**	**26,333**	**24,221**	**24,221**

DC: Divided City; CC: Changing Climates; GU: Growth Unbound;
B: Base Case; I: Ideal Case; M: MIT Case

TABLE III.6
3X3 COMMERCIAL CO_2 EMISSIONS
2000-2025

	Ktonnes/year								
Year	DC-B	DC-I	DC-M	CC-B	CC-I	CC-M	GU-B	GU-I	GU-M
2000	1,888	1,888	1,888	1,888	1,888	1,888	1,888	1,888	1,888
2001	1,881	1,881	1,881	1,890	1,890	1,890	1,873	1,873	1,873
2002	1,898	1,898	1,898	1,916	1,916	1,916	1,881	1,881	1,881
2003	1,944	1,944	1,944	1,993	1,993	1,993	1,931	1,931	1,931
2004	1,983	1,983	1,983	2,101	2,101	2,101	1,995	1,995	1,995
2005	2,038	2,038	2,038	2,221	2,221	2,221	2,068	2,068	2,068
2006	2,110	2,110	2,110	2,312	2,312	2,312	2,150	2,150	2,150
2007	2,120	2,120	2,120	2,374	2,374	2,374	2,234	2,234	2,234
2008	2,207	2,207	2,207	2,470	2,470	2,470	2,350	2,350	2,350
2009	2,236	2,236	2,236	2,590	2,590	2,590	2,431	2,431	2,431
2010	2,331	2,209	2,215	2,684	2,542	2,549	2,491	2,359	2,366
2011	2,361	2,237	2,243	2,755	2,610	2,617	2,603	2,465	2,473
2012	2,421	2,294	2,300	2,866	2,715	2,723	2,769	2,622	2,631
2013	2,446	2,318	2,324	3,004	2,845	2,853	2,933	2,777	2,786
2014	2,535	2,402	2,408	3,183	3,015	3,024	3,034	2,873	2,883
2015	2,603	2,336	2,342	3,290	2,952	2,961	3,124	2,801	2,811
2016	2,693	2,418	2,424	3,502	3,142	3,152	3,251	2,916	2,926
2017	2,797	2,511	2,517	3,676	3,298	3,309	3,393	3,042	3,053
2018	2,837	2,546	2,553	3,804	3,413	3,423	3,603	3,231	3,243
2019	2,901	2,604	2,611	3,973	3,565	3,576	3,747	3,360	3,372
2020	2,915	2,478	2,484	4,139	3,518	3,530	3,924	3,335	3,348
2021	3,022	2,569	2,576	4,289	3,646	3,658	4,112	3,495	3,509
2022	3,099	2,634	2,641	4,476	3,805	3,817	4,302	3,657	3,671
2023	3,168	2,693	2,700	4,591	3,902	3,915	4,533	3,853	3,869
2024	3,181	2,704	2,711	4,774	4,058	4,071	4,829	4,104	4,121
2025	3,254	2,766	2,773	4,987	4,239	4,253	5,084	4,322	4,339
TOTAL	**64,869**	**60,023**	**60,128**	**81,746**	**75,018**	**75,185**	**78,531**	**72,013**	**72,202**

DC: Divided City; CC: Changing Climates; GU: Growth Unbound;
B: Base Case; I: Ideal Case; M: MIT Case

TABLE III.7
3X3 INFORMAL NMHC EMISSIONS
2000-2025

	Ktonnes / year								
Year	DC-B	DC-I	DC-M	CC-B	CC-I	CC-M	GU-B	GU-I	GU-M
2000	22	22	22	22	22	22	22	22	22
2001	21	21	21	21	21	21	21	21	21
2002	21	21	21	21	21	21	21	21	21
2003	23	23	23	22	22	22	22	22	22
2004	23	23	23	22	22	22	23	23	23
2005	25	25	25	22	22	22	23	23	23
2006	26	26	26	22	22	22	23	23	23
2007	26	26	26	22	22	22	24	24	24
2008	28	28	28	22	22	22	24	24	24
2009	28	28	28	23	23	23	24	24	24
2010	30	28	29	23	20	22	24	22	23
2011	31	28	29	22	20	21	25	23	24
2012	32	29	31	23	21	22	26	24	25
2013	33	30	31	23	21	22	26	24	25
2014	35	32	33	23	21	22	26	24	25
2015	36	31	33	23	20	21	26	23	24
2016	38	33	35	24	21	22	27	24	25
2017	39	34	36	23	21	22	27	24	25
2018	40	34	36	23	20	21	28	25	26
2019	41	36	38	23	21	22	27	24	26
2020	42	37	39	23	20	22	28	25	26
2021	45	39	41	23	20	21	28	25	26
2022	46	40	42	23	20	22	28	25	27
2023	46	40	43	23	20	21	29	25	27
2024	46	40	42	24	21	22	29	26	27
2025	48	42	44	24	21	22	29	26	27
TOTAL	**871**	**795**	**826**	**592**	**550**	**567**	**661**	**616**	**636**

DC: Divided City; CC: Changing Climates; GU: Growth Unbound;
B: Base Case; I: Ideal Case; M: MIT Case

TABLE III.8
3X3 INFORMAL SO_2 EMISSIONS
2000-2025

	Tonnes / year								
Year	DC-B	DC-I	DC-M	CC-B	CC-I	CC-M	GU-B	GU-I	GU-M
2000	674	674	674	674	674	674	674	674	674
2001	672	672	672	675	675	675	668	668	668
2002	678	678	678	684	684	684	671	671	671
2003	729	729	729	711	711	711	671	671	671
2004	779	779	779	749	749	749	675	675	675
2005	836	836	836	791	791	791	681	681	681
2006	903	903	903	823	823	823	689	689	689
2007	945	945	945	845	845	845	696	696	696
2008	1,023	1,023	1,023	879	879	879	711	711	711
2009	1,076	1,076	1,076	921	921	921	713	713	713
2010	1,163	1,105	1,128	954	907	926	708	674	688
2011	1,220	1,159	1,184	980	931	951	717	682	696
2012	1,294	1,230	1,255	1,019	968	989	738	702	716
2013	1,351	1,284	1,311	1,067	1,014	1,035	755	718	733
2014	1,445	1,374	1,402	1,130	1,075	1,097	754	717	732
2015	1,530	1,378	1,439	1,168	1,053	1,099	748	675	704
2016	1,632	1,470	1,535	1,243	1,120	1,169	750	676	706
2017	1,744	1,571	1,641	1,304	1,175	1,227	752	678	708
2018	1,820	1,639	1,711	1,349	1,215	1,269	767	692	722
2019	1,913	1,723	1,799	1,408	1,269	1,325	764	689	719
2020	1,975	1,681	1,798	1,467	1,249	1,336	765	653	698
2021	2,102	1,788	1,914	1,520	1,294	1,384	765	653	698
2022	2,210	1,881	2,013	1,585	1,350	1,444	762	651	695
2023	2,260	1,923	2,058	1,626	1,384	1,481	802	685	732
2024	2,271	1,932	2,067	1,690	1,439	1,539	854	728	778
2025	2,324	1,977	2,116	1,765	1,503	1,608	898	766	819
TOTAL	**36,568**	**33,431**	**34,686**	**29,027**	**26,699**	**27,630**	**19,147**	**17,886**	**18,390**

DC: Divided City; CC: Changing Climates; GU: Growth Unbound;
B: Base Case; I: Ideal Case; M: MIT Case

TABLE III.9
3X3 INFORMAL PM_{10} EMISSIONS
2000-2025

	Tonnes / year								
Year	DC-B	DC-I	DC-M	CC-B	CC-I	CC-M	GU-B	GU-I	GU-M
2000	559	559	559	559	559	559	559	559	559
2001	558	558	558	558	558	558	557	557	557
2002	560	560	560	561	561	561	559	559	559
2003	573	573	573	573	573	573	567	567	567
2004	584	584	584	590	590	590	576	576	576
2005	598	598	598	608	608	608	587	587	587
2006	615	615	615	621	621	621	599	599	599
2007	622	622	622	630	630	630	610	610	610
2008	642	642	642	643	643	643	627	627	627
2009	652	652	652	660	660	660	637	637	637
2010	674	665	669	673	666	669	645	639	641
2011	685	676	679	682	675	678	659	653	656
2012	701	691	695	697	690	693	681	675	678
2013	711	701	705	716	708	711	702	696	698
2014	733	722	727	740	731	735	713	707	710
2015	751	729	738	753	736	743	723	711	716
2016	774	750	760	781	762	770	737	725	730
2017	799	774	784	803	783	791	753	740	746
2018	813	787	797	818	798	806	776	764	769
2019	831	804	815	838	817	826	791	778	784
2020	841	798	816	858	825	839	809	790	798
2021	868	823	841	876	842	856	827	808	816
2022	889	842	862	897	862	877	845	826	834
2023	902	854	874	910	874	889	872	852	861
2024	905	857	876	931	893	909	906	884	894
2025	919	869	889	955	915	932	935	912	922
TOTAL	**18,758**	**18,305**	**18,490**	**18,933**	**18,581**	**18,726**	**18,254**	**18,038**	**18,129**

DC: Divided City; CC: Changing Climates; GU: Growth Unbound;
B: Base Case; I: Ideal Case; M: MIT Case

TABLE III.10
3X3 INFORMAL NO_x EMISSIONS
2000-2025

	Tonnes / year								
Year	DC-B	DC-I	DC-M	CC-B	CC-I	CC-M	GU-B	GU-I	GU-M
2000	427	427	427	427	427	427	427	427	427
2001	426	426	426	428	428	428	424	424	424
2002	430	430	430	433	433	433	426	426	426
2003	460	460	460	450	450	450	426	426	426
2004	490	490	490	473	473	473	429	429	429
2005	524	524	524	499	499	499	433	433	433
2006	564	564	564	518	518	518	439	439	439
2007	588	588	588	531	531	531	443	443	443
2008	635	635	635	552	552	552	453	453	453
2009	666	666	666	577	577	577	455	455	455
2010	718	684	698	597	569	581	453	432	441
2011	751	716	730	612	584	595	459	438	446
2012	795	757	773	636	606	618	473	451	460
2013	829	790	805	665	634	647	484	462	471
2014	885	843	860	704	670	684	484	462	471
2015	935	846	882	726	658	685	481	438	455
2016	996	900	938	771	698	728	483	440	457
2017	1,063	960	1,001	808	732	762	486	442	459
2018	1,107	1,000	1,043	835	756	788	496	451	469
2019	1,162	1,050	1,095	871	788	822	495	450	468
2020	1,199	1,025	1,094	906	777	829	497	430	457
2021	1,274	1,089	1,163	938	804	858	498	431	458
2022	1,338	1,144	1,222	977	838	894	498	431	458
2023	1,368	1,169	1,249	1,001	859	916	523	453	481
2024	1,374	1,174	1,254	1,040	891	951	555	480	510
2025	1,406	1,201	1,283	1,085	930	992	582	504	535
TOTAL	**22,409**	**20,558**	**21,299**	**18,060**	**16,684**	**17,236**	**12,303**	**11,551**	**11,853**

DC: Divided City; CC: Changing Climates; GU: Growth Unbound;
B: Base Case; I: Ideal Case; M: MIT Case

TABLE III.11
3X3 INFORMAL CO EMISSIONS
2000-2025

	Tonnes / year								
Year	DC-B	DC-I	DC-M	CC-B	CC-I	CC-M	GU-B	GU-I	GU-M
2000	3,349	3,349	3,349	3,349	3,349	3,349	3,349	3,349	3,349
2001	3,343	3,343	3,343	3,344	3,344	3,344	3,342	3,342	3,342
2002	3,357	3,357	3,357	3,359	3,359	3,359	3,356	3,356	3,356
2003	3,401	3,401	3,401	3,419	3,419	3,419	3,407	3,407	3,407
2004	3,438	3,438	3,438	3,505	3,505	3,505	3,469	3,469	3,469
2005	3,489	3,489	3,489	3,598	3,598	3,598	3,538	3,538	3,538
2006	3,554	3,554	3,554	3,664	3,664	3,664	3,614	3,614	3,614
2007	3,566	3,566	3,566	3,705	3,705	3,705	3,692	3,692	3,692
2008	3,644	3,644	3,644	3,772	3,772	3,772	3,794	3,794	3,794
2009	3,671	3,671	3,671	3,856	3,856	3,856	3,866	3,866	3,866
2010	3,754	3,734	3,743	3,918	3,899	3,908	3,920	3,901	3,910
2011	3,782	3,761	3,771	3,963	3,943	3,952	4,015	3,996	4,005
2012	3,834	3,813	3,823	4,035	4,014	4,024	4,151	4,131	4,141
2013	3,858	3,837	3,847	4,124	4,103	4,113	4,281	4,261	4,271
2014	3,934	3,911	3,922	4,240	4,218	4,228	4,363	4,342	4,352
2015	3,991	3,946	3,967	4,303	4,258	4,279	4,434	4,392	4,412
2016	4,067	4,020	4,042	4,434	4,387	4,409	4,532	4,490	4,510
2017	4,151	4,103	4,125	4,536	4,488	4,511	4,639	4,595	4,617
2018	4,186	4,136	4,159	4,607	4,558	4,581	4,792	4,747	4,769
2019	4,239	4,188	4,212	4,701	4,651	4,675	4,896	4,850	4,872
2020	4,254	4,177	4,213	4,791	4,714	4,751	5,020	4,950	4,984
2021	4,340	4,259	4,297	4,869	4,791	4,828	5,150	5,078	5,113
2022	4,402	4,319	4,357	4,967	4,887	4,925	5,278	5,205	5,240
2023	4,452	4,367	4,406	5,022	4,940	4,979	5,433	5,358	5,394
2024	4,460	4,376	4,415	5,114	5,030	5,069	5,625	5,547	5,585
2025	4,513	4,428	4,467	5,220	5,134	5,174	5,789	5,708	5,747
TOTAL	**101,030**	**100,187**	**100,577**	**108,415**	**107,585**	**107,977**	**111,746**	**110,979**	**111,350**

DC: Divided City; CC: Changing Climates; GU: Growth Unbound;
B: Base Case; I: Ideal Case; M: MIT Case

TABLE III.12
3X3 INFORMAL CO_2 EMISSIONS
2000-2025

	Ktonnes / year								
Year	DC-B	DC-I	DC-M	CC-B	CC-I	CC-M	GU-B	GU-I	GU-M
2000	375	375	375	375	375	375	375	375	375
2001	374	374	374	375	375	375	372	372	372
2002	377	377	377	379	379	379	373	373	373
2003	401	401	401	393	393	393	375	375	375
2004	424	424	424	412	412	412	378	378	378
2005	451	451	451	433	433	433	382	382	382
2006	482	482	482	449	449	449	387	387	387
2007	501	501	501	460	460	460	392	392	392
2008	538	538	538	476	476	476	401	401	401
2009	563	563	563	497	497	497	403	403	403
2010	604	578	588	513	492	500	402	387	393
2011	630	603	613	525	504	512	408	392	399
2012	664	635	647	545	522	531	420	404	411
2013	691	660	672	568	544	554	431	414	421
2014	735	702	715	599	574	584	432	415	422
2015	774	705	733	618	565	586	431	398	411
2016	822	748	778	654	598	621	434	401	414
2017	874	796	827	684	625	649	437	404	417
2018	909	827	860	706	645	669	447	413	427
2019	952	866	900	734	671	696	448	414	428
2020	980	847	900	763	664	703	451	400	421
2021	1,039	897	954	788	686	727	454	403	423
2022	1,090	940	1,000	820	713	756	455	405	425
2023	1,113	960	1,021	839	730	773	477	423	445
2024	1,118	964	1,026	870	756	802	504	447	470
2025	1,143	986	1,049	906	787	835	527	467	491
TOTAL	**18,622**	**17,200**	**17,769**	**15,379**	**14,324**	**14,746**	**10,997**	**10,424**	**10,654**

DC: Divided City; CC: Changing Climates; GU: Growth Unbound;
B: Base Case; I: Ideal Case; M: MIT Case

APPENDIX IV
SUMMARY OF POLICY IMPACTS AND COSTS

IV. 1 COMMERCIAL SECTOR POLICY COSTS (NET PRESENT VALUE MX$B)

OPTION	#	PACE	Divided City	Changing Climates	Growth Unbound
Reformulation of paintings	11	M	0.001	0.002	0.002
		F	0.002	0.004	0.004
Reformulation/substitution of surface cleaners	12	S	0.022	0.037	0.045
		M	0.340	0.056	0.067
Phasing-out of perchloroethylene	13	S	0.002	0.004	0.005
		M	0.004	0.006	0.007
Fuel Reformulation –Diesel 200	21		0.705	0.852	0.922
Fuel Reformulation –Diesel 30	22		1.175	1.420	1.537
Fuel switching for boilers (GO to NG)	23	S	0.567	1.855	2.394
		M	0.723	2.143	2.750
		F	0.828	2.348	3.003
Fuel switching for boilers (GO to LPG)	24	S	0.002	0.007	0.009
		M	0.003	0.008	0.010
		F	0.003	0.009	0.012
Fuel switching for boilers (LPG to Solar)	25	S	0.076	0.140	0.192
		M	0.216	0.295	0.354
Fuel switching for burners (Diesel to NG)	26	S	0.625	2.142	2.915
		M	0.802	2.488	3.369
		F	0.923	2.738	3.701
Fuel switching for burners (D to LPG)	27	S	0.001	0.002	0.003
		M	0.001	0.003	0.003
		F	0.001	0.003	0.004
Closed-loop new machinery	31	M	0.010	0.013	0.015
		F	0.012	0.016	0.018
Remaining vapor recovery systems	41		0.029	0.050	0.070
Increase use of low-solvent inks	51	S	0.005	0.008	0.010
		M	0.007	0.012	0.015
Efficient lighting	61		0.069	0.103	0.112
Efficient equipment	62		0.104	0.154	0.169
Substitute oil-based by water-based coatings	71	S	0.033	0.055	0.067
		M	0.049	0.082	0.101
Maintenance (emission control) of off-road equip.	72		0.003	0.003	0.003

S: Slow; M: Moderate; F: Fast.

IV.2 INFORMAL SECTOR POLICY COSTS
(NET PRESENT VALUE MX$B)

OPTION	#	PACE	Divided City	Changing Climates	Growth Unbound
Reformulation of paintings	11	M	0.001	0.001	0.001
		F	0.001	0.001	0.001
Reformulation/substitution of surface cleaners	12	S	0.010	0.011	0.033
		M	0.015	0.016	0.050
Fuel Reformulation –Diesel 200	21		0.282	0.341	0.369
Fuel Reformulation –Diesel 30	22		0.470	0.568	0.615
Fuel switching for boilers (GO to NG)	23	S	0.220	0.268	0.155
		M	0.334	0.414	0.351
Fuel switching for boilers (GO to LPG)	24	S	0.001	0.001	0.000
		M	0.001	0.001	0.001
Fuel switching for boilers (LPG to Solar)	25	S	0.018	0.027	0.033
		M	0.046	0.059	0.066
Fuel switching for burners (Diesel to NG)	26	S	0.338	0.428	0.300
		M	0.468	0.602	0.497
Fuel switching for burners (Diesel to LPG)	27	S	0.000	0.000	0.000
		M	0.000	0.000	0.000
Increase use of low-solvent inks	51	S	0.002	0.001	0.000
		M	0.002	0.001	0.001
Brick kilns – banning used oils	81		0.870	1.452	1.876
Brick kilns – Substitution by NG	82		0.223	0.532	0.708
Brick kilns – Substitution by LPG	83		0.370	0.720	0.987

S: Slow; M: Moderate; F: Fast.

IV.3 COMMERCIAL SECTOR EMISSION REDUCTION POTENTIAL DIFFERENCIAL IN CUMULATIVE KILOTONNES 2000-2025

OPTION	#	PACE	NMHC			SO_2			PM_{10}		
			DC	CC	GU	DC	CC	GU	DC	CC	GU
Reformulation of paintings	11	M	-4.89	-4.70	-4.47	-	-	-	-	-	-
		F	-11.57	-11.18	-10.72	-	-	-	-	-	-
Reformulation/subst. of surface cleaners	12	S	-135.17	-131.28	-126.57	-	-	-	-	-	-
		M	-202.75	-196.92	-189.85	-	-	-	-	-	-
Phasing-out of perchloroethylene	13	S	-45.06	-43.76	-42.19	-	-	-	-	-	-
		M	-67.59	-65.64	-63.29	-	-	-	-	-	-
Fuel Reformulation –Diesel 200	21		-	-	-	-12.73	-16.54	-15.72	-	-	-
Fuel Reformulation –Diesel 30	22		-	-	-	-19.95	-25.92	-24.63	-	-	-
Fuel switching for boilers (GO to NG)	23	S	0.11	0.21	0.21	-56.51	-107.61	-105.77	-7.54	-14.36	-14.11
		M	0.16	0.25	0.25	-78.31	-128.46	-124.62	-10.45	-17.14	-16.63
		F	0.19	0.29	0.28	-94.96	-144.40	-139.06	-12.67	-19.27	-18.56
Fuel switching for boilers (GO to LPG)	24	S	0.06	0.11	0.11	-56.52	-107.63	-105.79	-7.53	-14.33	-14.09
		M	0.08	0.13	0.12	-78.33	-128.48	-124.64	-10.43	-17.11	-16.60
		F	0.10	0.14	0.14	-94.97	-144.42	-139.08	-12.65	-19.23	-18.52
Fuel switching - boilers (LPG to Solar)	25	S	-0.49	-0.93	-0.92	-0.02	-0.04	-0.04	-0.41	-0.79	-0.78
		M	-0.66	-1.10	-1.07	-0.03	-0.05	-0.05	-0.56	-0.92	-0.90
Fuel switching for burners (D to NG)	26	S	-2.80	-5.33	-5.24	-7.67	-14.62	-14.37	-0.04	-0.07	-0.07
		M	-3.88	-6.36	-6.17	-10.64	-17.45	-16.93	-0.05	-0.09	-0.08
		F	-4.70	-7.15	-6.88	-12.90	-19.61	-18.89	-0.06	-0.10	-0.09
Fuel switching for burners (D to LPG)	27	S	-2.84	-5.40	-5.31	-7.68	-14.63	-14.38	-0.04	-0.07	-0.07
		M	-3.93	-6.45	-6.26	-10.64	-17.46	-16.94	-0.05	-0.08	-0.08
		F	-4.77	-7.25	-6.98	-12.91	-19.63	-18.90	-0.06	-0.09	-0.09
Closed-loop new machinery	31	M	-122.00	-127.06	-132.17	-	-	-	-	-	-
		F	-142.34	-147.42	-152.50	-	-	-	-	-	-
Remaining vapor recovery systems	41		-17.83	-18.59	-20.99	-	-	-	-	-	-
Increase use of low-solvent inks	51	S	-30.01	-29.14	-28.10	-	-	-	-	-	-
		M	-45.01	-43.71	-42.14	-	-	-	-	-	-
Efficient lighting	61		-	-	-	-	-	-	-	-	-
Efficient equipment	62		-	-	-	-	-	-	-	-	-
Substitute oil- by water-based coatings	71	S	-197.90	-193.44	-188.87	-	-	-	-	-	-
		M	-296.84	-290.15	-283.30	-	-	-	-	-	-
Maintenance/control of off-road equip.	72		-	-	-	-	-	-	-7.96	-7.78	-7.60

S: Slow; M: Moderate; F: Fast.

IV.3 COMMERCIAL SECTOR EMISSION REDUCTION POTENTIAL (Continued) DIFFERENCIAL IN CUMULATIVE KILOTONNES 2000-2025

OPTION	#	?ACE	NOx			CO			CO_2		
			DC	CC	GU	DC	CC	GU	DC	CC	GU
Reformulation of paintings	11	M	-	-	-	-	-	-	-	-	-
		F	-	-	-	-	-	-	-	-	-
Reformulation/subst. of surface cleaners	12	S	-	-	-	-	-	-	-	-	-
		M	-	-	-	-	-	-	-	-	-
Phasing-out of perchloroethylene	13	S	-	-	-	-	-	-	-	-	-
		M	-	-	-	-	-	-	-	-	-
Fuel Reformulation –Diesel 200	21		-	-	-	-	-	-	-	-	-
Fuel Reformulation –Diesel 30	22		-	-	-	-	-	-	-	-	-
Fuel switching for boilers (GO to NG)	23	S	-1.06	-2.01	-1.98	-0.38	-0.73	-0.72	-4440	-8456	-8311
		M	-1.46	-2.40	-2.33	-0.53	-0.87	-0.84	-6154	-10094	-9792
		F	-1.77	-2.70	-2.60	-0.64	-0.98	-0.94	-7461	-11346	-10927
Fuel switching for boilers (GO to LPG)	24	S	0.63	1.20	1.18	-0.34	-0.64	-0.63	-576	-1096	-1078
		M	0.87	1.43	1.39	-0.46	-0.76	-0.74	-798	-1309	-1270
		F	1.06	1.61	1.55	-0.56	-0.86	-0.83	-968	-1471	-1417
Fuel switching - boilers (LPG to Solar)	25	S	-13.24	-25.31	-25.08	-1.83	-3.49	-3.46	-11641	-22253	-22057
		M	-18.04	-29.78	-29.08	-2.49	-4.11	-4.01	-15864	-26186	-25569
Fuel switching for burners (D to NG)	26	S	-0.61	-1.15	-1.13	-0.22	-0.42	-0.41	-2785	-5304	-5213
		M	-0.84	-1.38	-1.34	-0.30	-0.50	-0.48	-3860	-6331	-6142
		F	-1.02	-1.55	-1.49	-0.37	-0.56	-0.54	-4680	-7116	-6853
Fuel switching for burners (D to LPG)	27	S	0.13	0.24	0.24	-0.23	-0.43	-0.42	-772	-1471	-1445
		M	0.18	0.29	0.28	-0.31	-0.51	-0.50	-1070	-1755	-1703
		F	0.21	0.32	0.31	-0.38	-0.58	-0.55	-1298	-1973	-1900
Closed-loop new machinery	31	M	-	-	-	-	-	-	-	-	-
		F	-	-	-	-	-	-	-	-	-
Remaining vapor recovery systems	41		-	-	-	-	-	-	-	-	-
Increase use of low-solvent inks	51	S	-	-	-	-	-	-	-	-	-
		M	-	-	-	-	-	-	-	-	-
Efficient lighting	61		-	-	-	-	-	-	-419	-666	-755
Efficient equipment	62		-	-	-	-	-	-	-628	-1000	-1132
Substitute oil- by water-based coatings	71	S	-	-	-	-	-	-	-	-	-
		M	-	-	-	-	-	-	-	-	-
Maintenance/control of off-road equip.	72		-	-	-	-	-	-	-	-	-

-S: Slow; M: Moderate; F: Fast.

IV.4 INFORMAL SECTOR EMISSION REDUCTION POTENTIAL DIFFERENCIAL IN CUMULATIVE KILOTONNES 2000-2025

OPTION	#	PACE	NMHC			SO_2			PM_{10}		
			DC	CC	GU	DC	CC	GU	DC	CC	GU
Reformulation of paintings	11	M	-7.70	-4.30	-2.60	-	-	-	-	-	-
		F	-11.56	-6.45	-3.90	-	-	-	-	-	-
Reformulation/subst of surface cleaners	12	S	-29.74	-17.82	-49.07	-	-	-	-	-	-
		M	-44.60	-26.73	-73.60	-	-	-	-	-	-
Fuel Reformulation –Diesel 200	21		-	-	-	-3.24	-2.48	-1.50	-	-	-
Fuel Reformulation –Diesel 30	22		-	-	-	-5.08	-3.89	-2.35	-	-	-
Fuel switching for boilers (GO to NG)	23	S	0.03	0.02	0.00	-16.12	-10.14	-1.34	-2.15	-1.35	-0.18
		M	0.04	0.02	0.01	-17.89	-11.87	-4.26	-2.39	-1.58	-0.57
Fuel switching for boilers (GO to LPG)	24	S	0.02	0.01	0.00	-16.12	-10.76	-3.76	-2.15	-1.43	-0.50
		M	0.02	0.01	0.01	-18.41	-12.85	-5.60	-2.45	-1.71	-0.75
Fuel switching - boilers (LPG to Solar)	25	S	-0.27	-0.17	-0.05	-0.01	-0.01	-0.00	-0.22	-0.15	-0.04
		M	-0.30	-0.21	-0.08	-0.01	-0.01	-0.00	-0.26	-0.18	-0.07
Fuel switching for burners (D to NG)	26	S	-1.20	-0.80	-0.28	-3.28	-2.19	-0.77	-0.02	-0.01	-0.00
		M	-1.37	-0.95	-0.42	-3.75	-2.62	-1.14	-0.02	-0.01	-0.01
Fuel switching for burners (D to LPG)	27	S	-1.21	-0.81	-0.28	-3.29	-2.19	-0.77	-0.02	-0.01	-0.00
		M	-1.39	-0.97	-0.42	-3.75	-2.62	-1.14	-0.02	-0.01	-0.00
Increase use of low-solvent inks	51	S	-12.85	-7.05	-4.21	-	-	-	-	-	-
		M	-19.27	-10.58	-6.31	-	-	-	-	-	-
Brick kilns – banning used oils	81		-28.41	-31.24	-32.77	0.21	0.23	0.24	9.14	10.05	10.55
Brick kilns – substitution by NG	82		-3.24	-3.61	-3.84	-0.00	-0.00	-0.00	-0.91	-1.02	-1.08
Brick kilns – substitution by LPG	83		-2.23	-2.49	-2.64	-0.02	-0.02	-0.03	-0.91	-1.02	-1.08

S: Slow; M: Moderate; F: Fast.

IV.4 INFORMAL SECTOR EMISSION REDUCTION POTENTIAL (Continued)
DIFFERENCIAL IN CUMULATIVE KILOTONNES 2000-2025

OPTION	#	PACE	NOx			CO			CO_2		
			DC	CC	GU	DC	CC	GU	DC	CC	GU
Reformulation of paintings	11	M	-	-	-	-	-	-	-	-	-
		F	-	-	-	-	-	-	-	-	-
Reformulation/subst of surface cleaners	12	S	-	-	-	-	-	-	-	-	-
		M	-	-	-	-	-	-	-	-	-
Fuel Reformulation –Diesel 200	21		-	-	-	-	-	-	-	-	-
Fuel Reformulation –Diesel 30	22		-	-	-	-	-	-	-	-	-
Fuel switching for boilers (GO to NG)	23	S	-0.30	-0.19	-0.03	-0.11	-0.07	-0.01	-1267	-797	-105
		M	-0.33	-0.22	-0.08	-0.12	-0.08	-0.03	-1406	-933	-335
Fuel switching for boilers (GO to LPG)	24	S	0.18	0.12	-0.04	-0.10	-0.06	-0.02	-164	-110	-38
		M	0.21	-0.14	-0.06	-0.11	-0.03	-0.08	-188	-131	-57
Fuel switching - boilers (LPG to Solar)	25	S	-7.21	-4.68	-1.28	-0.99	-0.65	-0.18	-6338	-4119	-1124
		M	-8.23	-5.64	-2.17	-1.14	-0.78	-0.30	-7239	-4960	-1910
Fuel switching for burners (D to NG)	26	S	-0.26	-0.17	-0.06	-0.09	-0.06	-0.02	-1192	-796	-278
		M	-0.30	-0.21	-0.09	-0.11	-0.07	-0.03	-1361	-950	-414
Fuel switching for burners (D to LPG)	27	S	0.05	0.04	0.01	-0.10	-0.06	-0.02	-330	-221	-77
		M	0.06	0.04	0.02	-0.10	-0.08	-0.03	-377	-263	-115
Increase use of low-solvent inks	51	S	-	-	-	-	-	-	-	-	-
		M	-	-	-	-	-	-	-	-	-
Brick kilns – banning used oils	81		0.36	0.40	0.42	48.81	53.67	56.30	1730	1902	1995
Brick kilns – Substitution by NG	82		-0.01	-0.00	-0.01	-6.31	-7.04	-7.48	-555	-623	-663
Brick kilns – Substitution by LPG	83		-0.06	-0.07	-0.07	-6.23	-6.95	-7.38	-118	-131	-139

S: Slow; M: Moderate; F: Fast.

APPENDIX V
STRATEGY COST AND MAIN EMISSION IMPACTS

TABLE V.1
NPV AND POTENTIAL REDUCTION OF SELECTED POLLUTANTS

Strategies		TOTAL REDUCTIONS Ktonne		
	NPV	SO2	NMHC	PM10
INCOM-(DC)-SOLVENT1	0.002	0.00	12.59	0.00
INCOM-(CC)-SOLVENT1	0.003	0.00	9.00	0.00
INCOM-(GU)-SOLVENT1	0.003	0.00	7.07	0.00
INCOM -(DC)-SOLVENT2	0.003	0.00	23.13	0.00
INCOM -(CC)-SOLVENT2	0.005	0.00	17.63	0.00
INCOM -(GU)-SOLVENT2	0.005	0.00	14.62	0.00
INCOM -(DC)-SOLVENT3	0.071	0.00	249.73	0.00
INCOM -(CC)-SOLVENT3	0.111	0.00	222.62	0.00
INCOM -(GU)-SOLVENT3	0.163	0.00	243.56	0.00
INCOM R-(DC)-SOLVENT4	0.087	0.00	402.59	0.00
INCOM R-(CC)-SOLVENT4	0.145	0.00	388.69	0.00
INCOM R-(GU)-SOLVENT4	0.187	0.00	378.79	0.00
INCOM -(DC)-SOLVENT5	0.405	0.00	496.52	0.00
INCOM -(CC)-SOLVENT5	0.152	0.00	467.35	0.00
INCOM -(GU)-SOLVENT5	0.223	0.00	527.58	0.00
INCOM -(DC)-SOLVENT6	0.442	0.00	737.29	0.00
INCOM -(CC)-SOLVENT6	0.212	0.00	703.03	0.00
INCOM -(GU)-SOLVENT6	0.295	0.00	737.55	0.00
INCOM -(DC)- COMBUST1	0.991	99.58	6.53	9.74
INCOM -(CC)- COMBUST1	1.203	154.23	6.09	15.84
INCOM -(GU)- COMBUST1	1.304	141.92	5.48	14.66
INCOM -(DC)-COMBUST2	0.992	127.10	5.22	12.95
INCOM -(CC)-COMBUST2	1.205	180.43	7.28	18.91
INCOM -(GU)-COMBUST2	1.305	165.54	6.55	17.43
INCOM -(DC)-COMBUST3	1.645	132.91	4.67	12.71
INCOM -(CC)-COMBUST3	1.902	193.86	7.11	19.32
INCOM -(GU)-COMBUST3	2.168	184.96	6.84	18.61
INCOM -(DC)-COMBUST4	2.737	99.55	3.86	9.75
INCOM -(CC)-COMBUST4	5.619	153.58	5.90	15.79
INCOM -(GU)-COMBUST4	4.515	139.47	5.31	14.36
INCOM -(DC)- COMBUST5	3.317	126.56	5.05	12.91
INCOM -(CC)- COMBUST5	6.840	179.42	7.04	18.82
INCOM -(GU)- COMBUST5	8.258	164.17	6.33	17.29
INCOM -(DC)- COMBUST6	3.396	132.89	4.51	12.73
INCOM -(CC)- COMBUST6	7.074	193.82	6.86	19.37
INCOM -(GU)- COMBUST6	8.856	176.02	6.60	18.65
INCOM -(DC)- COMBUST7	2.353	30.39	6.01	0.70
INCOM -(CC)- COMBUST7	4.450	39.14	8.25	1.04
INCOM -(GU)- COMBUST7	5.382	35.33	7.56	0.91
INCOM -(DC)- COMBUST8	2.830	37.97	5.66	0.88
INCOM -(CC)- COMBUST8	5.080	49.48	8.46	1.20
INCOM -(GU)- COMBUST8	6.273	45.92	8.03	1.06
INFOR-(DC)-COMBUST1	1.857	16.18	28.41	9.14
INFOR-(CC)-COMBUST1	2.645	19.25	31.24	10.05

Strategies		TOTAL REDUCTIONS Ktonne		
	NPV	SO2	NMHC	PM10
INFOR-(GU)-COMBUST1	3.167	17.46	32.77	10.55
INFOR-(DC)-COMBUST2	1.186	10.95	7.24	0.97
INFOR-(CC)-COMBUST2	3.102	16.81	9.37	1.10
INFOR-(GU)-COMBUST2	3.923	15.14	9.36	1.15
INFOR-(DC)-COMBUST3	1.640	14.41	7.48	0.98
INFOR-(CC)-COMBUST3	3.810	20.09	9.80	1.12
INFOR-(GU)-COMBUST3	4.853	18.10	9.23	1.17
COMER-(DC)-EFFICIE1	0.173	0.00	0.00	0.00
COMER-(CC)-EFFICIE1	0.257	0.00	0.00	0.00
COMER-(GU)-EFFICIE1	0.281	0.00	0.00	0.00
COMER-(DC)-EFFICIE2	0.107	0.00	0.00	7.96
COMER-(CC)-EFFICIE2	0.157	0.00	0.00	7.78
COMER-(GU)-EFFICIE2	0.172	0.00	0.00	7.60