Greenhouse Gas Emission Baselines and Reduction Potentials from Buildings in Mexico

A Discussion Document

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Acknowledgements

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Chapter 1

Key Outcomes:
Summary for Decision-Makers

Key Outcomes:
Summary for Decision-Makers

This report represents the first comprehensive description of the factors that determine the present and future impacts of residential and commercial buildings in México on climate change.

1.1. PROCESS

The elaboration of the present document involved a process of information gathering on built space and energy use in Mexico´s residential and commercial sectors. It also involved the development of a model to estimate greenhouse gas emissions of those sectors based on the available information.

It is important to note that there is a systematic lack of data on these matters in Mexico, particularly for the commercial sector but also on more specific issues (like energy end use information) for both sectors. To deal with this lack of data, many assumptions were made by the author, most of them based on other related data but sometimes on his personal judgment.

1.2. ESTIMATED EMISSIONS

The present exercise estimates residential and commercial buildings emissions of close to 75 MTon in 2006. This means that buildings represented about 12% of total present CO_2 eqv. emissions in Mexico in that year.

To have reference values for the year 2000, a simple backwards extrapolation was performed based of the 2006 to 2007 growth rate. A total of 70,250 KTon in GHG emissions was estimated. A potential growth to up to close to 500 MTon for 2050 has been estimated. Therefore there would be an increase of GHG emissions by a factor of 6.7 if nothing is done.

1.3. A ZERO GROWTH SCENARIO

All of the assumptions for the parameters considered in the model use for this report were made to reach a zero growth target, that is, that total emissions have a constant value over the 2006-2050 period. To reflect this, two important assumptions are made: (1) that the average intensity of electricity use in households in temperate climate does not grow and (2) that the average energy intensity for space cooling in households in hot climate also remains constant.

1.4. OVERALL GHG REDUCTIONS

In general, measures in the residential sector are reflected in the average end use intensities of five end uses (lighting, space cooling, refrigeration, "other electrical" and water heating). In the commercial sector, reductions are reflected by energy end use intensities by building type. In the residential sector, the proposed measures would reduce the growth of CO_2 eqv. emissions from the residential sector to 63% of the baseline in 2050. Most of the reductions come from measures related to electricity (96%) and, by end uses, the largest fraction of the reductions come from greater efficiency in "other electrical" uses (50%), space cooling (42%), refrigeration (3%) water heating (3%), and lighting (2%). In the commercial sector, technology improvements would result in reductions in the energy intensities

of space cooling, lighting and auxiliary equipment by 75%, and of 60% in energy intensity for water heating, and auxiliary motors.

1.5. COST OF GHG REDUCTIONS

In the residential sector, the estimated cost of the measures, at 2008 values, would be close to 103 billion US$. In terms of unit costs per Ton of CO_2 eqv. avoided (under very general assumptions) the cheapest measure involves "other electrical" while water heating (which involves the use of solar energy) has the higher cost. In the commercial sector, the cost of the mitigation measures was estimated as a general percentage (3%) of the unit global construction costs of the buildings, so estimated cost is close to 21 billion US$ by 2050.

1.6. RECOMMENDATIONS

Short-term
- Establish the building sector as a priority in mitigation policy. To date, there are no specific laws involving sustainable development priorities for buildings in Mexico. There are, though, a number of policies and programs involving both the government and the private sector that have direct and indirect impacts on the CO_2 eqv. emissions that result from residential and commercial buildings operations. These policies and programs have mixed results, and lack coordination and a steady effort. Making buildings a stated by the federal government priority (be it for energy efficiency in particular or for GHG mitigation in general) could help solidify the efforts.
- Reinforce the Instituto del Fondo Nacional de la Vivienda para los Trabajadores (INFONAVIT) Green Mortgage program and go ahead with Consejo Nacional de Vivienda (CONAVI) sustainable housing program. The Green Mortgage program by INFONAVIT and the use of subsidies by CONAVI to increase the sustainability aspects of new housing are key programs to reach a zero emissions growth in the residential sector.
- Increase the intensity and broaden the scope of Comisión federal de Electricidad (CFE) Demand Side Management (DSM) programs. CFE has been operating (directly or through the Fideicomiso para el Ahorro de Energía Eléctrica-FIDE) a number of successful DSM programs, mainly aimed at lighting and space cooling in the residential sector. These programs should recover their wide scale scope.
- Start a formal, integrated and coordinated effort of data gathering to have a better idea of the size and the energy use characteristics of commercial buildings. Recognize, in the government's data collection system, the importance of buildings as a specific category of energy use and integrate comprehensive data bases that include—by building type—building stock, floor area, vintage, energy use by energy source and energy intensity.

Medium-term
- Strengthen federal, state and local agencies that enforce compliance of building regulation. Even though Mexico has two mandatory energy efficiency standards that apply to commercial buildings (one for lighting systems and the other for the building's envelope) [1, 2], they are not fully effective as they have been poorly enforced, particularly the one that applies to the building's envelope. This

implies the need for greater involvement of local governments to integrate the standard into local building codes.

- Use the Clean Development Mechanism (CDM) programmatic alternative to add resources to government programs. The CDM under the programmatic category, can help collect additional resources to government sponsored programs. This can be the case of the federal, state and municipal housing programs.
- Implement surveys and detailed audits by building types and climatic regions in to identify energy end-use technology and intensities. This work is to supplement the efforts done in the short term and would help to improve the design of programs in the sector and should be done for both the residential and commercial sectors.
- Promote "Green building" strategies. Either through their inclusion as mandatory in building codes or through tax incentives, local governments should, as its is becoming best practice in developed countries, promote the use of well established "Green building" certification systems.

Long-term

- Eliminate subsidies to energy use and use them to promote energy efficiency. Though it is clear that there is a need for economic support for low-income families, a large but not clearly defined fraction of the subsidies goes to households that do not need it, thus giving the wrong economic signal for energy efficiency. In this case, the recommendation is to use a significant fraction of the resources that are used to cover the subsidy to cover the cost of purchase of energy efficiency measures.
- Keep Minimum Efficiency Performance Standards (MEPS) of main energy using equipment harmonized with those of the US and Canada. Based on the fact that there are number of equipment (electric motors, refrigerators and AC units) that already have the same MEPS for the three North American countries, México should follow the lead of the US and Canada to strengthen its own standards.

Chapter 2

Context

Context

Mexico is a federal territory formed by 31 states and a Federal District (Mexico City or D.F.), and is divided into 2446 municipalities. There are close to 200000 populated locations in the country, of which only 178 have 50000 or more inhabitants; in contrast, there are close to 150000 populations with less than 100 inhabitants [3].

2.1. CLIMATE

Mexico's geographical location and variable altitudes give place to a wide variety of weather conditions. Located in the temperate region of North America, the Mexican territory comprises several climate conditions and zones, ranging from tropical to desert to some spots with very low temperatures in the winter.

In terms of climate conditions, three main zones can be identified in Mexico:

a. The very arid, arid and semi-arid zones comprise almost 56% of the territory and are located to the north and center of the territory. These zones are influenced by the high pressure extratropical belt which prevents cloud formation and rain incidence.
b. The sub-humid zones which comprise 37% of the territory and are located in the mountain regions (Sierras) and coastal plains of the Pacific Ocean, the Gulf of Mexico and the northeast of the Yucatan Peninsula. These zones are influenced by tradewinds.
c. The humid zones, located in the southern portion of Mexico, comprise the remaining 7% of the territory, where the ascent to the mountain regions begins and the climate conditions are influenced by the accumulation of a small portion of the humidity of the Gulf of Mexico and the Pacific Ocean.

In general terms, Mexico is a country with warm weather. About three quarters of Mexico´s territory has warm temperatures (above 18 °C), while only 1% of the territory has cold temperatures (<12 °C) (Table 1) [4].

Table 1. Temperature type distribution in Mexico

Definition	Temperature range	% of the territory
Warm	>22 °C	37%
Semi-warm	18° to 22 °C	39%
Tempered	12° to 18 °C	23%
Semi-cold and cold	<12 °C	1%

Source: Servicio Meteorológico Nacional (SMN) [4].

This means that the need for cooling is significant and heating is only needed in some areas of the country in the winter. This is also shown in terms of degree days, as there are many more locations with high levels of degree days that with high levels of cooling degree days (Fig. 1) [5].

Figure 1. Distribution of areas by heating and cooling degree-days (HDD65 y CDD50) for 1,400 locations in Mexico
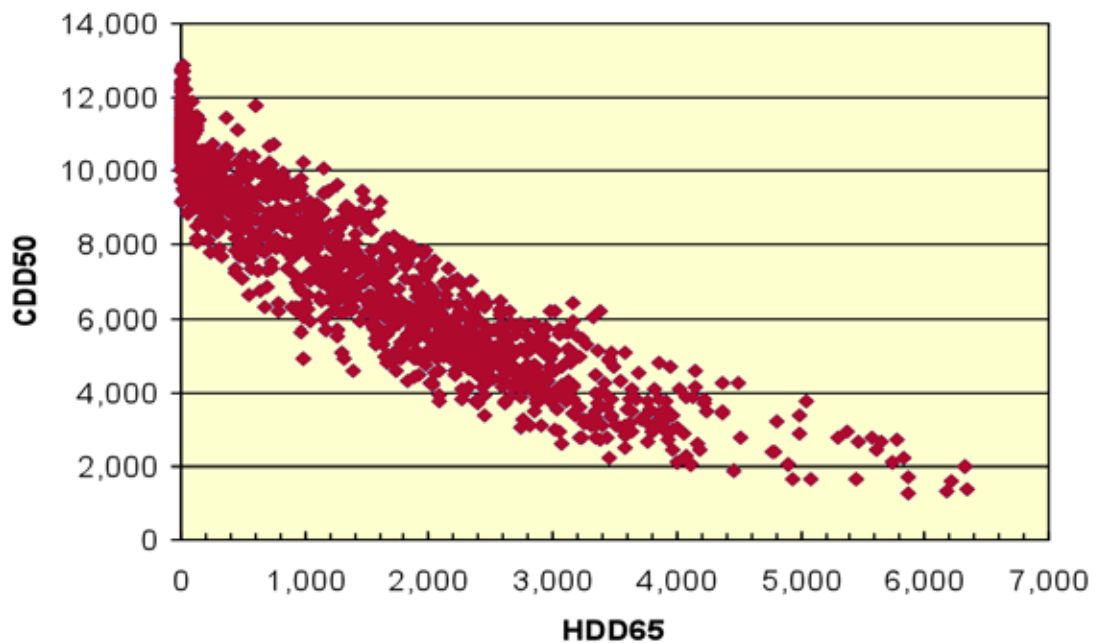
Source: Estimated from SMN data for 1400 locations of Mexico [5].

It is important to note that several regions in Mexico present extreme climatic variations throughout the year. The Chihuahuan Desert has recorded the lowest temperatures of the country during the winter, less than -20.0° C. The highest temperatures are registered in the Sonora Desert during the summer, frequently above 45.0° C. The coastal plains of the Gulf of Mexico and the Pacific Ocean register temperatures which oscillate between 15.6° C and 40.0° C. These regions together with the Tehuantepec Isthmus, the state of Chiapas and the Yucatan Peninsula also register the major rainfall ratio, with and average of 1500 mm of pluvial precipitation [6].

2.2.   POPULATION

According to the population census update of 2005, the total population of Mexico in 2005 was 103.3 million inhabitants, an increase from 97.5 in 2000. Thus, the average annual growth rate of the population in that period was of 1.19%. This rate of growth represents a reduction in growth rates of previous years, from 3.35% in the 1960-1970 period (Table 2) [3].

Table 2. Population growth rates in Mexico 1900-2000

PERIOD	1960-1970	1970-1990	1990-1995	1995-2000
Growth rate	3.35	2.59	2.03	1.54

Source: Instituto Nacional de Estadística y Geografía (INEGI) [3]

According to the 2000 census and the 2005 census update, urban population in Mexico represented 74.6% of total population in 2000 and 76.5% for 2005. The five largest metropolitan areas are Mexico

City Valley, Guadalajara, Monterrey, Puebla-Tlaxcala and Toluca, represent more than 28.7% of the total population. The metropolitan area of Mexico City Valley is the largest urban populated area, with 18.5 million inhabitants, that represent close to the 17.9% of the national population [3].

In terms of population density, the Consejo Nacional de Población (CONAPO) estimates a national average of 50.0 and 53.3 inhabitants per km^2 in 2000 and 2006, respectively. Mexico City has the smaller territorial extension and the greater population density, -5972 inhabitants per km^2 in 2005-. In contrast, the state of Baja California Sur, registers the lowest population density, only 7 inhabitants per km^2 [7].

In the rural context, population has significantly diminished over the past decade. In the period 2000-2006, the population living in the more than 182000 rural communities with less than 2500 inhabitants had a reduction, as it passed from 25.4% of Mexico´s total population in 2000 to 23.5% in 2006 [7].

CONAPO estimates that Mexican population will increase to 111.6 million in 2010, 127.2 million in 2030 and 129.6 million in 2050. Compared with the tendencies observed throughout the twentieth century, the average annual growth rate will be reduced to 0.88% in 2010 and than 0.38% in 2030.

For the purposes of this study, the number of households grows as population grows and the number of occupants per household diminishes. For the population projections, a rate of growth of 1.19 % starting in 2005 was used, with this latter rate reducing at 4.3% per year was. Under these assumptions, the population of Mexico totals, as estimated by CONAPO, 130 million people in 2050 (Fig. 2).

Figure 2. Population growth and tendencies in Mexico 2006-2050
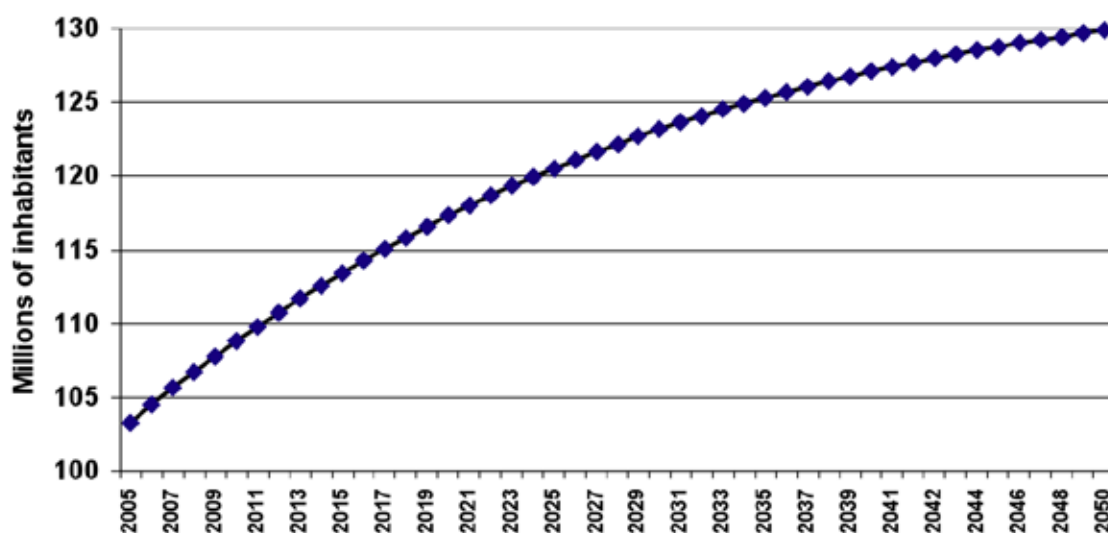
Source: Estimates by the author based on CONAPO´s data [7].

Also, the national urban population is expected to increase to 76.2 and 90.2 million inhabitants in 2010 and 2030, respectively, which will represent 68.2% (2010) and 70.9% (2030) of the total expected population.

2.3.   THE SERVICES SECTOR

In Mexico, economic statistics reflect the increasing importance of the tertiary (services) sector. This is evident in the growth of the gross domestic product (GDP), where the services sector has out-performed the industrial sector since 2000. The same situation occurs for the Gross Domestic Product (GDP) of the economy as a whole (Fig. 3) [8].

Figure 3. Annual growth rate for nationwide GDP and the GDP for industry and services sector (1996 to 2007) [2]
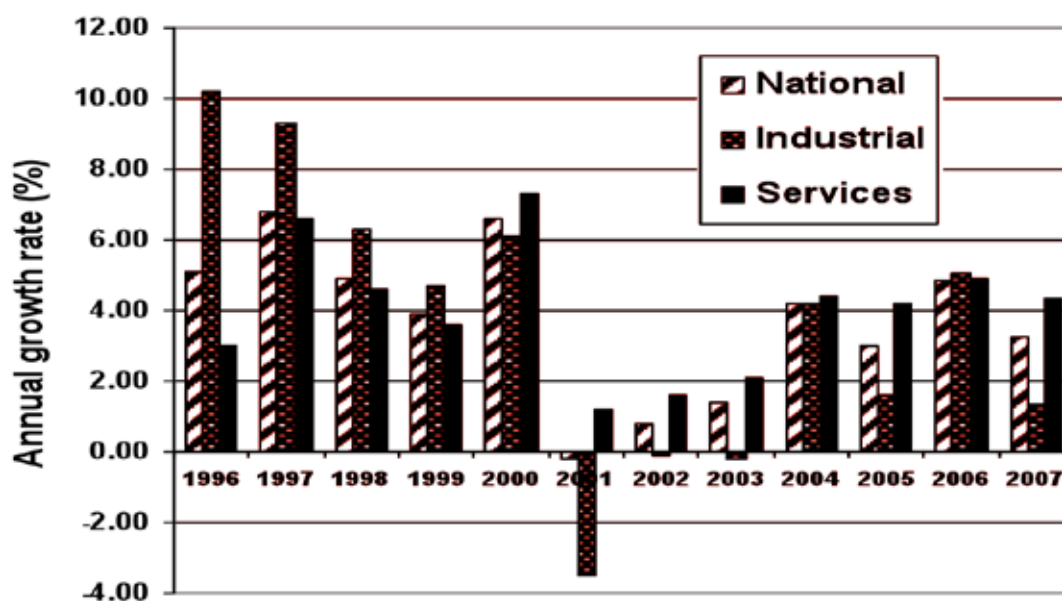
Source: INEGI [8]

To analyze the present and future Greenhouse Gas (GHG) emissions from the services´ sector, his study will incorporate the following types of commercial buildings: hotels, office buildings, retail and department stores, hospitals, restaurants, warehouses, and schools.

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2   INEGI. http://www.inegi.gob.mx/est/contenidos/espanol/rutinas/ept.asp?t=agr01&c=469&s=est

Chapter 3

Building Stock

Building Stock

3.1. HOUSEHOLDS

The number of households in Mexico increased from 22.3 to 24.8 million between 2000 and 2005 according to the latest census data, which represents an increase of 11.4 percent. In comparison, the number of households from 1970 to 2000 increased of 9.8 to 22.3 million, an increase of nearly 127.0 percent [3].

As Table 3 shows, demographic dynamics, with a tendency to the reduction of the population, have favored the reduction of the average number of occupants in a household in Mexico. Whereas in 1970 the average number of people living in a household was of around five members, for 2000 it was reduced to 4.3 people and 4.2 in 2005 [3].

Table 3. **Number of households and occupants in Mexico 2000 and 2005**

CONCEPT	2000	2005
Number of households (million) a/	22.3	24.8
Average household growth rate	3.0	2.0
Number of occupants (million) a/	95.4	100
Average occupants per household	4.3	4.2

Source: INEGI [8]

This trend is also reflected in the smaller presence of the homes of greater size and in the progressive increase of the small ones. Table 4 shows that the smaller households (one and two bedrooms with a separate kitchen) have represented the most important percentage of the total household number in Mexico.

Table 4. **Percentage of households and number of rooms in each household in Mexico 1960-2000**

Number of rooms	1990 a/	2000 a/
One room b/	27.1	23.2
Two rooms b/	26.7	24.4
Three rooms b/	20.3	23.1
Four or more rooms b/	25.9	29.3

a/ Based on total occupied households, b/ Not counting the kitchen as an additional room, NA/ Not available
Source: INEGI, Mexico [8]

To establish the baseline for residential buildings, numbers for the year 2005 were used and a number of assumptions was made in regard to the rate of change of the population (that includes a rate of change of the population growth rate) and of the number of occupants per household (Table 5).

Table 5. Values of parameters related to population and number of occupants per household used to estimate future GHG emissions from the residential sector

CONCEPT	Value	Units
Population in 2005	103.0	Million
Occupants per household in 2005	4.2	People/HH
Rate of population growth in 2005	1.2	%/yr
Rate of reduction of rate of population growth	4.3	%/yr
Rate of reduction of occupants/household from 2006 to 2030	1.2	%/yr

Under those assumptions, the number of households is estimated to grow to about 54 million in 2050 (Fig. 4).

Figure 4. Number of households in Mexico 2006-2050
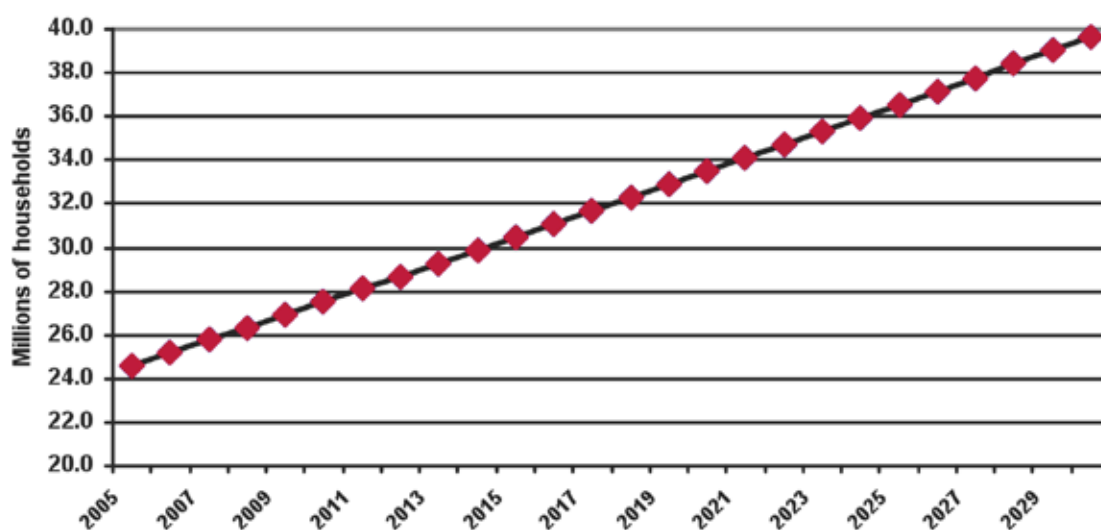
Source: Estimates by the author based on CONAPO´s data [7].

3.2. COMMERCIAL BUILDINGS

Energy use and built space data on commercial buildings in Mexico is scarce and dispersed.

In the case of energy use, the only data available for the services sector is that of use by type of energy source by not only buildings but municipal services (such as lighting and water pumping) [9].

For built space, there is not a single, unified data source either on the number of buildings or their area, so, in order to have and estimate, a survey of a number of data sources (mostly websites of chambers and associations related to the services sector) was performed. From that data obtained (that may not have

included total built area and/or average area per type of building) some very general considerations were made by the author in order to have an acceptable (but conservative) approximation.

To analyze the present and future GHG emissions from the services´ sector, this study will incorporate the following types of commercial buildings: hotels, office buildings, retail and department stores, hospitals, restaurants, warehouses, and schools.

3.2.1. Warehouses
According to data obtained from a business magazine, there are 25.5 million of m^2 of built space in Class A industrial parks in México [10]. Some of this space is used as warehouses for the services sector. So, for this type of buildings, an estimate of 5 million m^2 is used for the calculations.

3.2.2. Hotels and restaurants
According to Mexico´s Confederación Nacional Turística (CNT), in 2007 there were 14963 hotels in the country, with nearly 585 thousand rooms for an average of 39 rooms per hotel. Also, the rate of growth in the number of rooms has been 4.7% per year since 2000, while the number of installations has been 5.5% [11].

No data on built area for hotels was found so 30 m^2 per room (that includes common areas in the hotels) was used to estimate the total area of 12 million m^2.

Regarding restaurants and according to the Cámara Nacional de la Industria de los Restaurantes (CANIRAC), there are 243000 affiliated establishments and 96% are small businesses and 98% of them the service area is less than 150 m^2 [12].

To estimate built area for restaurants only those that are not small businesses (these are included under the "other" category) were considered and under the assumption of 400 m^2 per establishment (for a total of 2 million m^2).

In total, the total area for hotels and restaurants was estimated in 14.0 million m^2.

3.2.3. Office Buildings
Data obtained from the business sector of a national newspaper on office buildings built space indicates 4.6 million m^2 of class A, B and C buildings in 2008 [13]. This is the value used for the calculations.

3.2.4. Wholesale and retail
According to the Asociación Nacional de Tiendas de Autoservicio y Departamentales (ANTAD) this association (which represents the retail industry in Mexico) is composed of 14034 stores, of which 2244 are retail, 957 are department stores and 10833 are specialty stores, accounting for a total sales space of 15.2 million m^2 [14].

3.2.5. Theaters & Recreational Facilities
No direct is data available on this type of buildings but data on malls (that always include some type of theater) indicate 27.8 million m^2 (from a density of 0.27 m^2/person) of built area in México [15].

Assuming that theaters take 10% of total space in a mall, and estimated 2.8 million m^2 are considered for this type of buildings.

3.2.6. Hospitals

According to the National Health Information System (Sistema Nacional de Información en Salud), there are 4300 hospitals in Mexico with a total of close to 120 thousand beds [16].

No data on built area was found, so 50 m² per bed (that includes common spaces) was considered for an estimate of six million m².

3.2.7. Schools

According to Ministry of Education data, there are close to 242000 schools in Mexico. Close to 100000 are primary schools, 86700 for preschool, while more than 37000 are for secondary education (middle and high school) [17].

No data on built area was found so, assuming 500 m² per school, an estimate of 121 million m² for schools is considered.
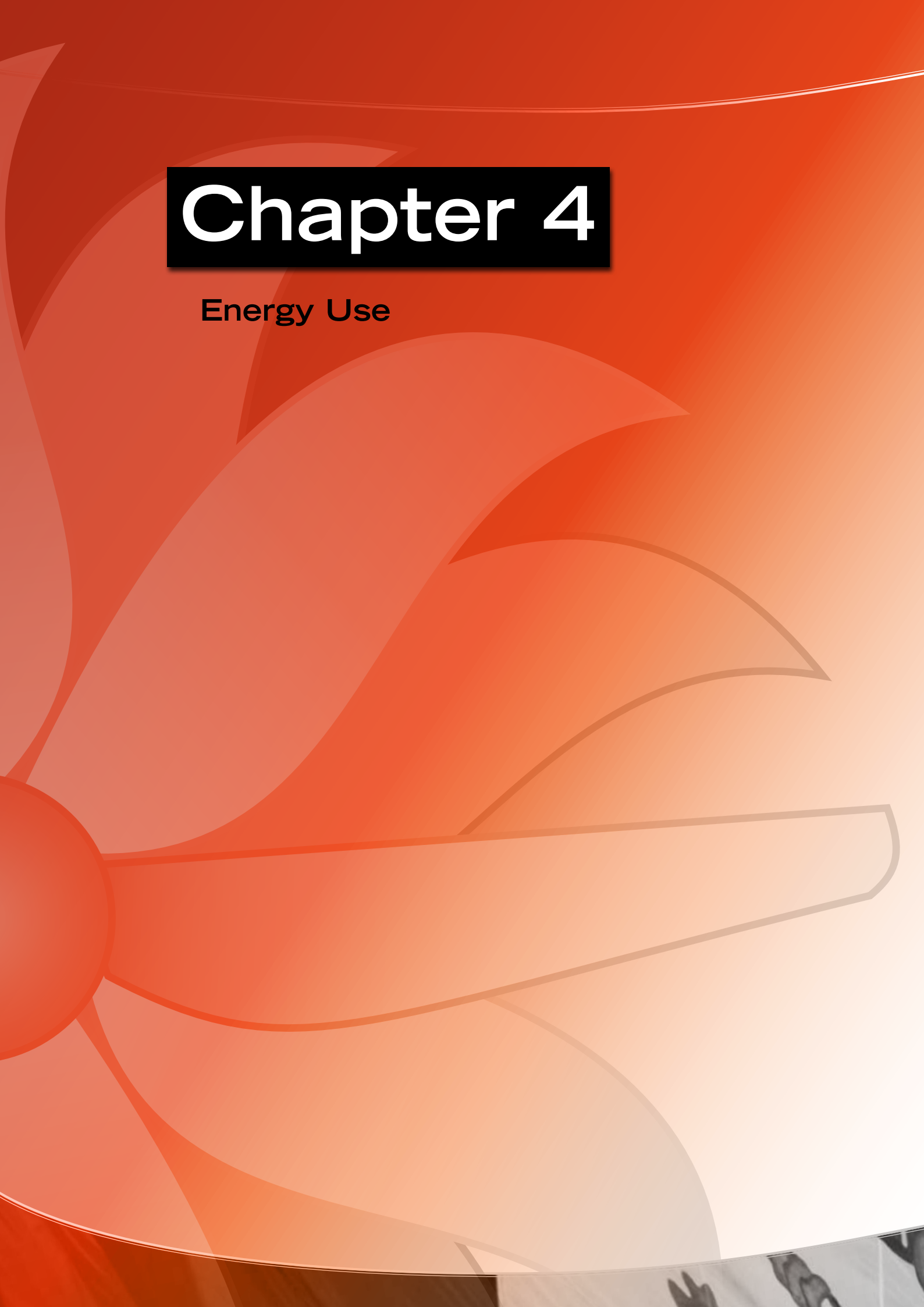
3.2.8. Other buildings

This category of buildings includes all of the small businesses for an estimate of 110,000 m².

Chapter 4

Energy Use

Energy Use

4.1.   RESIDENTIAL SECTOR.

4.1.1. Total energy use

Residential energy use in Mexico covers a number of services, mainly cooking, water heating, refrigeration, air conditioning, lighting and other electricity related end-uses.

According to the 2006 national energy balance, final energy consumption of the residential sector represented 705.1 Petajoules (PJ), which amounted up to 16% of the total final energy consumption in Mexico (4390.7 PJ) [18].

LPG was the main energy source used in the residential sector, with a participation of 37.8% (266.5 PJ), followed by firewood with 35% (247.2 PJ). Electricity contributed with 22.7% (160 PJ) of the final energy consumption, natural gas 4.2% (29.6 PJ) and kerosene 0.3% (1.8 PJ). Residential energy consumption grew 0.1% between 2005 and 2006 [18].

For the purpose of this study, electricity use by type of customer is classified under two groups by generic type of climate: temperate and hot. This classification is based on Mexico's residential electricity tariffs, that are defined by average temperature in the two hottest months and under seven different rates, one for temperate climate and six for different levels of average temperature above 25 °C. There is also a third group that is defined by its level of consumption above a certain threshold (that varies by rate and time of the year). This is identified as "high consumption" (Table 6) [19].

Table 6. **Electricity rate structure for the residential sector in Mexico**

Rate	Average minimum temperature for application (in °C)	High consumption limit (in kWh/month)
1	Less than 25	250
1A	25	300
1B	28	400
1C	30	850
1D	31	1000
1E	32	2000
1F	33	2500

Source: CFE [19]

For this study, the temperate category refers to households in locations under the temperate climate rate and the hot category to those households located in the locations with the other six rates.

In terms of electricity use, by the end of 2007 the Mexican electricity sector had little more than 26.3 million residential users. Of this total, 55% were located in temperate climates 43% in hot climates and 2% are high consumption (Fig. 5) [20].
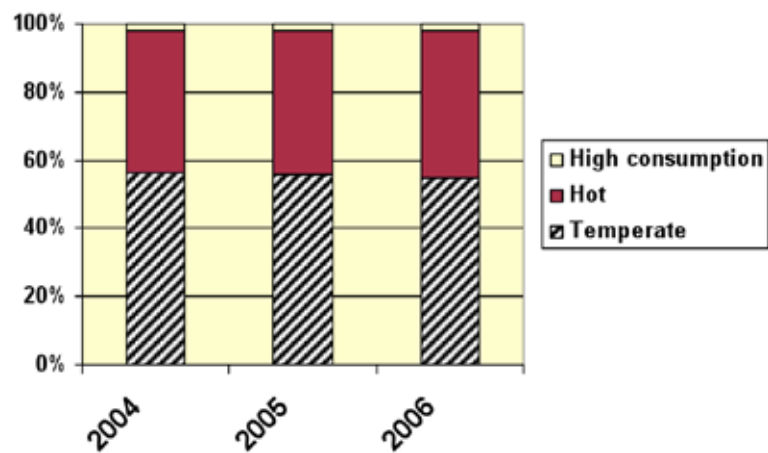
Figure 5. Residential end-users by type of climate 2004-2006

Source: CFE [20]

4.1.2. Average energy use

As there are no recent studies on average energy use by type of energy and/or end use, the numbers were estimated based on direct and indirect data obtained from different sources and on engineering estimates.

4.1.2.1. Water heating

For water heating the assumptions were that all of the residents of a household with hot water shower daily using 65 liters of water with a temperature increase of 15o C in a water heater that is 50% efficient. That results in 2.98 GJ per person per year.

For the purpose of calculating emissions, a mixture of natural gas and LPG was considered (based on the mixture referred in the national energy balance) [18].

4.1.2.2. Cooking

An energy consumption of 8.0 GJoules per household is used for the calculations [21]. This consumption is only for houses with gas stoves (70% of the total) [22].

As with water heating and for the purpose of calculating emissions, a mixture of natural gas and LPG was considered (based on the present mixture) [18].

4.1.2.3. Electricity

For 2006, average yearly power consumption for households in hot climate is 2,200 kWh, 1200 kWh in temperate climate and a little more than 6000 kWh by high consumption customers (Fig. 6) [20].

For the purposes of this study, an average consumption for 2005 of 1.4 and 2.2 MWh/yr for temperate and hot climate was, respectively, assumed.

Figure 6. Residential yearly consumption by type of climate (2004-2006)
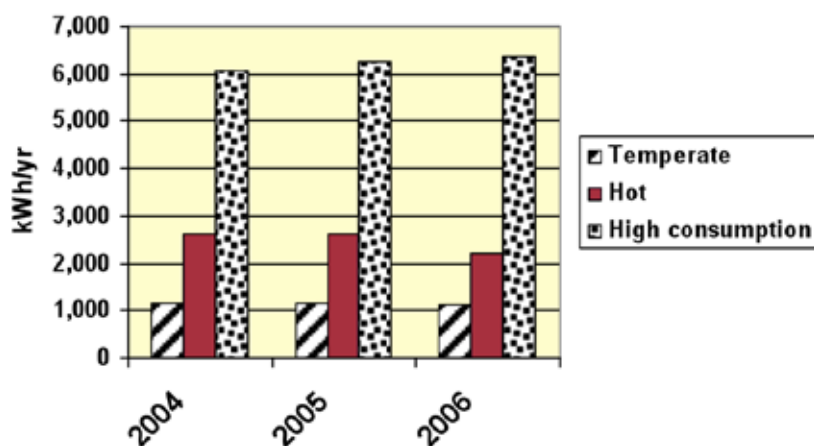
Source: CFE [20]

In terms of electricity end uses, the following considerations were made (for 2005):

*   Refrigeration. An average of 800 kWh/yr for the total number of households.[3]
*   Lighting. An average of 440 kWh/yr for the total number of households (Four 60 Watt lamps used five hours every day of the year).
*   Space cooling. An average of 600 kWh/yr for the hot climate households. The estimate is equal to the difference in the yearly unit consumption between temperate and hot climate households.
*   Other electrical. The intensity of this end use is defined as the difference between total intensity per household mines the three above.

4.1.3.   Projected energy consumption by the residential sector

Mexico's Secretaría de Energía (SENER) presents a series yearly planning exercises that projects energy consumption by types of energy and end-users for ten years [23-25]. Aggregating the different estimates by fuel a projection was made that is specific for the residential sector (Fig. 7)

Figure 7. Energy consumption in the residential sector (1995-2005) and trends to 2015
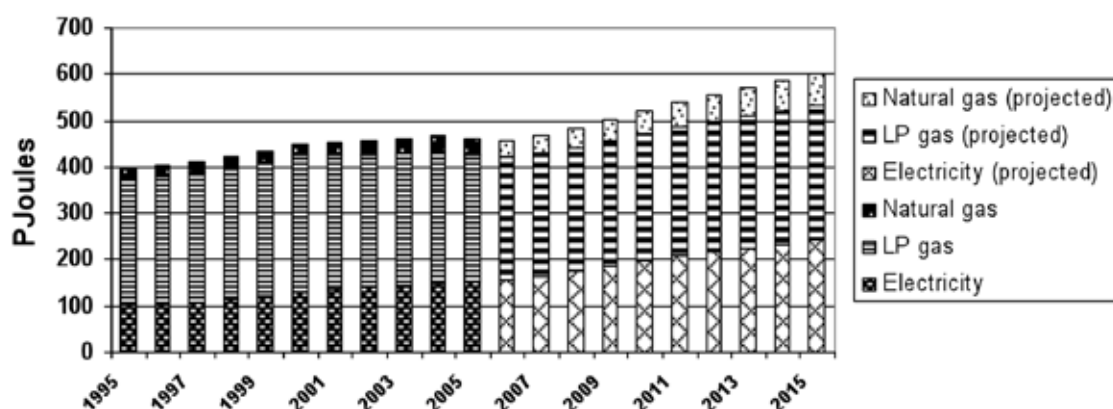
Source: SENER [23-25]

3   This is a value between the highest value (of 1,100 kWh/yr for a ten year refrigerator) and the lowest value (400 kWh/yr for a new refrigerator).

4.2.   COMMERCIAL BUILDINGS

4.2.1. Average energy use

There is very little data on average energy use of commercial buildings in Mexico and even less on energy end uses. Some data on electricity use for lighting and space cooling in commercial buildings can be found in a series of reports prepared by the Fideicomiso de Ahorro de Energía Eléctrica (FIDE) some years ago.[4]

To compensate such a limitation, data on commercial building energy use in Canadian commercial buildings from Natural Resources Canada (NRC) was used as a main reference for end-use intensity [26]. This was done under the assumption that the intensity of energy end-uses such as lighting and water heating are about the same and that other end uses can be adjusted for the specific conditions of Mexico. So the following assumptions were made:

a.   Energy use for heating was assumed to be zero.
b.   Consider the energy intensity for space cooling as twice the value of NRCan building data base, except for schools (that keep the same intensity as in the NRCan database).

The numbers that result from this process range from an intensity of 580 MJ/m^2-yr for warehouses to 1480 MJ/m^2-yr for hospitals (Fig. 8).

Figure 8. Estimated average energy use per year in Mexico´s commercial buildings by end use and building type (2005).
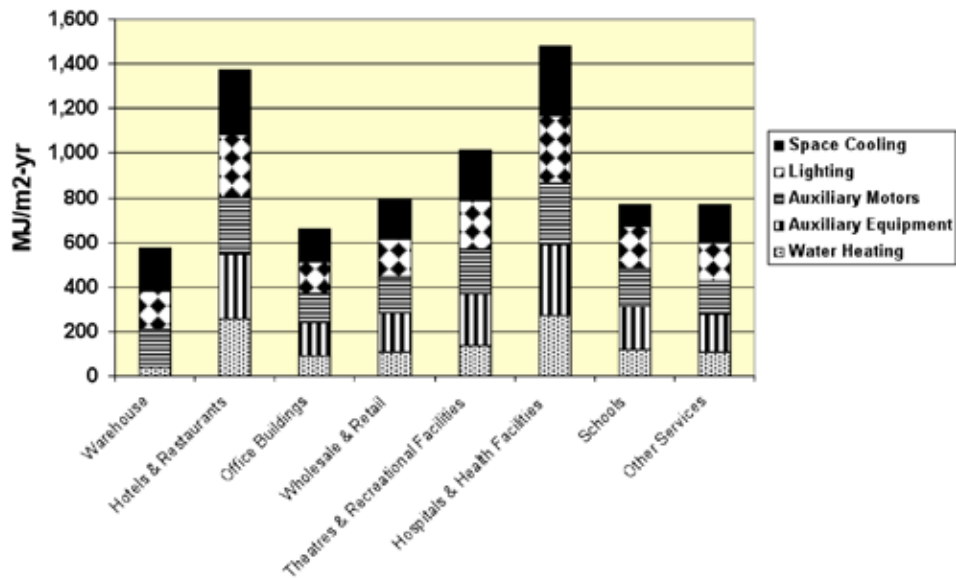
Source: Estimates by the author using NRCan data [26]

To calibrate these numbers, the resulting electricity intensity per unit of area for some of the building types (Fig. 9) was compared with data collected from sheets of individual projects published by FIDE.

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4   They are reports done on demonstration projects and do not have consistent information.

Figure 9. Estimated average electricity use in Mexico´s commercial buildings by end use and building type (2005).
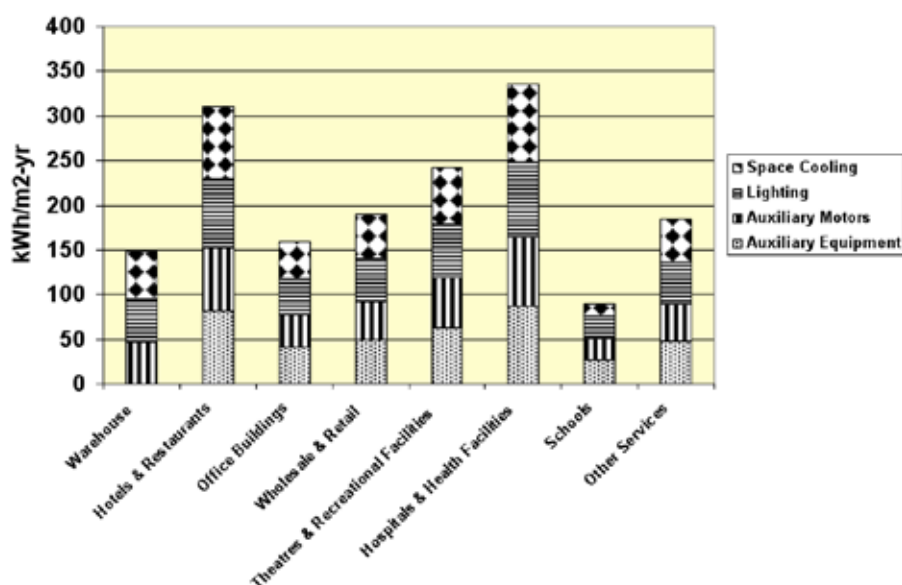
Source: Estimates by the author using NRCan data [26]

4.2.2. Total energy use

According to Mexico's National Energy Balance for 2006, the overall energy consumption of the commercial sector totaled 135.2 petajoules, with electricity representing 70.0 petajoules [18].

However, total energy use for the commercial buildings as reported by SENER´s energy statistics only partially reflect the sector's energy consumption, in particular electricity use, as the energy accounting by the national utility is based on voltage of service and not on type of installation.

Reviewing the "commercial" subsector's electricity use defined in National Energy Balance for 2005 against data from Comisión Federal de Electricidad (CFE) for that same year, it was found that the total refers to energy users at rates 2, 3 and 7, which correspond to distribution-level (low tension) services [20].

Also, upon reviewing the long list of case sheets from FIDE and data compiled by the Comisión Nacional para el Ahorro de Energía (CONAE) in its public buildings program, a majority of typical services-sector facilities (hotels, restaurants, shopping centers, schools and hospitals) are connected at OM and HM rates, which are categorized by CFE as "medium industry."

Thus, not only CFE statistics but also national energy reports underestimate the services or the services sector's weight in the energy balance.

To put the importance of commercial buildings in national energy consumption into perspective, and to show the extent of its evident underestimation, information on the size of the sector and its energy consumption was collected from various sources.

In particular, data from FIDE case sheets, an old version of the CONAE public building database [27], CFE sales statistics [20] and data from companies and associations involved in the sector that have been referred to in the building stock.

Using the area estimated for all types of buildings that are not small buildings (they are considered under "other" in the global estimates) and the electricity intensities defined above, the estimated total electricity use that is not included in the commercial buildings totals is 22350 GWh (Table 7).

Table 7. Estimated electrical power consumption in large service-sector buildings in Mexico

Type of building	Total building area (m^2)	Unit consumption (kWh/m^2-yr)	Total use (GWh)
Warehouse	5000	148.32	742
Hotels & Restaurants	14000	310.60	4348
Office Buildings	4600	158.91	730
Wholesale & Retail	15200	189.81	2885
Theatres & Recreational Facilities	3000	242.75	728
Hospitals & Health Facilities	6000	335.57	2013
Schools	121000	90.11	10903
TOTAL	168800	-	22350

Source: Estimates by the author from a variety of data sources [10-15]

4.2.3. Future energy use

Based on SENER´s projected energy consumption by types of energy and end-users for ten years, and the estimates for electricity use in large buildings not considered in the National Energy Balance (at a 2.3% rate), total energy use is expected to grow to 275 PJoules in 2015 (Fig. 10).[5]

Figure 10. Energy consumption in the commercial sector (1995-2005) and trends to 2015.
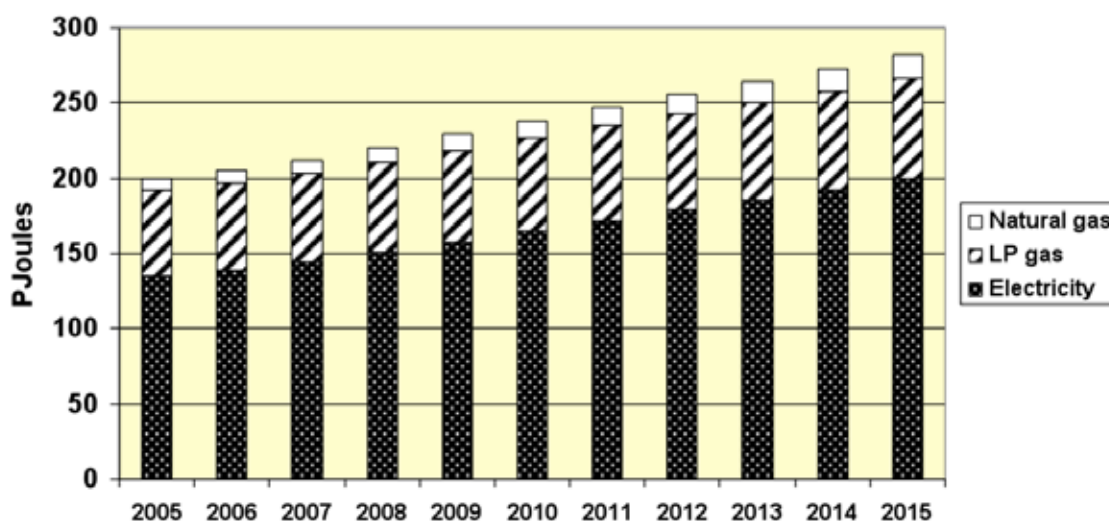
Source: Estimates by the author from a variety of data sources [10-16]

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5   SENER, 2007. Prospectiva del Sector Eléctrico, Prospectiva de Gas Natural y Prospectiva de Gas LP 2007-2016. Secretaría de Energía, México.

Chapter 5

Baseline: The Building Sector's Contribution To National Greenhouse Emissions

Baseline: The Building Sector's Contribution To National Greenhouse Emissions

5.1. ACTUAL CARBON-EQUIVALENT EMISSION TRENDS BY SECTOR[6]

The latest national GHG inventory was prepared by the Instituto Nacional de Ecología (INE) for 2002. For that year, GHG emissions for the six gases listed in Appendix A of the Kyoto Protocol were estimated at 643183 KTon of carbon dioxide equivalent (CO_2 eqv.), with the caveat that figures for the category of Land Use, Land-Use Change and Forestry (LULUCF) are still preliminary [28].

The results of the Inventory show a contribution of GHG emissions from the different categories in terms of CO_2 eqv. as follows: energy, 61% with 389497 KTon; LULUCF, 14% with 89854 KTon; waste, 10% with 65584 KTon; industrial processes, 8%, with 52102 KTon; and agriculture, 7% with 46146 KTon (Table 8).

Table 8. Total CO_2 eqv. emissions in 1990 and 2002 (LULUCF not included) in México (in KTon)

Source	1990	2002
Energy	312,027	389,497
Fossil fuel use	279,863	350,414
Fugitive emissions	32,164	39,082
Industrial processes	32,456	52,102
Agriculture	47,428	46,146
Waste	33,357	65,584
TOTAL	425,268	553,329

Source: Instituto Nacional de Ecología,[28].

By sectors, energy generation contributed 24% of the country's total emissions in 2002, while transport 18%, manufacturing and the construction industry 8%, residential, commercial and agricultural sectors 5%; and fugitive methane emissions 6%. GHG emissions in the energy category, expressed in CO_2 eqv., showed an increase from 312027 KTon to 389497 KTon from 1990 to 2002, which represents a 25% increase.

An estimate of CO_2 eqv. emissions from direct fossil fuel combustion based on energy use as reported in the 2005 National Energy Balance, comes to a total of 396000 KTon. By sectors, the transportation sector had the greatest share of those emissions with 36%, while power generation had 30%, the oil sector 19%, industry 9% and the sum of the residential, commercial and agricultural sectors with 6% (Fig. 11).

5.2. PROJECTED CARBON-EQUIVALENT EMISSION TRENDS BY SECTOR[7]

An estimate of CO_2 eqv. emissions from direct fossil fuel combustion based on SENER´s ten-year projections of energy consumption results in a 31% growth from 2005 to 2015 in direct CO_2 eqv. emissions (which represents a yearly growth rate of 2.74%).

6, 7   It should be noted that this estimation is based on government data and does not consider the assumption made in this document to reflect (as it is stated in this report) the fact that electricity use that goes to the services sector is accounted as industrial use.

By fuels, the greatest growth would occur in the combustion of gasoline and natural gas with 47%, while fuel oils would be reduced in 20% (Fig 12).

By sectors, the transportation will have 47% more CO_2 eqv. emissions in 2015 than in 2005, while the oil sector will grow by 30%, industry and the power sector by 21%, and the aggregation of the residential, commercial and agricultural sectors by 17% (Fig. 13).

Figure 11. Estimated contribution of direct CO2 eqv. emissions from fossil fuel combustion by sectors in 2005
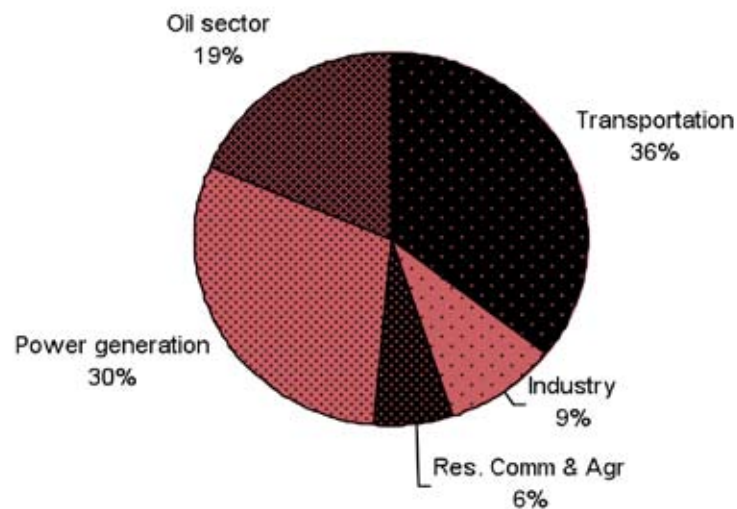
Source: Estimates by the author based on SENER and IPCC data [29] [30]

Figure 12. Estimated evolution of direct CO2 eqv. emissions from fossil fuel combustion by sectors (2005 to 2015)
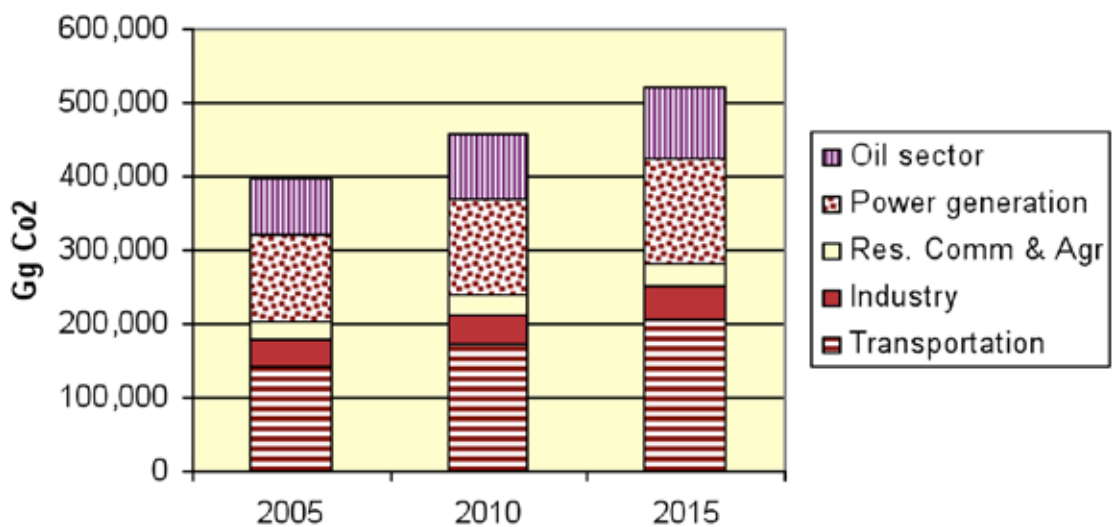
Source: Estimates by the author based on SENER and IPCC data [29] [30]

Figure 13. Estimated growth of direct CO_2 eqv. emissions from fossil fuel combustion from 2005 to 2015
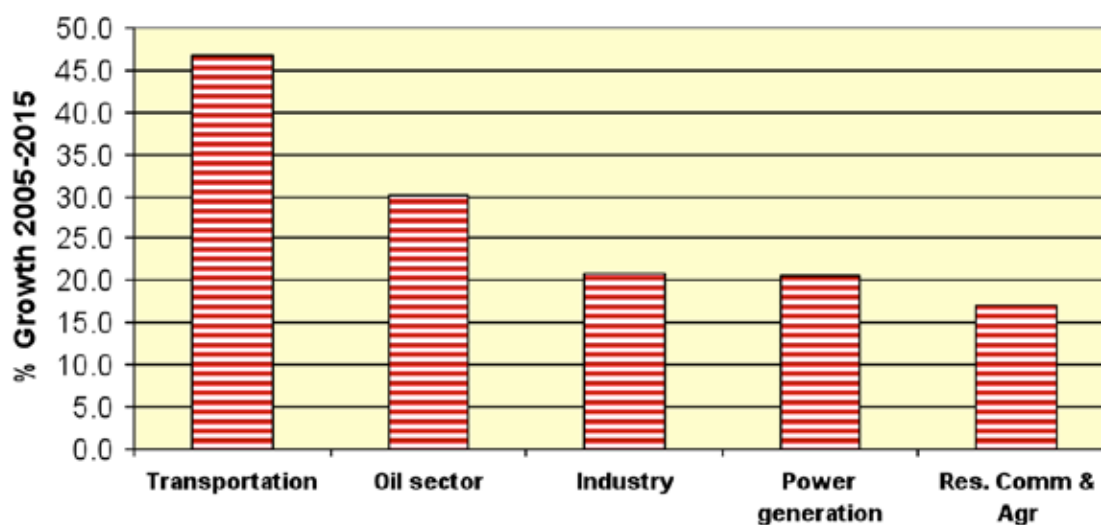
Source: Estimates by the author based on SENER and IPCC data [29] [30]

5.3.   BUILDING SECTOR'S CONTRIBUTION TO NATIONAL GREENHOUSE EMISSIONS

Baselines for both the residential and the commercial buildings are based on energy consumption projections that are assembled from a number of factors subject to change. These projections were assembled in a model integrated in an Excel spreadsheet (see ANNEX I: Methodology).

In order to define the baseline factors, the growth rates that determine the model projections were calibrated to obtain the same energy use values with the Ministry of Energy projections for 2015[8]. These baseline factors are reflected in both the numbers annotated above and the rates of change that are defined for each of the building sets.

CO_2 eqv. emissions are calculated with the emission factor referred in Table 9.

Table 9. CO_2 eqv. emissions factors for LP gas, natural gas and electricity in México

Type of energy	Emission factor
(Tons of CO_2 eqv./TJ)	
LP Gas	67.57
Natural gas	56.61
Electricity (2005)	166.00

Source: Estimates by the author based on SENER and IPCC data [29] [30]

To reflect the evolution of the power generation mix, it is assumed that the emission factor for electricity changes through the years at a rate of 0.5 % per year.

8   2015 is used because that is the latest year for which there are government projections in terms of energy use.

5.3.1. Residential buildings

For electricity consumption, the 2005 values for fraction of households in temperate climate and unit electricity use in hot and temperate climate are used (Table 10).

Table 10. Values of parameters related to electricity use[9]

CONCEPT [Source, where appropriate]	Value	Units
Fraction of households in temperate climate [20]	0.56	%
Unit electricity use in temperate climate (2005) [20]	1.50	MWh/yr
Unit electricity use in hot climate (2005) [20]	2.10	MWh/yr
Rate of growth of unitary power use in temperate climate	0.00	%/yr
Rate of growth of unitary power use in hot climate	4.00	%/yr
Rate of growth of refrigerator intensity	-1.00	%/yr
Power consumption by "other electrical" in 2005	0.20	MWh/yr
Rate of growth of "other electrical" use intensity	7.60	%/yr
Rate of growth of lighting intensity	-1.00	%/yr

This serves to establish power use for air conditioning as a general average for all the households located in hot climates. The use of differential rates of growth for these two parameters is done to reflect the growth of air conditioning.

It is important to note that the concept of "other" involves those uses that come from a growing electrification of households and includes clothes and dishwashers, more and larger TVs, computers, and systems with stand-by consumption (clocks, cable boxes, etc.) This is why (besides the fact that it serves to calibrate the aggregation of end-uses with total electricity estimations by SENER) its rate of growth is significant.

Also a negative growth rate for refrigeration and lighting reflect an on-going tendency as new, more energy efficient refrigerators and lamps replace older, less efficient technology.

For LPG and natural gas consumption, unit consumptions per household (for cooking) and per person (for water heating) were considered, together with levels of stove and water heater saturation. No growth of these parameters is considered (the uses will grow with the population and number of households) but a rate of growth of the fraction of solar heat is used to reflect the growth in the use of solar energy. Also the fraction of households using LPG as fuel (to apply the high emissions factor) were used (Table 11).

9   The growth rates that determine the model projections were calibrated to obtain the same energy use values with the Ministry of Energy projections for 2015.

Table 11. Values of parameters related to energy use in residential buildings

CONCEPT [Source, where appropriate]	Value	Units
Cooking [21]	8.00	GJ/hh-yr
Stove saturation [22]	70.00	% of hh
Water heater saturation [22]	50.00	% of hh
Unit hot water consumption	2.98	GJ/person-year)
Rate of growth of fraction of solar heat	0.00	% per yr
Fraction of households w/LPG [22]	89.00	%

With those assumptions, present (2008) CO_2 eqv. emissions are close to 50,000 KTon CO_2 eqv. per year. In terms of projections, while population is expected to grow 26% by 2050, residential sector emissions are estimated to grow close to nine-fold to that year (Fig. 14).

Figure 14. Baseline projections of CO_2 eqv. emissions of Mexico's residential buildings (2006-2050)
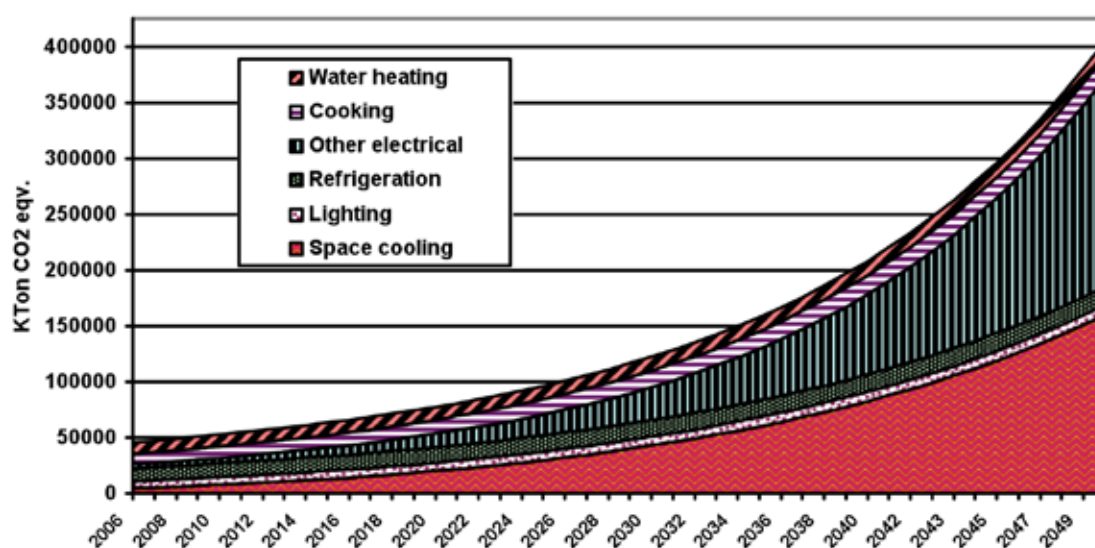
It should be noted that, given the assumptions, most of the growth in emissions will come from electricity generation to feed space cooling and the "other" uses, which were given growth rates to match the official projections for electricity and total energy use by the residential sector in 2015.

5.3.2. Commercial buildings

A set of values for the growth rates are defined to establish a baseline for commercial buildings that matches SENER´s projections for 2015. The year 2015 is used because that is the latest year for which there are government projections in terms of energy use.

First, there are rates of growth of built area by type of building (Table 12).

Table 12. **Growth per year of electricity use by type of commercial building**

CONCEPT	Value
Warehouses	4.0
Hotels & Restaurants	4.0
Office Buildings	4.0
Wholesale & Retail	4.0
Theatres & Recreational Facilities	4.0
Hospitals & Health Facilities	4.0
Schools	3.0
Other Services	3.0

Second, growth of energy intensity by end use was assumed as equal to zero.

Third, there are rates of growth of electricity use of the unaccounted fraction from large buildings and the evolution of CO_2 eqv. emissions factor (Table 13).

Table 13. **Values of parameters related to electricity use in commercial buildings[10]**

CONCEPT	Value	Units
Growth of electricity use	2.3	% per yr
Change in unit electricity CO_2 eqv. emissions	-0.5	% per yr

Under those assumptions, CO_2 eqv. emissions resulting from the energy use of commercial buildings in 2008 are around 31000 KTon, while this value grows close to 105000 KTon in 2050 (Fig. 15).

Figure 15. **Baseline projections of CO_2 eqv. emissions of Mexico´s commercial buildings (2005-2050)**
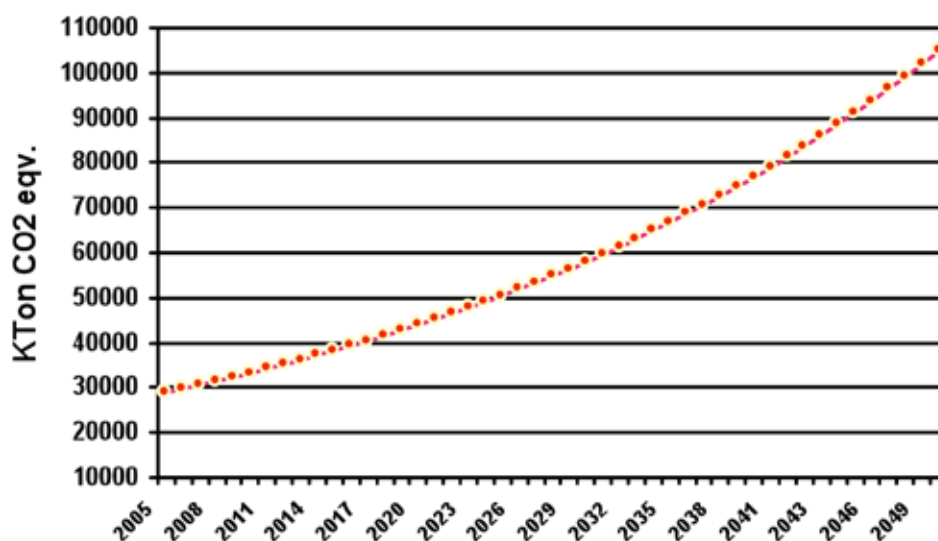
10   These numbers were established by the author and are conservative.

5.3.3. Consolidated residential and commercial buildings´ emissions

Consolidating the estimated CO_2 eqv. emissions´ numbers for residential and commercial buildings it was found that they were close to 75000 KTon in 2006 and, under the assumption stated above, they will grow up to close to 510000 KTon in 2050 (Fig. 16).

Figure 16. Baseline projections of CO_2 eqv. emissions of Mexico´s residential and commercial buildings (2006-2050)
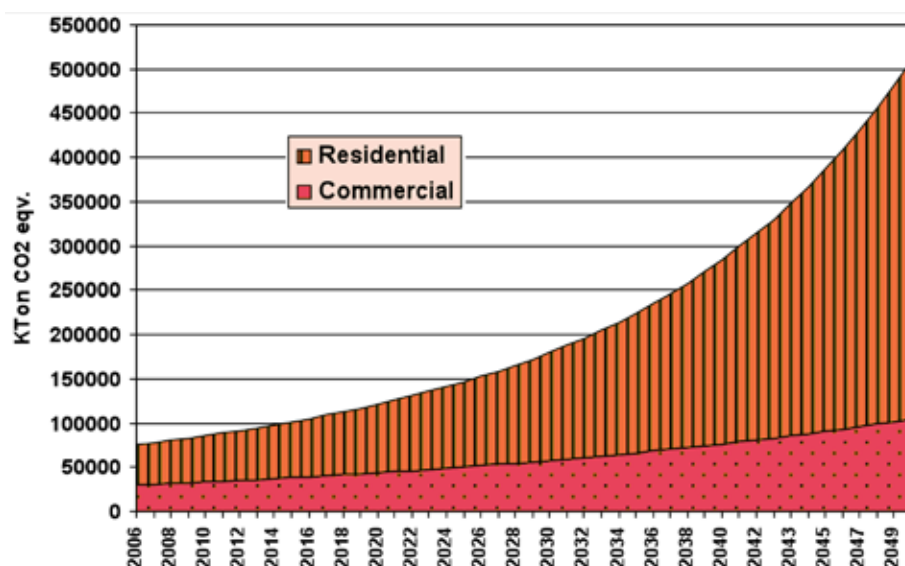
5.4. PARTICIPATION IN MEXICO'S TOTAL CO_2 EQV. EMISSIONS

As it was noted above, 61% the Mexico's GHG emissions came from direct fossil fuel combustion and an estimate of CO_2 eqv. emissions from combustion of fossil fuels—based on energy use as reported in the National Energy Balance in 2005—comes to a total of 396000 KTon. This would mean that total emissions for 2005 would be about 650000 KTon.

This means that buildings represent about 12% of total emissions in Mexico.

Chapter 6

Sustainable Development Priorities and Priority Issues for the Building Sector

Sustainable Development Priorities and Priority Issues for the Building Sector

The main purpose with regards to sustainable development set forth in the National Development Plan is to achieve environmental management which consolidates sustainable development both in the economic and social areas, consistent with the protection and preservation of natural resources. From a governmental stand point, the Secretaria del Medio Ambiente y Recursos Naturales (SEMARNAT) is responsible of conducting all sustainable development policies and programs.

6.1. GENERAL CLIMATE CHANGE POLICIES AND PROGRAMS

6.1.1. Mexico's federal government National Strategy on Climate Change

The National Strategy on Climate Change (ENACC) identifies specific measures for mitiga¬tion, with estimates of their potential for emissions reductions [31]. It also proposes a suite of research objectives as a tool for laying out more precise mitigation targets and outlines national requirements for capacity building for adaptation to climate change.

This strategy will be followed by an action plan that has only been presented as a draft.

6.1.2. Mexico City's Climate Action Program

Published in 2008, Mexico City's Climate Action Program defines strategies and specific measures to reduce, in the 2008-2012 period, 7 million tons of CO_2 eqv. emissions [32]. The measures considered include large water conservation programs, public transportation and waste management projects, and subsidies and incentives for residential and commercial buildings. In particular, tax exemptions for new and existing residential and commercial buildings that integrate energy and water conservation, and renewable energy measures could be put in place in 2009.

6.2. POLICIES AND PROGRAMS RELATED TO THE BUILDINGS´ SECTOR

There are no specific laws involving sustainable development priorities for buildings in Mexico.

There are, though, a number of policies and programs involving both the government and the private sector that have direct and indirect impacts on the CO_2 eqv. emissions that result from residential and commercial buildings operations.

- Energy efficiency standards for appliances
- Energy efficiency standards for lighting systems and building envelope of non-residential buildings.
- CFE and FIDE´s DSM programs
- The Instituto del Fondo Nacional de la Vivienda para los Trabajadores (INFONAVIT) "Green mortages" program.
- Comisión Nacional de Vivienda (CONAVI) Low Income Housing subsidies.
- Solar water heating standards
- Environmental regulation that mandate the use of solar water heating systems in non residential buildings in Mexico City.

6.2.1. Energy efficiency standards for appliances

The Federal Law on Metrology and Standards, in its Article 40 establishes the mandate to implement mandatory technical standards (Normas Oficiales Maxicanas or NOM) which define "the characteristics and/or specifications products or processes must meet in the case they may constitute a risk for the human safety or could endanger human, animal or vegetable health, overall or working environment, or for natural resources preservation" [33].

To date, eight NOMs have been implemented for equipment and appliances that are used in both residential buildings (Table 14) [34]. The minimum performance standards (and their corresponding test procedures) for refrigerators and AC units have been harmonized with those of the US and Canada [35].

Table 14. **Energy Efficiency Standards related to building energy use**

Product or system
Room air conditioners
Residential refrigerators and freezers
Residential clothes washers
Water heaters
Thermal insulation
Central-type air conditioners
Self-contained commercial refrigerators
One-phase motors

Source: CONAE [34]

These standards depend on the private sector for their implementation and are working well and having significant positive impacts [36].[11]

6.2.2. Energy efficiency standards for lighting systems and building envelope of non-residential buildings

Two other NOMs have been issued for interior lighting systems and the exterior buildings´ envelope [1, 2]. They have been in place for more than six years but have been poorly enforced as they require the involvement of the power utilities (for the interior lighting systems standard) and the municipal authorities (for the building envelope standard) to be applied. In the case of the envelope standard, no large city government has adopted it in its construction regulations; in the case of the lighting standard, the utilities have not been consistent of its application.[12]

6.2.3. CFE and FIDE´s Demand Side Management (DSM) programs

CFE has been involved (be it directly or through FIDE) in a number of DSM programs since the early 1990s. One has been ILUMEX, a program that help install more than 2 million compact fluorescent lamps in Mexico´s largest cities and was later taken over by FIDE [37]. Another program has been done to thermally insulate roofs in Mexicali [38]. This type of actions have continued but at a low key level.

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11 Energy efficiency standards have represented significant energy savings. According to CONAE´s information, standards related to electricity end uses have saved an aggregate of 16065 GWh to end-users by the year 2006 (equivalent to the power consumption of 10 million Mexican households in one year), and resulted in 2926 MW of avoided power capacity (equal to 6% of Mexico´s installed capacity by the end of 2006). Energy efficiency standards for water heaters and industrial thermal insulation have resulted in energy savings of 36 Pjoules of LPG by the year 2006 (equal to 10% of a years´ use by residential and commercial end-users).
12 This opinion is based on personal exchanges with professionals involved in the sector and government officials as no official data is available.

6.2.4. The Instituto del Fondo Nacional de la Vivienda para los Trabajadores (INFONAVIT) "Green mortages" program

INFONAVIT is a public fund designed and integrated to, mainly, get low interest rate credit in sufficient amount to facilitate the purchase of new housing for workers in payrolls of the private sector [39].

The funds resources come from contributions by the workers themselves, their employers and the government. Individuals can use their accounts in the fund to pay for all or a fraction of the cost of a new house or its remodeling of a used one. In its lifetime (from 1972) this fund has provided close to 5 million loans [40].

Starting in 2007, INFONAVIT started operating a program that has been named Hipotecas Verdes (Green Mortgages). This is a mechanism that increases the amount of credit in close to 1500 US$ (to be paid in a longer period) to finance water and energy conservation measures and the use of solar energy for water heating. Measures include: low-flow showers, compact fluorescent lamps, thermal insulation and high efficiency AC units [41].

The financing mechanism allows the home buyer to pay for the measures under the logic that the measures will reduce operating expenses and facilitate reimbursing the loan.

The program has involved several hundred new houses and is expected to grow to close to 100,000 per year in 2009.

6.2.5. Voluntary standards for solar water heating

Three voluntary standards have been issued through a private sector standardization initiative with a solar energy mandate (NESO -13) [42]. These standards apply to solar water heating components, systems and installations. To date, three standards are in place: flat plate collectors, installations and terminology. These standards are not mandatory but can be adopted voluntarily to be used in public and private programs. To support the flat plate collector standard, a test laboratory has been installed and is already certifying solar collectors.

Other standards under development apply to residential systems and to storage tanks.

6.2.6. Environmental regulation that mandate the use of solar water heating systems in non residential buildings in Mexico City

The Government of Mexico City mandates, starting in 2006 and through an environmental standard, that all new public-use installations (such as hotels and sport clubs) have to heat 30% of their hot water needs with solar energy (GDF 2006) [43].

The impacts of this standard are still to be evaluated as enforcement has not been fully implemented.

6.2.7. Comisión Nacional de Vivienda (CONAVI) Low Income Housing subsidies

CONAVI is a federal government institution with regulatory and planning capacities that define the rules by which subsidies are given for low income housing [44]. For 2007, CONAVI has defined the rules for the use of close to 400 million US$ worth of subsidies [45].

To date, CONAVI has been working to define the rules and best practices to allow the use of subsidies for the incorporation of sustainability measures in low-income housing that include water conservation

measures, energy conservation measures (compact fluorescent lamps, thermal insulation and high efficiency AC units) and the use of solar energy for water heating and for power generation (through photovoltaic systems).

CONAVI has not defined the potential impacts of these policies.

6.2.8. Mexico Green Building Council (Mexico GBC)

The Mexico Green Building Council (Mexico GBC) is a non-governmental, non-profit organization that works from within the construction industry in order to promote a broad-based transition towards sustainability [46]. This organization has had very little activity and influence in Mexico.

6.3. OTHER ISSUES

It is very important to note that there are significant subsidies for the residential sector in México, particularly for electricity. Just in the year 2006, more than 10 billion US$ were spent by the government to cover the costs no recovered through the power utility bill [47]. Of this total, more than 50 % goes to cover the difference in cost in the residential sector.

More specifically, more than half of residential electricity consumers pay about 0.05 US$ per kWh, which is about a fifth of real costs (which is paid by about 10% of all residential customers) [19, 20, 47].

This, of course, is an enormous barrier to energy efficiency measures by the end users.

Chapter 7

Mitigation Measures and
Estimated Costs

Sustainable Development Priorities and Priority Issues for the Building Sector

All of the assumptions for the parameters considered in the model are made to reach a zero growth target, so total emissions have a constant value over the 2006-2050 period. Given the lack of general information on energy intensity in buildings in Mexico the following are very general estimates based on informed assumptions made by the author, outlined below.

7.1. RESIDENTIAL BUILDINGS

Five general categories of measures for the same number of end uses are considered:

- Space cooling. This measure considers a general improvement of design practices and of use of energy conservation technology, such as an increase in thermal insulation and an improvement in the efficiency of the air conditioning units.
- Lighting. This measure considers an increase of the efficacy of lamps.
- Refrigeration. This measure considers a reduction in the unit energy use of refrigerators.
- Other electrical. This involves a slowing of the saturation and rate of growth of larger electric equipment and appliances.
- Water heating. This measure considers both an increase in energy efficiency in gas water heaters and greater use of solar energy.

7.1.1. Baseline conditions

The baseline conditions assume some changes in the energy intensity of some of the end uses that will happen with additional effort or resources.

Specifically, space cooling grows from 0.68 to 4.1 MWh/yr to reflect growing and fast saturation of AC units and greater intensity of use, while "other electrical" grows reflecting greater saturation of an increasing number of larger electric equipment and appliances (like computers, clothes washers, larger TVs, and, in general, greater stand-by uses).

Also, reductions are considered for lighting and refrigeration, as the energy intensity of these end uses is already decreasing as a result of government policies and programs (Table 15).

Table 15. Baseline end-use intensities (2006 and 2050)

End uses	2006	2050
Space cooling (MWh/yr)	0.68	4.10
Lighting (MWh/yr)	0.43	0.34
Refrigeration (MWh/yr)	0.79	0.62
Other electrical (MWh/yr)	0.21	0.86
Water heating (GJ/person-yr)	2.98	2.98

Source: Estimates by the author.

7.1.2. Scenario conditions, impacts and estimated costs

The scenario that has been considered is the one that maintains the 2006 level of GHG emissions constant (zero-growth target), so all of the assumptions for the parameters considered in the model are made so total emissions have a constant value over the 2006-2050 period.

7.1.2.1. Scenario conditions
The following assumptions were made in the model to make the estimates for GHG reductions (to maintain the 2006 level of emissions constant):

- Space cooling. To reflect the impacts of general improvement of design practices and of use of energy conservation technology (such as an increase in thermal insulation and an improvement in the efficiency of the air conditioning units), the rate of growth of unitary power use in hot climate was reduced from 4% per year to zero growth (0% per year).
- Lighting. An increase of the rate of decline of unitary use for lighting from 1 to 5% per year was used to reflect a reduction of close to a fourth of 2006 unitary consumption to reflect generalized use of compact fluorescent lamps in 2030.
- Refrigeration. An increase of the rate of decline of unitary use for refrigerators from 1 to 3.4% per year was used to reflect a reduction of a little more than half in 2006 unitary consumption for 2030.
- Other electrical. The rate of growth of unitary use for "other" is 1% per year to reflect some level of greater saturation of an increasing number of larger electric equipment and appliances.
- Water heating. The rate of growth of the solar heat fraction was established at 6% per year.

7.1.2.2. Impacts
The resulting energy intensities are shown in Table 16.

Table 16. **Scenario end use intensities (2006 and 2050)**

End uses	2006	2050
Space cooling (MWh/yr)	0.60	0.60
Lighting (MWh/yr)	0.43	0.04
Refrigeration (MWh/yr)	0.79	0.16
Other electrical (MWh/yr)	0.20	0.32
Water heating (GJ/person-yr)	2.98	0.18

Overall, these changes would reduce the growth of CO_2 eqv. emissions of the residential sector to 63% of the baseline in 2050 (Fig. 18).

Figure 18. Evolution of CO_2 eqv. emissions for baseline and scenario conditions for residential buildings (2006-2050)
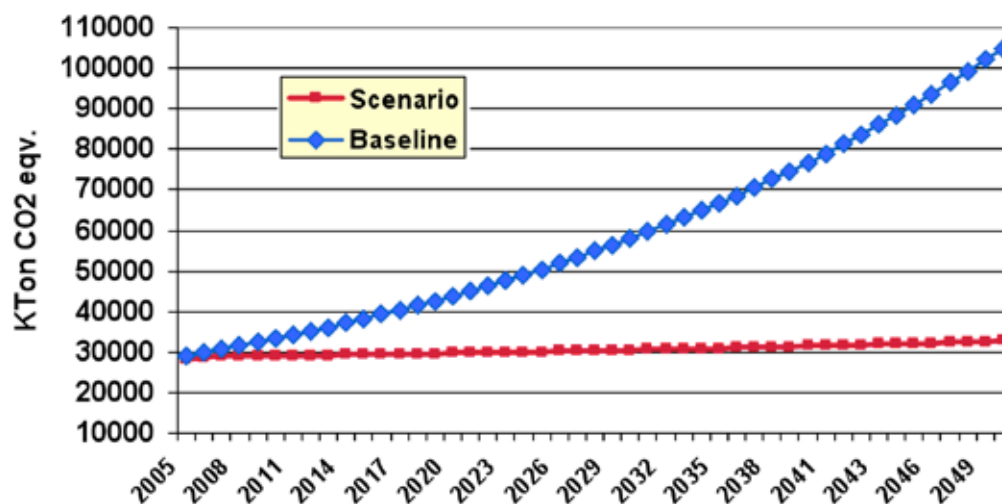
Most of the reductions come from measures related to electricity (96%) (Table 17).

Table 17. CO_2 eqv. emissions by energy source for baseline and scenario (2030) (KTon/yr)

Energy source	2006	2050		Diference
		Baseline	Scenario	
LP gas	17824	29760	18852	10909
Natural gas	1859	3104	1966	1138
Electricity	25497	364265	25261	339004
TOTAL	45180	397129	46079	351050

In terms of end uses, the largest fraction of the reductions come from greater efficiency in "other electrical" uses (50%), space cooling (42%), refrigeration (3%) water heating (3%), and lighting (2%) (Table 18).

Figure 19. Fraction of total reductions in CO_2 eqv. emissions by end use.
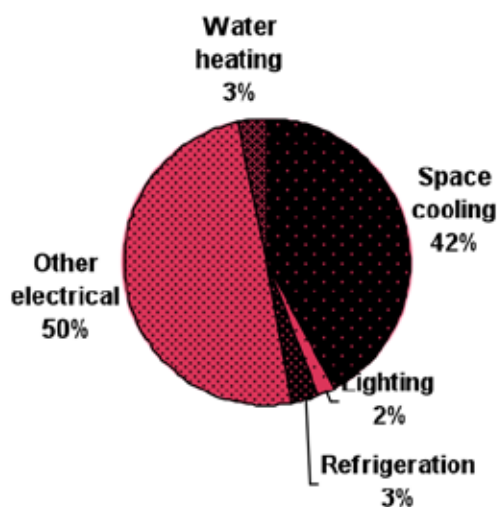
7.1.2.3. Costs

Assuming a unitary cost per household for the measures for each of the end-uses and for a fraction of the households, the estimated cost of the measures, at 2008 values, would be close to 104 billion US$ (Table 18).

Table 18. Total estimated costs of mitigation measures in the residential sector (2050)

End uses	Fraction of the total number of households with measures in 2050	Number of households with measures in 2050 (million)	Unit cost per household (2008 US$)	Total accumulated cost (2008 MMUS$)
Space cooling	50%*	26.95	2000**	53890
Lighting	100%	53.89	20	1078
Refrigeration	100%	53.89	200	10778
Other	100%	53.89	200	10778
Water heating	50%*	26.95	1000	26945
TOTAL				103469

* 50% would represent the total of households that are located in regions that require space cooling and water heating

** Includes thermal insulation and high efficiency AC units

7.2. COMMERCIAL BUILDINGS

As referred above, five general end uses are considered for commercial buildings: water heating, auxiliary equipment, auxiliary motors, lighting and space cooling.

Given the lack of general information on commercial buildings´ space and energy intensity in Mexico, the following are very general estimates based on informed assumptions made by the author.

7.2.1. Baseline conditions

Baseline conditions for commercial buildings assume no change in the intensity of the five end-uses, that is, energy consumption grows proportionately to the buildings area (Table 19).

Table 19. Values for baseline conditions for commercial buildings in 2006.

Type of building	Area (10e3 m^2)	Energy intensity (MJ/m^2-yr)
Warehouse	5000	576
Hotels & Restaurants	14000	1373
Office Buildings	4600	663
Wholesale & Retail	15200	792
Theatres & Recreational Facilities	2800	1013
Hospitals & Health Facilities	6000	1483
Schools	121000	660
Other Services	110000	768

7.2.2. Scenario conditions, impacts and estimated costs

7.2.2.1. Scenario conditions

The following assumptions were made for the parameters in the model to make the estimates for GHG reductions (to maintain the 2006 level of emissions constant).

Scenario conditions for commercial buildings assume a rate of reduction in the intensity of auxiliary equipment, lighting, and space cooling of 3% and of 2% for auxiliary motors and water heating (Table 20).[13]

Table 20. Rate or reduction of end-use intensity in scenario conditions for commercial buildings starting in 2006.

End use	Rate of reduction (% per yr)
Water Heating	2.0
Auxiliary Equipment	3.0
Auxiliary Motors	2.0
Lighting	3.0
Space Cooling	3.0

7.2.2.2. Impacts

Overall, these assumptions result in reductions of energy intensity 70% in energy intensity for all the building types in the 2005 to 2050 period (Table 22). This same fraction applies to the overall emissions (Fig. 20).

By end uses, technology improvements would result in reductions in the energy intensities of space cooling, lighting and auxiliary equipment by 75%, and of 60% in energy intensity for water heating, and auxiliary motors (Table 21).

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13   A higher rate of reduction is assumed for lighting as lamps and ballasts would be replaced more than two times in the period, while the others depend on longer periods for replacement and/or substitution.

Table 21. Energy end-use intensities in scenario conditions for commercial buildings in 2006 and 2050.

Building type	MJ/m^2	
	2005	2050
Warehouse	561	174
Hotels & Restaurants	1337	414
Office Buildings	779	230
Wholesale & Retail	771	235
Theatres & Recreational Facilities	986	300
Hospitals & Health Facilities	1444	447
Schools	642	197
Other Services	732	252

Figure 20. Evolution of CO$_2$ eqv. emissions for baseline and scenario conditions for commercial buildings (2006 to 2050)
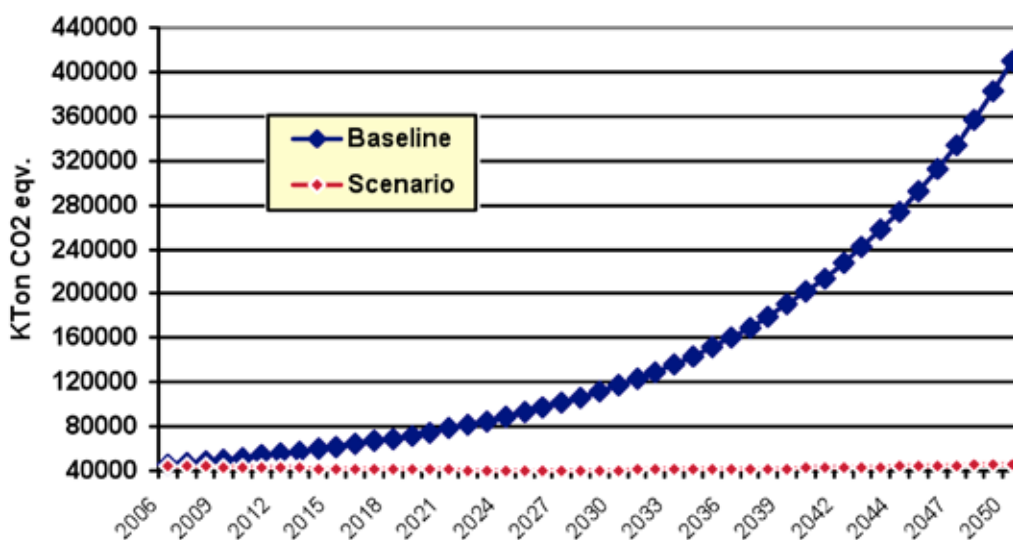
7.2.3. Estimated costs

No data could be found on the general cost of specific measures in commercial buildings so the estimated cost of the measures was obtained under the assumption that the mitigation measures add 3% per unit area in the cost of the buildings.[14]

The built area in 2050 is estimated to be close to 1.2 billion square meters (Table 22).

Table 22. Estimated total commercial building area for 2050.

Type of building	Area in 2030 (10e3 m²)
Warehouse	30374
Hotels & Restaurants	85048
Office Buildings	27944
Wholesale & Retail	92337
Theatres & Recreational Facilities	17010
Hospitals & Health Facilities	36449
Schools	471300
Other Services	428455
TOTAL	1188917

The average cost of construction in Mexico in December of 2007 was 600 US$/m² [48]. This means that an additional 18 US$/m² is used to pay for the additional measures in the buildings.

Therefore, the estimated cost of the measures for 2050 would be close to 21 billion US$.[15]

14   This is a conservative estimate.
15   No cost benefit analysis was done for the measures

Chapter 8

Conclusions and Recommendations

Conclusions and Recommendations

8.1.   CONCLUSIONS

This exercise explored the factors that result in GHG emissions from the operation of buildings in Mexico and produced estimates of future emissions by the residential and commercial sectors.

The estimates were produced under a number of assumptions that have been calibrated with the government's energy projections.[16]

8.1.1.   Emissions in 2006 and 2000

The present exercise has come up with estimated residential and commercial buildings emissions of close to 75000 KTon in 2006. This means that buildings represented about 12% of total present CO_2 eqv. emissions in Mexico in that year.

To have reference values for the year 2000, a simple backwards extrapolation was performed based of the 2006 to 2007 growth rate. A total of 70250 KTon in GHG emissions was estimated. Of this total, 43540 KTon came from the residential sector while 26,710 KTon came from the commercial sector.

8.1.2.   Baseline for the 2006 to 2050 period

A potential growth to up to close to 500000 KTon for 2050 has been estimated. Therefore there would be an increase by a factor of 6.7 of emissions if nothing is done.

Figure 21. **Evolution of CO_2 eqv. emissions for baseline conditions for commercial buildings (2006 to 2050)**

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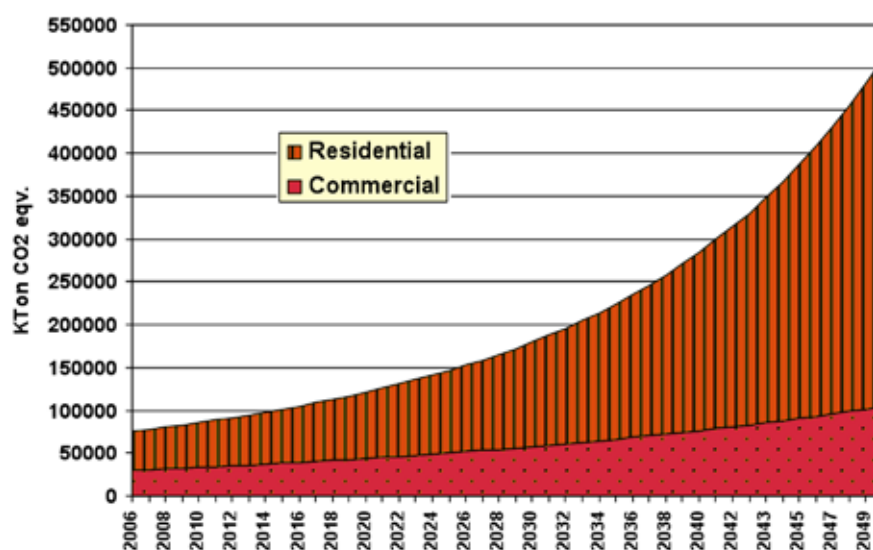
16   Government projections are for ten years and take into account federal energy conservation and renewable energy programs and some estimates of private sector activities.

8.1.3. Potential reductions for the 2006 to 2050 period

As has been stated in this report, assumptions were made in the parameters used in the model to maintain the 2006 level of GHG emissions constant for both the residential and commercial buildings.

8.1.3.1. Residential sector

In general, measures in the residential sectors are reflected in the average end use intensities of five end uses (Table 23).

Table 23. Scenario end use intensities (2006 and 2050)

End uses	2006	2050	Commentary
Space cooling (MWh/yr)	0.64	3.72	This is the global average, not the average of the households that have AC. The fact that the intensity grows is a reflection of the great growth potential for this end use
Lighting (MWh/yr)	0.43	0.04	This reflects the expectation that the LED technology will be widely available and cost effective in a couple of decades
Refrigeration (MWh/yr)	0.79	0.16	The 2050 number reflects the expectation that a household World be consuming less then 0.5 kWh/yr for refrigeration
Other electrical (MWh/yr)	0.20	0.50	As with space cooling, the intensity grows is a reflection of the great growth potential for this end use
Water heating (GJ/person-yr)	2.98	0.76	The reduction is a reflection of the generalization of the use of solar water heaters

Overall, these changes would reduce the growth of CO_2 eqv. emissions of the residential sector to 63% of the baseline in 2050. Most of the reductions come from measures related to electricity (96%) and, by end uses, the largest fraction of the reductions come from greater efficiency in "other electrical" uses (50%), space cooling (42%), refrigeration (3%) water heating (3%), and lighting (2%),

8.1.3.2. Commercial sector

In the commercial sector, reductions are reflected by energy end use intensities by building type (Table 24).

Table 24. Energy end-use intensities in scenario conditions for commercial buildings in 2006 and 2050.

Building type	MJ/m²	
	2005	2050
Warehouse	561	174
Hotels & Restaurants	1337	414
Office Buildings	779	230
Wholesale & Retail	771	235
Theatres & Recreational Facilities	986	300
Hospitals & Health Facilities	1444	447
Schools	642	197
Other Services	732	252

In the commercial sector, technology improvements would result in reductions in the energy intensities of space cooling, lighting and auxiliary equipment by 75%, and of 60% in energy intensity for water heating, and auxiliary motors.

8.1.4. Estimated cost of reductions for the 2006 to 2050 period

In the residential sector, the estimated cost of the measures, at 2008 values, would be close to 103 billion US$ (Table 25). In terms of unit costs per Ton of CO_2 eqv. avoided (under very general assumptions) the cheapest measure involves "other electrical" while water heating (which involves the use of solar energy) has the higher cost.

Table 25. Investments, reductions and unit costs by end use for residential buildings.

End use	Investment (2008 10e6 US$)	GHG Emission reductions (10e3 Ton CO_2 eqv.)	Unit cost (10e3 US$/Ton CO_2 eqv.)
Space cooling	53890	151007	0.36
Lighting	1078	7551	0.14
Refrigeration	10778	10979	0.98
Other electrical	10778	177018	0.06
Water heating	26945	12046	2.24

In the commercial sector, the estimated cost is close to 21 billion US$ by 2050.

8.2. RECOMMENDATIONS

Recommendations can be outlined from the exercise under four categories: data bases, minimum efficiency performance standards, building codes, and the use of energy subsidies to promote energy efficiency. These recommendations are made for the short, medium and long term.

8.2.1. Short-term recommendations

1. Establish the building sector as a priority in mitigation policy. To date, there are no specific laws involving sustainable development priorities for buildings in Mexico. There are, though, a number of policies and programs involving both the government and the private sector that have direct and indirect impacts on the CO_2 eqv. emissions that result from residential and commercial buildings operations. These policies and programs have mixed results, and lack coordination and a steady effort. Making buildings a legislated federal government priority (be it for energy efficiency in particular or for GHG mitigation in general) could help solidify the efforts.
2. Reinforce the INFONAVIT Green Mortgage program and go ahead with CONAVI sustainable housing program. The Green Mortgage program by INFONAVIT and the use of subsidies by CONAVI to increase the sustainability aspects of new housing are key programs to reach zero emissions growth in the residential sector.
3. Increase the intensity and broaden the scope of CFE´s DSM programs. CFE has been operating (directly or through FIDE) a number of successful DSM programs, mainly aimed at lighting and space cooling in the residential sector. These programs should recover their wide scale scope.
4. Start a formal, integrated and coordinated effort of data gathering to have a better idea of the size and the energy use characteristics of commercial buildings. Recognize, in the government´s data

collection system, the importance of buildings as a specific category of energy use and integrate comprehensive data bases that include—by building type—building stock, floor area, vintage, energy use by energy source and energy intensity.

8.2.2. Medium-term recommendations

1. Strengthen federal, state and local agencies that enforce compliance of building regulation. Even though Mexico has two mandatory energy efficiency standards that apply to commercial buildings (one for lighting systems and the other for the building´s envelope) [1, 2], they are not fully effective as they have been poorly enforced, particularly the one that applies to the building´s envelope. This implies the need for greater involvement of local governments to integrate the standard into local building codes.
2. Implement surveys and detailed audits by building types and climatic regions in to identify energy end-use technology and intensities. This work is to supplement the efforts done in the short term and would help to improve the design of programs in the sector and should be done for both the residential and commercial sectors.
3. Use the CDM programmatic alternative to add resources to government programs. The Clean Development Mechanism, under the programmatic category, can help collect additional resources to government sponsored programs. This can be the case of the federal, state and municipal housing programs.
4. Promote "Green building" strategies. Either through their inclusion as mandatory in building codes or through tax incentives, local governments should, as it is becoming best practice in developed countries, promote the use of well established "Green building" certification systems.

8.2.3. Long-term recommendations

1. Eliminate subsidies to energy use and use them to promote energy efficiency. Though it is clear that there is a need for economic support for low-income families, a large but not clearly defined fraction of the subsidies goes to households that do not need it, thus giving the wrong economic signal for energy efficiency. In this case, the recommendation is to use a significant fraction of the resources that are use to cover the subsidy to cover the cost of purchase of energy efficiency measures.
2. Keep Minimum Efficiency Performance Standards (MEPS) of main energy using equipment harmonized with those of the US and Canada. Based on the fact that there a number of equipment (electric motors, refrigerators and AC units) that already have the same MEPS for the three North American countries, México should follow the lead of the US and Canada to strengthen its own standards.

Annexes

Annex 1: Methodology for estimating GHG emissions from buildings in México

A. This is done an Excel spreadsheet
B. There are general assumptions (defined for each sector below).
C. The general process is as follows:
   a. Obtain data for 2005
   b. Obtain projections for as many parameters as possible
   c. Make assumptions for the parameters that are not available
   d. Define baseline calibrating with ten-year government projections
   e. Establish scenarios changing variables related to end-uses (that reflect the use of technology)

1. RESIDENTIAL SECTOR

a. General assumptions

i. Number of households is a function of population and the average number of people per households.
   1. The average number of people per household changes with a tendency to be reduced.
ii. Two types of households are considered based on climate: (a) temperate (no AC) and hot (with AC).
iii. Five energy end-uses are considered:
   1. AC
   2. Lighting
   3. Refrigeration
   4. Other
   5. Cooking
   6. Water heating
iv. Space heating is not considered as it is not a significant end-use.
v. AC, lighting, refrigeration and other are electrical. Cooking and water heating are done with LP and natural gas.
vi. Electricity end-uses are considered as average
   1. AC is established as the difference between the average unit electricity consumption between temperate and hot climate households.
   2. Lighting is established by an estimate the Watts and the number of lamps, and the hours of use per day
   3. Average unit electricity consumption for temperate and hot climate households can have different growth rates.
vii. Total use for water heating and cooking is estimated considering equipment saturation as a variable
   1. Water heating is established considering the number of people per household, a volume of water per shower, a temperature difference and an average water heater efficiency.
viii. Estimates are calibrated (for baseline) comparing aggregated values with ten year projections of total energy use by energy type made by the government.
ix. Scenarios are then made
   1. Modifying the variables affecting end-uses
   2. Modifying power sector emissions

b.   Data

   i. General

      1. CO_2 emission factors

         a. LPG

         b. Natural gas

         c. Electricity for Mexico

   ii. Population and number of households

      1. Population in 2005

      2. Expected rate of growth (to 2050)

      3. Occupants per household

      4. Rate of change of occupants per household

      5. Percentage of households in temperate climate

   iii. Energy use

      1. Average use (2005)

         a. Per household

            i. Electricity

               1. Temperate climate

                  a. Average electricity intensity per household per year

                  b. Rate of change of intensity per household

               2. Hot climate

                  a. Average electricity intensity per household per year

                  b. Rate of change of intensity per household

         b. Per end use

            i. Lighting

               1. Average number of light points

               2. Average hours of use per day

               3. Average power of light point

               4. Rate of change of lighting end use

            ii. Refrigerator

               1. Unit yearly consumption

               2. Rate of change of refrigeration end use

            iii. Other

               1. Unit yearly consumption

               2. Rate of change of "other" end use

            iv. AC (it is estimated on the base of the difference between average use in temperate and hot climate households)

            v. Water heating

               1. Average volume of water used per shower

               2. Average temperature of shower

               3. Average efficiency of water heater

               4. Water heaters´ saturation

            vi. Cooking

               1. Gas stoves´ saturation of water heaters

      2. Total use (to be used to compared with bottom-up aggregations) (2006-2015).

         a. Total use by energy type

            i. Electricity

            ii. LP gas

      iii. Natural gas
   b. Projections by energy type
      i. Electricity
      ii. LP gas
      iii. Natural gas
  3. Total emissions
   a. By energy source
   b. By end-use

c.   Process

  i. Establish projections
    1. Population
    2. Households
    3. Energy use by energy type
      a. Electricity
        i. Lighting
        ii. AC
        iii. Refrigerator
        iv. Other
      b. Water heating
      c. Cooking
  ii. Calibrate
    1. With government's ten year projections to establish baseline
      a. Electricity
      b. LP gas
      c. Natural gas
    2. By per climate type projections with those based on end-use aggregation
  iii. Define scenarios
    1. Modify end uses
      a. Tendencies
    2. Modify electricity generation emissions

2.   COMMERCIAL (NON-RESIDENTIAL) SECTOR

a.   General assumptions

  i. Eight types of buildings are considered
    1. Warehouses
    2. Hotels and restaurants
    3. Office buildings
    4. Wholesale & retail
    5. Theaters and recreational facilities
    6. Hospitals and health facilities
    7. Schools
    8. Other services
  ii. Five energy end-uses are considered (heating is not considered)
    1. Water heating
    2. Auxiliary equipment

3. Auxiliary motors
4. Lighting
5. Space cooling
iii. Water heating is primarily done with gas (LP or natural).
iv. Estimates are calibrated (for baseline) comparing aggregated values with ten year projections of total energy use by energy type made by the government.
v. Scenarios are then made:
1. Modifying end-use intensities
2. Modifying power sector emissions

b.   Data
i. General
1. CO2 emission factors
a. LPG
b. Natural gas
c. Electricity for Mexico
ii. Building stock
1. Area of buildings by type
a. Warehouses
b. Hotels and restaurants
c. Office buildings
d. Wholesale & retail
e. Theaters and recreational facilities
f. Hospitals and health facilities
g. Schools
h. Other services
2. Expected growth by building type
iii. Energy use
1. Total energy use by energy type
2. Energy intensity
a. By type of building
i. By end-use
1. Water heating
2. Auxiliary equipment
3. Auxiliary motors
4. Lighting
5. Space cooling
3. Expected growth by end-use

c. Process
 i. Establish projections
  1. With expected growth by type of building
  2. With expected changes in energy intensity by end-use (by type of building)
   a. Aggregated by end use
 ii. Calibrate
  1. With government's ten year projections to establish baseline
   a. Electricity
   b. LP gas
   c. Natural gas
 iii. Define scenarios
  1. Modify end uses
   a. Tendencies

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About the Sustainable Buildings and Climate Initiative

Launched in 2006 by the United Nations Environment Program (UNEP), the Sustainable Buildings and Climate Initiative (SBCI), formerly the Sustainable Buildings and Construction Initiative, is a partnership between the private sector, government, non-government and research organizations formed to promote sustainable building and construction globally.

SBCI harnesses UNEP's unique capacity to provide a convening and 'harmonizing' role to present a common voice from the building sector on climate change issues. More specifically UNEP-SBCI aims to:

1. Provide a common platform for and with all building and construction stakeholders to collectively address sustainability issues such as climate change;
2. Establish globally consistent climate-related building performance baselines and metrics for monitoring and reportingpractices in particular based on the life cycle approach;
3. Develop tools and strategies for achieving a wide acceptance and adoption of sustainable building practices throughout the world;
4. Implementation - Promote adoption of the above tools & strategies by key stakeholders.

UNEP SBCI
Sustainable Buildings & Climate Initiative

For more information, see **www.unepsbci.org**

About Sustainable United Nations (SUN)

Sustainable United Nations (SUN), is a UNEP initiative that provides support to UN and other organisations to reduce their greenhouse gas emissions and improve their sustainability overall. SUN was established in response to the call from UN Secretary General Ban Ki-Moon at the World Environment Day 2007 (5 June), to all UN agencies, funds and programmes to reduce their carbon footprints and "go green". This call was echoed in October 2007 in a decision of the UN Chief Executives Board (CEB/2007/2, annex II) to adopt the UN Climate Neutral Strategy, which commits all UN organisations to move towards climate neutrality. SUN is in this context working with the UN Environment Management Group – the UN body coordinating common environmental work within UN – to provide guidance, and develop tools and models for emission reduction within organisations.

Sustainable United Nations

SUN is using a "whole-organisation" approach in identification of sources and causes for emissions and opportunities for reduced emissions and improved sustainability. In this way opportunities for improvements are typically found within one of the three major focus areas for SUN:

a. Physical assets: building, equipment, vehicles…
b. Management processes: procurement, travel, management systems…
c. Organisational Culture: day-to-day office behaviour, "corporate" culture, green meetings…

SUN operates in synergy with existing initiatives and networks such as the Sustainable Buildings and Construction Initiative, the High Level Committee on Management Procurement Network, the UN Global compact, or the Marrakech Task Force on Sustainable Public Procurement and many others.

For more information, see **www.unep.fr/scp/sun**

About the UNEP Division of Technology, Industry and Economics

The UNEP Division of Technology, Industry and Economics (DTIE) helps governments, local authorities and decision-makers in business and industry to develop and implement policies and practices focusing on sustainable development.

The Division works to promote:
> > sustainable consumption and production,
> > the efficient use of renewable energy,
> > adequate management of chemicals,
> > the integration of environmental costs in development policies.

The Office of the Director, located in Paris, coordinates activities through:

> **The International Environmental Technology Centre** - IETC (Osaka, Shiga), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.

> **Sustainable Consumption and Production** (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.

> **Chemicals** (Geneva), which catalyzes global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.

> **Energy** (Paris), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.

> **OzonAction** (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.

> **Economics and Trade** (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies.

UNEP DTIE activities focus on raising awareness, improving the transfer of knowledge and information, fostering technological cooperation and partnerships, and implementing international conventions and agreements.

For more information,
see **www.unep.fr**

UNEP

UNEP-SBCI has commissioned the compilation of regional reports that quantify the influence of buildings on climate change in selected regions. This report represents the first comprehensive description of the factors that determine the present and future impacts of residential and commercial buildings in México on climate change.

The findings are based on a quantification and analysis of built space and energy use in Mexico's residential and commercial sectors. It also involved the development of a model to estimate greenhouse gas emissions of those sectors based on the available information.

Base-line greenhouse gas emissions from residential and commercial buildings of close to 75 Mt CO_2 eqv. were estimated using 2006 as the reference year. This means that buildings represented about 12% of total present CO_2 eqv. emissions in Mexico in that year. However, building-related emissions are projected to increase by an estimated 500 $MtCO_2$ eqv. – a factor of 6.7 by 2050, if nothing is done to improve the energy performance of new and existing buildings in Mexico.

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