WEC "Energy for Megacities" Study

Mexico City case study

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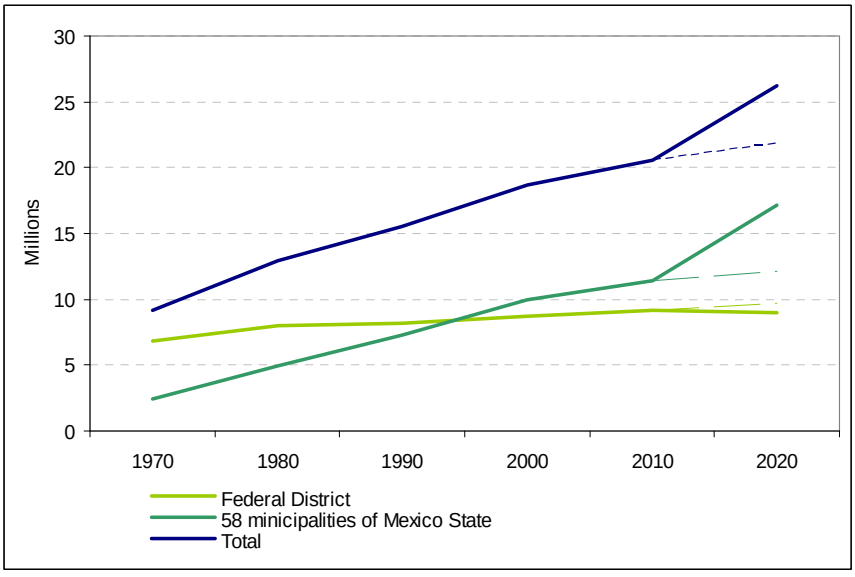
1. Data

Demographics, economics and city shape

The Metropolitan Area of Mexico Valley (Zona Metropolitana del Valle de Mexico – ZMVM) is composed by 16 delegations of the Federal District and 59 municipalities belonging to the State of Mexico. The Metropolitan Area will be referred as the ZMVM or the City of Mexico, and specifications will be made when referring to the Federal District (FD) and the State of Mexico (SM). According to population trends, most of future demographic growth in the City of Mexico will occur within the State of Mexico while the Federal District population might experience a slight decrease. In addition, the City of Mexico will experience a considerable change in age distribution. The higher growth - by age range - will happen in the latest adult part of the population that will pass from around 560 thousand in 2005 to 4.4 millions by the year 2030. The Federal District will actually multiply the population in this range by four during the same period.

Figure 1. Mexico City population growth



Source Elbenschutz (2009): Programa de Ordenacion de la ZMVM (Mexico City Workshop)

The City of Mexico is split between the State of Mexico and the Federal District. This is the result of sprawling process that started in the early 70's[1]. Mexico City sprawling was

[1] *Source Elbenschutz (2009): Programa de Ordenacion de la ZMVM (Mexico City Workshop)*

accompanied by a reduction of population density in the central area of the city that passed from around 200 hab/ha in the 70's to 100-150 hab/ha in the year 2000 [2]. Table 1 shows how both "natality" and fertility have reduced considerably in the Federal District and the State of Mexico

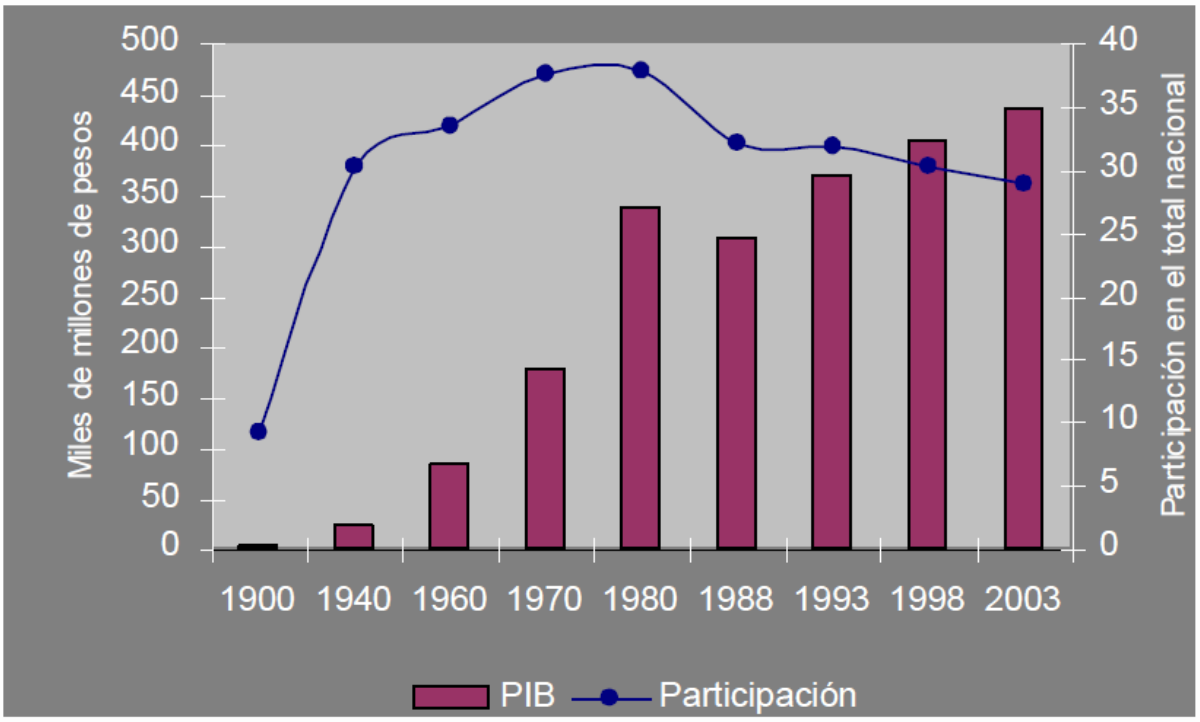
Table 1. Population growth, density and fertility rates

	2000	2004	2008	2010
"Natality" Federal District (by 1000)	18.8	15.2	14.8	14.6
"Natality" State of Mexico (by 1000)	24.1	19.7	18.1	17.4
Fertility Federal District*	2.0	1.7	1.7	1.7
Fertility State of Mexico*	2.6	2.2	2.0	2.0

Source: Gerardo Bazan (2010) * Average of children per 15-49 year women

Figure 2, evidences the importance of the ZMVM in Mexico's economy. However, while the ZMVM still counts for about 26% of Mexico's GDP its share in the economy has decreased since the early 80s.

Figure 2. GDP of the ZMVM and participation to national GDP

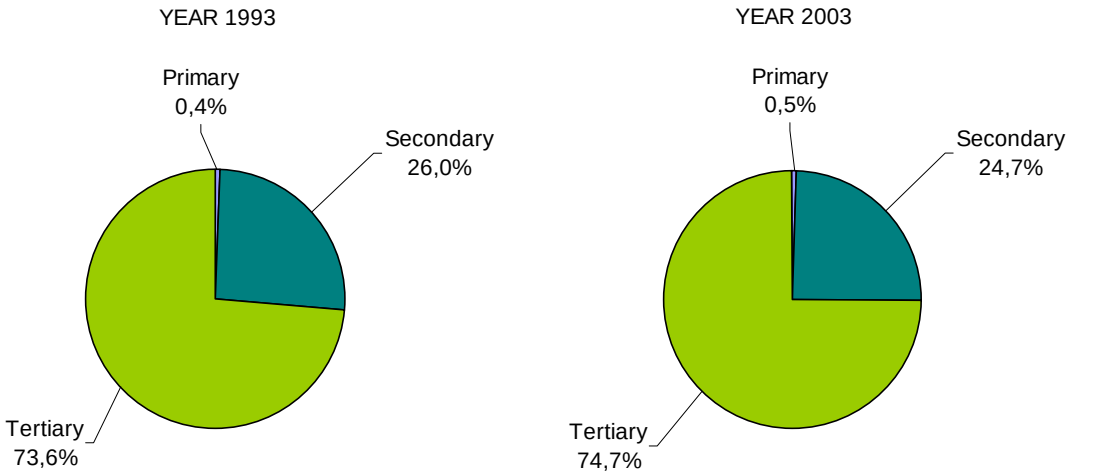


Source: PAREDES CASTILLO F.A. "La zona metropolitana de la Ciudad de Mexico: fortalezas y debilidades – foro economico de la Ciudad de Mexico 2010; Sistema de Cuentas Nacionales de Mexico

Looking at the share of GDP by economic sector (see Figure 3), it is interesting to see that between 1993-2003 the share of GDP by sector remained constant. The tertiary sector alone is generating around 75% of the metropolitan area GDP.

[2] Rodolfo Montagno : Expansion y Reconversion economica de la ZMVM 1970-2000

Figure 3. Share of GDP by economic sector in the ZMVM (1993-2003)



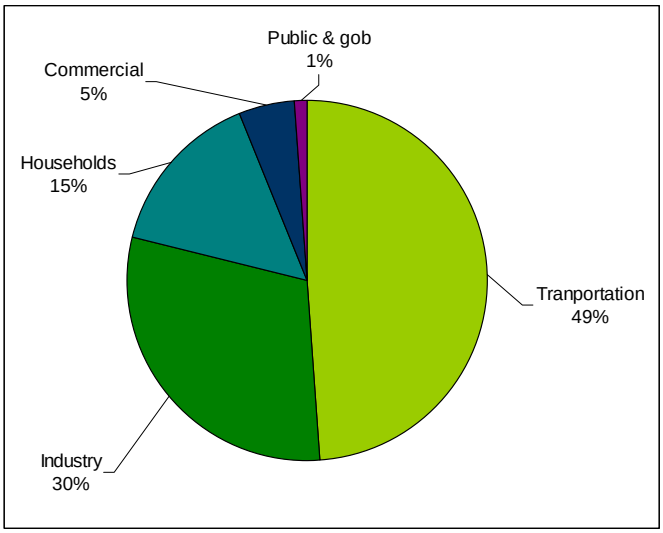
Source: adapted by author from *PAREDES CASTILLO F.A. "La zona metropolitana de la Ciudad de Mexico: fortalezas y debilidades – foro economico de la Ciudad de Mexico 2010; Sistema de Cuentas Nacionales de Mexico*

Energy and GHG emissions

Energy consumption

The total energy consumption in the ZMVM for the year 2008 is estimated at 545 PJ, compared to 443 PJ in the year 1990. Of the total energy needs, the transportation sector has the higher energy demands, followed by the industrial sector and the domestic sector. Despite the economic transition experienced in the city in the past three decades the commercial sector only stands for 5% of the energy consumption. While in the 70's, 52% of the economically active population worked in the industry sector, in 2000 close 70% of the population was employed in the service sector[3].

Figure 4. Energy consumption by sector

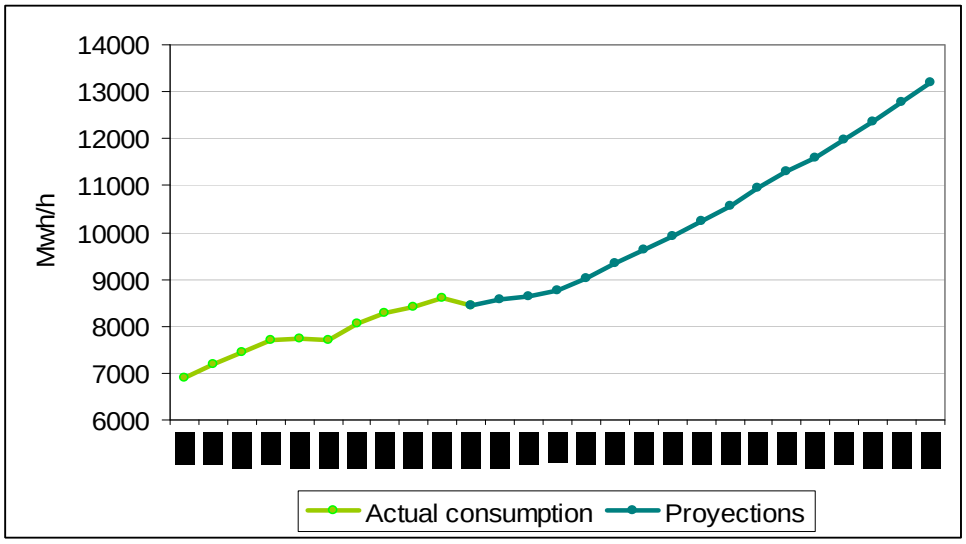


Source: SMA/GDF (2006) 'Estrategia Local de Accion Climatica Ciudad de Mexico'

[3] Rodolfo Montagno

As in most cities, electricity is mostly generated outside the city. In the case of the City of Mexico, 70% of the electricity is supplied from distant areas of the country. Given the distance between generation sites and the agglomeration (200-800kms), the City of Mexico might have problems of voltage collapse and security of supply. Additionally, the actual centrals are old and in bad conditions and while the demand for electricity continues to increase there is still a part of the demand that hasn't been covered. Bazan (2010) explains that in the Federal District, despite the growth in demand, the actual energy supply has diminished. In fact, during the past year the energy generation inside the FD has diminished increasing the pressure on external energy supply. He estimates that around 97% of the energy needs of the FD come from outside of the city. Furthermore, there isn't a lot of space available for the installation of new substations that will allow supporting the voltage in the metropolitan area. The following figure shows the actual electricity consumption and future projections. According to calculations, the average annual growth in consumption for the 1998-2008 was 2.05% while estimations suggest an increase of this average to 2.92% for the 2009-2024 period[4].

Figure 5. Electricity consumption and projections

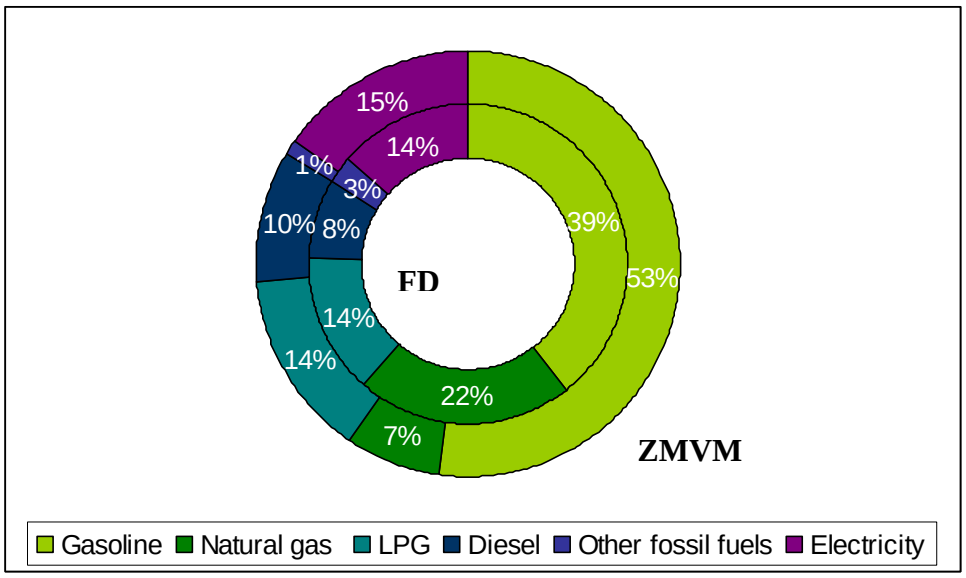


Source: CFE (2009) " Suministro electrico a la SMVM"

In terms of energy mix, most of the energy consumed in the ZMVM and in the Federal District comes directly from fossil fuels as compared to electricity. This is partly explained by the transportation sector which represents around 49% of the city's total energy consumption. If the energy mix used for electricity generation, the total share of energy needs supported on fossil fuels burning should be higher than 86% for the ZMVM. The energy mix by sector is shown in
Figure 6. The energy mix by sector is presented in Figure 7.

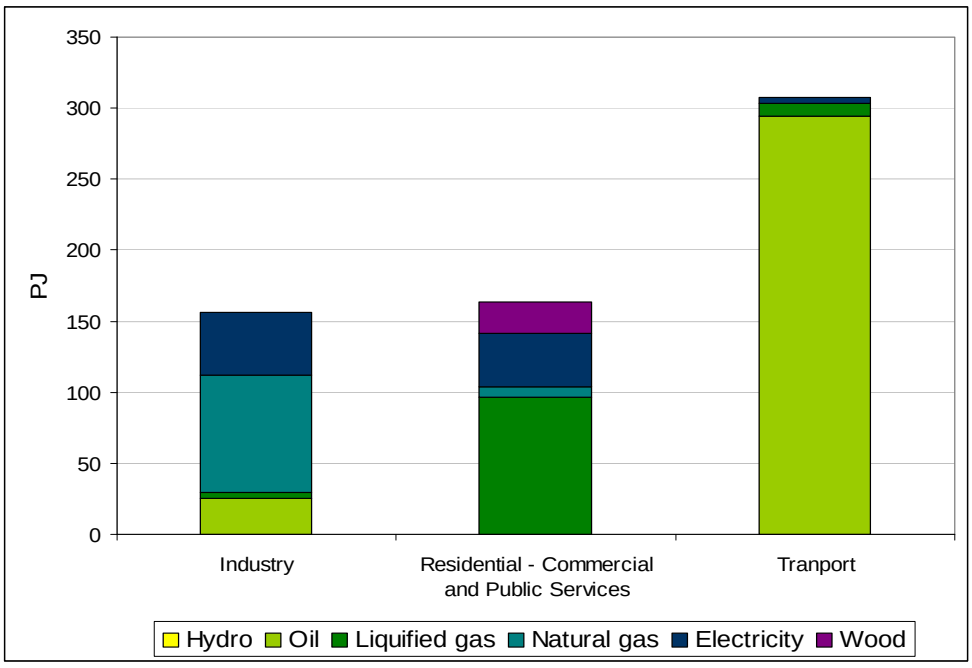
[4] *Workshop CFE " Suministro electrico a la SMVM"*

Figure 6. Energy mix (Electricity and fossil fuels)



Source:[*http://www.sma.df.gob.mx/sma/download/temporales/foroCACC/forocacc-2-05_balance_energia_inventario_gei_(beatriz_del_valle_cardenas).pdf*](http://www.sma.df.gob.mx/sma/download/temporales/foroCACC/forocacc-2-05_balance_energia_inventario_gei_(beatriz_del_valle_cardenas).pdf)

Figure 7. Energy mix by sector in the ZMVM (2001)



Source: Bazan (2001) 'Programa universitario de Energia UNAM'

Residential Buildings and Households

To satisfy cooking and water heating requirements in the year 2008, the total residential sector consumed around 70PJ. 93% corresponded to the use of liquefied petroleum gas while only 7% corresponded to natural gas[5]. According to official statistics, 98.6 % of the households living in ZMVM have electricity connection but the actual proportion, if only legal onnections are considered, should be much lower[6]. Non official sources, suggest that in the Federal District alone there are around a million illegal connections to electricity generating

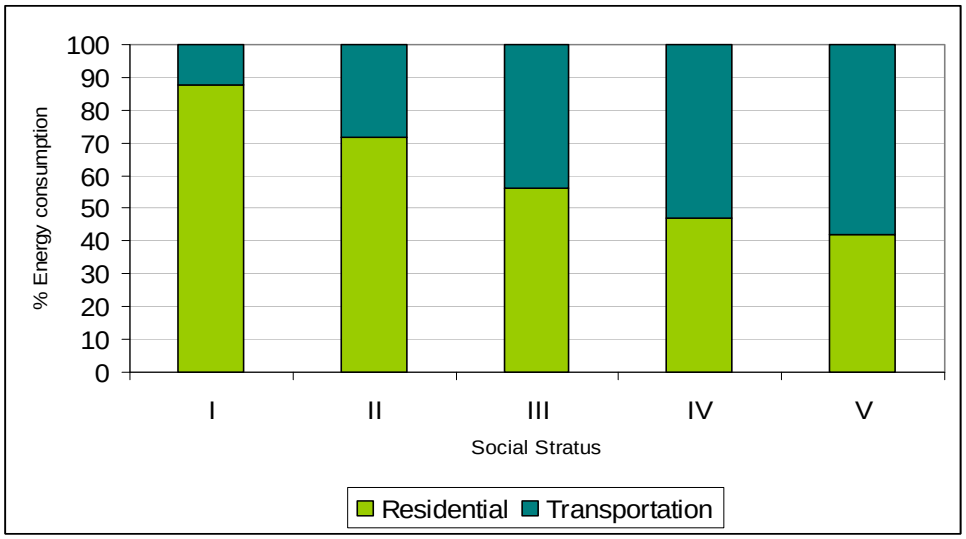
[5] Gerardo Bazan Navarrete, Workshop
[6] CFE , workshop presentation Luz y Fuerza del Centro

constant flaws in electricity supply[7]. Electricity theft is not only associated to informal settlements but to commercial and industrial institutions. Another source indicates that 50% of the losses of *LyFC,* company in charge of electricity supply of around 6 million households in the City of Mexico, are due to non-technical and low tension (residential sector) losses. Among these, 27% are due to altered meters, 22% due to illegal connections and 15% occur in informal settlements[8].

Electricity has been historically subsidised for the lowest levels of consumption. In February 2002 domestic tariffs were modified and a new range was created for high consumption households. The introduction of new tariffs was bound to eliminate subsidies for high consumption households and reduce them for medium consumption households without affecting lowest part of the distribution[9]. With the new tariffs in place, most of the population in the ZMVM is in the low consumption range. In the State of Mexico 78% of the households are in low consumption range and in the Federal District the proportion is around 71%. The proportion of households in the high consumption levels is around 2.1%.

The medium price of electricity augmented 30% between the 2001-2007 period. About half of it is due to the changes in tariffs and the other half to increase in tariffs above inflation. Figure 8 shows the distribution of energy consumption between residential and transportation. As income increases the proportion of transportation to total consumption also increases. In absolute values, the total energy demand of the richest group is around 40 times bigger which is partly explained by the growth in the number of trips (richer travel more) and the difference between the energy efficiency of transport systems of the rich(car) and poor (public system). The lower social stratus generally uses the bus or collective buses and the metro[i].

Figure 8. Energy consumption by social stratus

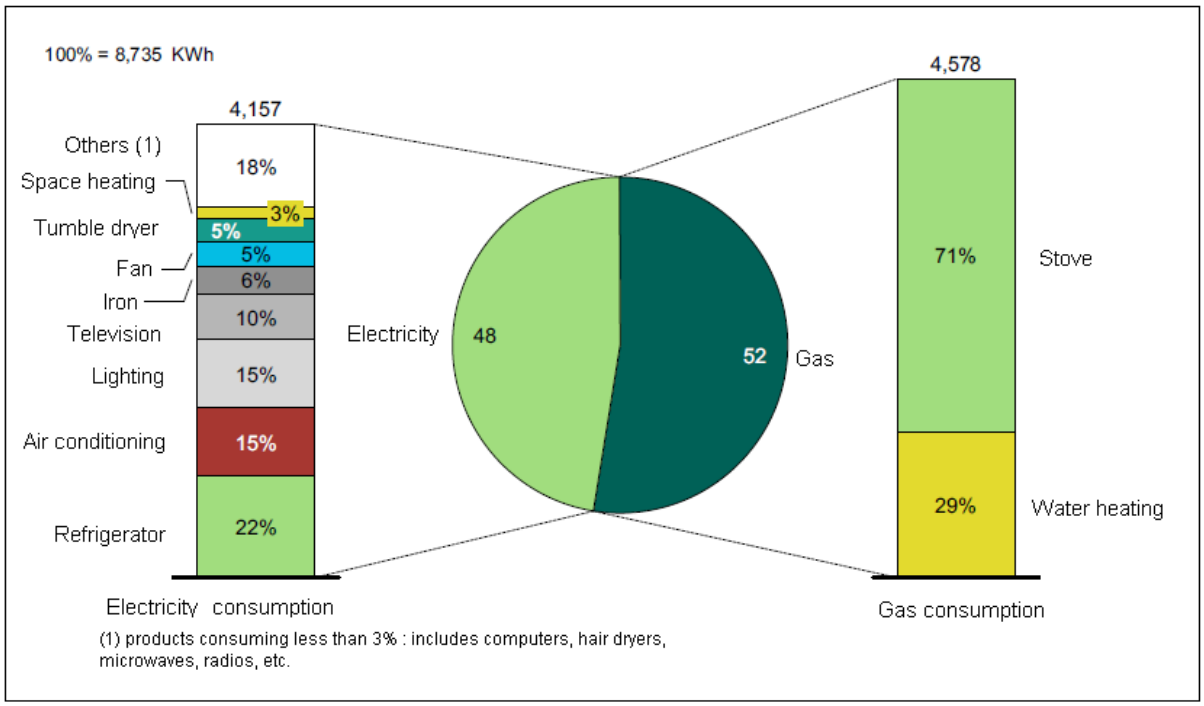


Source: Bazan (2001) "Balance de energia de la ZMVM"

[7] http://elporvenir.com.mx/notas.asp?nota_id=218968
[8] http://www.fte-energia.org/E63/e63-06.html
[9] Tarifas electricas

Household's energy mix (without considering transport) is almost split by half between electricity and gas. Water heating and cooking represent the highest energy requirements of households.

Figure 9. Energy mix (without transport) of the average Mexican household



SOURCE: (CFE, ENIGH 2006)

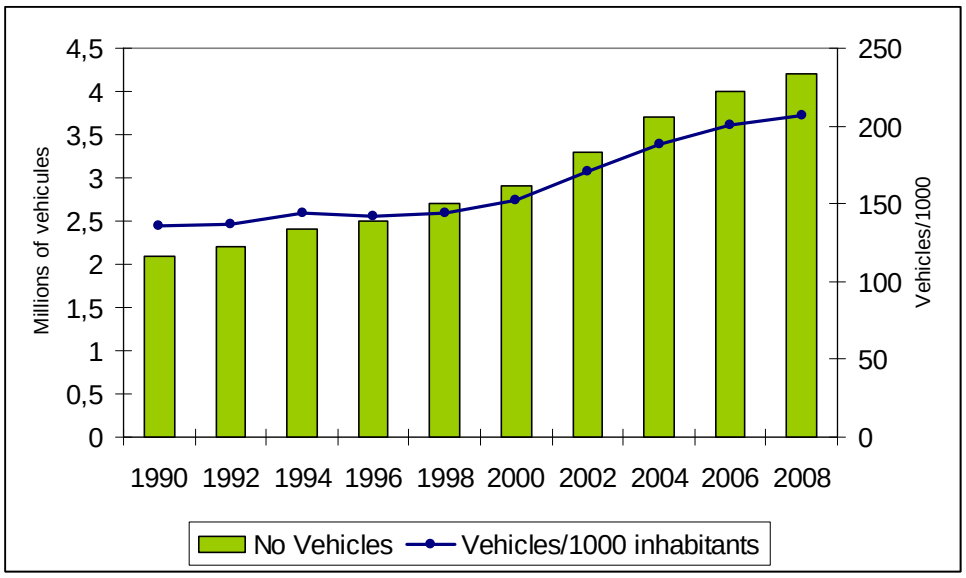
Commercial Buildings and services

The commercial sector has grown considerably both at a national and local level. The ZMVM has around 200 thousand registered establishments, of which 94% belong to the commercial and services sectors and 93% of them are small enterprises. The energy obtained from fossil fuels in this sector was satisfied by LNG (97%) and natural gas (3%).

Transport

The extension of the City of Mexico beyond its borders and the diminution of density in the central areas generated an increase in distances and commuting times. At the same time, the inclusion of new boundary municipalities into the city, the expansion beyond the federal district limits affected the efficiency and unification of the massive transportation system and influenced the preferences between public and private transportation. As we can appreciate in Figure 10, there has been a steep increase both in the absolute and relative number of private cars.

Figure 10. Mexico City absolute and relative number of private vehicles



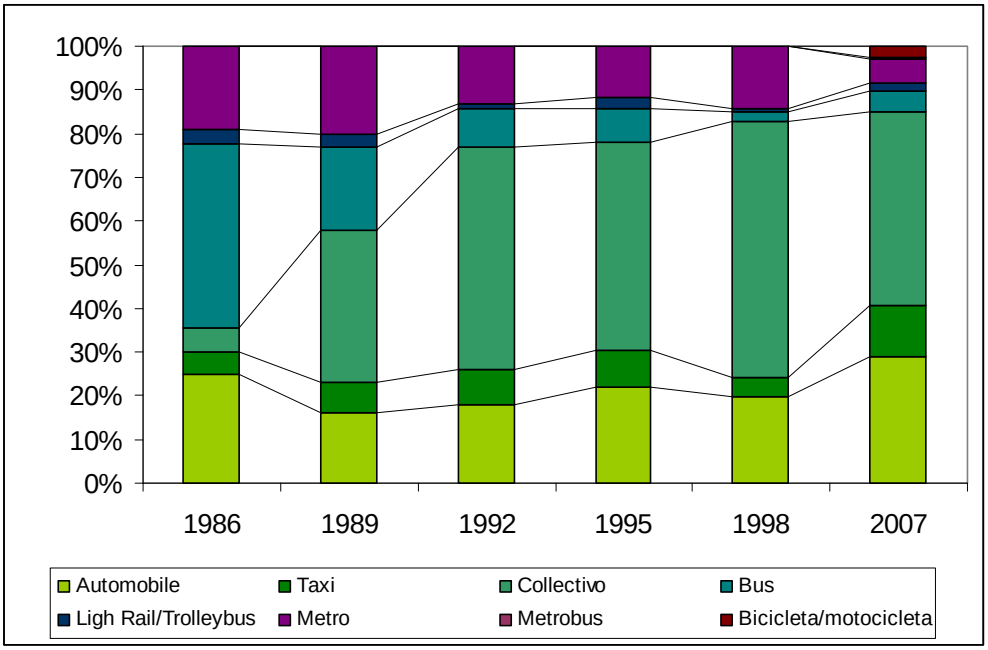
Source: Bazan (2009) Mexico City WEC Workshop

With 21.9 millions of journeys per day, an increase of 13% per year if vehicle ownership (between 1996-2007) and a fragmented public transportation system between the Federal State and the State of Mexico, the transportation challenges for the City of Mexico are enormous. In fact, a recent study shows that all of mobility indicators, except the number of trips person, have diminished considerably between 1994 and 2007. Number of trips per household has passed from 6 in 1994 to 4.6 in 2007 and number of persons commuting per household passed from 2.5 to 1.9 in the same period. The average time of commuting has also increased from 46 minutes to 60 minutes in the same evaluation period and it has increased more for private vehicle commuters than for public transportation users. The number of trips per person has also diminished from 1.36 to 1.16 and mobility tends to diminishes towards peripheral areas[10].

As we can see from the modal split evolution, there was a collapse in the city bus system starting in the middle 80's that gave birth to the massive use of *colectivos*. Colectivos can range from the size of a minivan to a small bus and provide frequent service. They are also one of the few options for informal settlement inhabitants or outlying areas where most low income workers live. Figure 11 also shows that in spite of the city's well developed metro system (11 existing lines and one in development), this type of transportation only accounts for less than 8% of the total trips made in the city. While latest statistics show around ¾ of the total commuting is done by public transportation, most of it is fuelled by fossil energy.

[10] Maria Eugenia Negrete (2009) 'Transporte y sustentabilidad en la Ciudad de Mexico''

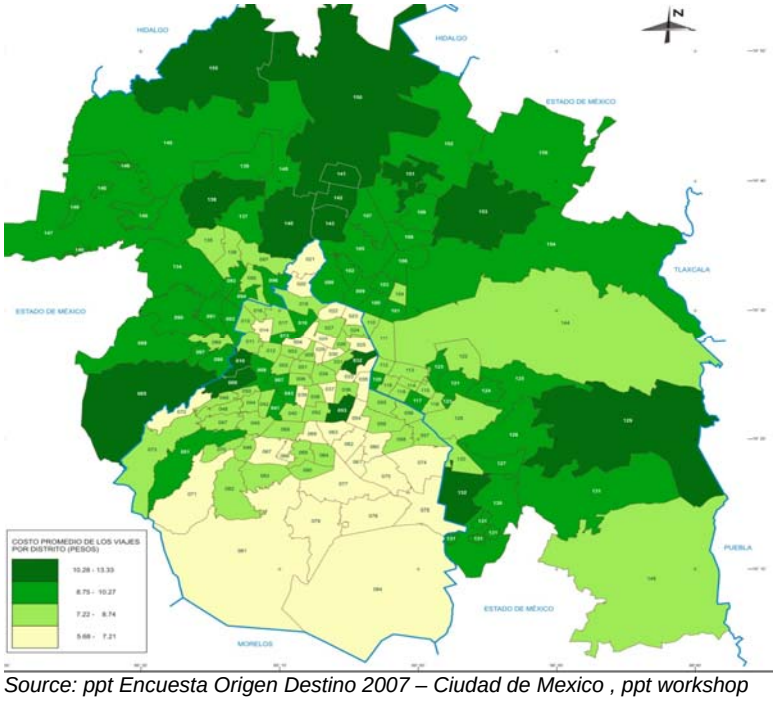
Figure 11. Modal split of Mexico City



Source: Ciudad de Mexico (2007) 'Encuesta Origen Destino 2007' ; AMANO (2005)

Furthermore, the tariffs of public transportation are very different in the State of Mexico and in the Federal District. While they are should be proportionate to the number of kilometres this rule is rarely respected. In general terms, tariffs in the Federal Districts are lower than those in the State of Mexico. Administrative division appears to have generated a lower mobility between the two parts of the City of Mexico. In the Federal District 87% of commuting is done inside its borders and in the Estate of Mexico internal commuting represents around 76%. Figure 1Figure 12 shows the spatial inequality for commuting costs between the FD and the State of Mexico.

Figure 12. Average commuting cost per trip



Source: ppt Encuesta Origen Destino 2007 – Ciudad de Mexico , ppt workshop

Public transportation is partially subsidized by the City of Mexico and subsidies are generally linked to politicians willing. Generally tariffs are lower in the city of Mexico than in other cities of Mexican Republic. For instance, the minimum cost of commuting in microbuses (minimum distance) in the City of Mexico is around 3 pesos compared to 7-10 pesos in other states of the Republic[ii].

Industry and commerce

At a national level, Mexico has around 328 thousand industries and 16% of these are within the ZMVM. The more common activities are food production, beverages production, metallurgy, paper and derivates production and electric energy generation[11]. While the City of Mexico has experienced a process of deindustrialization, the industrial sector is still one of the most important sectors in terms of energy demand due to the high use of fossil fuels in its productive processes. Around 83% of the energy demand (fossil fuels only) is covered by natural gas, 12% by LPG and 5% by low sulphur industrial diesel.

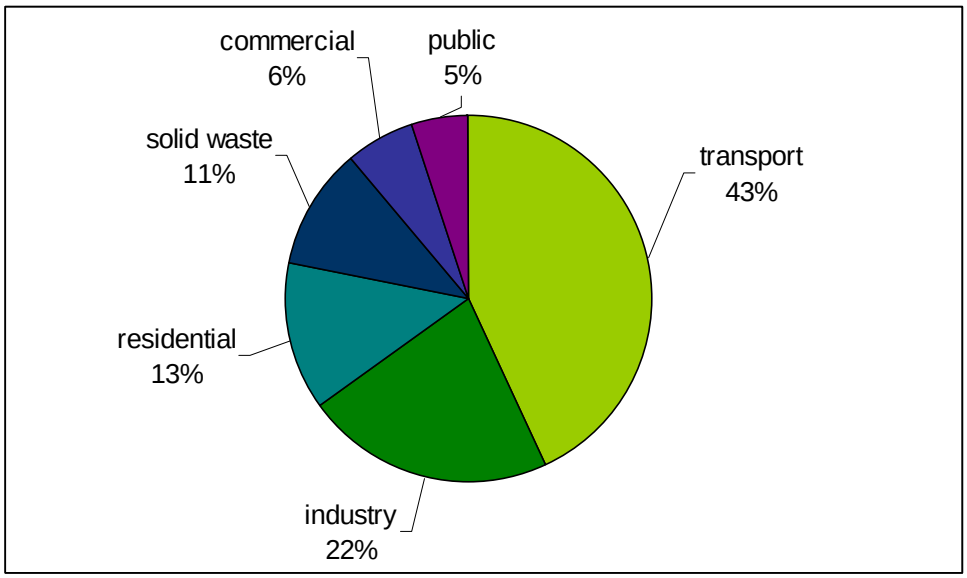
GHG Emissions

According to estimates around 23% of the increase in the GHG emissions can be explained by the growth in energy consumption[12]. The emissions per capita in 2006 were estimated at 2.2 ton eq CO_2 which is relatively small compared to the national value of around 4 tons[13].

A comparison of GHG emissions between different sectors of the economy is shown in Figure 13. As in the energy consumption section, the transport sector is responsible for the biggest share of GHG emissions, followed by the industry and the residential sector. This is normal given their high dependence on fossil fuels to cover energy needs. However, a segment that doesn't appear as energy intensive in the last section but that does appear as an important contributor to GHG is the disposal of solid waste. This is easily explained since most of the waste ends up sanitary landfills and little or none of the methane generated in these sites is being burned.

[11] INEGI , Censo Economico 2004
[12] Gerardo Bazan Navarrete, Workshop
[13] http://www.eia.doe.gov/oiaf/ieo/emissions.html

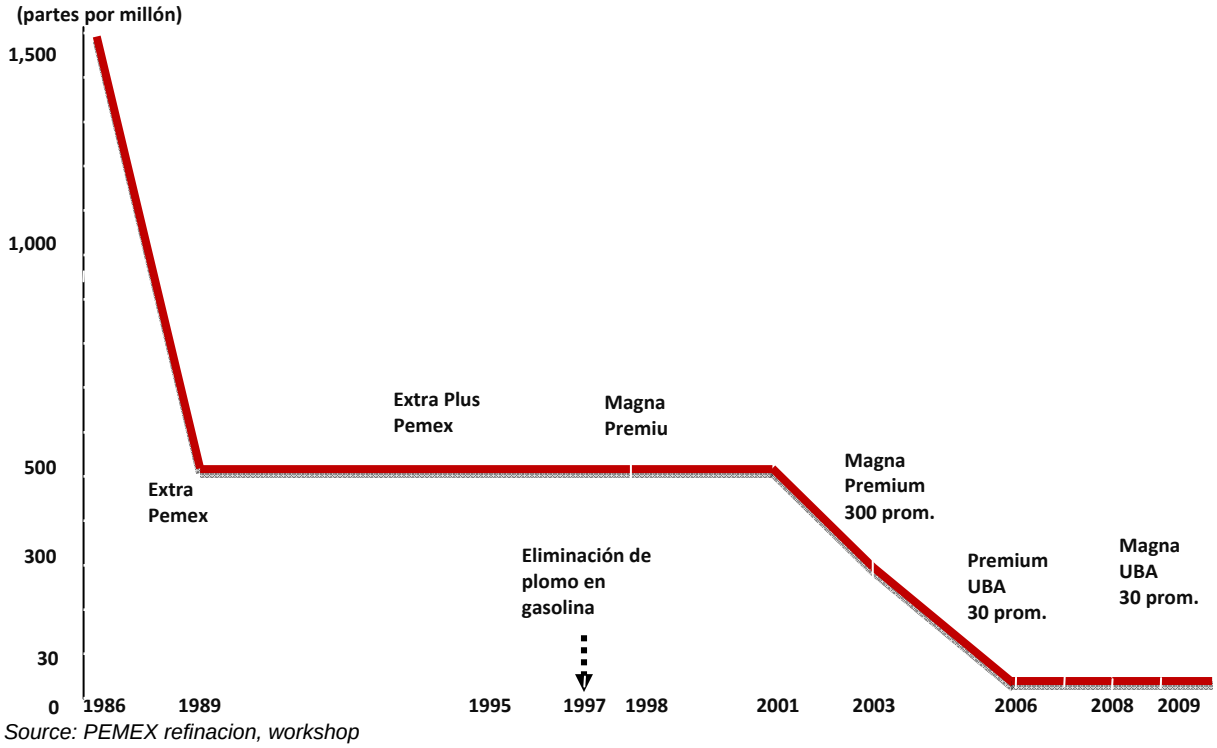
Figure 13. Emissions by sector



Source: SMA/GDF Estrategia Local de Accion Climatica Ciudad de Mexico 2008 - Workshop

When looking more closely at the transport sector, it is important to recall that there has been a considerable evolution in the types of fuels used and a renovation of a considerable part of the vehicles circulating. This was the result of a number of policies that looked at improving the dreadful quality of air of the city. In the case of car fuels, there was a considerable diminution of the sulphur and plum content. The renovation of the vehicle fleet was done through a number of policies: restriction of circulation for old vehicles *("Hoy no circula"*), the introduction of catalysers and other technologies to directly reduce emissions in new cars and the coordination with financial institutions to allow easy access to credit to renovate vehicles.

Figure 14. Evolution of quality of fuel oils in Mexico



Source: PEMEX refinacion, workshop

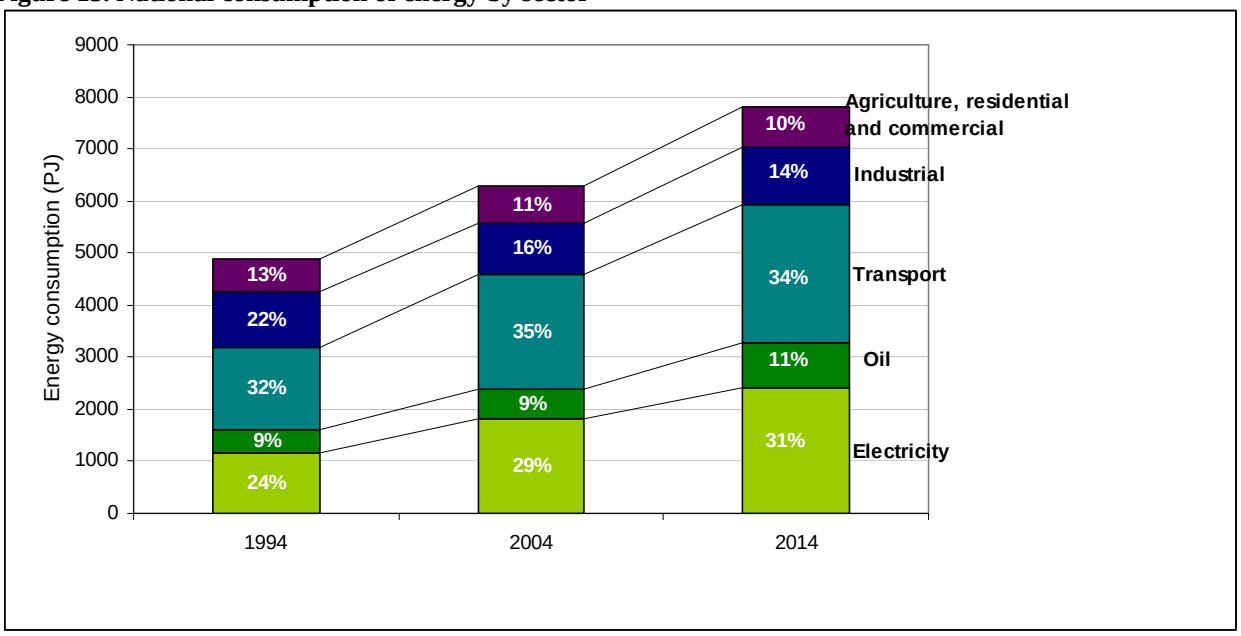
2. Policies

National energy plans and policies

Mexico ratified the Kyoto protocol but does not have any reduction commitments for the 2008-2012 period. At a national level there has been a slight decrease of the energy and carbon intensity in the past decade, trend that is expected to continue in the future. This is explained in part by the introduction of more energy efficient technologies, the gradual substitution of fuel (*combustoleo)* for natural gas and the evolution of Mexico to a service oriented economy. However, emissions per capita have continued to rise and are expected to follow the same trend in the near future.

The evolution of energy consumption by sector shows that there has been a considerable growth in energy consumption in absolute terms but that the share of each sector has remained about the same. The same is true for green house gases emissions that will grow by about 36% between 2004 and 2014. Electricity generation and transportation are the two main generators of green house gases.

Figure 15. National consumption of energy by sector



Source: Estrategia Nacional de Cambio Climatico: emisiones de GEI y Oportunidades de Mitigacion

In terms of national policies, a National Energy Strategy was set in 2007 which is valid for all of the Mexican Republic. A set of goals were designed in order to achieve (1) Energy security, (2) Productive and economic efficiency, and (3) Environmental sustainability. Achieving higher shares of renewables for electricity generation and higher levels of electricity connection are some of set of objectives[14].

[14] Secretaria de Energia (2007) 'Estrategia Nacional de Energia'

Figure 16 shows the instruments and targets of Mexican energy policies since 1975. One can see how climate change policies are mostly done through regulatory instruments and in many cases targeted to the energy production sector. In the case of energy efficiency incentives & subsidies and education & outreach seem to be the most used instruments and about 2/3 of the policies are targeted to buildings and appliances. One curious aspect is that there seems to be a lack of policies, at a national level, targeted to the transportation sector that remains the principal emitter of green house gases.

Figure 16. Instruments and targets for climate change, renewable energy and energy efficiency policies in Mexico

Source: Adapted by author from IEA database.

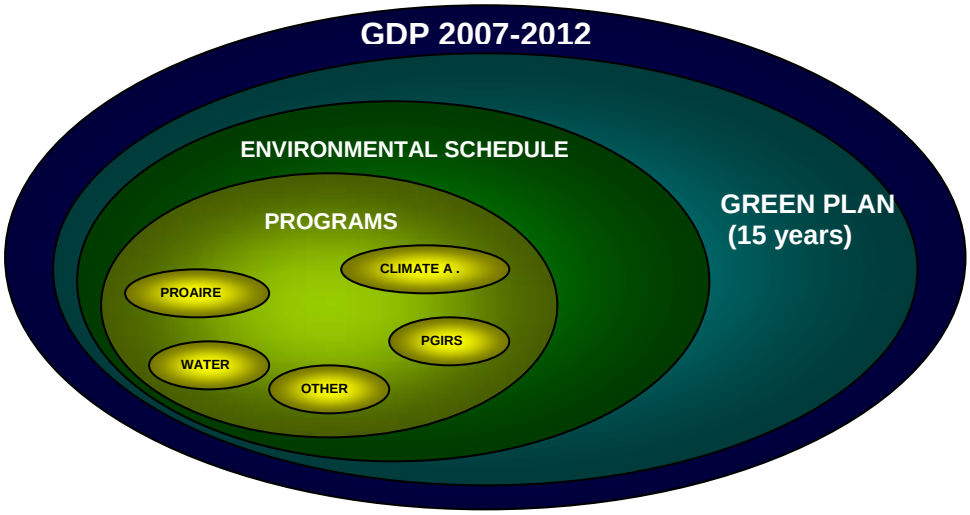
Local plans and policies

Climate action

The Federal District energy policies are subscribed within the General Development Plan (GDP) – *Plan Nacional de Desarrollo*, prepared for a period of 8 years. This plan is divided by axes and establishes a series of general strategies and policy lines in the most relevant subjects like climate change, housing, air quality and solid waste. A more specific plan which derives from the GDP and involves different sectors of the economy is the Green Plan – *Plan Verde*. The Green Plan is done for a broader period of time (15 years) and contains specific

strategies and actions. From the Green Plan an Environmental Schedule is fixed (6 years) and programs are developed in each axe of action. Figure 17 show the organization of this plans and programs.

Figure 17. Green Plan axes



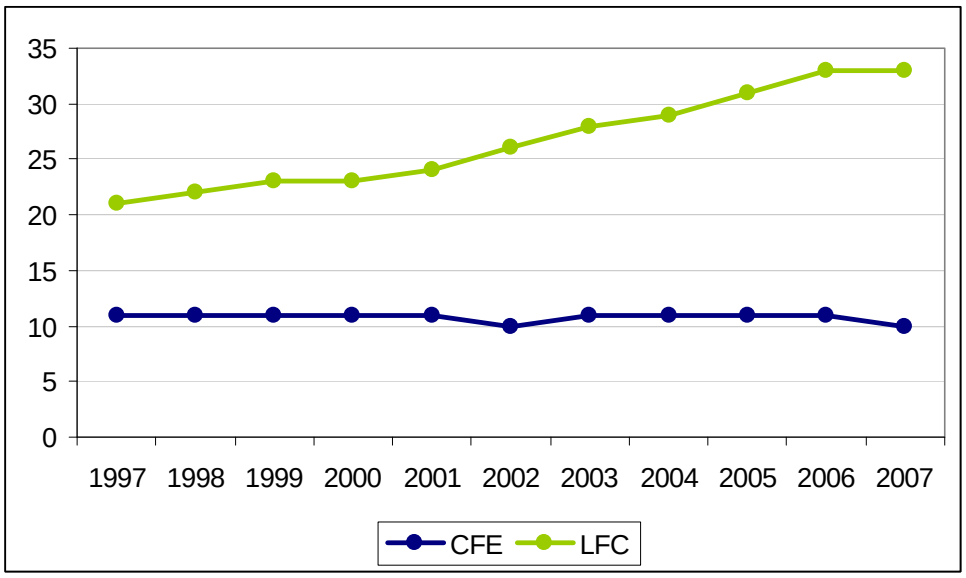
For the purpose of this document we will focus only on the Climate Action Program which contains 26 specific actions to mitigate climate change. The emissions reduction objective was set at 4.4 $MtCO_2e$ of emissions every year for the 2008-2012 compliance period, or minus 12% with 2008 as a reference year.

Electricity looking back and moving forward

Electricity transmission, distribution and commercialization in the City of Mexico was until recently the role of a centralized public organism called *Luz y Fuerza del Centro – LFC.* The 11 October 2009, by presidential judgment, it was order to liquidate LFC due to its low productivity and high technical and non technical losses. Figure 18 shows the increasing losses of electricity by LFC compared to the Federal Electricity Commision. Other indicators for the LFC like labor productivity and energy efficiency in thermal centrals were also deceiving. When compared to CFE, LFC energy efficiency in thermals was around 25% against 35% for the CFE. In addition, a comparative study done by *Banamex* in 2009, estimated that labor productivity for LFC was around 0.72 GWh/worker, for CFE around 1.75 GWh/worker while equivalent electricity companies worldwide has 7.5 GWh/ worker productivity.

The role of electricity generation, transmission and commercialization was given to the Federal Electricity Commision (CFE: *Comision Federal de Electricidad)*. While CFE has proposed to diminish technical loss to from 34% to 11%, National Energy Strategy (2007), electricity loss needs to be reduced to international levels of 8%. In 2008, at a national level, technical and non-technical losses were around 17.6%. The main causes of non-technical losses derive from the illegal use of electricity that are generally linked to : the growth of the informal sector, slums settlements and non payment.

Figure 18. Percenage of electricity loss CFE and LFC



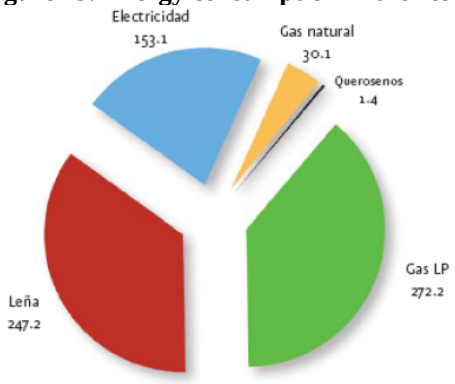
Source: CIDAC, algunos datos sobre LFC

3. Road maps

Combating energy poverty

Energy Poverty in Mexico is evidenced through the extensive use of wood and other energy sources due to restrained access – to the poorest part of the population - to legal and safe electricity (see Figure 19).

Figure 19. Energy consumption in the residential sector



Source: SENER (2006) 'Balance Nacional de Energia 2005, Mexico

In the past year, the President of Mexico has put into action a national program of appliances substitution (*Programa Nacional de Sustitucion de Electrodomesticos).* This program is targeted to poor households and is meant to reduce energy poverty through energy efficiency. According to data, households changing their refrigerators and air conditioning appliances could save from 35 ($2.5) to 200 pesos ($14) per month[15]. At a local scale Energy

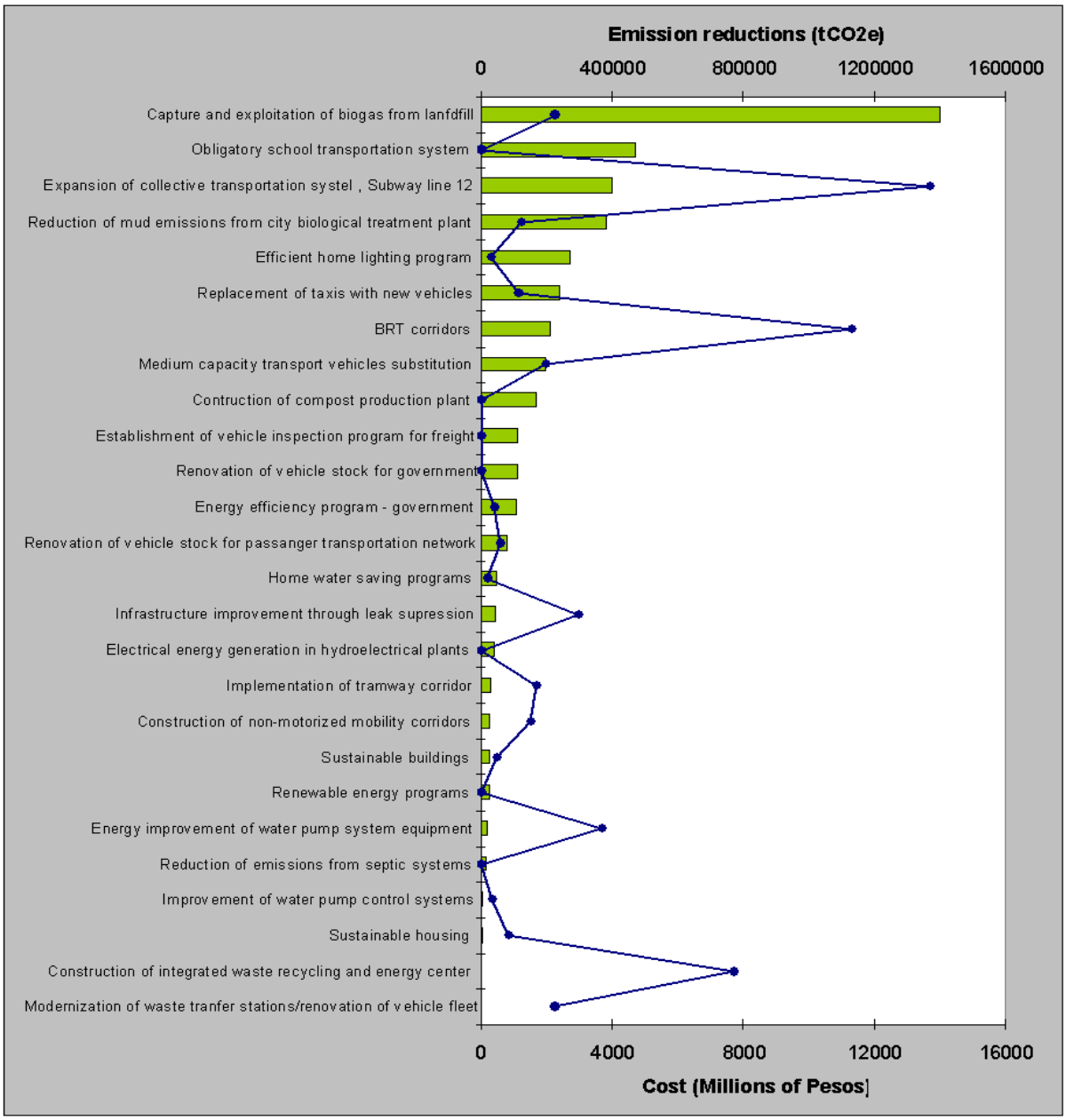
[15] http://www.univision.com/content/content.jhtml?cid=1886970

Poverty action needs to be better linked with the recognition of informal settlement and the adaptation of technologies, standards and forms of payment.

GHG emissions reduction

The Climate Action Program describes a series of 26 actions divided in four sub-themes (water, energy, transport and solid waste) that are expected to put the Federal District's development in a sustainable path. The following figure describes the expected reduction of emissions for each of the actions and the expected cost.

Figure 20. GHG emission reduction actions



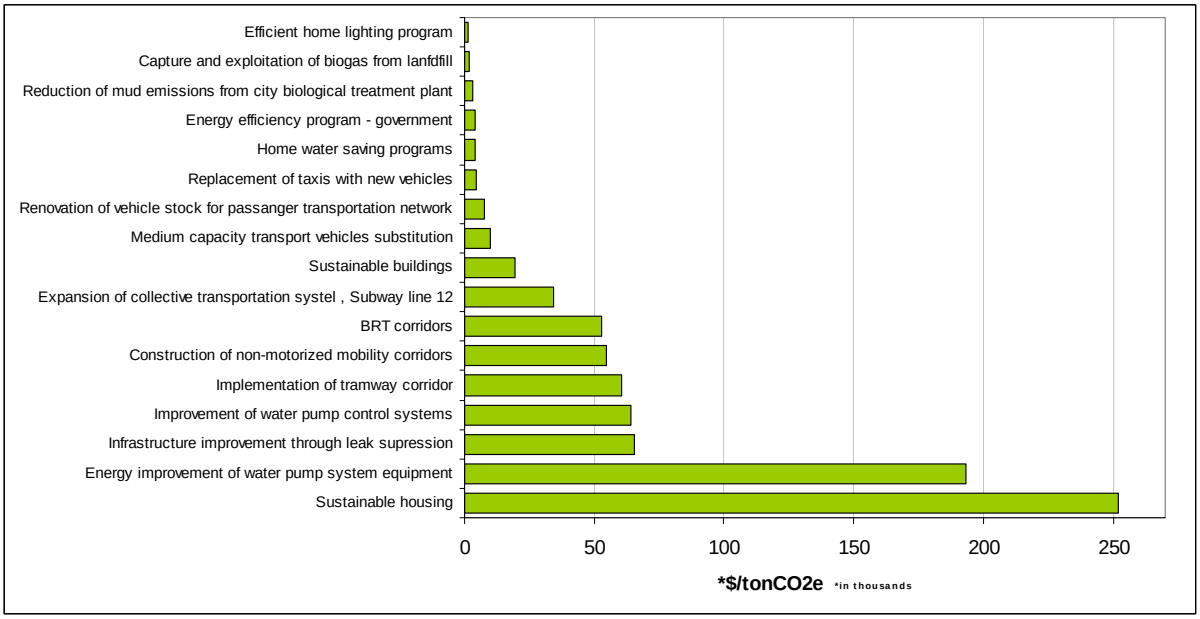
Source: Mexico City Climate Action Program

From the series of actions shown above the most cost effective are the energy efficiency program for homes and government offices, the biogas capturing program and the sludge emissions reduction program for biological treatment plants. These are followed closely by

the home water saving program and the renovation of taxi and vehicle fleet for passenger transportation. While the biogas capturing program is one of the most interesting solutions we will see in Figure 22 that it hasn't yet been implemented. In fact various problems of coordination between the different entities have delayed implementation. For instance, the Federal Government and the Federal District have not yet found an agreement to decide who will benefit from the Carbon bonus generated by the project (CDM).

One characteristic of the least cost efficient programs is that they suppose big changes in the urban landscape such as the construction of the new metro line, the creation of new BRT, tramway corridors of non-motorized mobility corridors. However, this actions need to be evaluated not only from their effectiveness in terms of emission reduction but from a more general perspective. For instance, the sustainable housing program is definitely the least efficient in terms of emissions reduction but it can serve other purposes like the provision of affordable housing for low income households. Moreover, other projects like the construction of an additional metro line have not only potential additional benefits (reduction of local pollution and associated health problems and the improvement of mobility) but also imply great emission reductions in absolute values.

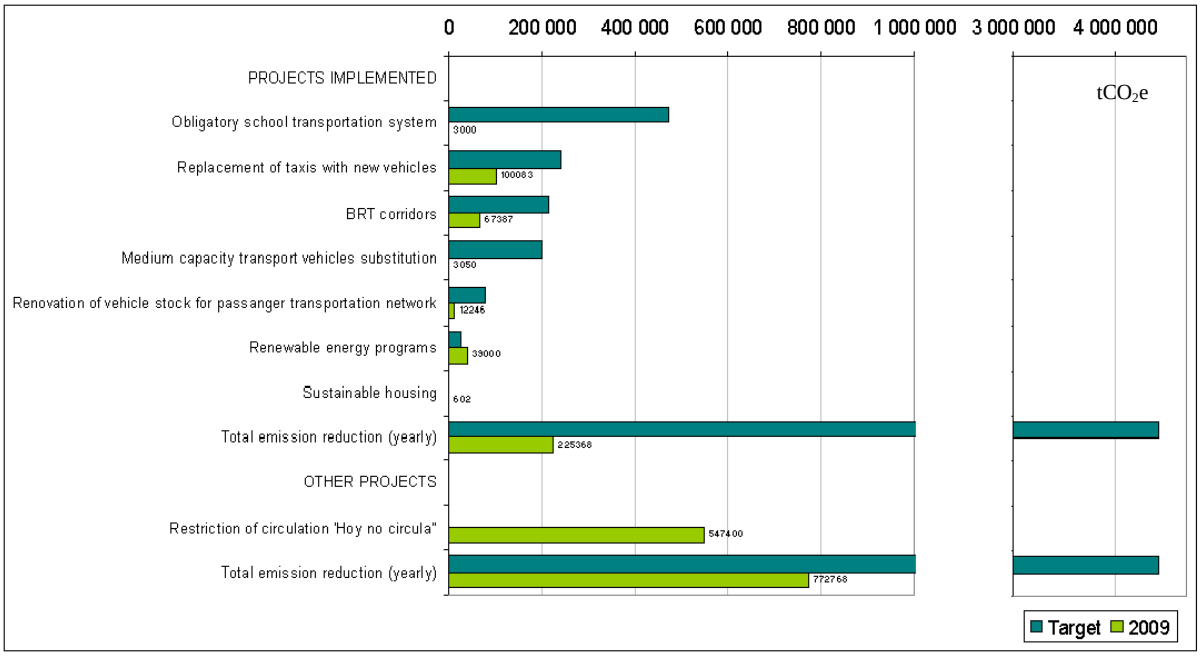
Figure 21. Cost-benefit of climate actions



Source: Adapted from Mexico City Climate Action Program

Of the 26 actions, 4 programs have are either programmed or being implemented and 8 other are being studied for implementation. Figure 22 shows what has been done so far in terms of yearly emission reduction comparing with the targets set. As we can see there has there has been little advances in each of the implemented projects and only 5% of the emission target was accomplished. In addition, the city's circulation restrictions for old vehicles program (*Hoy no circula*) was responsible for the largest share of emission reduction. The former was not included in the Climate Action Program since it has been running for a long time in the city and its initial objective was the reduction of local pollution. If the current speed is maintained the ambitious emission reduction targets will not be met.

Figure 22. Program and emission completion



Source: Workshop "Planeacion Ambiental" and data on Mexico City Climate Action Program

4. Discussion

Even though the City of Mexico has taken seriously the climate change challenge their achievements so far prove that targets were too ambitious. Furthermore to achieve substantial emissions reduction some radical changes need to be introduced in the transport sector. Policies that favor public transportation need to be put in action, but these generally need big investments and will probably take more time than 4 years to be implemented. In addition, the sprawl and expansion of the City of Mexico have generated serious coordination problems between authorities from the State of Mexico and the Federal government. Difficulties implementing biogas recuperation –which is one of the most cost-effective policies – evidences the recurrent problems of this split megacity. One of the main challenges will be to assure cooperation between the two authorities of this split megacity and guarantee consistence between energy and climate change policies.

[i] Balance de energía dentro de la planeación integral (mail de Bazar)
[ii] Bazan (2010)