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THE ARAB REPUBLIC OF EGYPT

FOR BETTER OR FOR WORSE: AIR POLLUTION IN GREATER CAIRO

A SECTOR NOTE

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SUSTAINABLE DEVELOPMENT DEPARTMENT

MIDDLE EAST AND NORTH AFRICA REGION

The Arab Republic of Egypt

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ACRONYMS

AFD	Agence Française de Développement
AAQ	Ambient Air Quality
CAIP	Cairo Air Improvement Project
CAPMAS	Central Agency for Public Mobilization and Statistics
CDM	Clean Development Mechanism
CEA	Country Environmental Analysis
CID	Central Inspection Department
CMB	Chemical Mass Balance
CNG	compressed natural gas
COED	cost assessment of environmental degradation
DALY	Disability Adjusted Life Year
DSS-IPC	Decision Support System for Industrial Pollution Control
EEA	European Environment Agency
EEAA	Egyptian Environmental Affairs Agency
EER	Energy Environmental Review
EIB	European Investment Bank
EMEP	Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP)
EPAP II	Second Egypt Pollution Abatement Project
GCMA	Greater Cairo Metropolitan Area
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GIS	Geographic Information System
JICA	Japan International Cooperation Agency
LE	Egyptian pound
LRTAP	Convention on Long-range Transboundary Air Pollution
MOHP	Ministry of Health and Population
MSEA	Ministry of State for Environmental Affairs
NOx	Nitrogen Oxides
NPV	Net Present Value
O_3	Ozone
Pb	Lead
PM or PMx	Particulate matter (regardless of size)
PM_{10}	Particulate matter of 10 micrometers
$PM_{2.5}$	Particulate matter of 2.5 micrometers
ppm	Parts per million
REIMP	Regional Environmental Information Management Project
SAS	Source attribution study
SMEs	Small and medium enterprises
SOx	Sulfur Oxides
SWM	solid waste management
USAID	United States Agency for International Development

VET	Vehicle emission testing
VSL	Value of Statistical Life
WHO	World Health Organization
WTE	waste to energy or waste-to-energy

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The Arab Republic of Egypt

For Better or for Worse: Air Pollution in Greater Cairo, A Sector Note

Executive Summary

This sector note presents the results of the World Bank–led study on the development of a strategy of the government of the Arab Republic of Egypt to respond to air quality problems in Greater Cairo. Following is the main summary of the report.

Good Air Quality in the Greater Cairo Metropolitan Area Is a Challenge

The Greater Cairo Metropolitan Area (GCMA) is the largest urban and industrial center in Egypt, which, in 2009, was ranked eighth among the world's top urban agglomerations. Twenty million people live and work in Greater Cairo, which is surrounded by major heavy industries to the north and the south, including large, as well as small and medium enterprises. Outside the residential and commercial belts of Greater Cairo lie the four largest solid waste disposal sites in the country, accounting for an estimated 9.5 million tons of municipal solid wastes per year. Greater Cairo also has Egypt's largest fleet of vehicles, including 1.4 million private passenger cars and hundreds of thousands of taxis and trucks, which use the largest road network in the country, extending more than 10,000 kilometers.

As in many megacities in the world, air pollution has been a chronic problem in Greater Cairo. Since 1999, the Cairenes have also been facing an episodic deterioration in air quality, the Black Cloud phenomenon, every October and November. Air quality degradation has taken a toll on the public health, environment, and economy of Greater Cairo. The main reasons for the degradation is the quickly growing population, uncontrolled rural migration and rapid urbanization, the past focus on the development of publicly owned chemical, metallurgical and other heavy industries close to population centers, the intensive and heavily subsidized use of energy sources in the transportation sector, and the lack of enforceable requirements for the proper management of solid, agricultural, and hazardous waste. These problems have been exacerbated by uncoordinated and sometimes contradictory policies and institutions and the inadequacy of governance structures. The persistent air quality problem represents a serious hurdle to the competitiveness that is a key to the socioeconomic development of Greater Cairo and therefore the nation.

The Government Has Taken Active Steps to Respond

The government has realized the seriousness of the problem and adopted various measures to address it. Overpass bridges, highways, and ring roads have been constructed around the city. Eight new satellite cities have been established to deconcentrate Cairo's population and develop new poles for economic growth. Two Greater Cairo underground metro lines are in operation, and a third line is under construction. Natural gas utilization now accounts for 99 percent of the total fuel consumption at all power plants connected to the gas grid. Most of the housing sector in Alexandria and Cairo use natural gas. Private car and taxi owners have been encouraged to switch to natural gas through successful incentive schemes. Cars must otherwise run on lead-free gasoline. The first vehicle emission testing (VET), tune-up, and certification systems aiming at the reduction of pollutants and improvements in fuel efficiency are operating in the Governorates of Giza and Qalyoubia.

The government has also launched an incentive mechanism for industrial firms based on a combination of grants and loans provided through the Second Egypt Pollution Abatement Project (EPAP II), cofinanced by the Agence Française de Développement (AFD), the European Investment Bank, the Japan

International Cooperation Agency, and the World Bank. To achieve compliance with the environmental law, the mechanism is supported through the KfW-financed Private Public Sector Industry Project and the Environmental Compliance Office established by the Federation of Egyptian Industry and the Danish International Development Agency. There has also been progress in adopting legal and institutional measures to improve air quality. The Environmental Protection Law No. 4 of 1994 (amended by Law No. 9 of 2009) prohibits waste burning by imposing heavy fines on offenders. The Ministry of State for Environmental Affairs (MSEA) has established continuous emission monitors in the cement industry that provide 24-hour monitoring of the main stacks and is in the process of extending the monitoring to the fertilizer and power sectors. The Central Department of Environment Inspection and Environment Compliance of the Egyptian Environmental Affairs Agency (EEAA) and its regional offices have been conducting inspection monitoring and assigning priority on companies with major sources of emissions, frequent reports of noncompliance, and public complaints. Noncompliant companies are fined and are referred to the EEAA legal department to determine the necessary follow-up.

Despite these accomplishments, uncoordinated policies may have accentuated the increase in pollution rather than reducing it. Rice cultivation in the Upper and Middle Delta has been allowed to expand to the governorates around Cairo. This has resulted in an increase in air pollution during the period of temperature inversion, which is associated also with the burning of rice straw, and has been responsible for the Black Cloud phenomenon. The government's inability to cope with traffic management and the undercapacity of the public transportation system has meant that the private sector continues to rely on old, inefficient minibuses, mostly with outdated diesel engines, to transport the low-income population. Thus, to facilitate displacement in periurban areas, vehicles with two-stroke engines (the Tok Tok manufactured in India, for example) are being imported without being subjected to emission standards, thereby contributing to air pollution. Middle-income households have taken advantage of subsidized fuel and easy access to bank loans to purchase one or more private vehicles per family, adding to traffic congestion and the blocking of secondary and tertiary roads with parked cars. Likewise, passenger cars and heavier trucks are being imported or assembled with no regard for emission standards such as Euro 3 and Euro 4. These standards are based on grams of pollutants per kilometer traveled, and they reflect both efficiency and the capacities of abatement equipment. Cairo is a constant, polluting traffic jam all day, every day, and long into the night.

The Results of These Interventions Have Been Mixed

Government action, combined with these barriers, have resulted in mixed outcomes. In terms of air quality pollutants, there has been general improvement since 1999. Specifically, up to 2007, the annual concentration of lead declined substantially to within national and international thresholds. This success can be attributed to successful government policies to eliminate lead in gasoline, to relocate small and medium enterprises (SMEs) involved in lead processing, and to decontaminate the sites of these SMEs in Shoubra El Kheima. Since 2007, however, lead concentration has increased by twofold, though it is still within the range of guidelines of the World Health Organization (WHO). The increase may be caused by the resumption of operations of small-scale lead smelters. Over the same period (1999–2009) and based on data provided by the EEAA, most of the monitored pollutants registered a drop between 1999 and 2009, except for ozone (O_3), which doubled during these years (+100 percent), primarily accompanying the growing use of transport. Despite the net decrease in particulate matter of 10 micrometers (PM_{10}) during the last decade, the concentration is still twofold the Egyptian standard and approximately sevenfold the WHO guideline. The concentration of particulate matter of 2.5 micrometers ($PM_{2.5}$) is around seven times the WHO guideline. The concentration of some other pollutants is moderately above the WHO guidelines. Only a daily concentration for ozone is now being provided, but, given that the daily concentration of pollutants is usually greater than the annual concentration, it is not unreasonable to assume that the daily ozone concentration is above 100 $\mu g/m^3$.

Source Attribution and Modeling Have Been Used to Identify the Root Causes of the Problem

To identify the root causes of the problem, a source attribution study was carried out as part of the preparation for this report. This marks only the second time that this type of study has been conducted in Greater Cairo; the first time was in 1999–2000 under the Cairo Air Improvement Project funded by the United States Agency for International Development. We selected five sites to represent diverse possible sources of pollutants; these included (1) Kaha, a Delta site with significant agricultural activity, was chosen to represent the upwind pollutants that impact the Greater Cairo area; (2) Shobra El Kheima, an industrial and residential area in a heavily industrialized zone downwind from numerous lead smelters and other industrial sources of pollutants; (3) El Qulaly Square, a site dominated by mobile sources of pollutants; the site is a downtown residential area with high light and heavy-duty (bus) vehicular traffic; (4) Zamalek, a residential location, was chosen to represent a site with limited nearby sources of pollutants; and (5) Helwan, a residential-industrial area with nearby sources of pollutants. We conducted two analyses, in the summer and the fall of 2010.

By comparing the results of the current source attribution study and the earlier study, we find that the concentrations of PM_{10} and $PM_{2.5}$ were lower in fall 2010 than in fall 1999 by a factor of 2.4 ($PM_{2.5}$) and 1.8 (PM_{10}). This decline may be attributed to several factors, namely, the expansion of the road and highway network, improved car efficiency, industrial pollution control, and efforts to contain open burning. Despite the decline, the PM_{10} concentration remains high, and more people are now being exposed to the effects of this pollution because the population in Greater Cairo increased by more than 3 million between 1999 and 2010, while the number of vehicles increased by some 300,000. Similarly, the study found that there had been a decline in particulate matter between the summer of 2002 and the summer of 2010, by 1.03 for PM_{10} and 1.17 for $PM_{2.5}$. This may have been caused by reduced traffic and congestion during the holiday season and the closing of schools and universities.

The major contributors to PM_{10} concentrations include soil dust material, mobile source emissions, and open burning. From fall 1999 to fall 2010, the contribution of open burning exceeded that of soil dust and mobile sources, likely because of ongoing agricultural burning. The major contributor to $PM_{2.5}$ is mobile source emissions, followed by secondary species (ammonium sulfate and ammonium nitrate), soil dust, and open burning. In relative terms, the top four sources of pollution remained the same in 1999–2010, but with slight changes in ranking. The seasonal number 1 ranked sources of pollution were all reduced in absolute terms over the period except for geological materials, which remained the same in relative and absolute terms between 2002 and 2010, suggesting that the pollutant levels are mainly attributable to natural causes such as eastern or western desert storms (the *khamasin*).

Our results show that the district of Shobra has the highest level of PM_{10} concentration among the five sites, including Helwan, where there is heavy industry to the south. Shobra showed the second highest concentration of $PM_{2.5}$ after El-Qulaly. Shobra has the highest population per square kilometer and includes the largest number of SMEs, in addition to a power plant. Furthermore, the four other sites have similar PM_{10} concentrations during the fall, irrespective of population, industrial activity, and traffic. Zamalek, which is considered a residential area for upper-middle-income households has PM_{10} and $PM_{2.5}$ concentrations similar to those in El Qulaly and Helwan, which include residential areas with lower-middle-income households. Rich and poor are all exposed to similar levels of air pollution in Cairo.

Economic Analysis Was Used to Determine the Cost of Degradation

The air-related degradation cost relative to gross domestic product (GDP) in Greater Cairo ranged from 0.9 to 1.3 percent over 1999–2009, with a yearly average of 1.03 percent, a low of 0.7 percent, and a high of 1.5 percent. The cost of the degradation associated with air pollution increased almost 1.5 times, from LE 6.6 billion in 1999 to LE 10.2 billion in 2009 in constant 1999 prices. The cumulative cost of degradation in Greater Cairo over the period amounted to LE 60.8 billion in current prices and LE 76.0

billion in 2009 constant prices. The net present value of the cost of degradation was LE 43.8 billion and LE 56.1 billion, respectively, with an equivalent annualized average of LE 4.0 billion in current prices and LE 5.1 billion in constant prices. PM_{10} was the pollutant most damaging to society because of the rising associated health care cost: it represented, on average, 76.6 percent of the total degradation cost in current prices over the period, and the related cost rose by 9.1 percent.

Meanwhile, there was also an upside. The cumulative social benefit in Greater Cairo in terms of averted costs attributable to the reduction in air pollution in 1999–2009 has been valued at LE 34.7 billion in current prices and LE 41 billion in 2009 constant prices. The net present value of these social benefits was LE 23.5 billion in current prices and LE 28.3 billion in 2009 constant prices.

Other Countries Have Successfully Faced Similar Challenges

At least partially, many countries have managed to address problems in air quality in megacities. Examples include the successful experiences of India, Indonesia, the Philippines, Thailand, and the United States in managing air quality in Mumbai, Jakarta, Manila, Bangkok, and Los Angeles, respectively. The programs implemented in these cities share common characteristics, namely, (1) the political will at the highest level to control air pollution; (2) the adoption of stringent emission standards, especially for vehicles and motorcycles; (3) improvements in the quality of gasoline and diesel fuel through reductions in the amounts of benzene and aromatic hydrocarbons in gasoline and in the sulfur content of diesel fuel; and (4) expansion of the use of compressed natural gas (CNG), especially in public transport and the two-stroke, three-wheeler Tok Tok, and the use of environmental permits to ensure compliance with stringent source emission standards.

We find a number of contrasts between Greater Cairo and these cities. First, the air quality standards are similar in Greater Cairo and the other cities, but Cairo has a more relaxed approach toward $PM_{2.5}$; the formulation of fuels in the other cities has been constantly improved, but Cairo continues to rely on high-sulfur diesel and heavy fuel oils. Second, the countries in which the other cities are located have adopted vehicle emission standards in line with the Euro 4 and Euro 5 standards, while emission standards in Egypt are more in line with the older Euro 2 standard. Third, VET is being used in the other countries, while, in Egypt, VET is confined to Giza and Qalyoubieh Governorates. Fourth, the monitoring and enforcement of vehicle emissions are being strengthened in the other cities, whereas it is seriously lacking in Greater Cairo. Fifth, CNG is used widely in the other cities, while, in Greater Cairo, it is confined to taxis. Sixth, environmental permits backed by stringent emission regulations are being issued to industrial facilities in Egypt, but the legal framework does not demand compliance with specific emission requirements; rather. Seventh and last, Thailand, for example, has prepared an open burning control plan within the context of a national master plan; meanwhile, Egypt has adopted several related measures and undertaken investments in composting, animal feeds, biogasification, and pelletizing for the fuel use of rice straw, but there is currently no strategy for rice straw and agricultural waste that is economically sustainable at both the local and the national levels.

The Business-as-Usual Approach Is Not the Answer

If no action is taken by the government to control air pollution, the situation is expected to deteriorate more quickly in coming years, as follows:

- More people in the GCMA will be exposed to higher levels of pollution. Isocontour plots for 2010, 2015, and 2020 show an increase in pollution in the new cities of Sheikh Zayed, 15 of May, and 6 of October that were established to reduce the congestion in Cairo. It is therefore expected that more than 4.6 million people will become exposed to pollution between 2010 and 2020. Moreover, residents in areas surrounding the GCMA will also be exposed to increased emissions that will affect agricultural yields and health.

- Ground-level emissions (such as the emissions from transport and from agricultural waste burning) contribute to ground-level concentrations that are 50 times more damaging than stack source emissions (that is, 1 ton of ground-level emissions causes the same amount of damage as 50 tons of stack emissions).[1]
- Between 2010 and 2020, an additional 137,000 persons will suffer from chronic pulmonary and cardiovascular disease; lower respiratory illness will affect about 11.1 million children; and premature mortality will increase to about 66,300 cases (Doumani 2011).
- Calculated emissions will show a slight increase in 2010, 2015, and 2020 under the business-as-usual scenario (see Table 7.1), assuming that fuel efficiency improves by 1 percent a year over the next 20 years, that existing vehicles will not be replaced by vehicles with lower exhaust emissions, and that there will be additional vehicles with cleaner engines. The sulfur content of fuels and the field burning of agricultural waste will continue unchanged.
- The cost of degradation is expected to rise to LE 19.7 billion by 2020 within the GCMA boundaries because of the increase in particulate matter (regardless of size). The cost assessment of environmental degradation may reach 1.2 percent of GDP because more people will be exposed to pollution and because of the cost of illness. During the last decade, the growth in environmental degradation (9.6 percent) almost matched economic growth (9.5 percent), it is anticipated that the growth in the rate of degradation will eventually surpass the economic growth rate given the slow pace of growth of the current economy in Egypt.

The Current Sociopolitical Situation Is Not Conducive to a Quick Fix

Additional reductions in air pollution depend on a number of external factors. The impact on the economy of recent political events in Egypt remains uncertain. GDP is projected to have expanded by less than 1 percent in 2011 and may recover to 5 percent by 2013. Further investments in the reduction of air pollution may not be among the government's most important economic and social priorities. Lowering energy subsidies is also not anticipated in the short term. The energy subsidies for the industrial sector have been gradually cut, and gasoline and diesel prices are expected to be less sensitive to fluctuations in international prices in the short term. There is no quick technological solution for air pollution in Greater Cairo given that problems related to informal housing, rural migration, population increase, the lack of urban and rural planning, poor transport management, and weak enforcement have accumulated over the last decades and are not likely to be resolved in the short or medium term.

A Flexible, Modular Strategy Has Potential

Notwithstanding these uncertainties and until the political and socioeconomic climate stabilizes, certain measures can be recommended provided they are flexible and realistic, can be phased in, are compatible with economic growth, and are administratively practical. Given the constraints and parameters, the proposed strategy should focus on addressing local air quality issues and problems as a priority; unless these are addressed first, the commitment of Greater Cairo and Egypt to international conventions will lack credibility in the eyes of Cairenes.

The proposed strategy is based on three pillars, as follows:

1. *Pillar 1: build institutions over the short term* (one to three years) by establishing an air quality management system in the GCMA; this is critical to the successful implementation of a strategy that would reflect the government's commitment and would justify the involvement of international financial institutions and donors.

[1] See Egypt: Energy-Environment Review, World Bank (2003).

2. *Pillar 2: target cost-effective investments over the medium term* (two to five years) that can have measurable and significant impacts on chronic air quality issues, namely, vehicle emission control and vehicle emission abatement, the management of the open burning of municipal and agricultural waste, the management of charcoal production, and industrial pollution control (in selected industries such as oil, chemicals, minerals, and metal production).
3. *Pillar 3: adopt a package of pricing and sectoral policies in the long term* (three to eight years) in transport and energy that can be implemented whenever the economic and political situation improves; the target is to reduce PM_{10} and $PM_{2.5}$ concentrations to 112 μ/m^3 and 65 μ/m^3 annual mean, respectively, by 2020, which are about five and six times higher, respectively, than the WHO guidelines, but are considered an upper limit for GCMA concentrations.

For the implementation of the three pillars of the strategy, the following steps were proposed:

Pillar 1: Establishing an air quality management system in the GCMA that consists of the following:

- Improving the institutional framework
- Developing local air quality management in the air sheds of the GCMA
- Developing stringent air quality standards for vehicles
- Improving public awareness of the benefits of good air quality and enhance the public's ability to make proper choices through environmental education

Pillar 2: Target cost-effective investments in the medium term

1. *Vehicle emission control and vehicle emission abatement*. Based on a cost-effectiveness analysis, we find that improving performance in vehicle emissions is a key recommendation provided the following occurs:

- Only the enforcement of emission standards will lead to large reductions in local damage costs.
- CNG conversion pays: there are signs of replication in the private vehicle sector, and such a scheme could be extended to those vehicles for which the remedial costs are lowest. This includes converting buses and microbuses to CNG and switching older vehicles such as old taxis and private vehicles from gasoline to CNG.
- The less promising option is to switch the diesel engines in taxis older than 10 years to CNG as the PM_{10} abatement costs are the highest for such vehicles or to buy buses fueled by fuel cells.

2. *The open burning of municipal waste*. The financial analysis conducted on the overall solid waste management (SWM) system in the GCMA shows that the new government plan for the GCMA—which consists of the expansion and creation of 18 transfer stations and the construction of two waste-to-energy (WTE) plants in Helwan and four integrated sorting-composting-recycling-sanitary stations—is ambitious and expensive. The estimated cost is LE 20.8 billion (US$3.5 billion), which is probably not affordable given the current situation. The SWM New Plan includes two parallel tracks to deal with waste: a WTE chain consisting of collection, transfer, WTE, and residual landfilling and a regular chain consisting of collection, transfer, segregation (recycling and composting), and landfilling. A financial analysis has been conducted on the EEAA plan from cradle to grave for the WTE chain, which would handle 2,990 tons a day, and the regular chain, which would handle 13,319 tons a day.

The full cost recovery of the SWM New Plan for Cairo will reach at least LE 1,527 (US$259.3) per ton of waste over 2014–33. If it is assumed that a family of five generates 1 ton per year of waste, this means that each family should pay LE 1,527 a year, which is LE 127 a month, compared with the LE 8 a month a family is now paying, that is, if the government is aiming to reach full cost recovery, the New Plan calls for a fee increase of about 16 times, which is unlikely to be affordable for the majority of households in Giza and Helwan.

- For the regular chain where the rest of the waste will be processed, the full cost recovery of the SWM New Plan for Greater Cairo will reach at least LE 371 (US$63) per household year over 2014–33 or LE 30.7 a month, compared with LE 8 a month, which would mean that a family of five would pay 3.8 times more than what they now pay.

3. Based on the above, *the proposed recommendations are as follows*:

- Reconsider the alternative of using WTE in Giza and Helwan.
- Consider a least-cost alternative to the SWM New Plan that would be limited to establishing the transfer stations and landfilling all the waste. The total capital expenditures would reach LE 4.1 billion (US$697 million), which would be fivefold less expensive than the SWM New Plan (see Table 7.3). Moreover, cost recovery is more affordable, at LE 290 a ton (US$49.3), although this could be further reduced should electricity be generated through fuel cells at the landfills.

4. *The open burning of agricultural waste*. In waste burning, the technology does not seem to be the issue. The major issues are (a) geographical and topological issues related to the landlocked lots, which are not inaccessible for the collection of the rice straws; (b) a lack of financial and economic analysis related to the large investments in composting or to burning in cement kilns; (c) the lack of an incentive scheme for both producers and users of the rice straw waste; and (d) a communication issue revolving around the need to increase awareness among farmers about the benefits of the collection of the rice straws.

Based on a financial analysis that was carried out based on three options for the reduction of open waste burning, namely, rationalized burning, composting, and burning in cement kilns, the key recommendations are as follows:

- Rationalized burning should be considered as a short-term option for one or two years, while other options (described below) are fully developed or implemented. This would reduce the load intensity of PM_{10} and black smoke over Greater Cairo during the fall and therefore could spare a great number of people from cardiopulmonary morbidity and mortality, thereby reducing the costs of illnesses.
- The EEAA would commission an economic and institutional assessment and a study on the requirements for landlocked lots and the most appropriate means and tools to increase the collection of rice straws from inaccessible fields.
- The agricultural extension staff of the Ministry of Agriculture should be trained to communicate and otherwise work with farmers on rationalized burning.
- The EEAA should launch awareness and communication campaigns among farmers on the adverse impacts of waste burning and on the benefits of collecting the rice straw for proper disposal and treatment.
- The EPAP II should continue to pilot the disposal and burning of agricultural waste in cement kilns so as to obtain better information and analysis on the requirements of replication.

5. *Industrial pollution control*. As the EPAP II will end in the next 18 months, the MSEA has indicated an interest in designing a third phase of the project, EPAP III. The results of our study should serve as background for the EPAP III, which could include the following in the project design:

- Pollution control among large enterprises that focuses primarily on mining and chemical industries (see chapter 3)
- Pollution control among SMEs primarily in Shobra, which our study has shown to be a hot spot
- The use of alternate fuels in the cement industry following the completion of a full feasibility study based on a pilot operation within EPAP II

- Leveraging financing so the private sector can scale up support for the valorization of municipal waste in terms of the 4 Rs (reduce, reuse, recycle, recover), and waste can become an asset rather than a liability
- Participate in a successful CNG-switching program by extending the program to microbuses in Greater Cairo and Giza.

Pillar 3: Adopting a Package of Pricing and Sectoral Policies in the Long Term

1. *Pricing policies*. Pillar 3 entails the adoption of a series of pricing and sectoral policies in transport and energy that could be implemented whenever the economic and political situation improves. Price reforms and sectoral measures are not mutually exclusive. Price readjustments would reduce both the environmental impacts and subsidy payments. Thus, it is likely to be cost-effective.

If price reform strategies cannot be comprehensive within the existing socioeconomic and political context, then the targeting of transport fuels appears to be a sensible compromise. There is a dual gain in the avoidance of subsidies and the avoidance of damage. Such a strategy has other advantages, too, namely, that there is relatively little substitution of other fuels in transport; so, leakage into other fuels not subject to price reform would be small. The most likely substitution would be the enhanced use of natural gas in transport, which is, in any case, a policy with much to recommend it. Moreover, natural gas is fairly abundant in Egypt, and electricity, as a product of natural gas, is also readily available. There is some justification in focusing price reform on fuels that are locally more scarce.

2. *Sectoral policies*. The EEAA has proposed two scenarios that include a package of targets that should result in reducing PM_{10} and $PM_{2.5}$ concentrations to acceptable levels.

The cumulative social and health benefits deriving from the averted costs attributable to the air-related burden in the GCMA would be LE 5 billion and LE 18 billion for scenarios 1 and 2, respectively, over 2010–20 in 2009 prices or a net present value of LE 3 billion and LE 12 billion, respectively, with an annualized LE 0.3 billion and LE 1.1 billion, respectively, over the period. Scenario 2 maintains air pollution at nearly the 2010 levels. However, this may not be sufficient given the aim of decreasing air pollution to below the 2010 level.

It is therefore recommended that a third scenario be included that would build on scenario 2 and target additional cost-effective interventions, especially with regard to transport, domestic and agricultural waste, charcoal production, unpaved roads, building construction or demolition, and other industrial processes involved in pillar 2.

Finally, an Action Plan was proposed

An action plan has been prepared for the implementation of the main sectoral policies described above (see chapter 7). This action plan will have to be developed and changed where required because it can only be implemented within a coherent framework of environmental, energy, and economic policies that need to be defined and adopted by the government. Therefore, the action plan, as presented in this report, should be considered as a basis for ongoing discussions with the government. These discussions must, in any case, be continued to support the implementation of the work that has been initiated through this report. The action plan also identifies the entities that should be involved in or responsible for implementing and monitoring specific activities.

1 Introduction

1.1 Background

As with all megacities of the world, Cairo has been struggling with severe air pollution. The main factors behind the emergence of this serious risk to human health and the quality of life for the 20 million people in this city include a rapidly growing population, uncontrolled rural migration and rapid urbanization, past focus on development of publicly owned heavy industries (such as chemical and metallurgical industries) close to population centers, the intensive and heavily subsidized use of energy sources in the transportation sector, and the lack of enforceable requirements for the proper management of solid and hazardous waste. These problems have been exacerbated by uncoordinated and sometimes contradictory policies and institutions and the inadequacy of governance structures. These problems, if left unresolved, pose a major threat to (i) the human health and the quality of life, (ii) the productivity and sustainability of natural resources to support livelihoods and improve the urban economy, and (iii) the efficient use of resources and the competitiveness of key sectors of the Egyptian economy.

Principal health impacts from air pollution include direct impacts, in the form of respiratory diseases, such as bronchitis and asthma, as well as indirect impacts in terms of weakening of the population resistance to other diseases (Table 1.1). Apart from reducing the quality of life of the population, these impacts also result in lost economic productivity.

Table 1.1. Health effects associated with primary exposure to criteria pollutants and noise

Pollutant	Health Effects
PM_{10} and $PM_{2.5}$	Chronic exposure contributes to the risk of cardiovascular and respiratory diseases, as well as lung cancer. $PM_{2.5}$ penetrates deeply into the lungs and could lead to chronic obstructive pulmonary diseases (COPD) and possibly cancer. Chemical substances may adhere to or be incorporated into these particulates.
SO_2	Chronic exposure affects the respiratory system and the functions of the lungs and causes irritation of the eyes. Inflammation of the respiratory tract causes coughing, mucus secretion, aggravation of asthma and chronic bronchitis and makes people more prone to infections of the respiratory tract. Hospital admissions for cardiac disease and mortality increase on days with higher SO_2 levels.
NO_2	Chronic exposure leads to reduced lung function and increased bronchitis in asthmatic children in association with long-term exposure.
O_3	Chronic exposure can cause breathing problems, trigger asthma, reduce lung function, and cause lung diseases.
CO	Chronic exposure affects the brain, the cardiovascular system, namely, the lungs at high concentration levels, exercising skeletal muscle and the developing fetus.
VOC	Chronic exposure can lead to intoxication.
Pb	Chronic exposure can lead to anemia, malaise, and damage to the nervous system. Children are particularly vulnerable to the neurotoxic effects of lead. Relatively low levels of exposure can reduce their IQ scores, cause learning disabilities, poor school performance, and violent behavior.
Noise	Noise exposure causes myocardial infarction, angina pectoris, hypertension and sleep disturbance.

Source: METAP 2009; WHO website, www.who.int

1.2 Efforts of the Government of Egypt to Improve Air Quality

The government of the Arab Republic of Egypt is fully aware of these issues and has had some success in investing in infrastructure that would lead to reducing environmental impacts from air pollution. Overpass bridges, highways, and ring roads have been constructed around the city. Eight new satellites towns were established to deconcentrate Cairo's population and to develop new economic growth poles. Two Greater Cairo underground metro lines are currently in operation, and the third line is under construction. There has been a widespread introduction of natural gas in the power, industrial, housing, and transport sectors. Natural gas utilization reached 99 percent of total fuel for all power plants connected to the gas grid. Furthermore, most of the housing sector in Cairo and Alexandria relies on natural gas. Private cars and taxis have been encouraged to switch to natural gas through successful incentive schemes. Additionally, cars have only access to lead-free gasoline. The first vehicle emission testing (VET), tune-up, and certification systems aiming at the reduction of pollutants and improvement in fuel efficiency are operational in the Governorates of Qalyoubia and Giza.

The government has also enabled an incentive mechanism for industrial firms in terms of a combination of grants and loans through the Second Egypt Pollution Abatement Project (EPAP II), cofinanced by the Agence Française de Développement (AFD), the European Investment Bank (EIB), the Japan International Cooperation Agency (JICA), the World Bank, and the KfW-financed Private Public Sector Industry Project to achieve environmental compliance with the environmental law. There has also been progress in adopting legal and institutional measures for improving air quality. The environmental protection Law #4 of 1994 was amended (by Law #9 of 2009) and prohibits waste burning by imposing heavy fines on offenders. The Ministry of State for Environmental Affairs (MSEA) has established continuous emission monitors in the cement industry that provide 24-hour monitoring of the main stacks. Also the Central Inspection Department (CID) of the Egyptian Environmental Affairs Agency (EEAA) and its regional offices are carrying out inspection monitoring, while placing a priority on companies with major sources of emissions, frequent reports of noncompliance, and public complaints. Noncompliant companies are fined and are referred to the EEAA legal department to determine the necessary follow up actions.

In spite of these accomplishments, uncoordinated policies may have, in fact, accentuated the increase in pollution rather than reducing it. Rice cultivation in the Upper and Middle Delta was allowed to expand to the contiguous governorates around Cairo. This has resulted in the increase in air pollution because of the burning of rice straws during the period of temperature inversion, leading to the Black Cloud phenomenon that has occurred since 1999 on October and November. The government's inability to cope with the poor traffic management and undercapacity of the public transport system has allowed the private sector to use old and inefficient minibuses mostly with diesel engines to ensure in a chaotic manner the displacement of the low-income population. It also allowed the importation of three-stroke engines (tok tok manufactured in India) with no emission standards to facilitate the displacement in peri-urban areas, contributing to air pollution. The middle class has also taken advantage of subsidized fuel and easy access to bank loans to purchase one or more private vehicles per family, contributing to traffic congestion and second and third road parking, which has resulted in blocking streets. Furthermore, cars and trucks are either imported or assembled with no due regard to emission standards (such as Euro 3 and Euro 4). These standards are based on grams of pollutants (PM_{10}, SO_x, NO_x, CO, VOC) per kilometer travelled, and they reflect both efficiency and abatement equipment. All in all, Cairo lives in a traffic jam all day long and part of the night.

Direct or indirect environmental policies are mainly sector-specific and independent of one another. Large infrastructure investments and patch up measures to control air pollution were made in the absence of "softer domains" of establishing an air pollution control strategy, a clear institutional framework, an analytical capacity (cost/benefit analysis, prospective, strategic environmental studies), and public participation in the formulation, implementation and monitoring of sector policies. This progress indeed has two speeds and shows the distance still left to reach the objective of improving air quality management in Greater Cairo. Thus, the policy and institutional framework will need to adjust to meet the demand of Cairenes for cleaner air in a competitive economy that creates employment and where the private sector could play a major role.

1.3 **Purpose of the Study**

The Minister of State for Environmental Affairs was given the responsibility to take the lead role in developing an air quality management strategy in his capacity as chairman of the National Committee on Sustainable Development, established in 2006 and composed of sector ministries, local governments, and representatives from the private and public sectors and NGOs.

In view of two decades of strong partnership between the World Bank and the MSEA in the environment field, the government of Egypt has requested the assistance of the World Bank in defining the elements of an air quality improvement strategy for Greater Cairo Metropolitan Area (GCMA). This report presents the main findings of this work.

1.4 **The World Bank as a Partner in Environmental Management in Egypt**

The World Bank has been an active partner in the development of environment management in Egypt. It assisted the government in developing the first national environment action plan in the Middle East and North Africa in 1992, the 2002 study of quantitative damage, the 2002 national strategy study on Clean Development Mechanism, and the 2004 Energy Environmental Review (EER). In 2005, the Bank also published a country environmental analysis (CEA) of Egypt that recognized the degradation of air quality in Greater Cairo and in the metropolitan and secondary cities as one of the most serious environmental issues.

As a result, the Bank financed the first phase of EPAP in 1996 (for US$35 million) and the second phase in 2006 (US$20 million World Bank financing, plus US$140 million from JICA, AFD, and EIB) to establish and scale up banking sector market-based mechanisms for the reduction of industrial pollution. The World Bank has also been involved in other sectors in ways that would lead to the improvement of air quality, such as the Natural Gas Connections Project (US$75 million). Two studies were conducted by the World Bank in 2006 and 2010. These are, respectively, the Urban Transport Strategy for Cairo and the Cairo Congestion Study. These studies include a short- and medium-term priority program, which depends on institutional strengthening, development of public transport system, traffic management and enforcement, toll road facilities, and sustainable funding. The most recent World Bank–funded study suggests that the total cost of traffic congestion for the 11 main corridors in Greater Cairo ranges between LE 13.1 billion and LE 14.2 billion per year, of which excess fuel costs range between LE 4.7 billion and LE 5.3 billion per year, with 45 percent accruing to users and 55 percent being subsidized by the government; whereas emission costs range between LE 174 million and LE 195 million. Still, a political commitment to tackle short- to long-term traffic management and improve mobility appears to be missing in Cairo, leading to increased traffic congestion, incremental pollutant and carbon emissions, and loss of opportunities. The World Bank has also partnered with the Egyptian Ministry of Finance and with EEAA to develop a Clean Development Mechanism (CDM) Program of Activities related to emission reduction from scrapping old taxis.

With these investments and the political commitment of the government, the World Bank recognized that it was timely to participate with the government in a more comprehensive approach for air quality improvement. The government requested that the World Bank go beyond industrial pollution control and assist in the development of the elements of a comprehensive strategy on air quality improvement for

Greater Cairo that will include mobile and area sources of pollution and provide the directions and priorities for its policy and institutional reforms. In view of the World Bank's forthcoming Environment Strategy focused on Greening Development, and placing heavy emphasis on mainstreaming environment matters across sectors, such a study will not only be crucial for the government, but would also enable the Bank to engage the government in policy and institutional reform using its own priorities. This would lead to air quality improvement through the right combination of lending and knowledge.

1.5 Structure of the Report

In order to determine the elements of air pollution management strategy, the following tasks (as presented in Figure 1.1) were carried out as part of this work and are presented in this report:

(1). An assessment of the existing inventory of pollutants, as well as the policy, institutional, and legal framework. Emphasis is on the existing national air quality guidelines as they are intended to protect human health and prevent environmental damage.

(2). An inventory of pollutants that identifies the relative contributions of different sources of each type of pollutant (PM_{10}, $PM_{2.5}$, SO_x and NO_x) and their concentrations over time. This inventory, which is an accounting of all air pollution sources within a geographical area, their sources, and locations, as well as the concentration related to each source, was based on three interlinked activities:

   a. A source attribution study (SAS) to assess the distribution of ambient concentrations of priority pollutants and attribute them to specific source categories at the location of the monitoring stations.
   b. A pollution load assessment (PLA) to estimate the pollution loads at the plant level and over GCMA based on emission factors
   c. Modeling to assess the spatial distributions of major pollutants over time and to simulate the dispersion of these pollutants in 2010, 2015, and 2020

(3). An assessment the cost of environmental degradation due to the different pollutants and their effects on the welfare and the economy.

(4). An evaluation of the necessary policy interventions based on the cost and benefits of these policies, as well as the identification of the elements of the strategy.

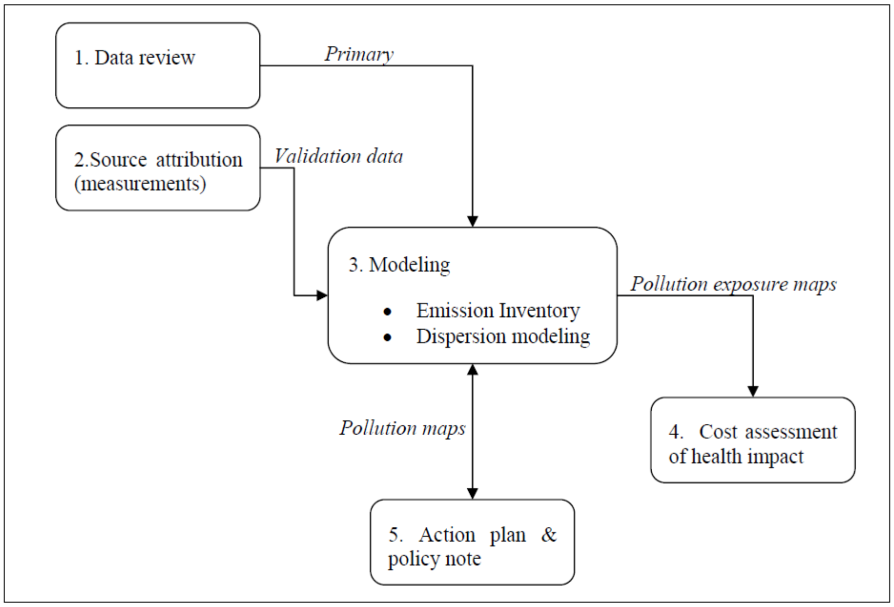


Figure 1.1. Tasks included in this work

The report consists of six chapters, plus annexes. The second chapter provides the status of air pollution and the main challenges to improve air quality in the GCMA. The chapter concludes with a comparison of air quality in Cairo and that in other megacities in the region and the world. Chapter 3 describes the methodology and findings of the SAS conducted in the summer and fall of 2010 to assess the spatial distributions of ambient concentrations of PM_{10}, $PM_{2.5}$ and to attribute them to specific source categories. Chapter 4 provides an assessment of the pollution loads of point source and nonpoint sources of pollution, as well as the results of the air dispersion models for 2010, 2015 and 2020. Chapter 5 provides an assessment of the economic cost of the degradation in air quality in the GCMA, as well as the economic benefit deriving from the air quality management program. Chapter 6 presents experiences in other countries and how the air pollution problem was addressed in megacities there. Chapter 7 concludes, summarizes the main findings, and outlines the proposed policy framework for improving air quality in the GCMA. Annex 1 presents a summary of the emission inventory conducted as a part of the dispersion modeling activities in this study. Annex 2 presents a summary of the economic valuation methodology used. Annex 3 summarizes, in a tabular format, the successful experience of megacities in combating air pollution, which was presented in Chapter 6. Finally, annex 4 presents the details of the cost benefit analysis for interventions. A list of references is at the end of the report.

2 Air Quality in Greater Cairo

2.1 Geographical Scope: The GCMA

The GCMA resident population is estimated at 20.2 million inhabitants in 2009 by applying a 2.27 percent annual growth rate based on the 2006 census. In 2009, Cairo was ranked eighth among the world's top urban agglomeration centers, with 10 million inhabitants or more (UN 2009). The GCMA includes the three contiguous governorates of Cairo, Giza, and Qaliyobeya (Figure 2.1). The GCMA's most vulnerable population is children under 15 year of age, which represent 29.3 percent of the population (CAPMAS 2006), among whom the scientific literature shows the exacerbation of asthma symptoms and allergies irrespective of gender (Sheikh et al. 2010).

The GCMA is Egypt's largest urban and industrial agglomeration. South of Central Cairo are the cities of Helwan and Tebbin, which include the Tebbin power plant, the Hewan Fertilizer company, the largest heavy industries of iron and steel, coke, and four cement plants. North of Central Cairo is the city of Shobra El Kheima in the Qaliyobeya Governorate, which includes the Shobra el Kheima power plants and the fertilizer plants in Abou Zaabal, as well as a multitude of small and medium enterprises. Outside the residential and commercial belts of the GCMA lie the four largest dump sites of El Wafaa wel Amal, Elsalam, Shabramant, and Abou zaabal, with an estimated 9.5 million tons a year of municipal solid waste (GIZ 2010).

The GCMA also has the largest fleet of vehicles, including 1.4 million private passenger cars, 120,000 taxis, and 234,0000 trucks and lorries (ECORYS and SETS 2010). It also has the largest road network—10,100 kilometers—and 64 kilometers of underground metro lines linking the three governorates; two lines are operational, and the third line is under construction. In 2007, it was estimated that public transport carried 14.4 million daily trips, that this would increase in 2102 to 16.0 million trips a day, and that the metro carries an average of 2 million passengers per day (ECORYS and SETS 2010).

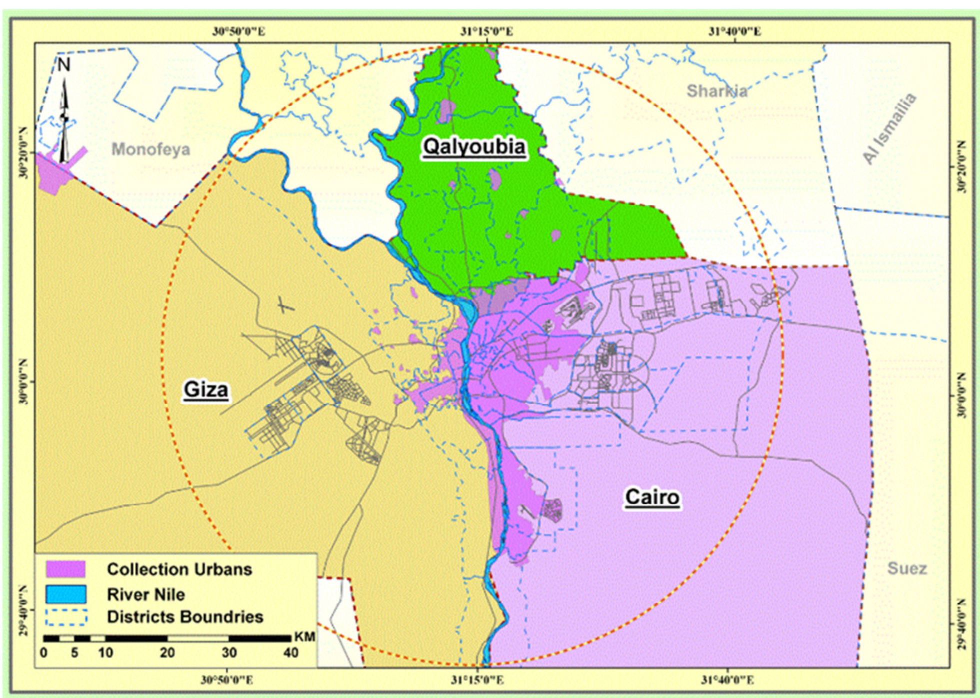


Figure 2.1. GCMA boundaries

2.2 Ambient Air Quality Standards

The most important priority pollutants regulated by the government are as follows:

- Total suspended particulates: TSP has now been revoked by the World Health Organization (WHO) due to the adoption of more robust compounds, such as particulate matter regardless of size (PM_x)
- Particulate matter: PM_{10}, $PM_{2.5}$ (suspended particulate matter with a diameter of less than 10 and 2.5 micrometers)
- Nitrogen oxides: NO_x, NO_2
- Sulphur oxide: SO_2
- Ozone: O_3 as more recent evidence underscores the need to focus on shorter exposure to higher levels rather than longer exposure to lower levels
- Carbon: CO, CO_2
- Volatile organic compounds: VOC
- Lead: Pb

Egypt air pollution standards exceed WHO thresholds (Table 2.1).

Table 2.1. Ambient air quality standards in Egypt and according to WHO

Standard / Criteria Pollutant	Criteria Pollutant Standards ($\mu g/m^3$ yearly mean unless specified)	
	Egypt	**WHO**
Total Suspended Particulates	90	Revoked
PM_{10}	70	20
$PM_{2.5}$	NA	10
NO_2	40	40
SO_2	60	20(24 h)
O_3	(8 hours) 120	Revoked: yearly 150 (8 hours) 100
CO	(8 hours) 10,000	(8 hours) 10,000
Black Smoke	60	Revoked
Pb industrial zones	(6 months) 1.5	0.5
Pb urban zones	0.5	

Source: Egypt's Environment Protection Law No. 4 of 1994 amended by Premiership Decree No. 1741 of 2005 and amended by Law No. 9 of 2009 ; WHO website: www.who.int; and USEPA website: www.epa.gov; .WHO 2005 standard for SO_2 is 20 $\mu g/m^3$ per 24 hours. The annual 50 $\mu g/m^3$ was considered by WHO in 2000.

2.3 Criteria Pollutant Monitoring in the GCMA

The MSEA set up the ambient Air Quality Monitoring Network (AQMN) in 1997 across the country. The network has 87 air monitoring stations (passive samplers, sequential samplers, and monitors providing data online or after laboratory analysis) at the present time and is to be extended to 120, of which 48 are in Greater Cairo urban, industrial, and commercial areas: 20 sampling stations, in addition to 28 continuous monitoring stations.

Moreover, the MSEA started the Industrial Emission Monitoring Network (IEMN) in 2004 with telemetry network for monitoring the TSP of industrial facilities, notably 92 stacks belonging to 17 cement companies, which include the four cement factories in the GCMA and one fertilizer company all over the country, although fugitive gases are not monitored. The IEMN will be expanded in the future to include all major industrial facilities and increase the number of pollutants being monitored.

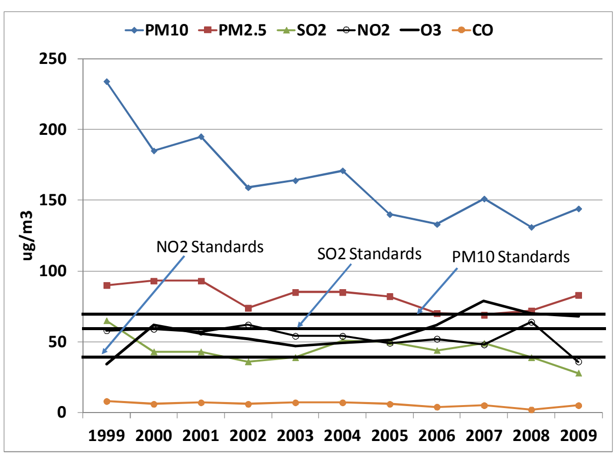
Based on the data provided by EEAA, most of the MSEA-monitored pollutants registered a drop between 1999 and 2009 (Table 2.2 and Figure 2.2), except for O_3, which doubled over the period (+100 percent). $PM_{2.5}$ registered a small reduction during the period (-2 percent), whereas PM_{10}, SO_2, NO_2, CO, and Pb were moderately reduced over the period (-5%, -3%, -3%, -8%, and -12 percent, respectively). Despite the net decrease of PM_{10} during the last decade in the concentrations of PM_{10}, such a high concentration is still twice the Egyptian standards and approximately seven times the WHO guidelines. The SO_x and NO_x concentration is moderately above the WHO guidelines, while the annual ozone concentration cannot be compared to the international standard, which was revoked, and only a daily concentration is now provided. Given that the daily concentration of pollutants is usually higher than the annual concentration, it is not unreasonable to assume that the daily ozone concentration is expected to be higher than 100 $\mu g/m^3$.

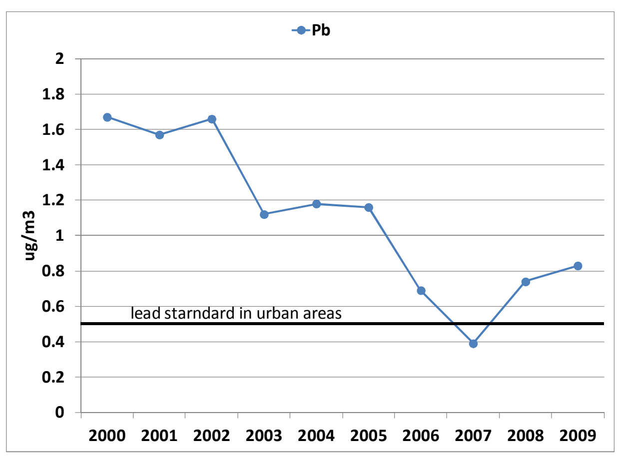
It is, however, interesting to note that the annual concentration of lead decreased by fourfold, to reach 0.39 $\mu g/m^3$ in 2007, which is below national and international standards. This was due to the successful policy of the government to eliminate lead in gasoline and to relocate small and medium enterprises (SMEs) for lead production and decontaminating their sites in Shoubra El Kheima. Since 2007, lead concentration has increased by twofold (but is still within the range of WHO guidelines). The increase could be due to the resumption of small-scale lead smelters and should be investigated (see section 2.4 below).

Table 2.2. MSEA yearly mean pollution in GCMA, $\mu g/m^3$, 1999-2009

Poll. \ Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Egypt Annual mean standard	Growth 2009/ 1999
	($\mu g/m^3$)												±%
PM_{10}	234	185	195	159	164	171	140	133	151	131	144	**70**	-5%
$PM_{2.5}$	90	93	93	74	85	85	82	70	69	72	83	NA	-2%
SO_2	65	43	43	36	39	51	50	44	49	39	28	**60**	-3%
NO_2	58	59	57	62	54	54	49	52	48	64	36	**40**	-3%
O_3	34	62	56	52	47	49	51	62	79	70	68		5%
CO	8	6	7	6	7	7	6	4	5	2	5		-8%
Pb	-	1.67	1.57	1.66	1.12	1.18	1.16	0.69	0.39	0.74	0.83	**0.50**	-12%

Source: MSEA-EEAA (2010).
Note: Period growth is obtained by averaging the logarithms of the year-to-year growth ratios.





Source: MSEA-EEAA (2010)

Figure 2.2. MSEA yearly mean pollution in GCMA, $\mu g/m^3$, 1999–2009

2.4 **Major sources of air pollution in the GCMA**

The major sources of air pollution are attributed to transport, energy, waste burning, and industry.

2.4.1 Industrial Pollution

Greater Cairo includes 750 smelters, 530 brick factories, 1,200 metallurgical factories, and 12,500 industrial facilities (Abou ElSeoud 2010) of medium and small scale. Large-scale industries are iron and steel, coke, cement, fertilizers, and aluminum. Some 240 facilities still emit small amounts of lead. Lead in dust remains a concern, especially during the windy season, when the correlation between the ambient lead measures and lead concentrations in street dust is high (USAID 2004). It is not clear whether these sources of lead could validate the slight resurgence of lead in the air in 2009, according to one source.

Industrial pollution control was initiated soon after the enactment of the Environment Protection Law No 4 of 1994, which provided a two-year grace period for industries to comply with national standards. This, however, did not occur. The government therefore resorted to a different policy of providing incentives to the industry to comply and requested international donors to provide such incentives. In 1995–96, the World Bank and the KfW separately initiated three complementary programs. EPAP I financed by IDA and IBRD, the pollution control project financed by the EIB, and the two projects in private and public industry financed by the KfW. All these projects provided a mixture of loans at preferential rate and 20–25 percent grants through commercial banks. These projects were continued in a second phase through EPAP II targeting hot spots in Greater Cairo and Alexandria. Various sectors have benefitted from these programs, including the cement, fertilizers, petrochemicals, pulp and paper, and brick manufacturing sectors.

In parallel, the United States Agency for International Development (USAID) implemented, during 1997–2004, the Cairo Air Improvement Project (CAIP), which targeted the industrial sources of lead, namely, factories smelting lead scrap. Lead smelters became the top source of this toxic metal following the government’s aggressive move to eliminate lead from gasoline beginning in 1997. By 2004, lead smelters had been dismantled, upgraded to become environmentally sound, and relocated to the northern Delta. The large-scale Awadallah Secondary Lead Smelter Site situated in Shobra El-Kheima was also cleaned up (Safar et al. 2009).

2.4.2 Transport

Greater Cairo has the largest vehicle fleet in the country, composed of 1.4 million private passenger cars, 120,000 taxis, 234,0000 trucks, and approximately 200,000 motorbikes. Almost all buses and trucks use diesel fuel running on old-generation diesel engines without catalytic converters or diesel particle filters, and about 90,000 taxis in Egypt are over 20 years old. About two-thirds of all motorized trips are made by public transport (mostly taxis and minibuses).

A number of policy measures have been adopted by the government with the help of development partners, including car inspections, the use of alternative cleaner fuels (compressed natural gas [CNG], LPG, and biodiesel), and promotion of the use of newer cars, buses, and trucks. The government launched the inspection program in 2002. As of June 1, 2003, owners of 500,000 vehicles in Qalyoubieh and Cairo were required to obtain emissions inspection certificates from one of 19 traffic departments before being able to register their vehicles.

The government has also introduced a smart card system that allows drivers to convert their car for free to use CNG as it costs about half as much as gasoline; the difference would be used to pay for the conversion. It is estimated that, in 2010, more than 133,700 CNG-powered vehicles were on the road.[2]

The National Taxi Replacement Scheme (NTRS) was designed by the government in 2008 to assist taxi-owners in complying with the 2008 Traffic Law, which stipulates that mass transport vehicles (including taxis) over 20 years old cannot be operated. The scheme, established as a public-private partnership involving financing institutions, five car manufacturers that supply hybrid cars (gasoline and CNG), scrapping companies, and vehicle administration bodies, supports taxi-owners through the provision of finance and facilitation of the replacement of the old taxis with new ones. The first government-financed phase, which was implemented from April 2009 to March 2010 through local banks mobilized by the government, succeeded in replacing over 21,272 taxis. A second phase aims at assisting taxi-owners in replacing a further 21,250 taxis throughout the country from March 2011 to December 2015. Each taxi-owner is granted LE 5,000 (US$906) from a special fund under the Ministry of Finance to be used as down-payment for the loan received from the NSB to replace their old cabs.

Cairo has a comparably low provision of road space per capita, an insufficient mass transit system, an inadequately developed secondary road network, and ineffective traffic management. Regarding the latter, the increasing number of private cars has led the government to adapt the Cairo infrastructure to the new mode of transport: flyovers, new bridges, new main thoroughfares, and a ring road have been built. This, in turn, has enhanced the rapid physical expansion of the city, since more distant areas could now easily be reached. With the establishment of eight satellite cities around Cairo, a completely new pattern of urbanization has emerged that is almost exclusively based on the use of private cars, taxis, and microbuses, so that the travel speed had fallen to around 12 kilometers an hour in 2005. At present, there is no intracity public transportation other than an overreliance on polluting minibuses. Paradoxically, instead of relieving the deconcentrating Cairo population, the new satellite cities have led to a high level of commuting to and from the city, thus increasing congestion (Amin 2000).

2.4.3 Energy

Greater Cairo includes seven thermal power stations with an installed capacity of 4,585 MW that generate 25,360 GWH.[3] Four stations (Shoubra El Kheima, Cairo West, Cairo West extension, and South Cairo) are fuelled with natural gas and heavy fuel oil; two stations (Cairo North and Wadi Hof) are powered with natural gas and light fuel oil; and one station (Cairo South II) is powered with natural gas. Egyptian crude has a sulphur content of 1.6 percent, which is a high content relative to most other crudes; however, Egyptian gas is considered sweet, with low sulfur content and a low level of contaminants. It is estimated that 47.8 percent of the energy generated is used in residential areas, followed by 20.4 percent for industry, and 18.3 percent of government and public sector utilities. Greater Cairo has one refinery, the Cairo oil refinery in Mostorod, with a capacity of 2 million tons a year. The refinery is planning to add a second-stage oil refinery that will produce over 4 million tons of refined products, including 2 million tons of Euro 5 diesel, which is the cleanest fuel type in the world.[4]

The government expects the demand for energy to increase between 6 and 7 percent in the next 10 years, which is about the same increase as in the previous decade. Thus, the government objective is to meet 20 percent of total energy generated from renewable energy sources by the year 2020 (8 percent from hydro and 12 percent from wind). This can be met by increasing wind energy capacity from 450 MW to 7,200 MW, providing about 31 billion KwH, and would save about 7 million tons of oil equivalent and reduce GHG by 17 million tons of CO_2. Solar energy will also be used in the Kureimat solar thermal power

[2] Source: Ministry of Petroleum; Gas Sector.
[3] www.moee.gov.eg
[4] http://abarrelfull.wikidot.com/cairo-refinery-project

station with a total installed capacity of 140 MW, of which 20 MW is the capacity of the solar component and hybrid solar combined cycle technology. The expected total energy generated is 852 GWH a year. Currently, hydro and wind generate 13.7 percent of the total installed capacity, with hydro accounting for 11.9 percent and wind for 1.8 percent.

Energy subsidies reached LE 62 billion (US$10.1 billion) a year in 2008/09 or around 6 percent of gross domestic product (GDP) and is encouraging overconsumption and social inequity and leads to a huge distortion in consumer choice and indirectly to high environmental damage. Such extensive subsidies not only lowers efficiency by distorting the perceived value of factor inputs, but they also obscure important aspects of government finance. Many fuels and energy products are sold at below the opportunity cost. Imported gas oil and LPG are sold to customers at below the purchase cost and clearly represent a burden to state finances, but many other products (e.g. residential electricity and mazout) are sold at prices that include an implicit subsidy to customers. The residential sector benefits the most from electricity subsidies, and the highest income class receives more than 2.5 times the subsidies provided to the poor. The richest segment of the population receives 93 percent of the gasoline subsidies as they own one or more personal vehicles. Also, 65 percent of the subsidies on natural gas are provided to rich and upper-middle-class neighborhoods. The only exception is kerosene, from which the poor are benefitting (World Bank 2010a). In 2010, the government increased fuel prices for the industrial sector and was considering removal of fossil fuel subsidies in accordance with a clear schedule. This was put on hold as a result of the January 25, 2011 revolution.

2.4.4 Waste

Greater Cairo generates 9.5 million tons per year of municipal solid waste (MSW), which represents 47 percent of the municipal waste generated in Egypt. Municipal collection coverage ranges between 40 and 90 percent in urban areas. A large amount of this waste (about 83 percent) ends up in four large open dumps, and the remainder accumulates in streets or on illegal dumping sites. Five percent is being disposed in sanitary landfills. Waste management is both inefficient and inadequate, and self-ignition and open burning are regular patterns on these sites.

A solid waste management (SWM) strategy for Greater Cairo has recently been formulated. This strategy is based on improving the MSW collection; establishing five new sanitary landfills with composting plants and 20 transfer stations; as well as improving the monitoring, inspection, and control of the MSW system (see below in section 2.5.1). A new Presidential Decree (86/2010) was issued in 2010 to regulate the closure of existing dump sites and landfills in Greater Cairo, the rehabilitation of sites, and the allocation of five new sites for sorting, recycling, and final disposal of municipal solid waste outside the residential and commercial belt. Yet, Egypt lacks both the legal framework for SWM and an institutional framework to be able to address in a comprehensive manner the policies and the technical and financial aspects of municipal SWM.

The government is also subsidizing the cost of the collection and disposal of MSW. Law 10/2005 was issued to create a solid waste collection fee on electricity bills, thereby establishing a partial cost recovery, ranging between 60 and 65 percent of the total cost, which is now estimated at LE 205–LE 215 per ton, of which LE 110–LE 120 per ton for collection, street sweeping, and transportation and LE 95 per ton for treatment and disposal. Hence, cost recovery will dwindle unless new cost recovery mechanisms are introduced (GIZ 2010).

In addition to MSW, the open burning of agricultural waste and especially rice straw is occurring, though many efforts have been made by the Ministry of Agriculture and MSEA to contain it, especially during the temperature inversion period of October–December known as the Black Cloud phenomenon. The five contiguous governorates to the north (Sharkiya, Dakhliya, Gharbiya, Qalyoubiya, and Kafr ElSheikh) generate an estimated 2.78 million–2.97 million tons of crop residue that are not utilized. The largest amount of unused crop residue is rice straw by a wide margin (METAP 2006). However, significant quantities of cotton stalks and small quantities of other residues may also remain unused. The inadequate management in Egypt of residues from these crops has been identified as a source of significant environmental cost. According to an estimate of the Egypt Energy-Environment review, the mean local damage cost (that is, not including the impacts of global warming) due to air pollution from the energy and agricultural residues sectors was LE 6.5 billion per year in 1999/2000. This is approximately 45 percent of the damage costs from all environmental degradation. It represents a real cost to the Egyptian economy of approximately 1.5 percent of GDP, corresponding to LE 100 per person per year.

Egypt does not have a comprehensive strategy for agricultural waste and rice straw. However, the MSEA and the Ministry of Agriculture have embarked on a series of investment projects without due consideration of their cost and benefits. The government is seeking a partnership with the private sector to recycle agriculture waste and stop waste burning. A pilot study is ongoing in four governorates to the north (Sharkiya, Dakhliya, Gharbiya, and Qalyoubiya) with promising results as private operators are collecting up to 500,000 tons of straw per year and making compost that is being certified by the Ministry of Agriculture; 185 sites for agriculture waste collection are ongoing in the Delta governorates; 30 recycling centers for compost and fodder for cattle are ongoing; farmers are being encouraged to use organic fertilizer produced with agricultural waste; two biogas units are being set up in villages; cement factories are beeing encouraged to use agricultural waste in their production processes (Abou ElSeoud 2010).

2.5 The Policies and the Institutional and Legal Framework on Air Quality

Emission and pollutant levels are one indicator of air quality degradation. Other factors that have contributed to air quality degradation are related to (a) the lack of a comprehensive policy for reducing air pollution and (b) the uncoordinated functions and responsibilities of ministries and institutions involved in air pollution control.

2.5.1 *Policies*

There is no unified strategy to reduce air pollution in Egypt. Government policy in this area is limited, and activities related to air pollution planning management and control are carried out in a piecemeal fashion through the adoption of ad hoc projects and solutions rather than the proper combination of policy measures that would yield economic and health benefits. There are, however, sector policies in industry, energy, transport, and the environment that address the air pollution issues. These are summarized below.

The Supreme Energy Council (SEC), which consists of major sectoral ministries and is chaired by the prime minister, is the body responsible for formulating energy policy. The SEC was established in the early 1970s and stopped meeting in 1982. As a result of the recent government decision to consider the use of nuclear energy, SEC meetings were resumed in 2007, and the chairmanship was delegated to the MSEA. SEC reformulated its energy policy to (a) enhance natural gas utilization, (b) adjust energy prices and remove subsidies, (c) apply energy conservation and efficient energy measures, and (d) promote renewable energy.

The policy of the Ministry of Petroleum consists of (a) expanding the use of natural gas in homes and in commercial and industrial establishments, (b) establishing the infrastructure for and expanding the use of compressed natural gas (CNG) in cars and buses; (c) eliminating lead in gasoline and eliminating the use of tetra ethyl lead completely by the year 2014; and (d) improving the specification of petroleum products and reducing the sulfur content to reach international standards.

Industrial policy in Egypt aims at (a) building domestic capabilities, (b) helping Egyptian companies access global markets, and (c) enhancing the presence of a set of social values conducive to the desired level of development, while maximizing the positive social and environmental impact of industrialization (IMC 2009). The third approach has been followed by providing a mandate to the General Industrial Development Authority (GIDA) to coordinate among the entities involved to ensure that environmental regulations are being complied with. As a licensing authority, GIDA does not provide a permit until the investor and operator obtain the MSEA approval of the Environment Impact Assessment (EIA).

The Electricity and Energy Strategy calls, inter alia, for the optimization of the use of the available energy sources and the minimization of environmental pollution, the expansion of the utilization of new and renewable energy resources, improvements in energy efficiency, and the application of energy conservation measures.[5] A draft Unified Electricity Law has been prepared that is aimed at gradually removing the burden of the state by encouraging the private sector to invest in electricity generation and infrastructure and encouraging investment in renewable energy and energy efficiency that does not cover only the electricity sector, but all forms of energy, including fossil fuels. The transport policy can be summarized as follows: (a) continuous development of major road infrastructure (bridges over the Nile, urban motorway viaducts, underpasses, ring roads, and radial motorways), (b) the expansion of the two operational metro lines into four operational metro lines, (c) liberalization of the public transport network so as to lead to a considerable expansion in private microbus lines (which are mostly old and polluting), (d) the control and limitation of fare increases on public transport networks to make the networks more accessible to the poor; (e) partially controlling exhaust emissions from vehicles; (f) encouraging the conversion of public vehicles (especially taxis and microbuses) and into CNG, and (g) the total removal of lead in gasoline and the reduction of the sulfur content of diesel fuel by 2012.

The Ministry of Housing and New Communities does not have a policy for reducing air pollution, although the construction sector, which is dominated by small and medium enterprises, is one of the major sources of air and noise pollution (see chapter 3), as well as high energy consumption, solid waste generation, global greenhouse, and resource depletion (ENCC 2010). The Unified Building Law 119/2008 and the related Executive Memorandum that was issued in April 2009 do not include any regulations aimed at preserving the environment.

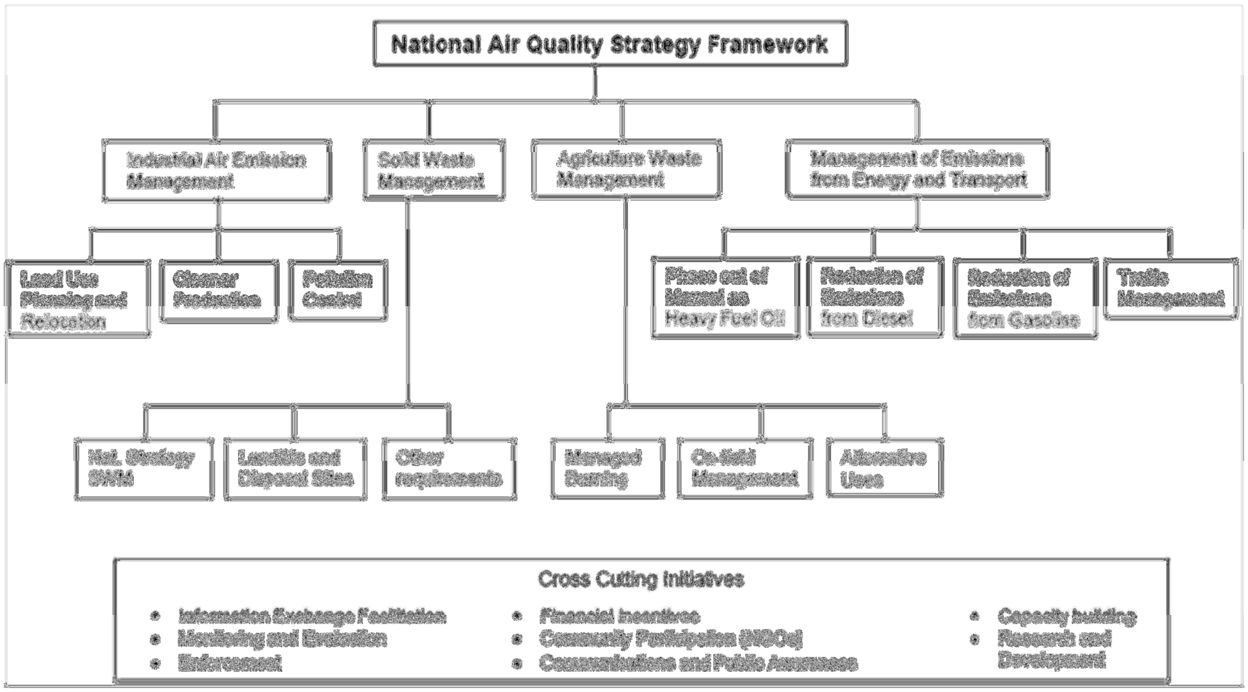
The Ministry of Civil Aviation has an environmental policy for its Cairo Airport Company. The policy involves improving environmental performance, enhancing the role of environmental departments, instituting employee training, providing appropriate education programs to all sectors involved in the airport to raise environmental performance, and applying local laws and international environmental standards for airports. The company established an integrated environmental monitoring network to measure ambient air pollution at Cairo International Airport, as well as at Sharm El Sheikh and Hurghada international airports. The environmental working group of the company and the airports carry out an annual inventory of emission sources at each airport through realistic measurements, including the most important sources of pollutants, and provide technical expertise and advisory services to companies operating at the airport.

The Ministry of Sate for Environmental Affairs was given the responsibility of preparing a strategy framework for air quality, cleaner production, and municipal waste, but this was not officially approved by the government. However, elements of the framework were implemented by the MSEA, in collaboration with various governorates.

In 2004, the national air quality strategy (NAQS) framework was formulated by the EEAA, in collaboration with USAID, to reduce significantly the levels of air pollution and the associated socioeconomic burdens suffered in many urban areas in Egypt. The framework covered four policy areas, as follows: (a) reduced emissions from industrial activities through land-use planning, cleaner production, and pollution control and abatement; (b) reduced emissions from the combustion of heavy oils, diesel, and

[5] www.moee.gov.eg

gasoline fuels; (c) improved collection and disposal and reduced burning of solid waste by strengthening and expanding the use of sanitary landfills and controlled disposal sites and the reuse and recovery of solid waste; and (d) reduced exposure to pollution from the burning of agricultural waste through managed burning and on- and off-field management. The framework could not be fully implemented in view of the lack of a necessary institutional structure to implement multisectoral policies and strategies, the lack of a champion, weak coordination among the sectoral ministries, the lack of finance, and the lack of adequate analytical tools for strategic planning to improve air quality management. However, investments were made to control industrial pollution, reduce the open burning of agricultural waste, and develop a strategy for MSW disposal.



Source: Aboul ElSeoud (2010).

Figure 2.3. National air quality strategy framework

The MSEA also prepared, in 2004, a draft strategy and action plan for cleaner production, of which the government supports the basic elements (EEAA 2004). The strategy calls for improving the average performance in the industry, increasing the use of cleaner production and the share of clean products in industrial establishments, and providing knowledge and technical capacities. These objectives have been partially addressed and implemented through the modification of the EIA guidelines to include cleaner production practices, access to clean development mechanisms, the provision of a pollution abatement fund through EPAP I and II, and the use of the Environment Protection Fund to promote cleaner production to the extent feasible rather than rely on end-of-pipe treatment.

In 2010, the MSEA was given the responsibility for two sanitary landfills that are presently under construction. Furthermore, the MSEA has taken a series of measures to reduce the open burning of rice straw. These include a reduction in the areas of rice cultivation in the contiguous governorates of Cairo, more inspection campaigns against violators, and investments in the compressing of rice straw and in recycling to produce fertilizer and feed for live stock. These measures have decreased the pollution loads of PM_{10} from 40,000 tons to 32,000 tons and of SO_2 from 274 tons to 219 tons. Despite these efforts, there is no concerted policy to reduce the pollution loads from municipal and agricultural waste in accordance with predetermined targets and in a cost-effective manner.

2.5.2 Institutional Framework

Relevant departments in sectoral ministries are also involved, whether directly or indirectly, in the management of air pollution. These include the following:

- Ministry of State for Environmental Affairs, which includes the Central Department for Air Quality and Noise Abatement, the Central Department for Monitoring and Enforcement, and the Industrial Unit
- The Ministry of Petroleum, through the General Department for Environmental Affairs, which reviews environmental impact assessment reports and oversees the implementation of pollution controls in the companies belonging to the ministry
- The Ministry of Trade and Industry, through the General Department for Environmental Protection
- The Ministry of Electricity and Energy, through the Environmental Studies Department
- The Ministry of Civil Aviation, through the General Department for Environmental Operations in the Cairo Airport Company, the Environmental Impact Assessment and Monitoring Department in the Egyptian Company for Airports, and the Department of Follow-up
- The Ministry of Transportation, through the Environmental Strategic Impact Assessment Unit for Transportation Projects
- The Ministry of Agriculture, through the Central Department for Afforestation and Environment
- The Ministry of Health and Population, through the Central Department for Environmental Affairs, the Center of Environmental Monitoring and Working Environment Studies, and the National Network for Air Pollution Monitoring
- The Ministry of Local Development, through the environmental units in each governorate that have responsibility for monitoring the status of pollution in the governorate

The major functions and responsibilities of these ministries are summarized in

Table 2.3. All these ministries have established an environmental unit or department and are involved in the formulation of policies and pollution management in their respective sectors. Only the ministries of health, electricity and energy, and civil aviation and the ministry of state for environmental affairs have an air quality monitoring network. The Ministry of Transport is the only ministry that has fewer environmental management actions, although transport is a major source of air pollution.

Table 2.3. Responsibilities of the various ministries in environmental management

Item	Ministry \ Subject	Policies	Decisions & Actions	Management	Monitoring Networks	Investments (last 5years)	Institutional Structure
1	Environment	√	√	√	√	√	√
2	Petroleum	√	√	√	-	√	√
3	Electricity & Energy	√	√	√	√	√	√
4	Trade & Industry	√	√	√	-	√	√
5	Agriculture	√	-	√	-	√	√
6	Transport	√	-	-	-	√	√
7	Civil Aviation	√	√	√	√	√	√
8	Health & Population	√	√	√	√	√	√
9	Local Development	√	√	√	-	√	√

Table 2.4 summarizes concrete actions undertaken and planned to be undertaken by each ministry that could contribute to reducing air pollution in Greater Cairo.

Table 2.4. Actions related to air quality taken or planned by ministries

Ministry	Activities
Environment	- Air quality monitoring - Climate change mitigation and adaptation - Enforcement and compliance of environment regulations - Industrial pollution abatement - Vehicle exhaust test and control
Petroleum	- Expansion in the use of natural gas - Expansion of unleaded fuel in 95 percent of Egypt - Improve specifications of fuel and reduce sulfur content
Electricity and Energy	- Increasing electricity generation from renewable resources (increase of 20 percent by 2020) - Energy efficiency (reduction of 20 percent by 2022) - Combined fuel usage (oil + G)
Trade and Industry	- Reallocation of pollution industries - Development of industrial zones - Increasing clean and green production
Agriculture	- Decrease in rice plantation area - Recycle and reuse of agricultural waste - Reuse of manure waste
Transportation	- Expansion of metro network - Enhancement of transportation facilities - Expansion of NG buses - Upgrading of railway and river transportation
Civil Aviation	- Air quality monitoring - Reducing waiting time for planes - Using NG instead of fuel in the airport

Health and Population	- Air quality monitoring network - Enhancement of health services - Epidemic diseases abatement
Local Development	- Contracting private companies for municipal waste - Development of slum areas to reduce slums - Urban development and improvement of services

2.5.3 Legal Framework

The main legal instrument pertaining to the environment is Law Number 4 of 1994, which promulgate dthe Environment Protection Law and the related Executive Regulation No 338/1995. The main parts of the law and regulation that are relevant to air pollution are the following:

- Article 34 of the law requires an environmental impact assessment (EIA) for appropriate activities; the establishments subject to the provision of the law are specified in annex 2 of the Executive Regulation; this includes industrial establishments, tourist facilities, energy companies, power generation, and infrastructure projects
- Articles 35 and 40 provide for quantitative upper limits for the maximum permissible concentrations of various emissions and prescribe emission limits for individual sources that are not to be exceeded by establishments subject to the law
- Article 40 also allows for the specification of chimney heights and other means of controlling emissions
- Article 37 requires the disposal of solid wastes in special sites and specifically prohibits burning of such wastes; it also includes concentration limits for vehicle exhausts

Article 34 of the Executive Regulation requires that the air quality in any area must conform to the permissible levels set out in annex 5 of the regulation and summarized in

- Table 2.5
- Article 37 of the Executive Regulation prohibits the use of machines, engines, or vehicles for which the exhaust emissions exceed specified limits; these limits are different for vehicles licensed before and after 1995; new vehicles would have tighter emissions limits than the existing stock
- Article 42 of the Executive Regulation specifies limits for the concentration of gaseous emissions from fuel-burning sources; the limits vary depending on whether the source is new or older; the limits have to be seen as upper bounds; this prohibits the use of mazout and other heavy oil products in residential areas and specifies that the percentage of sulfur in the fuel used in urban areas should not exceed 1.5 percent

There is also provision for controlling air pollution in civil Aviation Law No. 28 of 2010 regarding procedures for the protection of the environment, through compliance with the emissions determined in the law; otherwise fines will be imposed.

In 2009,the environment protection law was amended as Law 9 of 2009 and provided the following additional requirements:

- Article 17 states that all enterprises should include in the environment register the pollution loads of air emission and water discharge; in case information is incorrect, or noncompliant, the enterprise is given 60 days to take corrective measures; otherwise the enterprise will be closed without affecting the salary of the workers
- Article 37 (2) prohibits open burning and prohibits the placement, sorting, and treatment of wastes in areas other than those specified beyond residential, industrial, and agricultural areas and

waterways; in addition, a fine was introduced in 2009 on uncontrolled straw burning, ranging from LE 2,000 and LE 5,000, with mixed results so far

Table 2.5. Ambient air quality standards in Egypt and according to WHO

Standard / Criteria Pollutant		Criteria Pollutant Standards											
		Executive Regulations No 338/1995				Draft Executive Regulation for Law 9/2009				WHO Guidelines 2005			
		1h	8h	24h	1yr	1h	8h	24h	1yr	1h	8h	24h	1yr
TSP				230	90			230	125				
PM_{10}				150	70			150	100	-	-	50	20
$PM_{2.5}$		-	-	-	-			100	70	-		25	10
NO_2	Industrial	400		150		300		150	60	200	-	-	40
	Urban					300		150	80				
SO_2	Industrial	350		150	60	300		125	50	500 (10 min)	-	20	
	Urban					350		125	60				
O_3	Industrial		120	240		180	120			-	100	-	-
	Urban					180	120						
CO (mg/m^3)	Industrial	30	10			30	10	3	10	30	10		
	Urban					30	10	3					
SP (Black Smoke)				150	60			150	60				
Pb	Industrial		1.5						0.5				0.5
	Urban		0.5						1				

The air quality standards set forth in the executive regulations of 1995 were revised in 2005 and further revised as a result of the enactment of Law 9 of 2009, but these executive regulations have not yet been issued by the Council of Ministers. Given that these regulations are likely to be enacted, the following observations are made as the regulations could influence policies aimed at reducing air pollution.

a) The draft executive regulations introduced new emission levels for $PM_{2.5}$ of 100 $\mu g/m^3$ (24 h average) and 70 $\mu g/m^3$ annual mean, which is 4 and 7 times the corresponding WHO guidelines, respectively. Similarly, the national PM_{10} guidelines of 150 $\mu g/m^3$ (24 h average) and 70 $\mu g/m^3$ (annual mean) are 3 and 3.5 times the corresponding WHO guidelines. It is doubtful that the level of PM_{10} and $PM_{2.5}$ emissions of the WHO could be met, as the major source of pollution is anthropogenic, and, as described in the next chapter, the annual mean PM_{10} emission due to geological materials is as high as 50 $\mu g/m^3$, which is already 2.5 times the WHO guidelines. In accordance with these guidelines, whenever the $PM_{2.5}$ level is 35 $\mu g/m^3$ (annual mean) and the PM_{10} level is 70 $\mu g/m^3$ (annual mean), which is much below the national standards, these are associated with about a 15 percent higher long-term mortality risk relative to the WHO air quality guidelines.

b) The 8h exposure to ozone is maintained at 120 $\mu g/m^3$ compared with the WHO guideline of 100 $\mu g/m^3$. In accordance with the WHO risk assessment, exposure to this level of ozone is associated with an estimated 1.6–3.0 percent increase in daily mortality (based on findings of daily time-series studies).

c) The draft executive regulations of 2009 introduced pollutant emission levels for urban areas and industrial areas. It is not clear whether these two expressions are sufficiently precise to make the provisions of Law No 9 of 2009 operational. In fact, the emission levels for industrial areas are more stringent than those in urban areas and similar to the emission levels in Law 4 of 1994. This distinction in emission levels between urban and industrial areas is not commonly practiced internationally, and it is not clear why the relaxation of pollution levels for urban areas has been determined in this way for these areas, given that the population is also more exposed to pollution. Thought should be given to combining the permissible emission limits for both industrial and urban areas, since, in the GCMA, small and medium polluting enterprises such in Shoubra El Kheima (Qalyoubieh governorate) are, in fact, located within the urban areas.

d) The draft executive regulations of 2009 propose more stringent guidelines in terms of carbon monoxide (CO) and unburned hydrocarbons (HC). Different categories are specified for cars built on or after 2010, cars built between 2003 and 2009, and cars built before 2003. Similar stringent emissions are also imposed on two- and four-stroke diesel engines based on the category of cylinder capacity. However, no emissions are provided for CO_2, NO_x, and PM. The proposed unit of ppm is not the international unit, which is g (of emissions)/km (travelled) or g/mile. Therefore, it has not been possible to compare the emission levels with those available as such as Euro 1 to Euro 5 emission standards. Europe, for example, has introduced stringent fuel regulations[6] that require a maximum sulfur content in gasoline of 150 ppm in 2000 and 50 ppm in 2005. They also require a maximum sulfur content in diesel engines of 350 ppm in 2000 and 50 ppm in 2005 and require that sulfur-free diesel and gasoline fuels (≤ 10 ppm Sulfur) must be available beginning in 2005 and is mandatory beginning in 2009.

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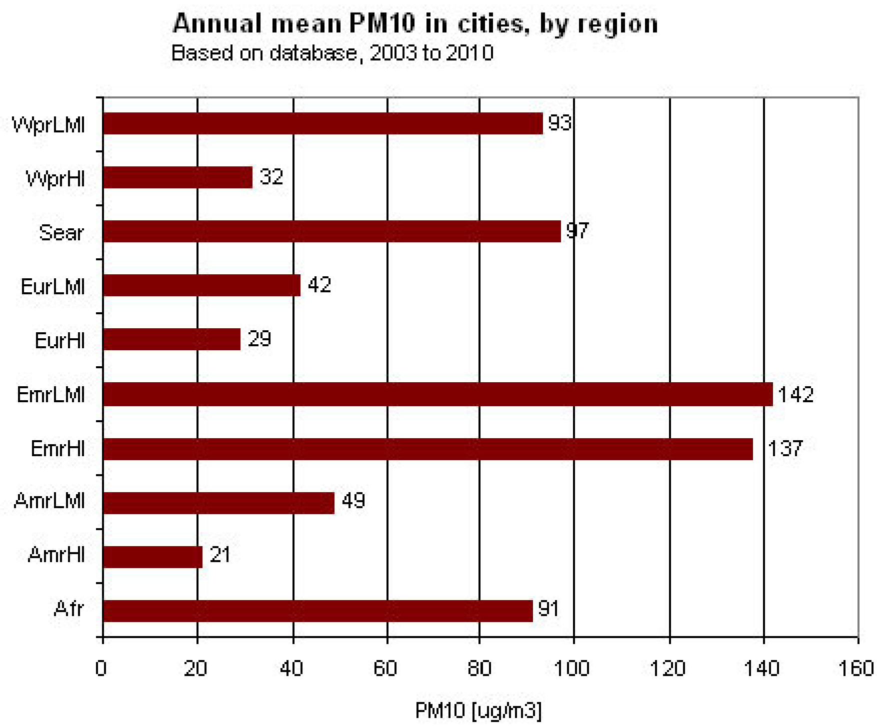
[6] http://www.dieselnet.com/standards/eu/ld.php.

2.6 Comparison with Other Cities in the World and in the Middle East and North Africa

According to a recent WHO publication[7] on outdoor air pollution in the world, the low- and middle-income Mediterranean region (to which Egypt belongs) displays the highest annual PM_{10} concentration in the world (**Error! Reference source not found.**). Greater Cairo ranks 33rd on the list of cities with the highest annual mean PM_{10} worldwide (Figure 2.5).

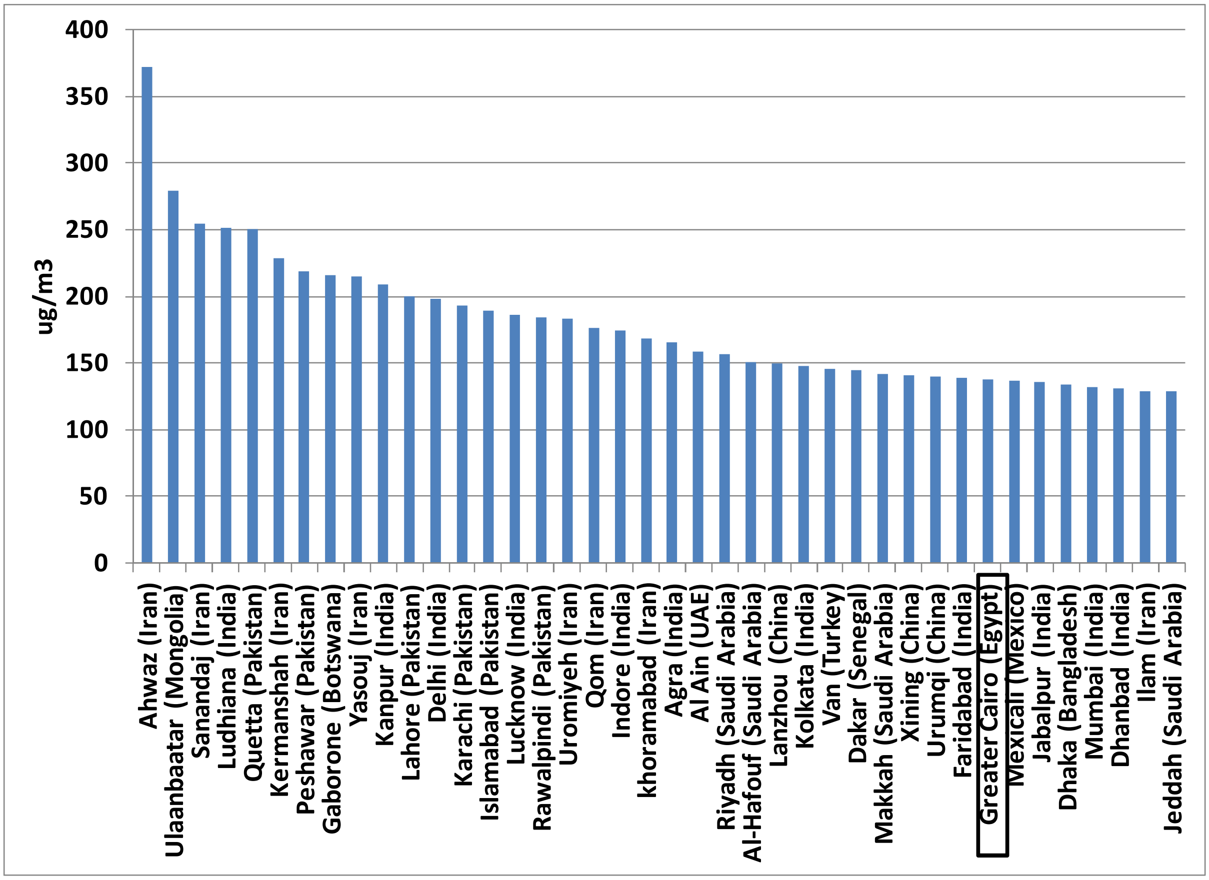


Source: WHO 2008.

Note: Afr: Sub-Saharan Africa; Amr: Americas; Emr: Eastern Mediterranean; Eur: Europe; Sear: South-East Asia; Wpr: Western Pacific; HI: high income; LMI: low and middle income; PM10: fine particulate matter of 10 microns or less.

Figure 2.4 Comparison of annual mean concentrations of PM_{10} in some Arab countries

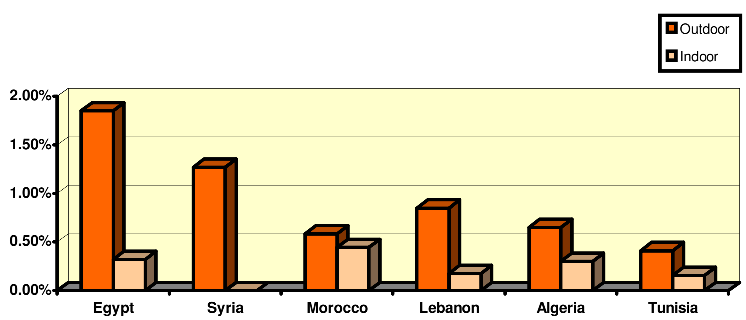
[7] http://www.who.int/phe/health_topics/outdoorair/databases/en/



Source: WHO 2008.

Figure 2.5. Top 40 cities with the highest annual mean PM10 in ug/m^3

Also, Egypt stands first among selected countries in the Middle East and North Africa in terms of the cost of environmental degradation due to outdoor air pollution, with an air quality deterioration of 2.1 percent of GDP (1999) as determined by the World Bank and METAP (Croitoru and Sarraf 2010).

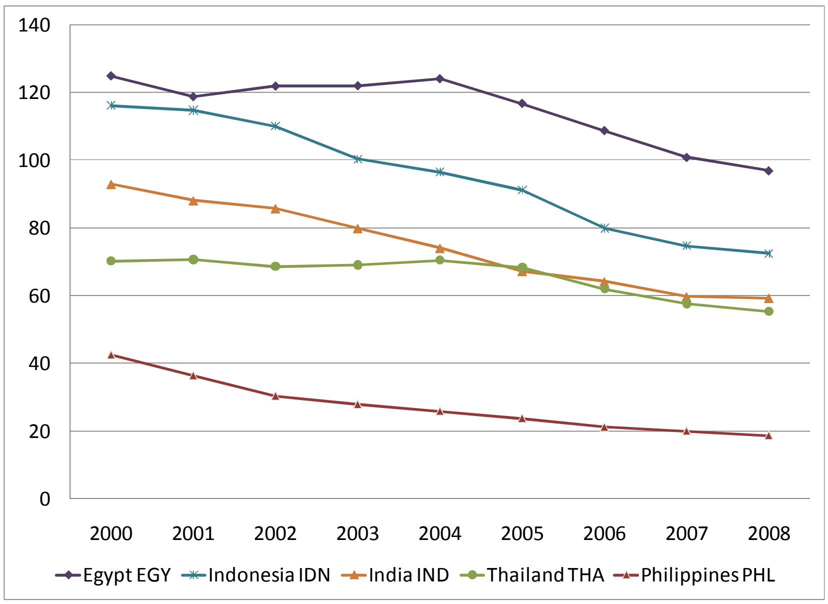


Source: Croitoru and Sarraf 2010.

Figure 2.6. The cost of environmental degradation in air quality in the Middle East and North Africa

The most significant impacts on health and the quality of life are caused by urban air pollution originating from various industrial activities, the open burning of municipal and vegetative wastes, and the transport sector. Although the revised cost assessment of environmental degradation (COED) (see chapter 5) shows a decrease to 1.3 percent of GDP because of the increase in GDP per capita from 1999 to 2009, the cost is still high.

Some megacities have made an effort to improve air quality and successfully mitigated air pollution by a certain level. Figure 2.7 shows a comparison of the PM_{10} concentration trend from 2000 to 2008 in Egypt against the corresponding trends in some other developing countries that have similar megacities. The PM_{10} concentrations in Asian countries show a decreasing trend because of the efforts made since the 1990s to improve air quality. The levels of concentration in Egypt and Indonesia were similar in 2000, and now Egypt is following the trend of Indonesia, after peaking in 2004.



Source: World Bank Data (annual average of the all data in the populated areas)

Figure 2.7. Comparison of PM_{10} trends in urban centers in some countries

Another interesting worldwide comparison of current and predicted PM_{10} is shown in Figure 2.8.

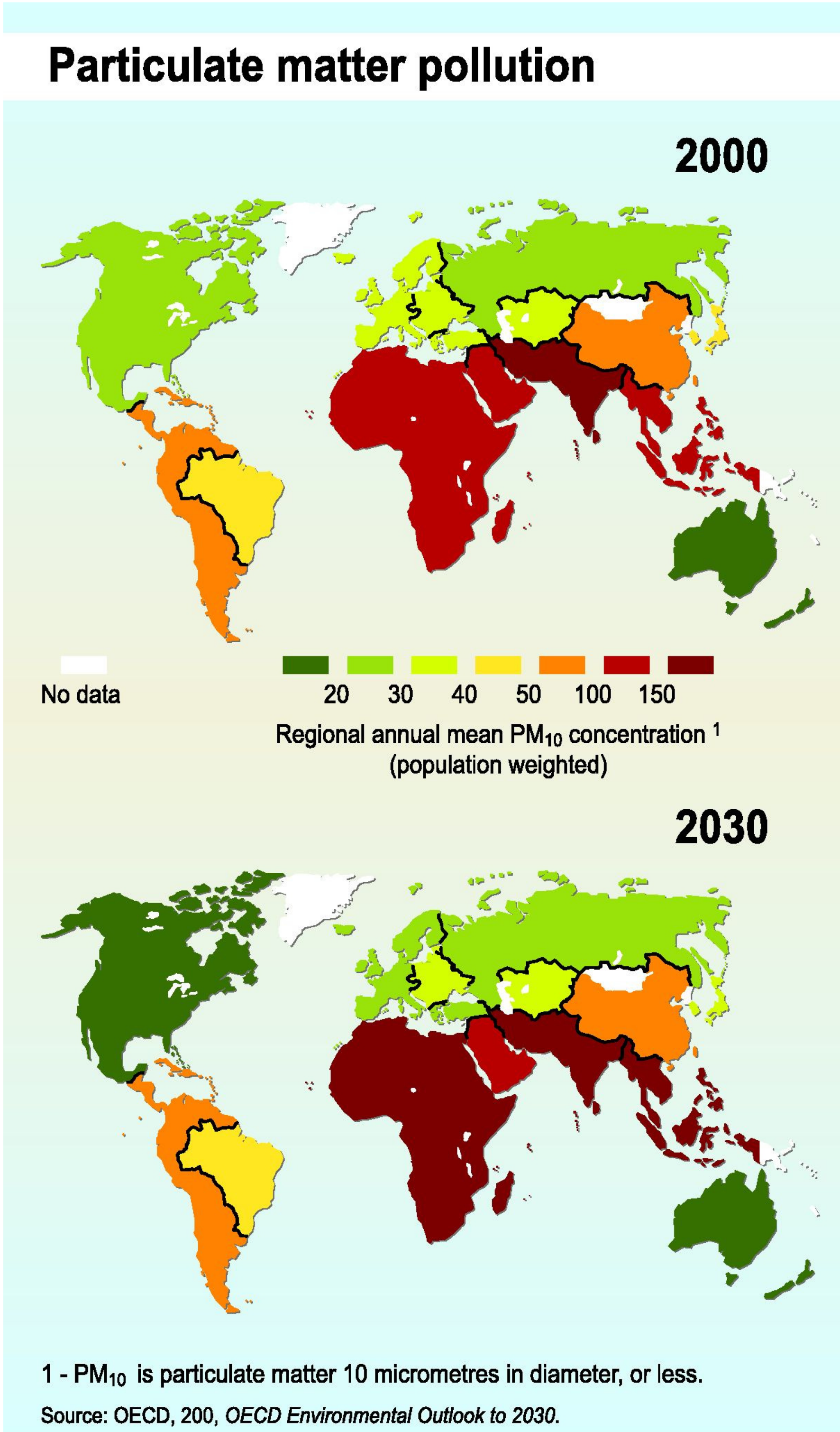


Figure 2.8. Worldwide comparison of annual average PM_{10} in 2000 and projection for 2030

3 Sources of Air Pollution in the GCMA: Source Attribution Study

The objectives of this activity are to (1) conduct a source attribution study that builds on the previous 1999 and 2002 apportionment studies that were financed by USAID under the Cairo Air Improvement Project (CAIP),[8] (2) confirm the major sources of particulate matter (PM) and assess how controls have impacted the source contributions over time, and (3) provide data for improving and validating the Cairo emissions inventory for particulate matter. Particular emphasis has been placed on determining the sources of airborne lead and PM observed in Greater Cairo and the effectiveness of lead control strategies on ambient lead concentrations.

3.1 Sample Locations and Rationale

Five representative sampling sites (Figure 3.1) have been monitored in this study. Samples were collected by the EEAA Air Quality Department’s technical staff every other day for 24-hour periods during the summer (May 30 to June 19, 2010) and the fall (October 10 to October 30, 2010), which is the period of the Black Cloud phenomenon. The locations are as follows:

1. Kaha, a delta site with significant agricultural activities, was chosen to represent the upwind levels of pollutants that impact the Greater Cairo area
2. Shobra, an industrial/residential area located in a heavily industrialized area and downwind from numerous Pb smelters and other industrial sources
3. El Qulaly Square, a mobile source–dominated site; this site is a residential area and located downtown and has high light- and heavy-duty (bus) traffic
4. Zamalek, a residential location, was chosen to represent a site with limited nearby sources
5. Helwan, a residential-industrial area with nearby sources

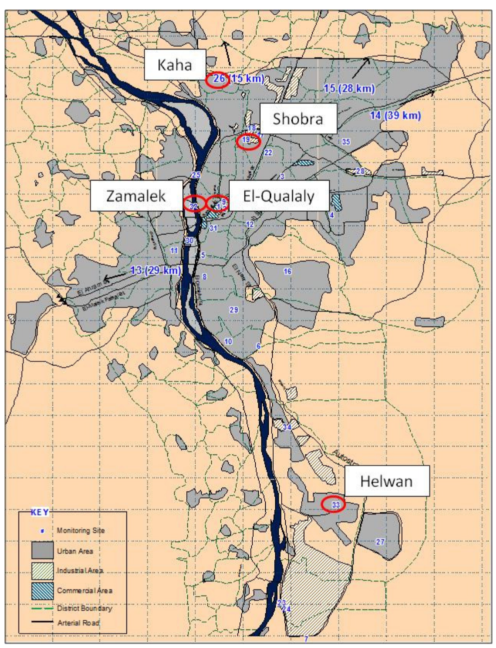


Figure 3.1. 2010 Source attribution study: ambient monitoring locations

[8] As part of the USAID-supported Cairo Air Improvement Project (CAIP), source attribution studies were performed in 1999 and 2002 to assess the impact of various sources (for example, lead smelters, motor vehicles, oil combustion, open burning, geological material, and so on) on ambient pollutant levels.

3.2 Methodology for Source Attribution

The Chemical Mass Balance (CMB) receptor model[9] was used to apportion PM and its chemical constituents to their sources (Watson et al. 1984). The CMB procedure requires several steps (Lowenthal and Gertler 2011). First, the contributing sources must be identified, and their chemical source profiles must be assembled. The source profiles are the fractions of chemical species of emitted PM mass and their uncertainties. Data for the ambient samples include the concentrations and uncertainties of PM mass and the chemical species. The source profiles and ambient concentration data are entered into the model. Then, the sources and chemical species to be included in the model must be selected. The final step is the solution of the set of chemical mass balance equations for the source contributions. These procedures are described in detail in an application and validation protocol (Pace and Watson 1987).

PM_{10} and $PM_{2.5}$ emissions and secondary emissions resulting from oxidation reactions in the following categories were observed:

- Geological material (sand and soil dust): windblown desert dust, resuspended road dust, sand, and soil from construction activity
- Open burning and the burning of agricultural waste as witnessed by the presence of soluble potassium in the PM, which is an important marker for biomass burning (Chow et al. 2007)
- Motor vehicle emissions: gasoline and diesel tailpipe emissions; vehicle emissions also create secondary particulate matter (described below)
- Heavy oil: mazout (heavy fuel oil) burning from all sources, including brick kilns and power generation. Contributions from mazout burning are higher than listed only in this category as (i) some other industrial sources use mazout, and (ii) mazout can lead to the secondary particulate matter listed below
- Cement: windblown cement dust and emissions from the stack; some emissions may also create the secondary particulates listed below
- Lead smelters: emissions from lead smelter activity; some emissions may also create the secondary particulates listed below
- Copper smelters: emissions from copper smelter activity; some emissions may also create the secondary particulates listed below
- Steel industry: emissions from cast iron and steel foundries; some emissions may also create the secondary particulates listed below
- Marine: sea salt from the Mediterranean (common in any area downwind of a body of salt water)
- Secondary PM from vehicles or industry: ammonium sulfate and ammonium nitrate due to the oxidation of SO_2 and NO_x, respectively; the ammonium sulfate tends to come from the sulfur in mazout and diesel fuel
- The ammonium nitrate from the oxidation of NO_x emitted from mobile sources and power plants; some of these pollutants are also emitted from industrial sources
- Secondary PM from NH_4Cl: due to the reactions of HNO_3 from combustion sources and the NH_3 possibly emitted by fertilizer and farming activities, including fertilizer industries and poultry farms in the Nile Delta, and a source of chlorine

3.3 Limitations of the Source Attribution Study

The limitations of this approach can be summarized as follows (Lowenthal and Gertler 2011):

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[9] The CMB consists of a set of linear equations that express the ambient concentrations of a chemical species as the sum of products of source contributions and source composition profiles.

- The model identifies the contributions from source categories, but cannot identify the contributions from individual sources. For example, the model can provide information on how much of the observed $PM_{2.5}$ comes from lead smelters, but cannot tell us how much comes from one individual smelter.
- Sources that have emissions with similar chemical composition may not be resolvable. Open garbage burning and the burning of agricultural waste both have a significant fraction of combusted organic matter, and the emissions are predominately composed of organic carbon. Thus, these sources often cannot be separated, and the contributions are lumped together as burning. Similarly, it is difficult to resolve the contributions from road dust versus windblown soil, soil from different locations, and emissions from gasoline vehicles versus diesel vehicles.
- Some of the PM is formed by chemical reactions of gaseous species in the atmosphere. These are called secondary particles and generally consist of ammonium sulfate ($(NH_4)_2SO_4$), ammonium nitrate (NH_4NO_3), and ammonium chloride (NH_4Cl), as explained above. The model cannot specifically tell us the sources of this PM, but it can tell us if these species have been formed and contribute to the observed PM. For example, high levels of ammonium nitrate are generally due to emissions of oxides of nitrogen (NO_x) from motor vehicles, power plants, and industrial operations.

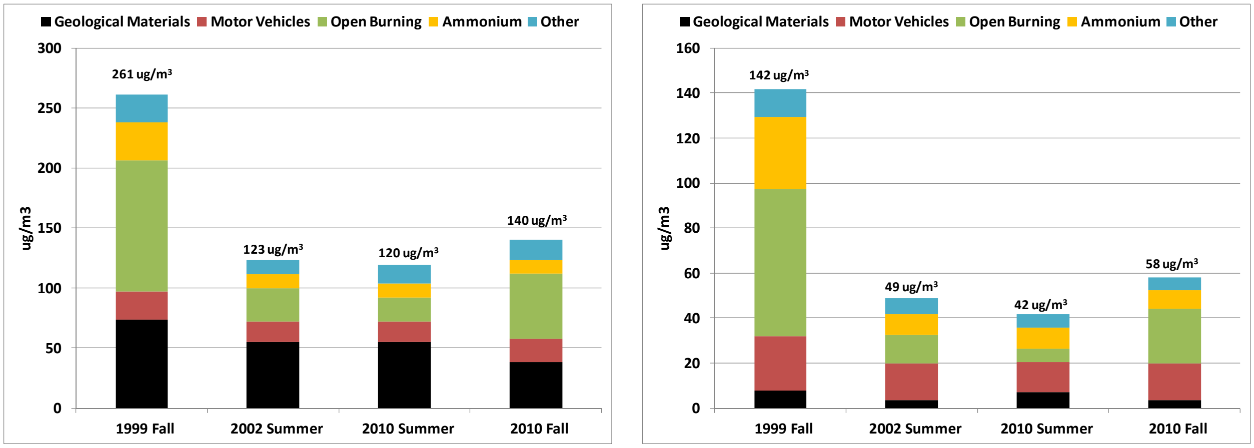
3.4 Summary of the SAS Results

The SAS results are shown in Table 3.1 and Figure 3.2. The concentration levels of PM_{10} and $PM_{2.5}$ are lower in fall 2010 compared with fall 1999 by a factor of 2.4 ($PM_{2.5}$) and 1.8 (PM_{10}). This decrease may be attributed to several factors, namely, the expansion of roads and highways, improved car efficiency, industrial pollution control, and efforts to contain open burning. Despite the decrease, the PM_{10} concentration remains high, and more people are exposed to the level of pollution because the population of Greater Cairo increased by more than 3 million from 1999 to 2010, while the number of vehicles increased by 30 percent. Similarly, a smaller decrease was observed in particulate matter during the summer periods of 2010 and 2002, reported as 1.03 for PM_{10} and 1.17 for $PM_{2.5}$. This could be due the reduced traffic and congestion because of the holiday season and the closing of schools and universities.

Table 3.1. Mean PMx source attribution (µg/m3 and %), five monitoring locations

Source Pollutant	Geological Material		Motor Vehicles		Open Burning		Ammonium		Other		Total	
	$\mu g/m^3$	%	$\mu g/m^3$	%	$\mu g/m^3$	%	$\mu g/m^3$	%	$\mu g/m^3$	%	$\mu g/m^3$	%
PM_{10}												
1999 Fall	73.9	28	23.4	9	109.0	42	31.8	12	23.2	9	261.2	100
2002 Summer	54.8	44	17.6	14	27.7	22	11.4	9	11.7	10	123.1	100
2010 Summer	54.7	46	17.5	15	19.8	17	11.6	10	15.9	13	119.5	100
2010 Fall	38.4	27	19.3	14	54.4	39	11.1	8	17.1	12	140.3	100
$PM_{2.5}$												
1999 Fall	7.7	5	24.3	17	65.3	46	32.1	23	12.3	9	141.8	100
2002 Summer	3.6	7	16.1	33	13.0	27	9.0	19	7.0	14	48.6	100
2010 Summer	7.1	17	13.4	32	5.8	14	9.6	23	5.8	14	41.6	100
2010 Fall	3.6	6	16.1	29	24.4	42	8.3	14	5.7	10	58.0	100

Source: Lowenthal and Gertler (2011).
Note: Average data from five sites located within or on the fringes of Greater Cairo. Color coded cells are for the source that seasonally ranks first.



(a) (b)

Figure 3.2. Graphical representation of the evolution of the main sources of air pollution in the five sites, for (a) PM_{10}, and (b) $PM_{2.5}$

The major contributors to PM_{10} included soil dust material, mobile source emissions, and open burning. For the fall 1999 and 2010 period, the contribution of open burning exceeded that of soil, likely due to continued agricultural burning. Whereas $PM_{2.5}$ is dominated by mobile source emissions, secondary species (ammonium sulfate and ammonium nitrate), soil dust, and open burning. For the fall 1999 and 2010 periods, the contribution of open burning exceeded that of mobile sources.

In relative terms, the four main sources of pollution remain the same over the 1999–2010 period, but with slight changes in ranking. All the seasonal number one ranking sources have been reduced in absolute terms over the period except for geological materials, which remain the same in relative and absolute terms between 2002 and 2010, suggesting that pollutant levels are mainly attributable to natural causes such as eastern or western desert storms (the *khamasin*), as shown in Figure 3.3.

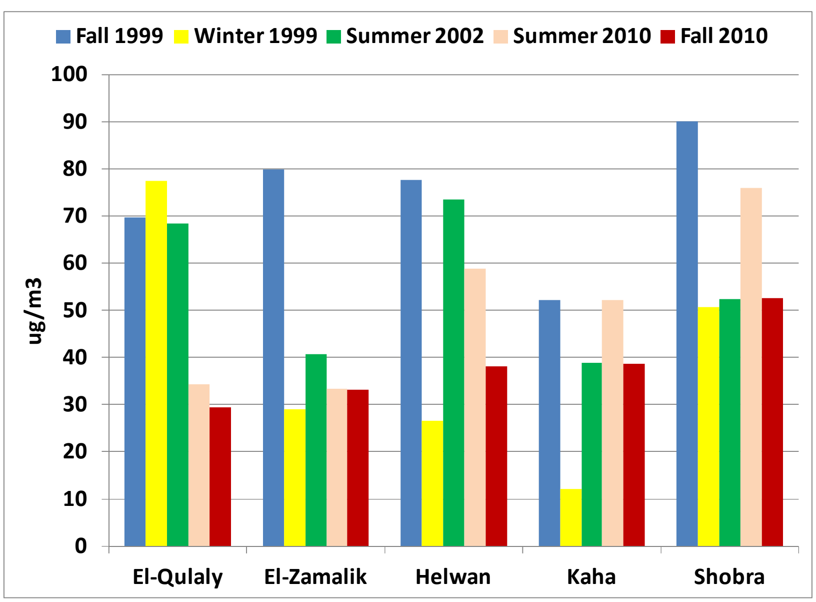
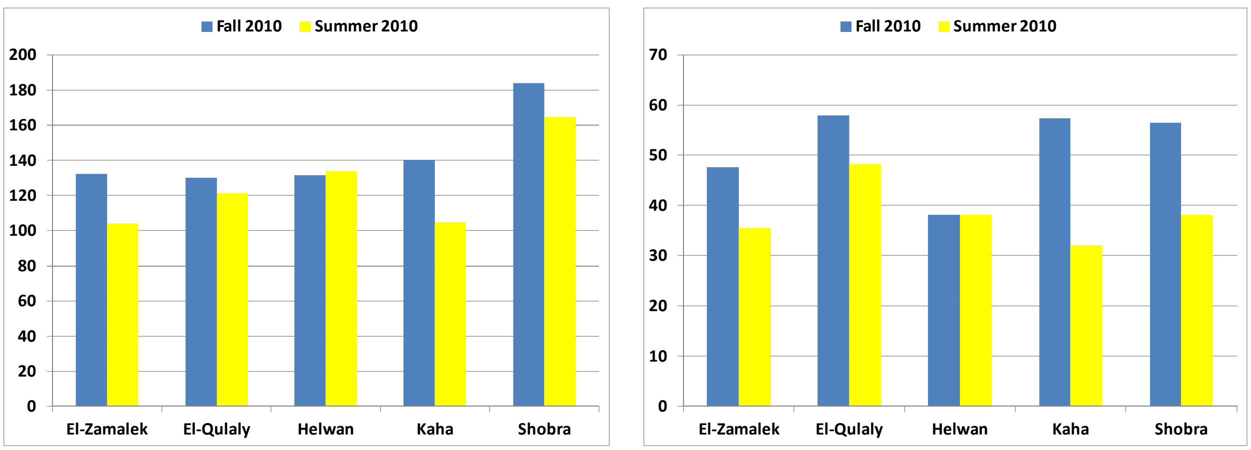


Figure 3.3. Temporal trends in PM_{10} geological dust contributions in Cairo, 1999–2010

The emission levels among the five districts where the monitoring stations were placed showed the following features:

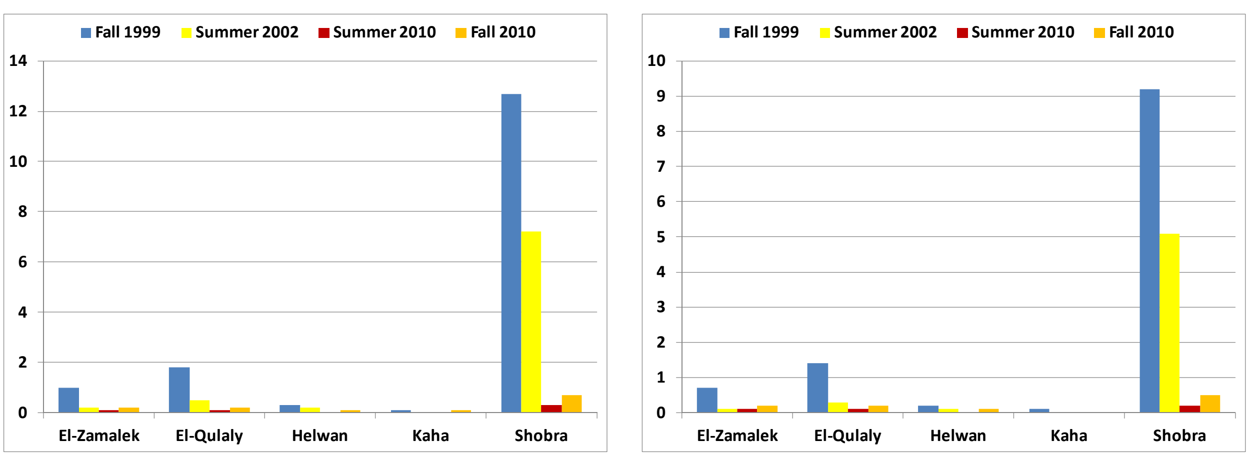
- The district of Shobra is considered to have the highest level of PM_{10} concentration among all the districts, including Helwan, where heavy industry is located. It has the second highest $PM_{2.5}$ after El-Qulaly. Shoubra El Kehima has the highest population per km^2 and includes the largest number of SMEs, in addition to the power plant (Figure 3.4)
- With the exception of Shoubra, the districts have similar PM_{10} concentrations during the fall season irrespective of their populations, industrial activities, and traffic. Zamalek, which is considered a residential area for the upper-middle class, has PM_{10} and $PM_{2.5}$ concentrations similar to El Qulaly and Helwan, which are lower-middle-class residential areas. Both the poor and the rich are exposed to similar levels of air pollution in Cairo.



(a) (b)

Figure 3.4. Trends in seasonal average concentrations of (a) PM_{10} and (b) $PM_{2.5}$ mass in the summer and fall monitoring period, 2010

The lead emission as shown in Figure 3.5 decreased by a factor of 10 and 6 during the summer and fall of 2009, respectively. This is due to the government's policy of eliminating lead in gasoline and relocating SME smelters, particularly in Shoubra El Kheima.



(a) (b)

Figure 3.5. Trends in seasonal average concentrations of PM_{10} lead in the (a) fall and (b) summer monitoring period

4 Emission Inventory and Dispersion Modeling of Air Pollutants in the GCMA

4.1 Objectives and Scope

Chapter 3 examines a sources attribution study based on measurements that indicate the main sources of particulate matters in the air at five monitoring stations. To obtain an overview of the pollutants and their sources in the GCMA, air quality modeling is required. This modeling is based on statistics and verified by long ambient air monitoring. Through the emission inventory, the model can indicate the source of air pollution.

The flow chart in Figure 4.1 illustrates this for an industrial sector, along with a brief explanation of the modeling steps.

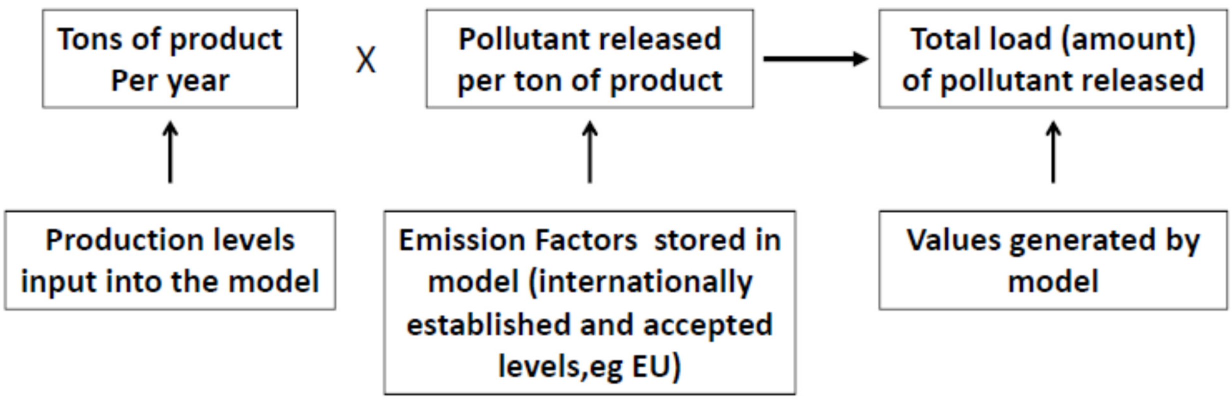


Figure 4.1. Calculation of pollution load

Air quality concentration levels are extrapolated by combining the calculated loads with the physical air parameters (meteorology, geography, area of city, and so on) of the receiving body of the air quality area. This is illustrated in Figure 4.2.

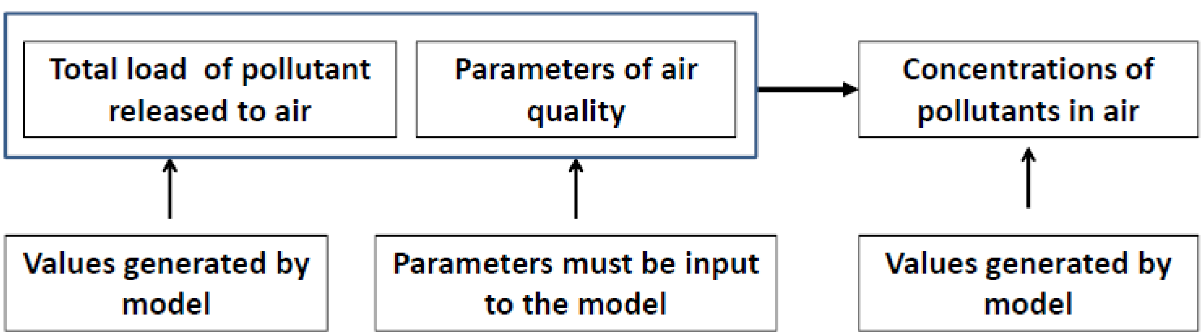


Figure 4.2. Calculation of air quality pollutants

The modeling has been obtained for the base year, 2010, and extrapolated for future years, 2015 and 2020, based on indicators of the development of the activities and expected technology improvements.

4.2 Methodology

An emission inventory is an approximation because the details on the technology and the operational modes of the activities are not known precisely. The selected approach consists of using typical emission factors that are geared to the available activity data level. Local emission factors have been used whenever available. For other activities, the main source of emission factors is the EMEP/EEA Air Pollutant Emission Inventory Guidebook (2009), available from the European Environment Agency (EEA) website.[10] The EMEP/EEA Air Pollutant Emission Inventory Guidebook (formerly referred to as the EMEP CORINAIR emission inventory guidebook) provides guidance on estimating emissions from both anthropogenic and natural emission sources. It is designed to facilitate the reporting of emission inventories by countries to the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution and the EU National Emission Ceilings Directive. The EEA publishes the guidebook; the UNECE Task Force on Emission Inventories and Projections has responsibility for the technical content of the chapters.

The EMEP/EEA Air Pollutant Emission Inventory Guidebook has been selected as the main reference for the methodology and the emission factors. The guidebook offers a practical way to estimate emissions in line with international reporting requirements (UN FCCC and LRTAP)[11] and has multiple tiers in a calculation methodology geared to the available information. The tier 1 methodology has been used to calculate the sector totals. The tier 2 methodology can be applied if detailed information on the actual processes is available. Furthermore, the guidebook offers not only one emission factor number, but also indicates a 95 percent confidence interval and full background information. This enables the analyst to reflect improvements in technology.

The factors are a compilation of European and international references (including US-EPA) and represent different levels of technology given that the situation in the different regions in EMEP countries varies. In principle, these factors are suitable for activities in Egypt because they concern the same processes, though the abatement level may differ. For our study, if we use emission factors of the EMEP/EEA guidebook, we have selected the mean and upper (95 percent confidence interval) values. Based on a comparison with the monitoring results, the mean values have been selected for NO_x emission factors, except for transport, and upper values have been selected for PM_{10} and $PM_{2.5}$ emission factors. SO_2 emission factors are based on the sulfur content of the fuel in most cases.

The spatial distribution of the estimated emissions is modeled along (a) point sources where the location of stationary sources is known and (b) area sources where emissions are generated by a multitude of sources or the location of the sources is unknown. Areas have been defined in GIS maps. A limited set of areas have been used for the spatial distribution, namely, (a) the number of people in an area, (b) industrial zones (surface), and (c) agricultural area. The meteorological data of the period 2006–10 have have been used at the monitoring stations, and one year of meteorological data (2010) have been used to plot the concentration contours given the required runtime and the objective of the study.

In estimating the pollution loads, the following classification has been based on the UNECE Nomenclature for Reporting (NFR), which integrates the common reporting format (CRF) of national greenhouse gas (GHG) emission inventories. The classification is different from the CMB classification in chapter 3 and is explained below in section 4.3.2.

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[10] http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009.

[11] The Convention on Long-Range Transboundary Air Pollution addresses the air pollution problems of the UNECE region through scientific collaboration and policy negotiation. The convention has been extended through eight protocols that identify the specific measures to be taken by parties to cut their emissions of air pollutants. Fifty-one states are currently parties to the convention.

Two dispersion models have been selected among the extensive software available, namely, CALPUFF and AERMOD. AERMOD is a steady-state plume model that incorporates air dispersion based on the planetary boundary layer turbulence structure and scaling concepts, including the treatment of both surface and elevated sources and both simple and complex terrain. CALPUFF is a non-steady-state puff dispersion model that simulates the effects of time-varying and space-varying meteorological conditions on pollution transport, transformation, and removal. CALPUFF can be applied for long-range transport and for complex terrain computation. Both models are the regulatory dispersion programs of the U.S. Environmental Protection Agency (EPA). These are highly recommended due to their general acceptance by the scientific community, their recognition in many different parts of the world, and the high level of expertise among the consultants, as well as their low cost and relative user friendliness.

A multicriteria analysis has been performed to select the most well suited program. The main considerations from which the criteria have been derived are the project's allocated time and financial resources, as well as their suitability for the future use of the model by the EEAA staff. This has resulted in the selection of AERMOD as the model of choice for this work.

4.3 **Emission Inventory Results**

4.3.1 Emissions Overview 2010

The emission calculation results are presented in annex 1, where the activity data, the applied emission factor, and the calculated emission are described. An overview of the emission loads of the various sectors for the year 2010 are presented in Figure 4.3.

a) For PM_{10}, industrial noncombustion processes (such as construction and demolition, mineral products, chemical industry, and metals products) are the major contributor of the modeled sources (53 percent) of PM_{10}, followed by fuel combustion in residential, commercial, and agricultural sectors (13 percent) and transport (12 percent). Construction and demolition and cement production are the main contributors of the modeled PM_{10} in Greater Cairo. The burning of rice fields and charcoal production in the Nile Delta are major sources outside Greater Cairo. It should be noted that major sources of PM_{10}, namely, regarding geological material, marine particles, and secondary particles (ammonium nitrate and sulfate), are not accounted for in the emissions study. Approximately 35–55 percent of the total concentration of PM_{10} is attributable to airborne geological material during the summer. During the winter, this percentage varies between 25 and 35 percent.

b) For $PM_{2.5}$, the major contributors are transport (24 percent, mainly trucks), industrial noncombustion processes (25 percent), and fuel combustion in residential, commercial, and agricultural sectors (19 percent). Transportation is one of the main contributors of $PM_{2.5}$, caused by both fuel combustion and the wear on brakes, tires, and road surfaces.

c) For SO_x, the major contributor is the manufacturing industries and construction (50 percent), followed by the transport (22 percent) and energy industries (17 percent). Sulfur-containing fossil fuels used in the industry are the main sources of SO_2 emissions, but diesel and gasoline used for transportation are also a major source.

d) For NO_x, transport is the major source (79 percent), followed by fuel combustion in residential, commercial, and agricultural sectors (9 percent), manufacturing industries (8 percent), and energy industries (4 percent). In transport, heavy-duty vehicles contribute the most NO_x emissions.

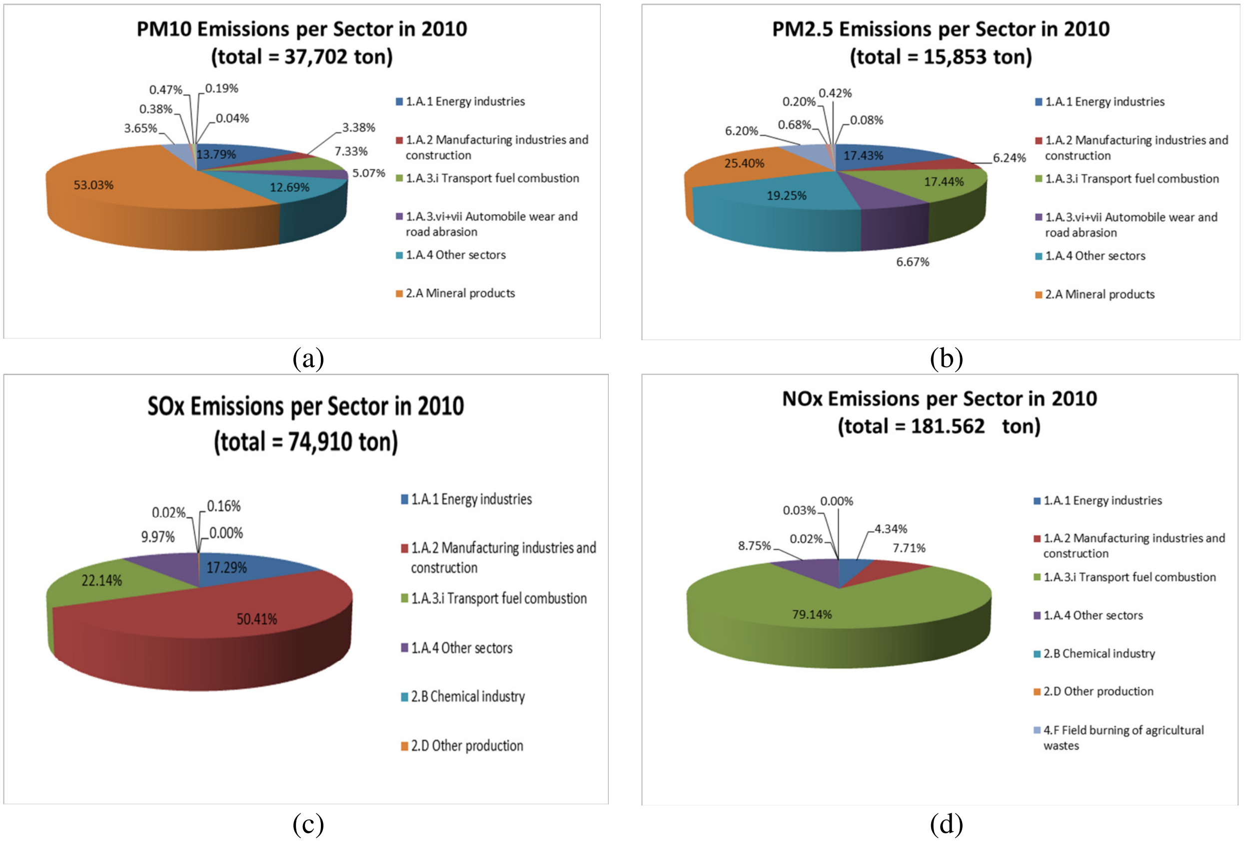


Figure 4.3. Emissions per sector in 2010 for (a) PM_{10}, (b) $PM_{2.5}$, (c) SO_x, and (d) NO_x

4.3.2 Links between the CMB and Pollution Loads

The Chemical Mass Balance (CMB) receptor model has been used to apportion PM and its chemical constituents to their sources. The indicated source groups are based on their chemical fingerprint (source profile), and there is thus no direct link for all source groups with the source classification used in this chapter (or other socioeconomic classifications). The source groups that can be linked are listed in Table 4.1.

Table 4.1. Source groups used in the analysis

CMB Source Groups (used in the Source Attribution Study)	NFR Source Category (used in the emission inventory)	Remarks
Ammonium nitrate Ammonium sulfate	None	These are secondary compounds without further indication of the sources
Marine aerosols	None	Marine aerosols refer to sea salt, which is not considered in the emission inventory
Open burning	1.A.1.c – Manufacturing of solid fuels waste	Charcoal production (which is produced predominately upwind of the GCMA)
	1.A.4.b – Fuel combustion in households	Charcoal combustion
	4.F – Field burning of agricultural waste	Rice straw field burning, upwind of the GCMA
	6.C.e – Small-scale waste burning	
Motor vehicles	1.A.3.b – Road transportation	
Heavy oil	Part of 1 - Fuel Combustion: • 1.A.1.a - Electricity production • 1.A.1.b – Petroleum refining • 1.A.3.d – Navigation • 1.A.2 – Manufacturing industries and construction	Heavy oil is one fuel used in the listed source categories Navigation is not considered in the emission inventory (there is no marine shipping in the GCMA)
Steel industry	1.A.2.a – Fuel combustion of iron and steel production 2.C.1 – Iron and steel production	2.C.1 refers to non-combustion processes; it's unclear whether the "steel industry" of the CMB group includes its fuel combustion processes
Copper smelters	1.A.2.b – Fuel combustion of non-ferrous metals production 2.C.5.a – Copper production	2.C.5.a refers to non-combustion processes, which have not been taken into account in the emission inventory as no data on lead and copper smelters were provided. It is assumed that these are no longer operational in the greater Cairo area. It's unclear whether "copper smelters"' of the CMB group includes its fuel combustion processes
Lead smelters	1.A.2.b – Fuel combustion of non-ferrous metals production 2.C.5.b – Lead production	2.C.5.b refers to non-combustion processes, which have not been taken into account in the emission inventory as no data on lead and copper smelters were provided. It is assumed that these are no longer operational in the greater Cairo area. It's unclear whether lead smelters of the CMB group includes its fuel combustion processes
Geological material	2.A – Mineral products (cement, lime, dolomite, soda ash, asphalt,mining) 2.A.7.b – Construction and demolition 4.A/B – Livestock	The source attribution study names soil material and road dust of paved and unpaved roads as main sources of geological material. These have not been included in the emission inventory as such

4.4 Emission Predictions

4.5 Baseline Scenario

The pollution loads were estimated for 2010. Projections for the years 2015 and 2020 were also estimated to show the potential increase of the major pollutant loads in case no actions are taken to control and reduce such pollution loads. These are considered to be the business as usual scenarios or no actions. The development factors used for the emission predictions are shown in Table 4.2. The calculated emissions for 2010, 2015, 2020 for the development scenario are presented in Table 4.3.

Table 4.2. Factors used for future growth predictions

Projection Indicator	Indicator Value	Associated Source Categories
Population growth	2010→2015: + 8 % 2010→2020: + 14.1% (Population estimates based on the results of 2006 population census; medium variant scenarios; CAPMAS)	4 – Agriculture 6 – Waste
Transportation growth	2010→2015: + 40 % 2010→2020: + 80 %	1.A.3.b – Road Transport
Industrial growth	2010→2015: + 27.1% 2010→2020: + 61.5% (Average growth of 4.9%/year for last 2.25 years (2008-first quarter of 2011) amounted to. 4.2% (2009) and 5.4% (2010) and 6.2% (2011Q1) per year. (Source: Ministry of Trade and Industry)	1- Fuel combustion 2 - Industrial processes

Table 4.3. Calculated emissions for the baseline scenario [ton per year]

Pollutant	**2010**	**2015**		**2020**	
	[Ton/year]	[Ton/year]	Increase [%]	[Ton/year]	Increase [%]
NO_x	181,562	198,727	9%	211,257	16%
SO_x	74,910	88,845	19%	101,912	36%
PM_{10}	37,702	45,554	21%	54594	45%
$PM_{2.5}$	15,833	18,592	17%	21,491	36%

From the table, it is clear that the emission level for all pollutants will rise due to expected population growth and increased industrial production. The penetration of cleaner technology may not be sufficient to offset the increase in the PM_{10} and $PM_{2.5}$.

The relative contribution to the atmospheric emissions of the various sectors remains roughly the same in the baseline scenario.

4.6 Mitigation Scenarios

Two mitigation scenarios additional to the baseline scenario (autonomous development, that is, development without further measures to improve air quality) have been considered, as follows:

- Scenario 1: execution of the existing and envisioned environmental policy
- Scenario 2: execution of air quality improvement measures additional to scenario 1

The main air quality measures in the three development scenarios are presented in Table 4.4. The aim is to illustrate the general trend and expected impact.

Table 4.4. Definition of the Projection Scenarios

Projection Scenario	**Projection Indicator**	**Applicable Source Categories and Indicator Values**
Baseline scenario: **(Autonomous development)**	Technology improvement (Estimated fuel efficiency improvement of 1%/year):	1 - Fuel combustion (with exception of 1.A.1.c Charcoal production) 2010→2015: - 5 % 2010→2020: - 10 %
	Road transport • No replacement of existing vehicles by vehicles with lower exhaust emissions • Additional vehicles with cleaner engines than existing vehicles	1.A.3 – Transport Refer to separate section '1.A.3 - Road Transport (Combustion)'
	Unchanged (amongst others) • Sulfur contents of the fuels • Field burning of agricultural wastes	
Scenario 1: **(Existing and envisioned environmental policy)** The text in italics is copied from the policy summary	Energy security policy "*Utilization of sustainable, renewable and clean energy resources to achieve 20% of electricity demand from it by the year 2020*". It is assumed that this will be achieved without atmospheric emissions (e.g. wind, solar, hydropower).	1.A.1.a Electricity production 2010→2015: - 10% 2010→2020: - 20%
	Energy security policy "*Maximize energy efficiency to reduce consumption 20 % by the year 2022*" This corresponds approx. with a fuel efficiency improvement of 1%/year	1 - Fuel combustion (with exception of 1.A.1.c Charcoal production) 2010→2015: - 5 % 2010→2020: - 10 %
	Field burning of agricultural wastes "*Recycling of rice straw and other agricultural waste*"	4F – Field burning 2010→2015: - 25 % 2010→2020: - 50 %
	Transport: Programs and projects of the environmental policy include vehicle exhaust testing, replacement of old taxis, replacement of two stroke motorcycles by four stroke ones and expansion of natural gas in vehicles.	1.A.3 – Transport *Refer to separate section* '1.A.3 - Road Transport (Combustion)' 2015: 5% replacement of the 2010 fleet 2020: 15% replacement of the 2010 fleet
	Unchanged: Sulfur contents of the fuels • The policy summary document mentions low sulfur fuel as but doesn't state maximum sulfur content for the internal Egyptian fuel market. "*Improving the specification of petroleum products and reduce the sulfur content to access the international standards as well as the harmful exhaust emissions which to compete in world export markets and export high-quality Egyptian products, which include implementation of a number of important projects for the production of high octane gasoline*"	

Projection Scenario	Projection Indicator	Applicable Source Categories and Indicator Values
Scenario 2: **(Additional environmental policy)**	Transport • Partial replacement of existing vehicles (emission factors typical EU-15 fleet in 1995) • Additional vehicles 2000-2020 calculated as average emission factor complying with Euro5 standard (this standard entered into force in Jan. 2000)	1.A.3 – Transport (combustion) • *Refer to separate section* '1.A.3 - Road Transport (Combustion)' 2015: 5% replacement of the 2010 fleet 2020: 15% replacement of the 2010 fleet
	Low sulfur fuel • Gasoline (S content from 500 ppm to 10 ppm) • Diesel (S content from 4000 ppm (10 g/kg) to 10 ppm) • Heavy fuel oil (S content from 2.5% to 1%) Low industrial sulfur technology (by using desulfurization and/or low sulfur fuels in industry)	1.A.3 – Road transport (combustion) • Gasoline (SO_2 from 1 g/kg in 2010 to 80 mg/kg in 2020) • Diesel (SO_2 from 20 g/kg in 2010 to 16 mg/kg in 2020) 1.A.1 Energy sector and 1.A.2 Industry (combustion) • Refer to separate section '1.A – Fuel Combustion and 2 - Industrial Processes'
	Cleaner industrial technology, achieved by a variety of mitigating measures, selecting less polluting processes or end-of-pipe techniques for example: • Low NOx burners • Controlling fugitive emission • Fabric filters instead of or additional to cyclones and electric precipitators	1.A.1 – Energy industries (combustion) 1.A.2 – Manufacturing industry and construction (combustion) 1.A.4 – Fuel combustion in commercial, institutional, residential & agricultural sectors 2 – Industrial processes (non-combustion) • The mean value of the emission factor range is selected instead of the maximum value: Refer to separate section '1.A – Fuel Combustion and 2 - Industrial Processes'

The modeled developed scenarios do not include specific air pollution mitigating measures for other activities, for example, livestock dust, small-scale waste burning, wear on tires and brakes, and road abrasion. The emissions per scenario are presented in Figure 4.4.

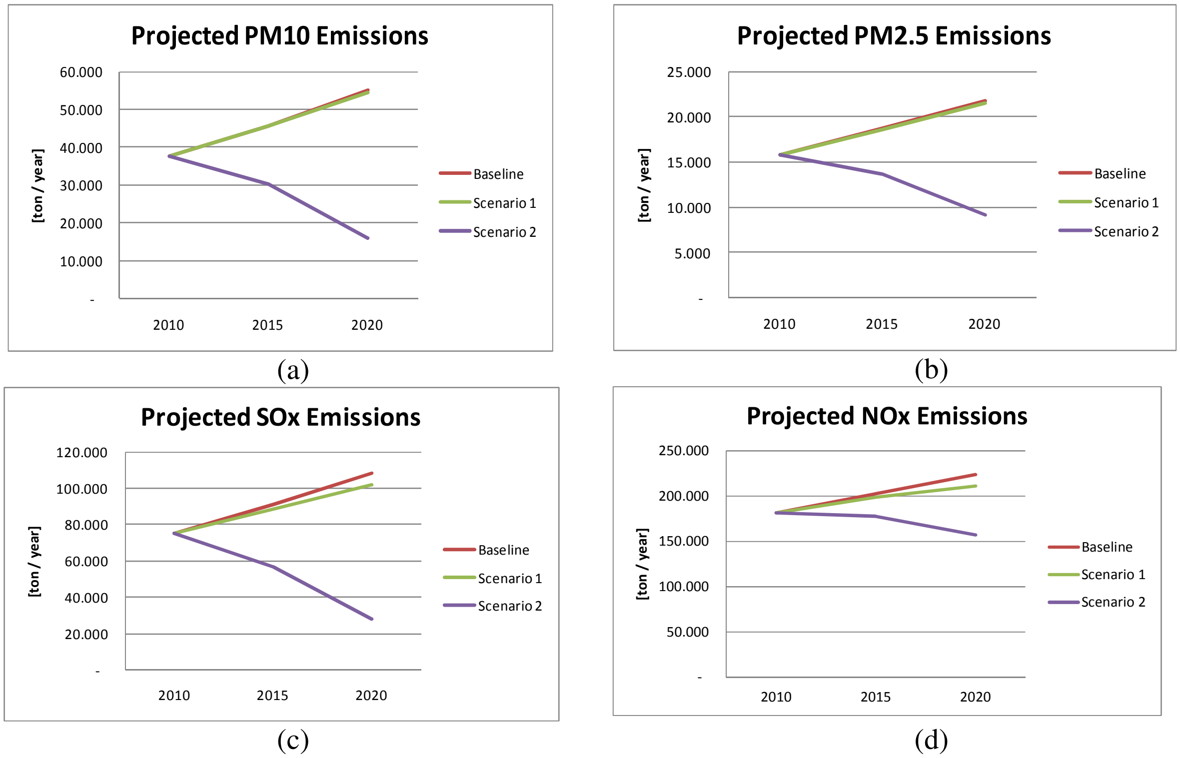


Figure 4.4. Development of emissions per scenario for (a) PM_{10}, (b) $PM_{2.5}$, (c) SO_x, and (d) NO_x

The following can be concluded from the figures.

PM_{10} and $PM_{2.5}$: Scenario 2 demonstrates that additional (policy) measures are required to reduce PM_{10} emissions, for example, by the replacement of old uncontrolled exhaust vehicles by new controlled exhausted vehicles, a speed up in banning rice field burning, and cleaner technology in, for example, cement production and charcoal production.

SOx: Major reductions in SOx emissions are feasible if the sulfur content is restricted to the low levels of many developed countries. Scenario 2 demonstrates that a reduction of at least 63 percent is feasible, which would also be beneficial for PM air quality, because less secondary particles (ammonium sulfate) will be formed.

NOx: Although transportation is expected to grow more quickly than other activities, the share of transportation remains similar in the baseline scenario and scenario 1 because of the introduction of cleaner automotive technology. Scenario 2 demonstrates that additional (policy) measures are required to enforce and speed up the replacement of old uncontrolled vehicle exhausts by new controlled vehicle exhausts. Scenario 2 demonstrates that it is possible to stabilize and reduce NOx emissions, which is also beneficial for PM air quality because less secondary particles (ammonium nitrate and sulfate) will be formed.

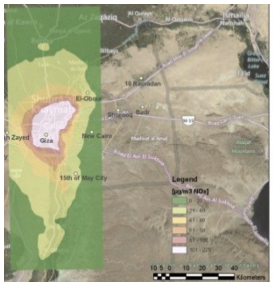
4.7 Modeled Air Quality

Based on the calculated pollution loads for the baseline of 2010 and the meteorological data, dispersion models were used to represent the geographical distribution of the calculated air pollution. The contour plots for the pollutants are displayed in Figure 4.5 through Figure 4.8. The contour plots are the output of the dispersion modeling and graphically represent the geographical distribution of the calculated air pollution. A careful analysis is needed to compare the results of the monitoring stations with the model. The monitoring stations reveal the air quality at a specific location, while the model indicates the air quality of an area. Because, for example, traffic emissions could not be located accurately, the resolution is too low for a comparison of the modeling results at the specific location with the monitoring station data. However, the shape of the modeled NOx concentration contours is in accordance with the shape of the satellite NO_2 observations.

In general, the areas in and around the cities of Cairo, Shoubra El Kheima, and Giza constitute the core of the highest concentrations in PM_{10}, $PM_{2.5}$, SO_x, and NO_x. For PM_{10}, the iso-contours showed that the overall geographic area in the form of a northern delta corridor 58 km wide and 70 km long is polluted, with a monitored concentration of 130–144 $\mu g/m^3$ (corresponding to WHO guidelines of 20 $\mu g/m^3$) and above. This extends up to the secondary cities of Benha and Zagazig and includes the new satellite city of El Obour and New Cairo. Similar concentrations are extended south of Cairo and include the cities of Helwan and Tebbin and the new city of 15 of May. $PM_{2.5}$, which includes the contribution of rice straw burning, showed similar contours over the same corridor, with monitored concentrations of 72–83 $\mu g/m^3$ and above (corresponding to the WHO guidelines of an annual average of 10 $\mu g/m^3$).

For SO_2, the highly polluted areas with monitored concentrations of 28–39 $\mu g/m^3$ (corresponding to the WHO guidelines of 20 $\mu g/m^3$) are more localized into the industrial areas of Shoubra El Kheima, Giza, and Tebbin. For NO_2, the monitored concentrations amounting up to 60 $\mu g/m^3$ (corresponding to WHO guidelines of 40 $\mu g/m^3$) are also more localized around the three core cities of Cairo, Giza, and Shubra El Kheima.

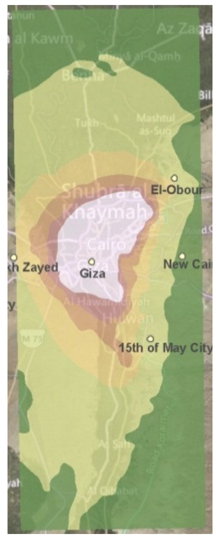
Year 2010



Year 2015

Baseline

Scenario 1

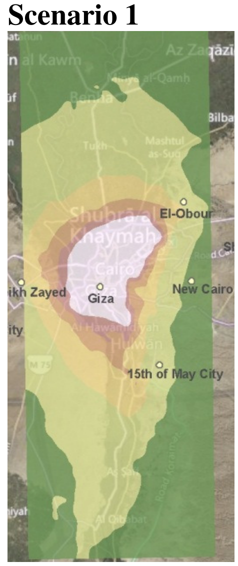


Scenario 2

Year 2020

Baseline

Scenario 1



Scenario 2

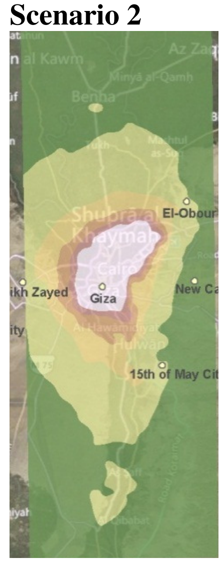


Figure 4.5. Calculated NOx Concentrations for the Baseline Scenario, Scenario 1, and Scenario 2 (annual average)

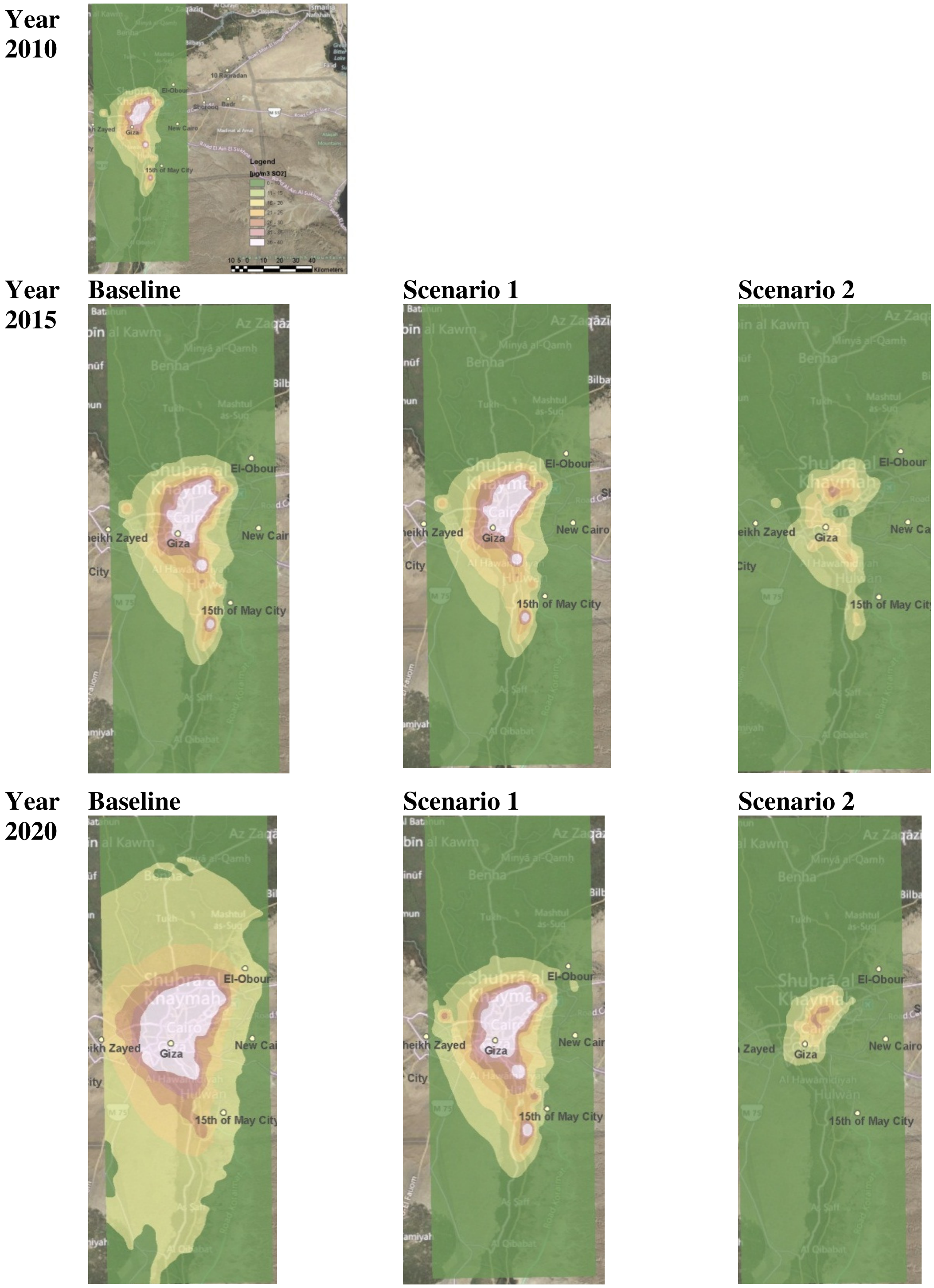


Figure 4.6. Calculated SO_2 Concentrations for the Baseline Scenario, Scenario 1, and Scenario 2 (annual average)

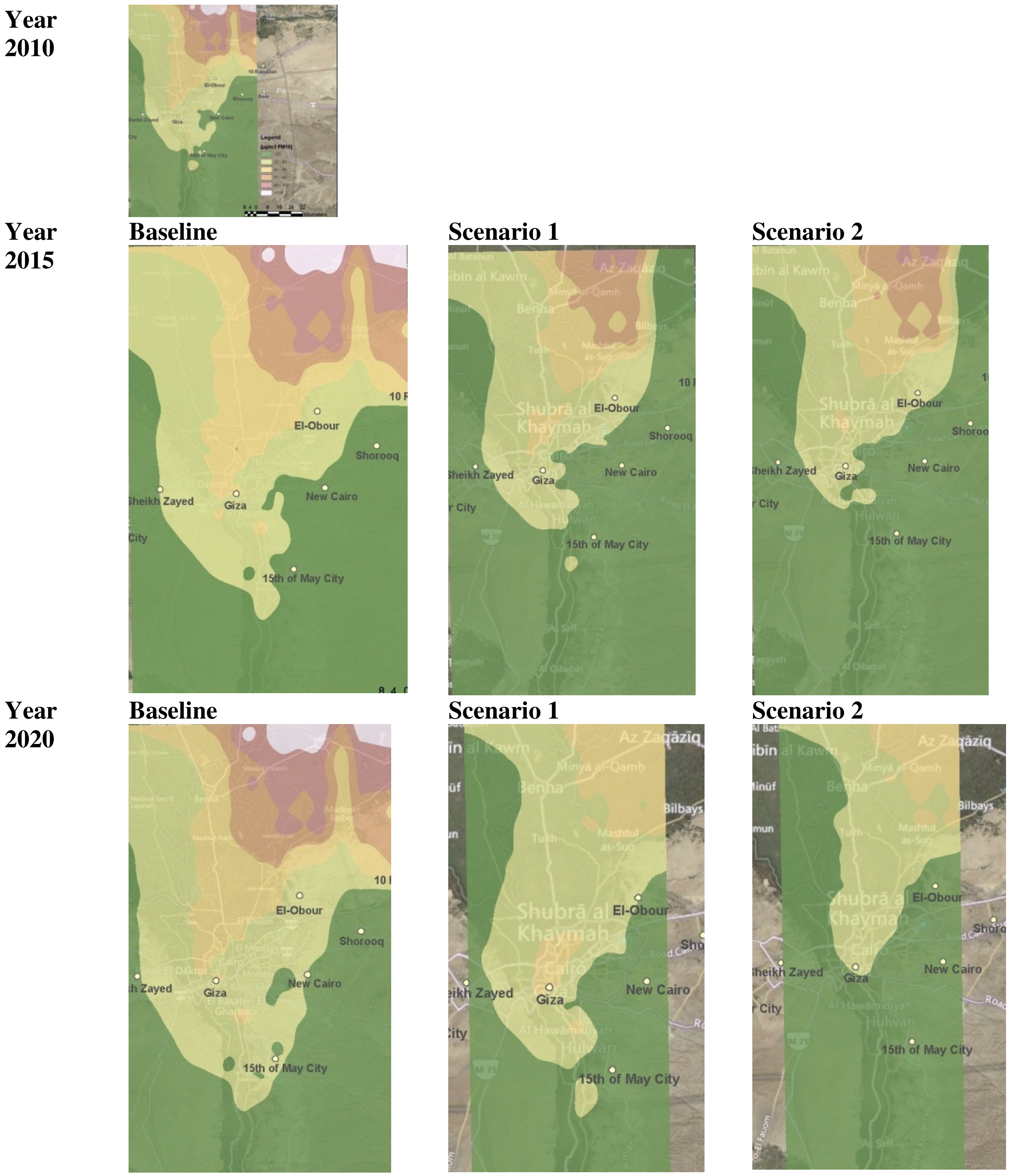


Figure 4.7. Calculated PM10 Concentrations for the Baseline Scenario, Scenario 1, and Scenario 2 (annual average, including the contribution of rice straw field burning)

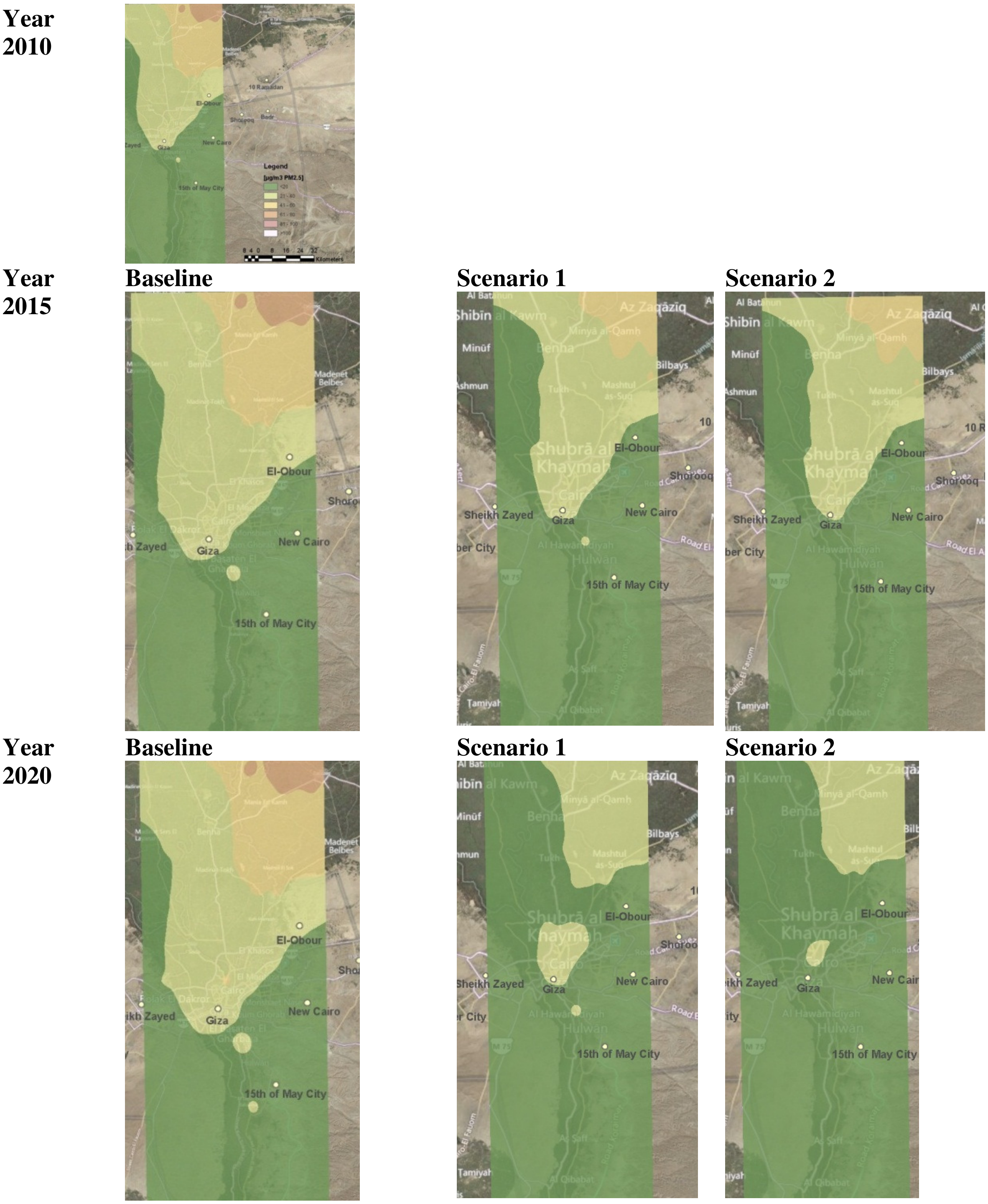


Figure 4.8. Calculated $PM_{2.5}$ Concentrations for the Baseline for the Baseline Scenario, Scenario 1, and Scenario 2 (annual average, including the contribution of rice straw field burning)

4.8 Calculated Concentrations versus Monitoring

The calculated concentrations in populated districts have been averaged and compared with the average GCMA concentration levels monitored by the EEAA (and presented in chapter3). The average of the calculated concentrations has been weighted by the size of the population to reflect the average exposure to air pollution in the GCMA.

Table 4.5. Modeled versus calculated concentrations

Pollutant	Monitored Annual Concentration 2008-2009 [μg/m^3]	Calculated Annual Concentration 2010 [μg/m^3]	Explanatory Note
NOx	121 – 68**	140	The calculated NOx concentrations are approx. 20 percent above the monitored range..
SO_2	28–39	23	The calculated SO_2 concentration is lower than the monitored range but in the right order of magnitude.
PM_{10}	131 - 144	41	The SAS indicates that approx. 65 percent of the contribution is caused by not modeled phenomena*. In view of this, the calculated PM_{10} levels appear to underestimate the levels by approx. 10 percent.
$PM_{2.5}$	72 - 83	26	The SAS indicates that approx. 50 percent of the contribution is caused by not modeled phenomena*. In view of this, the calculated $PM_{2.5}$ levels appear to underestimate the levels by approx. 30 percent.

** Geological material, marine particles, secondary species.*
*** The monitored NOx concentrations as presented in the table are based on the monitored NO_2 concentrations (presented in the previous chapter) and the observed NO_2/NOx ratio during 2008-2009 at 14 stations (amounting to 53 percent).*

It can be concluded that the averaged modeled NOx concentrations overestimate the situation. The calculated emissions or concentrations are strongly influenced by the transport emission factors. If we use mean values instead of the maximum, the calculated concentration would amount to approximately 80 μg/m^3 and falls within the monitored range. Annex 1 presents more details. SO_x concentrations correspond fairly well with the averaged monitoring data, whereas the modeled PM emission appears to underestimate the monitored levels by 10–30 percent.

A comparison of the calculated concentrations with the monitored concentrations of the individual monitoring station is not possible because the location of many significant emission sources is not known precisely, for example, the exact location of traffic. The traffic density and vehicle distribution (and driving conditions) were not available at the street level during the study.

4.9 Conclusions from Modeling Activities

Development—growth in population, industrial production, and transportation—will result in an increase in emissions and, therefore, in the concentration levels of NO_x, PM_{10}, $PM_{2.5}$, and SO_x in ambient air compared with the 2010 (baseline) situation. This means that, without proper policy, the inhabitants of the GCMA will be exposed to higher levels of harmful pollutants as a result of the expected increases in population, industrial production, and transportation.

Existing and envisioned environmental policies related to air quality mainly target the energy industry and (rice straw) field burning. The study shows that these environmental policies are beneficial for PM air quality, but are insufficient to improve air quality with respect to NO_x and SO_2 levels. Improvement in NO_x levels is possible, but will require the accelerated introduction of cleaner technology, especially in transportation, but also in power generation and industry. Improvement in SO_2 levels is also possible, but will require the gradual introduction of low sulfur (desulfurized) fuels.

The introduction of the best available technology can further reduce PM concentrations. It should be noted that lower NO_x and SO_2 levels will also reduce the potential for the formation of secondary particles (ammonium sulfate/nitrate). However, low PM levels are not deemed feasible given the high (semi) natural background concentrations.

5 Cost Assessment of Air Quality Degradation

5.1 Background

Based on the emission inventory established in chapters 3 and 4, the cost of the environmental degradation (COED) associated with outdoor air pollution has been estimated to show the monetary cost of air pollution degradation and the benefits that can accrue as a result of improving air quality in the GCMA. The estimates of environmental damage due to air pollution and the environmental benefits accrued as a result of interventions to reduce air pollution should be considered as orders of magnitudes and not as accurate figures. This is because of the lack of data in many sectors and the use of many assumptions and simplifications. Furthermore, the cost of environmental damage is usually compared with GDP, which should be carefully acknowledged because most of the costs of environmental damage have been calculated based, notably, on stated or revealed preferences (economic welfare analysis, cost-benefit analysis), whereas GDP is based on the added value of products and services (economic impact analysis, input-output models) (METAP 2009). Hence, the comparison of the cost of degradation to GDP is only an indicator and should be interpreted with care because economic growth has encountered a number of shocks over the last decade, notably, in 2005 with the devaluation of the Egyptian pound and in 2008 (see below) with the global financial crisis, the effects of which are still being felt in several regions. Nonetheless, the estimates in this chapter reflect the severity and magnitude of air pollution in the GCMA.

5.2 Methodology

Cairo air pollution has been evaluated on the basis of the dose response coefficients of PM_{10}, $PM_{2.5}$, SO_2, NO_2, and lead that were used in many previous studies (for example, Ostro et al. 1999, 2004; Pope et al. 2002, 2009). For urban air pollution, the impacts on health have been based on ambient air quality data provided by the EEAA (see chapter 2). The timeframe covers the period 1999–2009 depending on data availability.

The dose response coefficient represents a relationship between an incremental increase in the pollution concentration above the WHO guidelines and the burden on health of air pollution, which is expressed by the disability adjusted life years (DALYs) metric. This methodology has been developed and applied by WHO, the World Bank, and international experts. DALYs represent a measure of the disease burden of various illnesses and premature mortality and morbidity (Murray and Lopez 1996). A mild illness or disability represents a small fraction of a DALY; a severe illness represents a larger fraction of a DALY. A year lost to premature mortality represents 1 DALY, and future years lost are discounted at a 3 percent rate. In other words, a DALY lost is equivalent to *one year of healthy life lost*. The analysis relies on WHO standards instead of Egyptian standards to be compatible with the DALY methodology. Besides, these standards, which are more stringent than the national ones, provide an upper limit for protecting human health. Mortality and morbidity will therefore be expressed in terms of DALYs. For morbidity, the damage costs have been estimated by multiplying the number of DALYs by the cost of the illness. For mortality, there are two approaches to the valuation of life: (a) the human capital approach considers a lower bound, which is valued on the basis of GDP per capita, that is, if a person's life is lost, the economy loses at least the person's potential future contribution to production; and (b) the value of a statistical life (VSL) provides an upper bound in the monetary value of health damages. It represents the willingness to pay to avoid death by analyzing the individual behavior involved in trading health risks for money. In this study, the valuation adopts an approach at a midpoint between the human capital approach and the VSL.

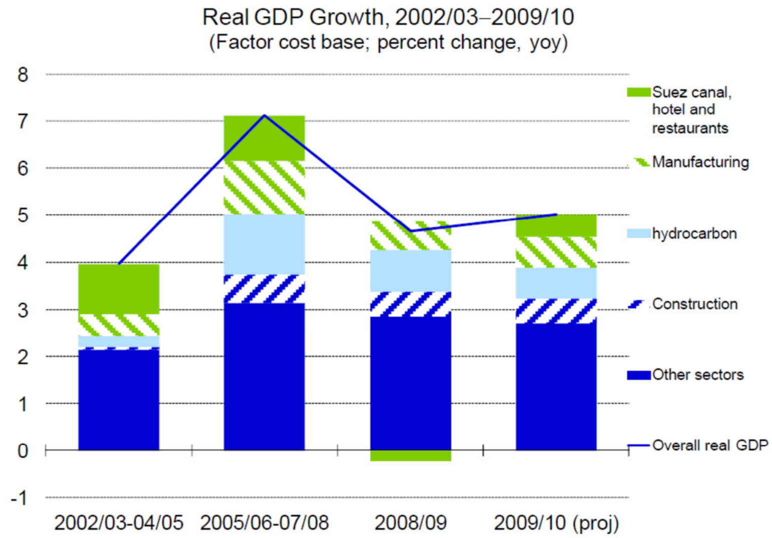
The degradation due to air pollution in any given year represents estimated costs in the present, as well as in the future, that is, physical impacts may occur in a particular year, but the economic consequences may span over several future years. For example, the death of a person may occur in a particular year, but the loss of this person's potential contribution extends a number years because the person could have lived longer if the degradation due to air pollution had not occurred. In our study, the 1999–2009 period is considered, and monetary results are presented in current and 2009 constant terms. Moreover, some of the 1999–2009 period benefits are discounted at 3 percent to put all present and future costs and benefits in a common metric, that is, their value in 2009.

Consideration has also been given to the cost of any mitigation action and the cost of such action in comparison with any benefits. The mitigation costs have been based as much as possible on data series derived from EEAA's planned or ongoing programs or on costs derived for similar investment activities. All remediation and damage costs have been calculated by using the discounted net present value (NPV). Figures have been obtained for (i) the cost of degradation, which is the actual degradation; and (ii) the averted cost, which is usually discounted at 3 percent and is the discounted flow of net benefits—if benefits accrue—over the lifetime of the project, divided by the number of years needed to bring all the figures to the same denominator.

5.2.1 World Bank 2002 Degradation Cost and Current Analysis Method Comparison

In 2002, the World Bank produced estimates of the damage cost of environmental degradation (COED) in Egypt for the year 1999. The estimate was 3.2–6.4 percent (with a mean of 4.8 percent) of GDP. The cost of indoor and outdoor air pollution in Greater Cairo (urban and rural), Alexandria, and rural areas (indoor pollution) was assessed at 1.1–3.2 percent (with a mean of 2.15 percent) of GDP (urban outdoor and rural indoor). The analysis did not account for lead, although it applied a benefit transfer to determine the population level of discomfort and the international tourism losses due to haze and poor air quality.

We have revised and updated the 2002 COED because it was not limited to the GCMA, but included other cities such as Alexandria, and because it did not include the damage cost associated with lead. Furthermore, the 2002 methodology has been refined by the World Bank (this study was the second of eight COED studies carried out in the Middle East and North Africa). In the current analysis, recent evidence on lead and PM_x exposure has been used to determine the burden on health associated with air pollution. Although the degradation associated with building and infrastructure decay, as well as the reduction in crop yields are problems, they have not been considered in the calculations. Also, the population living outside Greater Cairo bears some of the air pollution effects, but this has also not been considered in the analysis. Furthermore, because the EEAA data on air pollution are available for the last 10 years, the analysis could determine the cost of degradation as a function of GDP, recognizing that the increase in GDP over the last 10 years has not been linear because economic growth was about 4 percent until mid-2005, but economic activity picked up after the devaluation of the Egyptian pound against the U.S. dollar, notably the manufacturing and construction sectors (Figure 7.1). Hence, bringing these new factors into the current analysis weakens our ability to make comparisons with the 2002 World Bank analysis based on 1999 figures. Therefore, we have recalculated the cost of degradation from 1999 until 2009 by measuring the relative share of the burden of outdoor air pollution according to GDP.



Source: IMF 2010.

Figure 5.1. Real GDP growth, Egypt, 2002–10

5.2.2 The Burden of Air Pollution and the Cost of Degradation

In general, the decrease in major pollutants since 1999 has contributed to a reduction in morbidity and a reduction and then stabilization in the mortality rate, especially because of a reduction in the mortality attributed to lead. The decrease has occurred despite the growth of the population in the GCMA, which translates into a larger population exposed to harmful pollutants.

The relative share of morbidity in terms of the burden of disease is 54 percent over the 1999–2009 period, although it decreased in absolute terms by 30 percent between 1999 and 2009 and by 3.3 percent per year on average over 1999–2009 periods. PM_{10} remains the most harmful compound, at 60 percent in relative term, although it decreased in absolute terms by 29.4 percent between 1999 and 2009 and by 3.2 percent per year over 1999–2009. Moreover, ambient lead has not constituted a serious threat since 2006, whereas $PM_{2.5}$ has been almost constant over the periods (Table 5.1 and Figure 5.2). SO_x levels are no longer considered harmful because they are below WHO standards over the period, whereas the association of NO_2 concentrations and a range of adverse health effects is insufficient to establish causality based on the effects of NO_2.[12] It is likely that many observed health effects have arisen as a result of exposure to confounding traffic-related pollutants, mainly PM_x, and secondary pollutants that include O_3 and acid aerosol. The annual averages for NO_2 and NO_x are marginally above WHO standards and the effects are considered to be captured by considering the PM_x levels.

[12] WHO (2003).

Table 5.1. Greater Cairo Air Pollution Burden by Compound, DALY lost

Burden of Disease	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Yearly ±% 2009/99
Total DALY lost by Mortality and Morbidity												
Mortality	80,452	85,316	79,321	77,449	74,471	76,663	74,835	70,750	72,291	72,996	78,616	-1.1%
Morbidity	122,581	94,564	104,890	85,902	88,842	95,449	77,613	74,106	86,868	75,021	85,509	-3.3%
Total	203,033	179,880	184,210	163,350	163,313	172,112	152,448	144,856	159,159	148,018	164,124	-2.3%
Total DALY lost by Compound												
PM_{10}	134,565	104,320	114,672	97,053	98,457	105,492	85,670	82,442	96,608	83,406	95,068	-3.2%
$PM_{2.5}$	62,029	68,977	63,767	59,520	63,596	64,688	65,023	62,414	62,551	64,611	69,056	0.3%
Pb	6,439	6,583	5,771	6,777	1,260	1,932	1,755					-24.5%
Total	203,033	179,880	184,210	163,350	163,313	172,112	152,448	144,856	159,159	148,018	164,124	-2.3%
Population mn	15.8	16.2	16.5	16.9	17.3	17.7	18.0	18.4	18.7	19.0	19.4	2.2%

Source: Doumani (2011).

Note: 82 percent of the population was considered for the burden of disease calculation.

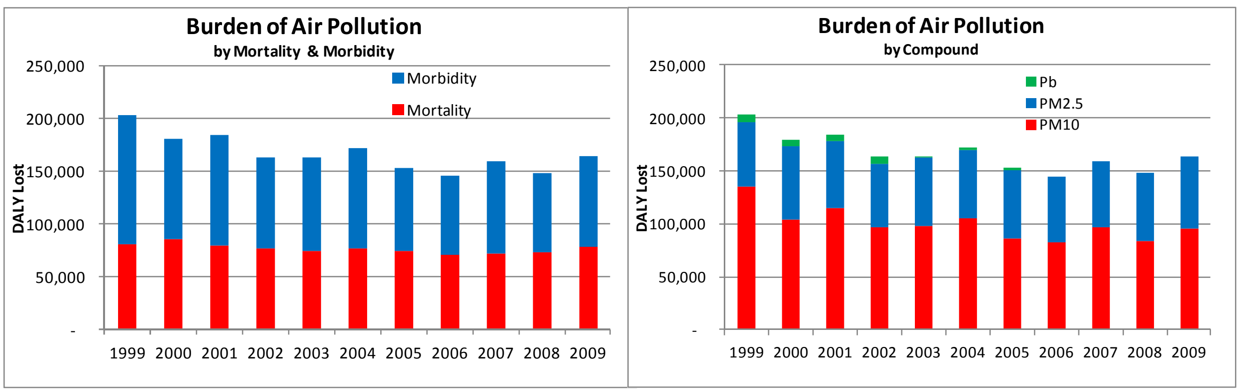


Figure 5.2. Greater Cairo Air Pollution Burden, DALY Lost

Relative to GDP, the cost of air-related degradation in Greater Cairo ranges between 0.9 and 1.3 percent over 1999–2009, with a yearly average of 1.03 percent, a low of 0.7 percent, and a high of 1.5 percent (Table 5.2 and Figure 5.3).

Table 5.2. The Cost of Degradation Related to Air Pollution in Greater Cairo, % of current GDP and LE, billions

Indicator	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Degradation Cost LE Bn	4.1	3.7	4.2	3.8	4.2	5.2	4.9	5.4	7.3	7.9	10.2
GDP current LE Bn	307.6	340.1	358.7	378.9	417.5	485.3	538.5	617.7	744.8	895.6	1,038.6
% of GDP	1.3%	1.1%	1.2%	1.0%	1.0%	1.1%	0.9%	0.9%	1.0%	0.9%	1.0%
% of GDP low	1.1%	0.9%	1.0%	0.8%	0.9%	0.9%	0.8%	0.7%	0.8%	0.7%	0.8%
% of GDP high	1.5%	1.2%	1.3%	1.1%	1.1%	1.2%	1.0%	1.0%	1.1%	1.0%	1.1%

Source: Doumani (2011).

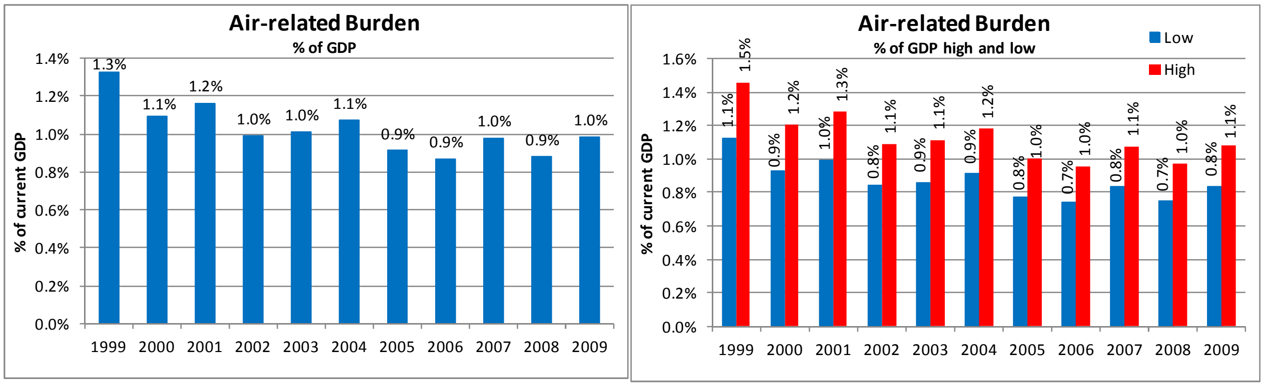


Figure 5.3. The Cost of Degradation Related to Air Pollution in Greater Cairo, % of current GDP

Nonetheless, two factors have influenced the variation over the period: the increase in environmental degradation (+9.6 percent per year) almost matches economic growth (+9.5 percent per year) in current prices as key progress in wide-ranging structural reforms accelerated after 2004, and, after more than 10 years of efforts, public policies have been brought to bear that help keep the pollutants and the relative degradation to GDP in check even though the effects are being felt over a larger population.

If calculated in constant 2009 Egyptian pounds, the cost of degradation due to air pollution increased almost 1.5 times, from LE 6.6 billion in 1999 to LE 10.2 billion in 2009 (in constant 1999 prices) as shown in Table 5.3 and Figure 5.4.

Table 5.3. Greater Cairo Air Pollution, Cost of Degradation, current and 2009 constant LE, millions

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total	Yearly ±% 2009/99
Current													
PM_{10}	3,327	2,809	3,291	2,867	3,271	4,063	3,651	4,020	5,665	5,866	7,732	46,562	9.1%
$PM_{2.5}$	684	838	814	799	938	1,105	1,228	1,347	1,623	2,009	2,483	13,868	12.9%
Pb	63	76	70	86	18	31	29					373	-17.7%
Total	4,075	3,723	4,174	3,752	4,227	5,199	4,909	5,367	7,288	7,875	10,214	60,803	9.6%
2009 constant													
PM_{10}	5,350	4,286	4,851	4,128	4,564	5,446	4,685	4,827	6,352	6,139	7,732	58,360	4.1%
$PM_{2.5}$	1,100	1,279	1,200	1,151	1,308	1,481	1,576	1,618	1,820	2,103	2,483	17,117	7.7%
Pb	101	116	103	124	25	42	37	-	-	-	-	548	-20.6%
Total	6,552	5,681	6,153	5,403	5,897	6,969	6,298	6,445	8,172	8,242	10,214	76,026	4.6%
Deflator	62.2	65.5	67.8	69.5	71.7	74.6	77.9	83.3	89.2	95.6	100.0		

Source: Doumani (2011).

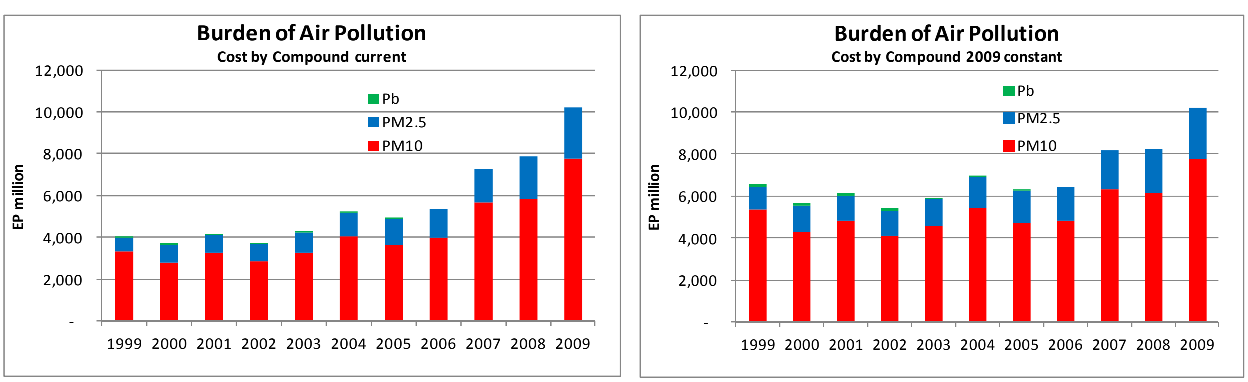


Figure 5.4. Greater Cairo Air Pollution, Cost of Degradation, current and 2009 constant LE million

The COED increased in absolute terms, but was kept almost constant as a function of GDP. Nonetheless, there have been significant gains as a result of government policies and infrastructure investments that led to a decrease in pollutant concentrations, particularly lead. The estimated gains accrued since and even before 1999. Hence, the mean pollutant levels of 1999 were, conservatively, kept constant until 2009 to derive the benefits that are the difference between the with and without government intervention scenarios (Table 5.4 and Figure 5.5).

The cumulative degradation cost in Greater Cairo over 1999–2009 amounts to LE 60.8 billion in current prices and LE 76 billion in 2009 constant prices. The net present value of the degradation cost amounts to LE 43.8 billion and LE 56.1 billion, respectively, with an equivalent annualized average of LE 4.0 billion in current prices and LE 5.1 billion in constant prices. The degradation cost increased over the 1999–2009 period (by 9.6 percent in current prices and 4.6 percent in 2009 constant prices). PM_{10} was the compound that was the greatest burden to society because of the rising health care costs: it represents, on average, 76.6 percent of the total degradation cost in current prices over the period and the related cost increased by 9.1 percent over the period.

The cumulative social benefits in Greater Cairo over 1999–2009 (in terms of averted costs attributable to the reduction in air pollution) amounts to LE 34.7 billion in current prices and LE 41 billion in 2009 constant prices. The net present value of social benefits amounts to LE 23.5 billion in current prices and LE 28.3 billion in 2009 constant prices over the period (Table 5.4 and Figure 5.5).

Table 5.4. Greater Cairo Air Pollution, Degradation Cost, LE, billions

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total	Yearly ±% 2009/99
Current													
With Gov.	4.1	3.7	4.2	3.8	4.2	5.2	4.9	5.4	7.3	7.9	10.2	60.8	9.6%
Without Gov.	4	5	5	6	6	7	8	10	12	15	17	95.5	15.0%
Benefit	-	1	1	2	2	2	3	4	5	7	7	34.7	24.3%
2009 constant													
With Gov.	7	6	6	5	6	7	6	6	8	8	10	76	4.6%
Without Gov.	7	8	8	8	9	10	11	12	13	15	17	117	9.7%
Benefit	-	2	2	3	3	3	4	5	5	7	7	41	18.4%

Source: Doumani (2011).

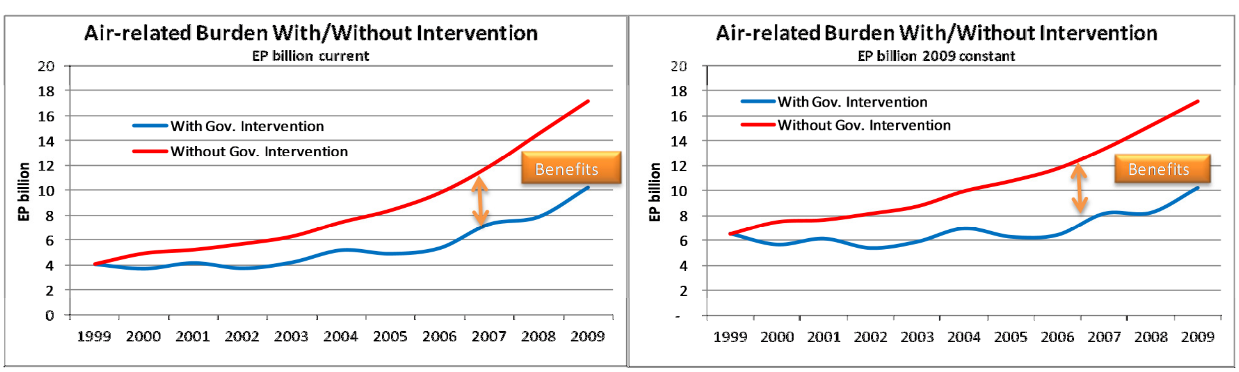


Figure 5.5. Greater Cairo Air Pollution, Degradation Cost, LE, billions

5.2.3 Summary

The health risks associated with ambient pollution in Greater Cairo gradually diminished over 1999–2009. However, the reduction in morbidity associated with the dramatic reduction of PM_{10} and Pb was outweighed by the effects of $PM_{2.5}$, which was reduced by 2 percent over 1999–2009 periods and had a direct impact on mortality in a megacity with a growing population. The benefit of a reduction in pollution in Greater Cairo related to the with and without government intervention scenarios shows a slowdown in degradation growth: 9.7 percent per year in the without government intervention scenario compared with 4.6 percent per year in the with government intervention scenario between 1999 and 2009 in constant terms. Conversely, the degradation cost in relative terms is increasing due to both an increase in the cost of illness associated with PM_{10}, despite the sensible reduction in this compound over 1999–2009 (-5 percent per year) and the accelerating pace of the economy that is, notably, increasing the car population and therefore traffic jams despite the efforts undertaken to reduce emissions from vehicles (inspection, CNG cars and buses, and so on). Nonetheless, the urban air pollution management in Greater Cairo seems effective, though it cannot be directly assessed from an efficiency standpoint because the budgets for these policies are not readily available.

6 Similar Experiences in Other Megacities

In this chapter, the experiences of selected cities in combating air pollution are presented. Cities like Los Angeles in USA, Bangkok in Thailand, Jakarta in Indonesia, Manila in the Philippines, Mumbai in India display several characteristics similar to Greater Cairo and succeeded in controlling air pollution through the adoption of a series of policy instruments.

6.1 Bangkok (Thailand)

Bangkok has an official population of 8.2 million residents, and the greater Bangkok area has about 14.5 millions. The major sources of air pollution in Thailand are industries, power plants, transport, and area sources that include agricultural wastes and biomass burning. The main pollutant of concern is PM_{10}. Air quality in Thailand has improved significantly in the past decade (World Bank, 2002a). Lead, particulates, and carbon monoxide in Bangkok and other urban centers had decreased to an acceptable level and the data shows decreasing trends. Such improvements in air pollutant levels in recent years can be attributed to the government's efforts to policy corrections, massive public spending in infrastructure, stringent enforcement, and the market's response to advanced technologies.

The major actions for reducing transport pollution: (a) fuel reformulation by reducing benzene and aromatic compounds to 3.5and 35 percent respectively and reducing sulfur content from 1.0% to 0.5 percent by weight; (b) adopting European Union reference standards for vehicles (Euro 5 was came into force in September 2009 and more stringent Euro 6 will be introduced in 2014) and shifting 80 percent of Thai motorcycle production to 4-stroke engines. The number of Tuk-Tuk[13] used to be one of the biggest polluters in Bangkok, were reduced and those remaining were required to run on liquefied petroleum gas (LPG); (c) expansion of natural gas for vehicles. Fewer than 10,000 vehicles out of registered 26 million use natural gas for fuel, the most notable of which are taxis, city buses, and municipal garbage-collection trucks.

In order to reduce industrial pollution; (a) new stringent emission standards were enacted and factory's operating, license are revoked in case of non compliance; (b) reducing sulfur content of not more than 2 percent by weight (c) imposing self monitoring requirements in all industries

Thailand is an agricultural country, which grows plants, such as rice, corn, and sugarcane in all parts of the country. In 2003, there was about 67.4 million tons of agricultural waste, which the farmers often burn in order to prepare for new planting area. This method of burning is the most convenient and economic for the farmers but would create about 0.28 million tons of dust. Therefore, open burning is the main cause of Haze pollution, especially dust, ash and particles. On July 22, 2003, the cabinet agreed on the National Master Plan on open burning control and appointed concerned organizations to draft the Open Burning Control Plan of Implementation under the National Master plan on Open Burning Control. The objective of the National Master plan on Open Burning Control is (1) to prepare action plans and guidelines under ASEAN[14] Agreement on Trans-boundary Haze Pollution and (2) to introduce an open burning control policy as a strategy that every related organization has to participate in the prevention, reduction, and mitigation of air pollution arising from open burning, and (3) to be a framework for involving organizations to work in the same direction. The aim, inter alia is to manage 96,000 ha of agricultural waste instead of burning, use commercialize agricultural waste as a biomass energy source at 24 percent of energy requirements in 2006 and 25 percent in 2007, and reduce open burning of solid waste by using sanitary waste disposal methods for 50 percent of all provinces and utilize 30 percent of waste generated in 2006.

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[13] A three-wheeled cabin cycle.

[14] Association of South East Asian Nations is a geopolitical and economic organization of ten countries in South Asia, committed to economic growth ,social progress and protection of peace and stability

6.2 Beijing (China)

Beijing is one of the most populous cities in the world with population of about 20 million. The main source of PM10 and PM2.5 is industry and power plants (41 and 44 percent, respectively), mobile-related sources (31 and 33 percent, respectively) and domestic, construction sources and soil (28 and 23 percent, respectively) (Zhang et al, 2004). Although TSP and PM10 concentrations have been decreasing in Beijing in the period 1996–2004, they still exceed their respective Class II standards[15] (BJEPB, 2005). The PM_{10} standards for one year and 24 hours are more lenient than the EU limit values, the WHO guideline values and the USEPA annual standard but the Chinese PM_{10} standard for 24 hours equals the USEPA 24 hour standard. The annual Class II standards for SO_2 and NO_2 are more stringent than those of the USEPA, but are lenient or equal to the EU limit.

China has implemented a number of regulations to help prevent and control air pollution from mobile sources including standards to regulate exhaust emissions from gasoline and diesel vehicles with normal and full loads. Both gasoline and diesel fuels distributed in the city need to comply with legal specifications for each fuel type, however, the sulphur contents of are still relatively high. These fuel specifications are only Euro 1 compliant.

Stationary sources of air pollution are also regulated in Beijing. Emissions from thermal power plants; cement plants; coal-burning, oil-burning and gas-fired boilers; coke ovens; industrial kilns and furnaces and even cooking fumes are all subject to emission standards. Specific regulations and standards are also being implemented for solid waste – specifically on incineration of municipal solid wastes and hazardous wastes; storage and disposal sites of solid wastes from general industries; and on pollutants from fly ash use in agriculture (SEPA, 2006).

6.3 Jakarta (Indonesia)

Jakarta has a population of 9.6 million and the population of the greater Jakarta reaches almost 30 million. A 1998 estimate of emission levels in Jakarta indicated that about 70 percent of NO_x and PM_{10} were emitted from the transport sector, and about 25 percent from industrial sector. The health impacts and costs of air pollution in Jakarta for PM_{10} and NO_x in 1998 have been estimated to cost $181 million equivalent to 1 percent of Jakarta's GDP. This is mainly due to PM, while NOx estimates accounts for $4.24 million.

In order to reduce vehicle and industrial pollution, the government developed for Jakarta emission standards that are stricter than the national standards for some pollutants. It introduced an inspection and maintenance (I&M) program that requires all vehicles to comply with emission quality standards and established stricter emission standards for industries

6.4 Los Angeles (USA)

With its population of 14 million, Los Angeles was known to have frightening smog in the eighties and nineties, because of its topography, weather conditions increased population, and transport and industrial pollution. Los Angeles has the highest rate of lung diseases and premature death in the United States[16]. In order to try to reverse the situation, the local government decided to (a) have a strong political will by putting air pollution on the top of its priorities and by determining that improving fuel quality programs are most cost effective than traffic management measures; (b) change the legislation by adopting emission

[15] National ambient air quality standards are categorized into three classes. Designated industrial areas are expected to comply with Class III standards, residential areas with Class II standards, and parks and specially protected areas with Class I standards. Regulation GB3095-1996 requires Beijing to comply with Class II standards.

[16] http://scipeeps.com/los-angeles-air-pollution/

standards that are as tough as the federal standards; and (c) focusing on strict monitoring and enforcement of industrial and transport pollution.

6.5 Manila (Philippines)

Manila has a population of 1.7 million and greater Manila population reaches 20.7million[17]. Based on the 2006 National Emissions Inventory, the transport sector is the major source of air pollution in many regions of the country. It was estimated that 65 percent of the pollutants came from mobile sources, 21 percent from stationary sources, and the remaining 14 percent from area sources[18]. A recent World Bank study shows that more than 1 million people get sick and about 15,000 people die prematurely every year due to outdoor air pollution in urban areas in the Philippines. The cost of disease from outdoor air pollution is estimated at more than US$20 million yearly; considering income lost from deaths would bring the cost to more than US$120 million annually.

Several measures were taken to control air pollution. Emission standards were revised to be more stringent and similar to the WHO guidelines. All fuels sold in the country are mandated to contain locally-sourced biofuels components (bio-ethanols). In addition to promoting the use of biodiesel and bio-ethanol, the government also implements a Natural Gas Vehicle Program for Public Transport (NGVPPT) and an Autogas program. A National EST Strategy and Action Plan for the Philippies were formulated. Its overall strategy is to reduce the annual growth rate of energy consumption and associated greenhouse gas emissions from the transport sector in urban areas in the country, promotes transportation systems of low carbon intensity and shift towards the use of more sustainable transport modes. A permitting, adjudication and reporting system is in place to ensure companies comply with environmental laws including the Clean Air Act.

6.6 Mexico City (Mexico)

The Mexico City Metropolitan Area (MCMA) is the second largest populated city in the world, with 26 million inhabitants. Mexico City has experienced high levels of ozone and particulate air pollution in the mid-1980s. In the 1990s, there were successful reductions in the concentrations of some pollutants such as lead, carbon monoxide and sulfur dioxide.

Comprehensive air quality management programs were developed and carried out. The government strengthened monitoring and evaluation of air pollution, and enforcement of a vehicle inspection and maintenance program. Fuel switching to natural gas was introduced in industry and the power sector. Among other measures, specific actions reduced volatile emission from gasoline stations and storage tanks in industry, as well as removal of lead from gasoline and the implementation of catalytic converters in automobiles. In addition, programs such as "No driving day" have been used as incentives to modernize the vehicle fleet and to help insure the proper maintenance of vehicles.

6.7 Mumbai (India)

Mumbai is the most populated city in India and the fourth most populated city[19] in the world with a metropolitan population of 20.5 million. It is also the richest city in India, and has the highest GDP of any city in South, West or Central Asia. A comprehensive emission inventory was conducted in 1997 for

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[17] "World:metropolitan areas". World Gazetteer. http://world-gazetteer.com/wg.php?x=&men=gcis&lng=en&dat=32&srt=npan&col=aohdq&pt=a&va=&srt=pnan. Retrieved 2010-01-22

[18] DENR and UNEP. 2009. National State of the Brown Environment Report (2005-2007). http://www.emb.gov.ph/eeid/2010/publication/NSOBER.pdf

[19] http://en.wikipedia.org/wiki/Mumbai

Mumbai as part of the Urban Air Quality Management Strategy (URBAIR). It was found in the study that the TSP exposure was primarily due to re-suspension from roads caused by vehicles (40 percent), followed by domestic wood and refuse burning (31 percent), and emission from diesel and gasoline vehicles (14 percent) (World Bank, 1997).

The following measures were taken to mitigate emissions. India started adopting European emissions and fuel regulations for four-wheeled light-duty and for heavy-duty vehicles. Sulfur content in diesel was decreased to 0.05 percent by weight and gasoline with 1 percent benzene was supplied to the whole of NCR. All government vehicles were required to fit CNG kits or catalytic converters in December 1996 and emission norms for CNG/LPG vehicles and for diesel vehicles fitted with LPG engines were made effective from May 2003.

Table 6.1. European Union reference standards for vehicles

Standard	Gasoline		Diesel
	Lead	Sulfur (ppm)	Sulfur (ppm)
Euro 1	**0**	**NA**	**NA**
Euro 2	**0**	**500**	**500**
Euro 3	**0**	**150**	**350**
Euro 4	**0**	**50[a]**	**50[a]**
Euro 5	**0**	**NA**	**50[a]**

(a) 10 PPM is in the late stages of Adoption by the European Union
Source: ADB http://www.adb.org/documents/guidelines/vehicle_emissions/im_ch03.pdf

Table 6.2. Ambient Air Quality Standards (µg/m3)

		WHO	US EPA	EU	Philippines	Thailand	Indonesia	India	Egypt	Beijing
TSP	Daily				230	330			230	300
	Annual				90	100			125	200
PM10	Daily		150	50	150	120	150	150/100/75	150	150
	Annual		50	40	60	50		120/60/50	100	100
PM2.5	Daily							60	70	
	Annual			25				40	100	
Pb	1-month		1.5 (3 mon)			1.5			0.5-1	
	Annual	0.5		0.5	1		1			
O3	1-hour		235			200	235			160
	8-hours	120	157	120	60				120	
SO2	Daily	125	365	125	180	300	365	120/80/30	125	150
	Annual	50	80	20	80	100	60	80/60/15	50-60	60
NO2	1-hour			200		320	400	120/80/30 (	150	240
	Annual	40	100	40	1		100	80/60/15	60-80	40

6.8 Conclusion

There are common characteristics that the above cities have adopted namely: (a) a political will at the highest level to be able to control air pollution; (b) adopting stringent emission standards especially for vehicles and for motorcycles; (c) improving the quality of gasoline and diesel, by reducing the amount of benzene and aromatic hydrocarbons in gasoline and sulfur content in diesel; (d) expanding on the use of CNG especially for public transport and the two stroke, three wheelers Tuk-Tuk; and issuing environmental permits for ensuring compliance with stringent source emission standards.

In analyzing these characteristics with those applied in Cairo, the following can be observed:

a) Egypt has similar air quality standards to the above cities but has a more relaxed concentration on $PM_{2.5}$.
b) Fuel formulation in the above cities has constantly improved though Egypt continues to use high sulfur diesel and heavy fuel oil.
c) Countries have adopted vehicle emission standards at the level of Euro 4 and Euro 5 with less emissions of NO_x, $PM_{2.5}$, PM_{10} and CO while Egypt emission standards are similar to Euro 2.
d) VET is being used in these cities, while, in Egypt, VET is confined to Giza and Qalyoubieh Governorates.
e) Monitoring and Enforcement of vehicle emissions is being strengthened in these cities, whereas it is seriously lacking in Greater Cairo.
f) CNG has been widely used in these cities though it is confined only to taxis in Greater Cairo.
g) Environment permits are being issued for industrial facilities with stringent emission regulations though the legal framework in Egypt does not require the issuance of an environment permit which includes compliance with specific emission conditions, rather the MSEA approval is required for all EIA, and subsequently for the review of the environmental register.
h) A country like Thailand has prepared an Open Burning Control Plan of Implementation under the National Master plan on Open Burning Control. Although Egypt has taken several measures and investments such as composting, animal feeds, biogasification, and pelletizing for the fuel use of rice straw, there is currently no strategy formulation for rice straw and agricultural waste that is economically sustainable at both the national and local levels [20]

A comparison of the costs and benefits leads to the prioritization of the measures, therefore various measures are listed in the Annex 3 with description of cost and benefit. From a cost-benefit point of view the measures that should receive priority are (World Bank. 1997):

a) Inspection and maintenance scheme;
b) Introducing unleaded gasoline; and,
c) Introducing low-smoke lubricating oil.

As to Inspection and maintenance scheme, Egypt has vehicle inspection system, including emissions testing; I/M program for transit buses. Euro 2 standards were meant to be in effect from January 2002, but fuel specs were incompatible with high sulfur content. The sulfur level in diesel fuel contributes significantly to high emission rates of PM and it remains high in Egypt according to the study conducted by the United Nations Environment Program's (UNEP) 'Partnership for Clean Fuels and Vehicles' initiative in 2009.

As to phase-out from leaded gasoline, Egypt has already phased out from leaded gasoline according to the UNEP study, however, the sulfur level remains still high. Algeria, Iraq, and Yemen are the only countries in the region which still use dual system.

It is noted that a strategic approach for the air pollution control with integrated several instruments should be developed rather than focusing primarily on one or two measure. From experiences in Asian cities, such strategic and integrated approach would incorporate the following:

- Developing clean air implementation plans as formulated in the Strategic Framework. This includes addressing the greatest challenges such as emission inventories and health and environmental impact assessments.
- Extending dedicated air quality legislation to other sectors, involving all stakeholders, and strengthening the use of economic instruments.

[20] Data Collection and Survey on Agricultural Waste Management, JICA, September 2009

- Emphasizing transport demand management and transport planning. This would include reducing the need to travel for essential services, providing attractive and efficient public transport systems, developing an urban environment that is clean, safe and more conducive to walking and cycling.
- Accelerate car replacement programs using incentives to take ageing, polluting cars off the road, and establish a vehicles emission testing program.
- Upgrade the quality of fuels, particularly by reformulating gasoline and reducing sulfur content in diesel.
- Increasing the use of land use planning tools in AQM (e.g. zoning) and taking into consideration air quality information in roads and industrial site planning.
- Promoting the adoption of sustainable integrated SWM strategies with emphasis on a preventative waste management hierarchy.
- Developing policy, legal, and institutional frameworks supportive of sustainable integrated SWM.
- Tightening air quality standards towards the EU limit values and/or WHO guideline values.
- Increasing political and public awareness of the health and environmental impacts of air pollution and their costs in relation to the costs of air pollution abatement.
- Promoting more public health and environmental studies in the framework of environmental impact assessment.

7 Policy Analysis and Recommendations

7.1 A Glass Half Full: Improvements in Ambient Air Quality

The major investments undertaken by the government of Egypt in the last decade has been successful in combating a number of serious air pollution issues in Greater Cairo, such as:

- Eliminating lead by the introduction of unleaded gasoline and the relocation of lead smelters,
- decreasing SO_2 concentration levels by the fuel shift from heavy fuel oil to natural gas,
- Moving industrial air pollution hot spots away from residential areas,
- Introducing cleaner technology in the most polluting industrial sectors,
- Partially regulating and controlling of open burning (rice straw and open waste burning),
- Expanding on roads, highways and mass transit.

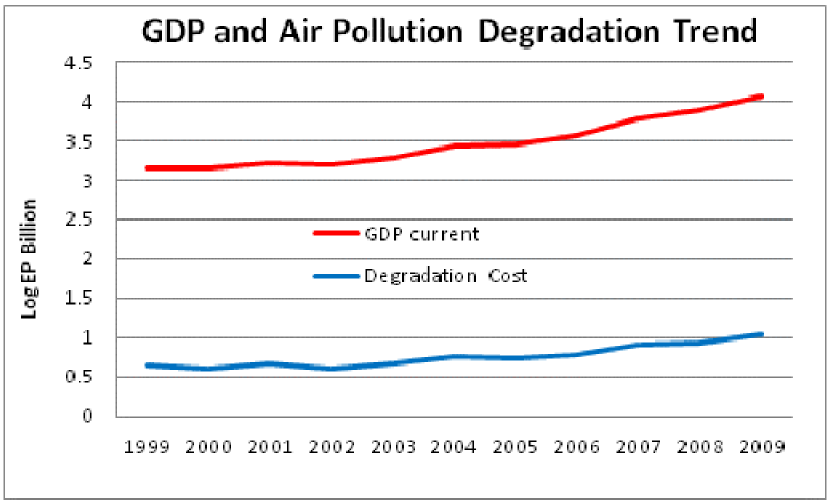

Figure 7.1. Egypt GDP and Greater Cairo Cost of Air Degradation, 1999-2009

These interventions led to:

a) **A gradual improvement of public health** as the reduction of morbidity has decreased due to a decrease of PM_{10} by more than 38 percent and lead by more than 50 percent, however, the reduction of mortality due primarily to $PM_{2.5}$ was slow and was reduced only by 8 percent between 1999 and 2009.

b) **Improvement of social benefits** in terms of averted cost attributable to the reduction of air pollution and amounted to LE 34.7 billion in current prices and LE 41 billion in 2009 constant prices over that period. The net present value of social benefits amounts to LE 23.5 billion in current and LE 28.3 billion in 2009 constant prices over the periods. The relocation and cleanup of the Shoubra El Kheima lead smelter alone generated in itself LE 474 million in social benefits. (USAID, 2004).

c) **Stabilizing the cost of environmental degradation** in the range of 0.9-1.3 percent with 1 percent in 2009. The environmental degradation growth (+9.6 percent) almost matches economic growth (+9.5 percent) over the periods as key progress in wide-ranging structural reforms accelerated after 2004; and the combined public policies were brought to bear after more than 10 years of efforts that helped keep the pollutants and the relative air degradation to GDP in check although the spread is over a larger population.

7.2 A Glass Half Empty: Improvements Should be Interpreted Cautiously

Despite the decrease of ambient concentration during the last decade, the level of pollution remains high compared to WHO guidelines. PM_{10} is the main cause of morbidity and $PM_{2.5}$ is the main cause of mortality. Both could be of anthropogenic origin, but may also have a natural or semi-natural origin (desert dust, marine particles, re-suspended dust). As the natural sources of particulate matters are functions of topography, meteorological conditions and increasingly climate change, interventions for combating natural dusts are difficult and costly unless Cairo could be surrounded by a green belt that was already initiated at a small scale.

Major sources of manmade PM_{10} include road transport, open burning (rice straw and, to a lesser extent, other agricultural residue burning; traditional charcoal production and open waste burning), construction and demolition, and cement production. The main sources of $PM_{2.5}$ are similar to those of PM_{10} but combustion related sources are more significant as this combustion consists of relatively smaller particulates. Also sulfur dioxide emissions are caused by consumption of fuel with "high sulfur"[21] content: 2.5%, 1%, and 0.05 percent for heavy fuel, diesel, and gasoline, respectively. which is the main cause of SO_2 levels (lower than Egyptian and WHO thresholds of 60 and 50 $\mu g/m^3$respectively) with the most significant sources emanating from road transport and manufacturing industry. Nitrogen oxides emissions are caused by road transport (passenger cars, trucks and buses), which is by far the most important source to NOx/NO_2 concentrations in urban areas. However, many NOx/NO_2-related health effects observed occur as a result of exposure to confounding traffic related pollutants, mainly PMx and/or secondary pollutants that include O_3 and acid aerosol (see Chapter 5).[22] In industrial areas, the contributions of both industrial sources and road transport are significant.

In absolute terms, the damage costs resulting from this pollution has increased by more than two fold from LE 4.1 billion in 1999 to LE 10.2 billion in 2009 due to the increase of population, increase in heath costs and increase of cost of living such as additional vehicles and expansion of construction areas and new cities.

Nevertheless, relaxing national standards for PM_{10} and $PM_{2.5}$ which were issued in the executive regulations for law 9 of 2009, gives the wrong signal of "Polluting More" than "Polluting Less". Mortality and morbidity can be decreased whenever the national standards reach the WHO annual concentration of PM_{10} (20 $\mu g/m^3$) and $PM_{2.5}$ (10 $\mu g/m^3$). It is clear that the more stringent the air quality standards, the larger are the social benefits and the decrease in COED relative to GDP.

7.3 Continuing with the "Business As Usual" Approach is Not the Answer

In case of no actions are taken by the government to control further air pollution, the situation is expected to deteriorate faster in the coming years as reflected below:

- More people in the GCMA will be exposed to higher level of pollution. Isocontour plots in 2010, 2015 and 2020 show an increase in pollution for the new cities of Sheikh Zayed, 15 of May and 6th of October which were established to partly reduce the congestion of Cairo. It is therefore expected that more than 4.6 million people will be further exposed between 2010 and 2020. Moreover, residents surrounding GCMA will also be exposed to increased emissions that will affect their health and agricultural yields.

[21] Ministry of Petroleum (June 2011).
[22] WHO (2003).

- Ground level emissions (such as those from transport and agricultural waste burning) make a contribution to ground level concentrations 50 times greater than stack sources (i.e., 1 ton of ground level emission causes the same level of damage as 50 tons of stack emissions).[23]
- It is also anticipated that an additional 137,000 persons will suffer from chronic pulmonary and cardiovascular diseases, lower respiratory illness in children will reach about 11.1 million cases (Doumani, 2011) and that premature mortality will increase to about 66,300 between 2010 and 2020.
- The calculated emissions for 2010, 2015 and 2020 will show a slight increase in emissions under the business as usual scenario as shown in Table 7.1 assuming that fuel efficiency will improve by 1 percent a year over the next 20 years and that there will be no replacement of existing vehicles by vehicles with lower exhaust emissions and that there will be additional vehicles with cleaner engines. The sulfur contents of the fuels and field burning of agricultural wastes will remain unchanged.
- As a result, the damage costs are expected to further increase to reach LE 19.7 billion (see Figure 7.1) in 2020 within GCMA boundaries due to increase in PMx and the COED can reach 1.2 percent of GDP as more people will be exposed to pollution and because the cost of illness and that the figure associated with mortality was estimated to increase 4 percent per year over the 2010-2020 periods. Although it was stated earlier that during the last decade the environmental degradation growth (+9.6 percent) almost matches economic growth (+9.5 percent), it is anticipated that the degradation growth rate will surpass the economic growth given the slow pace of the present economy in Egypt.

Table 7.1. Air Pollutant Projection by Scenario, 2010-2020

Item **Pollutant (Mean annual)**	**Unit**	**2010**	**2015**	**2020**
Business as Usual				
$PM_{2.5}$	$\mu g/m^3$	76	77	78
PM_{10}	$\mu g/m^3$	141	144	145

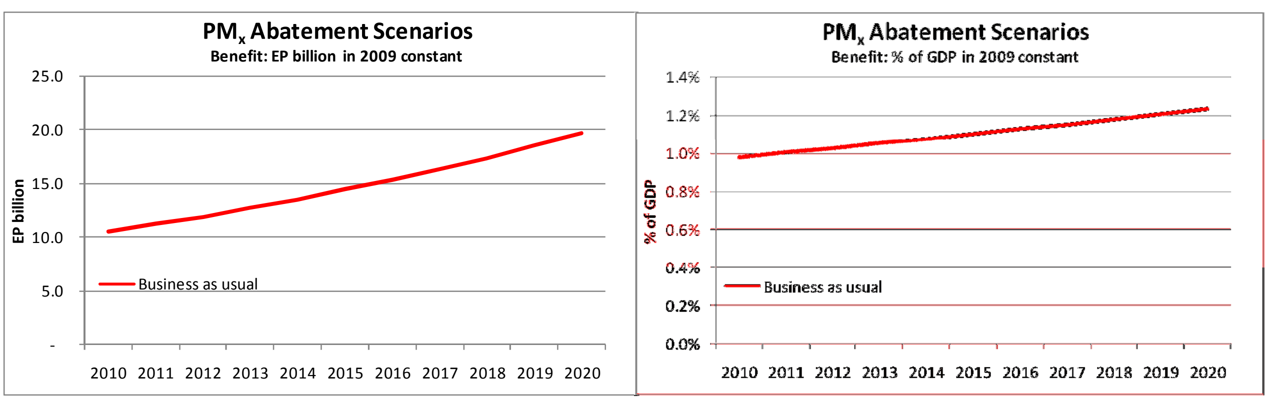

Figure 7.2. Greater Cairo Business as Usual Air Degradation Cost

[23] Egypt: Energy-Environment Review, the World Bank (2003).

And the current socio-political situation is not conducive to a quick fix. Further reduction of air pollution is dependent on a number of external factors which could seriously impact the reduction of air pollution:

- The recent political events on Egypt's economy remain uncertain. The GDP is projected to expand by less than 1 percent in 2011 and could recover to 5 percent growth by 2013.[24] It is unlikely that the government priority will provide further investments for reducing air pollution as it may not be among its most important economic and social priorities.
- A move to reduce energy subsidies is also not anticipated in the short term. The removal of energy subsidies from the industrial sector has been slowly implemented and the gasoline and diesel prices are expected to be less sensitive to the fluctuation of the international prices in the short term.
- There is no single quick fix technological solution for reducing air pollution in Greater Cairo, as issues related to informal housing, rural migration, increase in population, lack of urban and rural planning, transport management and weak enforcement have accumulated over the last decades and are not likely to be resolved in the short and medium term.

Notwithstanding these uncertainties and until the political and socio-economic climate stabilizes, adopting measures can be recommended provided that they are flexible, realistic and phased in and are compatible with economic growth and are administratively practical.

Given these constraints, the proposed strategy should focus on addressing as a priority the local air quality issues and problems, unless these are addressed first, Egypt commitments towards the international conventions will lack credibility in the eyes of the Cairenes.

7.4 The Proposed Strategy

It is, therefore, necessary to prepare and implement a strategy that is flexible and realistic through a three inter-related pillars:

- **Pillar 1: Building institutions in the short term (1-3 years)** by establishing an air quality management system in GCMA. This is key to the successful implementation of the strategy that would reflect the government's commitment and would justify involvement of the International Financing Institutions and Donors.

- **Pillar 2: Targeting <u>cost-effective</u> investments in the medium term (2-5 year**s) that have measurable and significant impacts on existing chronic air quality issues namely:
    - Vehicle Emission Control and Vehicle Emission Abatement
    - Management of Open Waste Burning from municipal and agricultural waste
    - Management of Charcoal production
    - Industrial Pollution Control (for selected Industries such as oil, chemicals, minerals and metal production)

- **Pillar 3: Adopting a package of price and sector policies in the long term (3-8 years)** in transport and energy that could be implemented whenever the economic and political situation would improve. The target is to reducing PM_{10} and $PM_{2.5}$ concentration to 112 and 65 μ/m^3 annual mean respectively by 2020, which are about 5 and 6 times respectively higher than the WHO guidelines, but are considered to be an upper limit for GCMA concentration

In order to reach such objectives, specific components are described under each of the three pillars.

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[24]World Bank website: <www.worldbank.org/globaloutlook>.

7.4.1 Pillar 1: Building Institutions in the Short Term

The Establishment of the Air Quality Management System in GCMA **c**onsists of:

- Improving the institutional framework
- Developing a local air quality management in the air sheds of GCMA
- Developing stringent air quality standards for vehicles
- Improving public awareness of air quality and enhance the public's capability of making choices through environmental education

A. The Institutional Framework

At present GCMA does not have a comprehensive air quality management system to provide a clear and simple policy framework on improving air quality in Greater Cairo, which includes the setting of objectives, monitoring air quality, conducting emission inventories, predicting pollution concentrations, monitoring and enforcement and allocations of resources. A key function of such system is to inform and promote awareness of air quality issues; involve the multi-stakeholders, guide the implementation of goals and objectives to ensure continuing cooperation and consultation among the interested parties for air quality management.

The air quality management system will distinguish between *Execution* and *Implementation*: the Executing Agency of the strategy will be responsible for the strategic actions in GCMA as a whole and is the institution that takes responsibility for achieving its overall objectives. The Executing Agency would conduct reviews at least annually, and would give a "stamp of approval" to the activities of the Implementing agencies (see below). The Executing Agency would also request and assess proposals for modifications to policies and for new policies.

The implementing agencies will be the line ministries and/or governorates for the sector involved: the Ministry of Transport for the transport sector; the Ministry of Local Government with each of the three governorates for the municipal waste; the Ministry of Industry for industrial pollution control; and the Ministry of Agriculture for agricultural waste. These ministries will be responsible to implement their strategic actions using **clear objectives based on air quality indicators**. In certain cases, there could be a choice where the appropriate action may be to tender the work. For example, the Ministry of Agriculture can tender the work for the collection and disposal of the agricultural waste. The Ministry of the Interior can tender the work to the private sector for managing the VET facility.

There is little reason why the implementation mechanism of strategic actions cannot fit within the existing ways of working of line ministries. The major difference will be the requirement for detailed monitoring and evaluation of each strategic action. Such monitoring and evaluation should be based on specific indicators and targets and should generally be carried out by an organization independent of the executing or the implementation policies.

MSEA through EEAA is mandated through Laws 4/94 and Law 9/2009 to protect and promote the environment. It is thus an obvious candidate to be the Executing Agency for the Strategy as a whole as recommended by the line ministries consulted during the preparation of this report. As an agency, it has a Board of directors formed by representatives of the line ministries and experts but very few executive powers; these reside with the Competent Authorities, line Ministries and governorates (who will be acting as implementing ministries). The responsibility of the Board would be to integrate air quality concerns into the sectors concerned, assess, and where required respond and follow up on the air quality objectives and actions determine by the implementing agencies.

It is proposed that the EEAA Board of Directors will establish a subcommittee chaired by the CEO of EEAA for Improving of Air Quality in GCMA. This subcommittee will include the secretary generals of the three governorates, the managers of the EEAA regional branch in Greater Cairo as well as technical experts from universities and local NGOs. This subcommittee would identify and approve actions that would help identify, anticipate and prevent air quality issues from becoming problems that would be difficult to manage. The subcommittee will also identify the necessary tools and indicators to manage the significant air quality issues in an effective, efficient and timely manner and will oversee the awareness campaigns on air pollution. This sub-committee will be supported by a Policy Support Group (PSG) in MSEA which will report to the EEAA CEO. The Unit would have dedicated staff from the Air Quality Department, the Central Department for Environment Inspection and Environment Compliance and the General Department of Industrial Improvement. It could be housed under the Environment Quality Department. The main functions of this group will be to:

- Set objectives, monitor air quality, conduct emission inventories and predicting pollution concentrations for GCMA.
- Conduct and support Cost-Benefit Analyses of policies and projects.
- Monitor and ensure compliance towards achieving established targets by the implementing agencies.
- Inform and promote awareness of air quality issues.

B. Development and Implement a local air quality management as a tool for improving air quality within the airshed of GCMA

The objective of this approach is to deal with identified air quality problems within specific hot spots throughout GCMA at the local level. The definition of these hot spot areas would depend on: emissions sources and volumes, emission dispersion characteristics, impacts of emissions and management considerations. This approach would include:

- Managing emissions from both point sources and non-point sources within specific hot spot areas.
- Restricting the occurrence of urban expansion, industrial or commercial activities within specific areas in which air quality concentrations are the highest on PM_{10} and $PM_{2.5}$. Priority for such restriction should be the Governorate of Giza followed by the Governorate of Qaliyoubieh and then the Governorate of Cairo.
- Managing the combined effects of a concentrated of number of point sources.
- Establishing a decision making mechanism for determining when an air quality issue is significant enough and determine the roles of the local government, industry and the public for problem solving within the hotspot area.

The Regional Branch of EEAA would be responsible to develop with each of the three governorates and within their host spots in this governorate, a proposed approach to better manage urban transportation especially the use of micro-buses, and the two and four stroke motorcycles or to assess measures for including air quality indicators in urban and rural planning, or to identify with the stakeholders the necessary mechanisms of municipal waste collection.

C. Stringent Air Quality Standards

Ambient air quality standards are impossible to enforce all the time because it is difficult and expensive to monitor all the point and non-point sources. Egypt's air quality standards identify the maximum allowable concentration of pollutants over specified period of time. It is not clear whether the total emission of point sources, plus the contaminants imported from wind or desert storms and the expected emissions from all industrial sources will not exceed the ambient air quality standards. The revised executive regulations in Law 9 of 2009 have relaxed the national standards in PM_{10}, SO_x and NO_x with no supporting justification. It neither provided emission standards for vehicles nor the fuel quality standards. The proposed recommendations would be to:

- Revise the national standards for PM_{10}, $PM_{2.5}$, SO_x and NO_x in the executive regulations of Law 9 of 2009 to reach at most a concentration of 70 $\mu g/m^3$ for PM_{10}, of 30 $\mu g/m^3$ for $PM_{2.5}$ and 40 $\mu g/m^3$ for NOx.

- Prepare the necessary fleet fuel efficiency and fuel quality standards and comparable to European Standards using Euro 3, Euro 4 and even Euro 5 (the updated Mostorod refinery will produce Euro 5 diesel grade in 2012). Particular emphasis would be on fuel efficiency in two and four stroke motorcycles, mini and micro-buses, heavy truck trucks.
- Reach agreement with the private sector which either import vehicles or assemble vehicles to comply with the fuel efficiency and fuel quality through including the required performance standards in their license to operate by a mutually agreed upon date.
- Design an incentive system to enable the buyers of mini-buses, trucks and passengers vehicles alter their decision in order to purchase efficient vehicles.
- Implement a mandatory vehicle emissions testing program to cover the three governorates in a transparent manner.

D. Improving Public Awareness of Air Quality

The lack of information or disinformation is considered to be barriers for the implementation of the strategy. Until now price, but not quality nor performance, stimulate investment decisions at the government level or even at the personal level. The consumers or the public are not involved in decision making and there is no existing award or incentive to enable the public (let alone the drivers) to change their behavior. An important element to develop the strategy is that awareness should target all the ages, and principally young generation. It is essential for MSEA in collaboration with the media, the environment NGOs and the Ministries of Education and Information to design a program that integrates information, persuasion and education into the overall strategy. This program should include the following components:

- Setting clear objectives and specific goals. Priority should be given to littering, driving, municipal disposal and dust from construction and roads.
- Designing the methods for reaching the target audience with involvement from stakeholders.
- Developing appropriate resource and information on health impacts, safety and dangers.
- Seeking partnership and collaboration with local NGOs in awareness campaigns and information dissemination.
- Introduce pilot programs starting from areas or part of the cities where there are large chances of success and a leadership in the community.

Moreover, the World Bank has launched the Broadcasting and Raising Awareness through Environmental Monitoring Program (BRAEM) in Egypt, which is public-driven and allows citizens to use moral suasion to put pressure on industrial polluters to be more environmentally responsible.

7.4.2 Pillar 2: Targeting Cost-effective Investments in the Medium Term

The following priority areas are expected to have measurable and significant impacts on reducing PM_{10} and $PM_{2.5}$ which are considered existing chronic air quality issues namely:

- Vehicle emission control and vehicle emission abatement
- Open waste burning from municipal waste
- Open waste burning from agricultural waste
- Charcoal production
- Industrial and energy pollution control (selected industries such as oil, chemicals, minerals and metal production)

Although the government already has programs and projects in each of the five priority areas, the emphasis is not on financing these investments but on whether these investments are cost effective in the long term using financial and/or economical analyses that were not conducted by the government before investing in these priority areas. Yet, it is important to keep in mind that policy choices are usually based on several criteria where pollution abatement is one of them. For instance, switching old taxis with new taxis not only reduce air pollution but also allows for an increase in energy efficiency with its positive effect on the balance of payment, enhanced and safer mobility for citizens and tourists alike, the set up of a local manufacturing industry base (several car brands) which creates jobs, the increase of the production-based GDP, the implication of the banking sector to provide financing to taxi owners, etc.

Hence, cost-effectiveness analysis was used to determine PM_{10} abatement which is one of many criteria within policy choices for analyzing the above-mentioned five priority areas already financed by the government. Its principal advantage is that it allows setting the target and determining the means (costs) of reducing pollution (in this particular case PM_{10} and by extension $PM_{2.5}$) as usually they represent roughly half the PM_{10} especially when it comes to transportation) to be incorporated in the assessment of the five priorities above. Its systematic use leads to:

- Better allocation towards pollution abatement of scarce government resources, time and capital;
- Quicker decision making: a common language for dialogue including a shared baseline and methodology;
- Facilitation of the dialogue with the Ministry of Finance and international financing institutions and donors.

A. Vehicle Emission Control and Vehicle Pollution Abatement

The government launched the inspection program in 2002 as safety inspections were seen as more critical than emissions checks. Nevertheless, a large number of old cars, buses and trucks still evade car inspection. Efforts must be deployed to improve the inspection of old cars through better governance, monitoring and enforcement as most old cars, buses and trucks are usually heavy polluters.

In Greater Cairo, there are about 1.8 million vehicles including cars, buses, microbuses, trucks and motorbikes. Nevertheless, only interventions are derived for cars and buses by comparing interventions to cars older than 28 years and diesel buses that are not fine-tuned. Although there is also a reduction of CO_2 as well as other compounds, they are not however covered in this context. Clearly implementing vehicle emission testing for all vehicles is a massive undertaking for GCMA. It appears sensible to bring out the scheme on these vehicles whose effects on air pollution impact is the largest and abatement cost of PM_{10} is the lowest. In this regards, within the type of vehicles and/or fuels, there are investments that could be cost-effective and therefore should be carried on a priority basis and others that are expensive or not affordable because the abatement cots of PM_{10} is high and therefore should not be considered as a first priority.

A marginal cost-effectiveness for the cost per ton per year of PM_{10} reduced for fine tuning engine and switching fuels as well as switching vehicle was estimated as illustrated in Figure 7.2. Such measures are intended to show the various additional costs associated with the reduction of the emission loads from various transportation sources when the PM_{10} criterion is considered in the policy choice. The analysis showed that the first priority of two-pronged interventions should target fine tuning engines and enforcing a switch of fuel for older vehicles, especially when owners cannot afford to buy new vehicles; and switching vehicles.

Fine tuning engines and enforcing a switch of fuel for older vehicles are, comparatively to switching vehicles, cost effective as the calculated interventions could range from LE 2 to LE 423 per PM_{10} ton per year reduced (Figure 7.3):

- Fine-tune old motorcycles, especially two-stroke motorbikes, through more effective testing before considering an incentive schemes to encourage a trade in with four-stroke motorbikes (about 322,000 motorbikes in 2007 in Cairo).
- Fine-tune cars, mini-buses, buses and trucks, while building on the USAID Cairo Air Improvement Project (CAIP) to reduce car, private mini-bus, bus and truck emissions in Greater

Cairo as the CAIP Inspection and Maintenance of Transit Buses program targeted 5,000 transit buses that helped cost-effectively fine tune 65 percent of them while the remaining 35 percent were due for more significant maintenance, including even engine overhaul or replacement.

- Target the oldest car first by switching engine fuel to CNG for old private vehicles running on gasoline or diesel by their owner if the latter cannot afford to buy a new vehicle.

Switching vehicles cost for car, buses, and definitely motorbikes and trucks (although they were not calculated) are less cost effective than previous interventions but could be justified on so many other grounds in terms of policy choices. Hence, these interventions are relatively affordable when compared to PM_{10} reduction cost from other sources (see below) and range between LE 115 and LE 2,981per PM_{10} ton per year reduced (Figure 7.3):

- Implement the second phase of the National Taxi Replacement Scheme that aims at assisting taxi-owners in replacing a further 21,250 taxis throughout the country from July 2013 to December 2015 to switch to CNG fueled taxis made locally.
- Pursue the effort initiated under CAIP to switch old mini-buses and buses with CNG fueled buses made locally.

The following interventions are considered ineffective in terms of abatement costs for PM_{10} namely:

- Switching more than 10 year old taxis from diesel or gasoline fuels to CNG as it is twice as expensive to reduce PM10 as switching 28 year old taxis from diesel or gasoline fuels to CNG.
- Purchasing fuel cell fueled buses as CNG buses are much more effective in reducing PM10: LE 115 against LE 2,277.

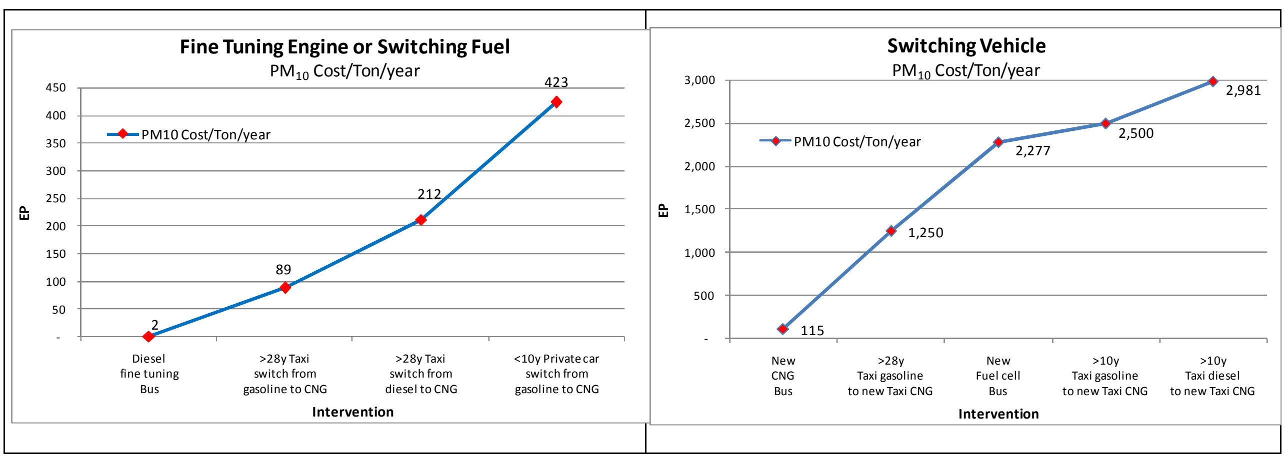


Figure 7.3. Transportation Marginal Remedial Cost per Ton of PM_{10} Reduced per Year, LE

Key conclusions of this section

- Improving vehicle emissions performance is a key policy provided that:
  - Only enforcement of emission standards will lead to large reductions in local damage costs.
  - CNG conversion pays: there are signs of replication from private vehicle sector; and such scheme could be extended to those vehicles for which the remedial costs is lowest. This includes converting buses and micro-buses to CNG, switching old vehicles in terms of taxis and private vehicles from gasoline to CNG.

- The less promising option is to switch diesel engine in taxis older than 10 years to CNG as the PM_{10} abatement costs is the highest or to buy fuel cell fueled buses.

B. Open Waste Burning from Municipal Waste

Reducing air pollution associated with the lack of waste collection will require the improvement of GCMA waste management. Only 65 percent of solid waste generated in Greater Cairo is collected, transported and disposed in 2011. The problem manifests itself in large accumulations of waste in residential areas, and open self igniting dumpsites which increases the emission of air pollutants namely PM_x and CO_2.

The SWM New Plan for Greater Cairo was formulated in 2010. The first phases of the plan is to be implemented for Greater Cairo Region comprising the governorates of Cairo, Giza but excludes 6th of October and Qaliobiya Governorate which has the lowest collection coverage among the 3 Governorates (see Annex 4 Table A4.7). Hence, with the first and second phases of the plan, 11 percent of the non-collected waste in 6th of October and Qaliobiya will remain a potential for haphazard flaring in Greater Cairo if the collection and processing are not duly addressed.

In particular, the new plan is to engage the private sector in raising the necessary investments to replace the existing dumpsites. The SWM New Plan calls in its first and second phases for the:

- expansion and creation of 18 transfer stations of which some will be used for pre-segregation by scavengers;
- building of two waste-to-energy (WTE) plants in Helwan and Giza that will produce electricity, reduce air pollution including CO_2 emissions;
- the setting up of one sorting and composting facilities with recycling capabilities and the 15th of May landfill will be closed down in 2014 and transformed into a pre-segregation station for scavengers; and
- Four integrated sorting/composting/recycling/sanitary landfills including leachate treatment and gas collection, and one segregation station.

The SWM New Plan includes two parallel tracks to deal with the waste: a WTE chain consisting of collection, transfer, WTE and residual landfilling and a regular chain consisting of collection, transfer, segregation (recycling and composting) and landfilling. A financial analysis was conducted on the EEAA plan from “cradle to grave” for each of the WTE chain handling 2,990 ton/day and the regular chain handling 13,319 tons/day and explained in Annex 4 which results in Table 7.2 are as follows:

- The total capital expenditures (CAPEX) for both waste chains (collection through sanitary disposal) amount to LE 20.8 billion (US$3.5 billion). This represents the uncollected waste including the WTE in Giza and Helwan.
- The WTE share alone, which only includes the transfer, transport and WTE processing of the Helwan and Giza waste, amounts to about LE 13 billion (US$2.2 billion) or 62 percent of total CAPEX, i.e., each WTE will cost LE 4.3 billion or US$735 million each.
- The reduction of PM_{10} according to the cost derived for the SWM New Plan when considering the regular chain is 4.4 fold less expensive as compared to the WTE chain: about LE 58,461 (US$9,929) per ton of PM_{10} averted for the WTE chain against LE 13,042 (US$2,215) per ton of PM_{10} for the regular chain. The smoke depollution system usually accounts for 30 to 50 percent of the cost of a whole WTE unit and its operations and maintenance (O&M) account for about 40 percent with dioxin being the most dangerous and complicated compound to abate and its real impact needs to be addressed in an Environmental Impact Assessment. Three 800,000 ton/day

capacity units would partially cover the needs of Greater Cairo's SWM New Plan over the next 20 years and would cost US$1.8 billion.

- When considering the WTE chain, the full cost recovery of the SWM New Plan for Cairo will reach at least LE 1,527 (US$259.3) per ton of waste over the 2014-2033 periods. If it is assumed that a family of 5 generates 1 ton per year of waste, this means that each family should pay LE 1,527/year which is LE 127/month compared to what a family is paying now which is LE 8/month, i.e., if the government is aiming at reaching full cost recovery, the new plan calls for the increase of the fee by about 16 times which is unlikely to be affordable by the majority of households in Helwan and Giza.
- When considering the regular chain where the rest of the waste will be processed, the full cost recovery of the SWM New Plan for Greater Cairo will reach at least LE 371 (US$63) per year over the 2014-2033 periods or LE 30.7/month compared to LE 8/month which would require that a family of five should pay 3.8 times more than what is actually paid.
- The total budgetary subsidy of the SWM New Plan for Greater Cairo if the waste fee is kept unchanged would amount to LE 2.8 billion per year (US$475 million) with LE 1.6 billion (US$265.2 million) towards to the WTE chain and LE 1.2 billion (US$210) towards the regular chain.

Table 7.2. Greater Cairo New Plan Capital Expenditures and Dynamic Fee Summary for the WTE Chain and the Regular Chain, 2012-2033, US$ million

Indicator	**Unit**	**Collection Sweeping**	**Transfer Station**	**Transfer Transp.**	**WTE**	**Segregation**	**Landfill** 12% Rec. 30% Com.	**Total for WTE Chain**	**Total for Regular Chain**
Capacity	Ton/day	17,921	16,249		2,990	13,319	7,750	2,990	13,319
CAPEX	US$ million		548		2,104	766	107	2,205	1,320
Dynamic Fee discounted at 5%									
-CAPEX	US$/ton		12.9		116.2	7.6	2.3	129.4	23.0
-OMEX	US$/ton	20.4	4.6	6.3	89.2	3.6	5.4	129.9	40.0
Total Cost Recovery	US$/ton	20.4	17.5	6.3	205.4	11.1	7.7	259.3	63.0

Note: The difference between Collection/Sweeping and Transfer Station is due to pre-segregation. Segregation volume includes WTE residues. Land costs are not included in the analysis. Transportation is considered to be contracted out and is based on US$0.14 per ton per km. Existing transfer stations are not included in this table. Costs do not include the rehabilitation of the 15th of May dump site. Inert material landfilling only includes site development, capping and development, and aftercare. Recycling processing plants at the segregation sites as formulated by the strategy are not included in the analysis. Recycling and composting are assumed to reduce waste by 12% and 30 percent respectively.

Key conclusions of this section

From the above results the new government plan appears to be ambitious and, expensive and not affordable and should be revised along the following lines:

- When only considering the regularchain in terms of good collection, segregation through recycling and composting and landfilling, the SWM New Plan appears to be feasible with a recovery cost of LE 371/ton (US$63/ton). At present the cost per ton charges by the private sector in Greater Cairo varies between LE 105-117.6/ton (US$17.8–US$19/ton) which is the lowest when compared to the other countries in the Middle East and North Africa[25] such as in Morocco (US$58/ton), Algeria (US$61–US$86/ton), Tunisia (US$36–US$50/ton), and Jordan

[25] www.sweep-net.com

(US$36/ton). Therefore, the total recovery cost of LE 371/ton appears to be within the regional benchmarks that the private sector is charging for these services.

- The least cost alternative to the SWM New Plan was calculated by using the same the transfer stations but avoiding segregation and landfilling all the waste. The total capital expenditures reaches LE 4.1 billion (US$697 million) which is 5 fold less expensive that the SWM New Plan (Table 7.3). Moreover, the cost recovery is more affordable with LE 290/ton (US$49.3) although this amount could further be reduced should electricity is generated through fuel cells at the landfills. Hence in-depth financial and economic analysis is needed to determine the best waste alternatives as parts of the New Plan seem unrealistic. The total budgetary subsidy of this least cost alternative for Greater Cairo if the waste fee is kept unchanged would amount to LE 1.2 billion per year (US$206 million) or 2.5 fold less than the SWM New Plan that combines WTE and regular chains.

Table 7.3. Alternative Greater Cairo SWM Plan Capital Expenditures and Dynamic Fee Summary, 2012-2033, US$ million

Indicator	**Unit**	**Collection Sweeping**	**Transfer Station**	**Transfer Transp.**	**Landfill** 0% Rec. 0% Com.	**Total for Collection, Transfer and Landfilling chain**
Capacity	Ton/day	17,921	16,249		16,249	
CAPEX	US$ million		548		149	697
Dynamic Fee discounted at 5%						
-CAPEX	US$/ton		12.9		1.5	14.4
-OMEX	US$/ton	20.4	4.6	6.3	3.6	34.9
Total Cost Recovery	US$/ton	20.4	17.5	6.3	5.1	49.3

Note: land costs are not included in the analysis.

C. Open Waste Burning from Agricultural Waste

The burning of agricultural waste and the use of the rice straw has been the subject of many studies. In 2006, the GIZ International Services financed by the EC financed Regional Project of Solid Waste Management in the Mashrek and Maghreb Region conducted a study in 2006 that identified the priority Governorates of Sharkia, Gharbia, Qaliobeya, Kafr El-Sheikh and Dakhlaya where the burning of the rice straw residues constituted the major cause of black smoke over Greater Cairo during fall. The largest amount of unused crop residue is rice straw with significant quantities of cotton stalks and small quantities of other residues remained also unused. A financial analysis has therefore been undertaken under the overall assumption that each option would be implemented by the private sector with the following four options and the corresponding Net Present Value (NPV). Five alternatives were considered:

- Alternative 1: Composting of crop residues with manure at a dedicated site serving several communities.
- Alternative 2: Composting of crop residues with the organic component of municipal solid waste at a municipal solid waste treatment location.
- Alternative 3a: Adding ammonia to crop residues to create fodder.
- Alternative 3b: Adding urea to crop residues to create fodder.
- Alternative 3c: Adding "el mufid" to crop residues to create fodder.[26]

[26] El mufid is a mixture of urea, molasses and salts.

Alternative 1 has a Net Present Value (NPV) of LE 228,482 over a 10 year period, and an Internal Rate of Return (IRR) of 15 percent. The financial analysis identifies that Option 1 has a NPV of LE 900,370 over a 10 year period and an IRR of 25 percent. Other options have a negative NPV and a negative IRR.

At present, EEAA has contracted the services of private entrepreneurs to produce compost or animal feeds stock in the contiguous governorates of Dakahlia Sharkia, Gharbia and Qualiobieh Governorates.

The ongoing EEAA-backed subsidy scheme that started 7 years ago subsidizes entrepreneurs up to LE 82 per ton of rice straws to produce compost for a total amount of subsidies varying between LE 83.4 million to LE 111.6 million/year (US$13.9 million to US$18.6 million per year) and covering 30-40 % of the total cultivated areas estimated at 1.7 million feddans. EEAA makes sure that the rice straw residues are turned into compost. There are two major issues related to this scheme: (a) the lack of access to the cultivated lands to be able to collect and transport the rice straw. At present about 1.0 million feddan which is 50-60 percent of the cultivated are almost inaccessible for collection of the rice straws because of the narrow and small lot of lands, lack of rural roads, lack of small tractors; (b) transport from land plot to the collection centers and subsequently to the composting treatment centers are lacking and expensive or seriously constrains the markets for agricultural residues and products made; and (c) lack of incentive for the farmers to collect the rice straws and transport them to a central collection center. Until these issues are solved, there is a possibility that rice straw burning would continue and would contribute to air pollution in the GCMA as farmers burn residues for a reason: essentially it represents the best solution to the problem of removing residues from the field such that the fields can then be replanted as soon as possible.

A financial analysis was carried out using three options:

- Option 1: Rationalized burning
- Option 2: Composting
- Option 3: Burning in cement kilns

Option 1: Rationalized burning

The damage caused by the burning of residues in the field depends on whether the pollution will reach Cairo and what the meteorological conditions will be in particular, whether there is temperature inversion and how low it is). The Ministry of Agriculture already uses weather forecasting tools to inform farmers of optimal irrigation times. A network of extension workers helps to convey the information to the farmers. These tools and networks could be extended to be used with the burning of residues using a sustained awareness campaigns. For example burning of residues when winds were in the right direction and when the inversions over Cairo were weak or absent. Night-time burning (when temperature inversions fall to their lowest heights) would be banned. Similarly burning could be prohibited when burning could have the worst negative impact on GCMA air quality.

Rationalized burning should be considered as a short term option of 1-2 years while other options described below are fully developed or implemented. This is because such rationalized burning may not have a large impact on pollution levels and the resulting damage costs, as neither it reduces PM_{10} nor CO_2 emissions but reduces the load intensity of PM_{10} and black smoke during fall over Greater Cairo and therefore could spare a great number of cardiopulmonary morbidity and mortality and reduce cost of illness.

There are however two major constraints: (a) the post-harvesting period tends to feature very stable weather conditions, with the weather conditions on one day being very similar to that of another; and (b) farmers have a very short period between harvesting one crop and planting the next one. If burning residues were banned throughout this period, farmers would burn their residues anyway. It is recommended therefore that:

- A study be commissioned to determine ways to bring rice straws in landlocked lots to access points to be collected to process compost and/or refuse derived fuel;
- Strengthen the existing network of extension of the Ministry of Agriculture which has close links with farmers and should have enough persuasive powers to largely enforce rationalized burning by informing the farmers of the meteorological conditions and optimal time for burning; and
- Accompany such process by training the extension workers and launching a large public awareness campaigns through TV, radio and the press.

The detailed cost of options was estimated to be LE 30 million or US$5 million/year and detailed in Annex 4. Such cost could be paid from the existing subsidy scheme that EEAA is providing at a level of LE 83.4 million to LE 111.6 million/year (US$13.9 million to US$18.6 million per year).

Option 2: Composting

A financial analysis was undertaken and indicated that turning rice straw from lots with easy access into compost was found to be cost-effective and ranges between LE 2,775 and 4,299 per ton of PM_{10} averted. The estimate scheme of investments is LE 353 million for 100 units that could be provided by the private sector and LE 88 million of the EEAA-backed scheme will be maintained).This option seems the most viable although marginal as the process is no longer viable when the sensitivity analysis is performed (i.e., if the capital investments or the operation and maintenance cost increase by only 1%). The METAP (2006) input was used although the production capacity is very low with 20,000 tons of fertilizers produced of which only 8,000 tons of rice straws. Hence, the project investment cost, (CAPEX) estimated from the METAP study to be LE 3.6 million (US$0.6 million) should be replicated 200 to 300 times if the residual rice straws that are still being burnt should be considered. The total cost of investment for 100 units would be LE 236 million for 100 units that could be provided by the private sector and LE 88 million of the EEAA-backed scheme will be maintained. The project is only viable if the land is provided free of charge by the government and the assumptions made in Annex 4 are included such as the financial analysis is carried out over the 2012–22 periods or 11 years and all designs and construction are performed over 1 year. This option could only be considered unless the landlocked lot issue has been resolved under Option 1.

Option 3: Burning agricultural waste in cement kilns

Under EPAP II, a recent study conducted by Broader (2011) looked at the alternative of using the agricultural waste residue to be used as a burning fuel by the cement companies with a 10 percent replacement rate that would gradually reach 30 percent: Lafarge, Cemex, Suez Cement Company and Ameriya Cement. The cement kiln is a safe and secure disposal route for combustible wastes as ash becomes part of the cement product.

As cement company prerequisites, the financial analysis was conducted over a 3 year period, which meant that the investment was to be recouped over 3 years. A minimum agricultural waste capacity amounting to 3.3 million tons per year in 2009 to reach 4.4 million tons per year in 2012 was needed to consider the agricultural waste as an alternative fuel. A total agricultural waste residue was estimated at 15 million tons with rice straw amounting to 5 million tons per year. The transport routes and therefore costs were optimized to transport (200 km on average) the residue to the closest cement company. Most financial analyses took advantage of the CDM. The average cost of transferring agricultural waste from farm gate to cement kiln amounted to LE 250 for bulk straw and LE 270 for shredded straw. At that rate, none of the alternatives was viable unless gas price subsidy was partially removed to bring the gas price closer to international prices

A financial analysis was built up on the EPAP II study (Broader, 2011) but over 11 instead of 3 year periods. Broader (2011) input was used although the production capacity is relatively low with 100,000 tons per kiln of which only 75,000 tons of rice straws. If further kilns are to be added we assume that a further 50 percent will be the extra capital requirement. Hence, the project investment cost of LE 65 million (US$10.9 million), including the recycling facility should be replicated 10 to 15 times amounting to LE 650 million to LE 975 ((US$10.9 million to US$162.5 million) if the residual rice straws that are still being burnt should be considered.

The total capital cost, which includes design, permitting, equipment, cavils, buildings, erection and commissioning, also considers the de-baling equipment. Also, the cost of the material recycling facility is included in the analysis. This option is viable and efficient when CDM is considered and transportation costs are not. However, the latter could range from LE 200 to LE 300 per ton and the current EEAA subsidy of LE 82/ton is not sufficient to cover these costs. Nevertheless, this option is much more efficient at reducing both PM_{10} and CO_2 (LE 458 per ton of PM_{10} averted and LE 30 per ton of CO_2 averted) than composting in options 2 above. If this option were to be considered, a jump start of this economic segment is needed that: either necessitate the increase of the current EEAA subsidy of LE 82/ton to cover LE 250 to cover transportation costs; or increase the price of gas by 50 percent to make the project financially viable especially since most of the energy subsidy still benefits industries including cement industries. Currently, Option 3is only financially viable when cement companies have mazout-fired kilns that could be switched to refuse derived fuel as the CO_2 emission differential is higher than switching from gas. Yet, this option could only be considered when the landlocked lot issue has been resolved under Option 1.

Key conclusions of this section

There is no quick fix for resolving the issue of disposing of all agricultural wastes especially the rice straws in the five contiguous governorates. So far, the government has been focusing primarily on technological solutions and has injected funds for subsidies and for shredding, compacting and collection equipment. This technology is not the issue, the major issues are: (a) geographical and topological related to the landlocked lots that are not inaccessible; (b) a financial and economical issue of financing large investments related to composting and/or burning in cement kilns and providing an incentive scheme to both producers and used of the rice straw waste; and (c) a communication issue for increasing awareness among farmers about the benefits of collecting the rice straws.

While the existing schemes are already implemented by EEAA, it is essential that the following be undertaken:

- EEAA would commission a study on an economic and institutional assessment and requirements related to the landlocked lots and the most appropriate means and tools to increase the collection of the rice straws from the inaccessible fields.
- The agricultural extension staff of the Ministry of Agriculture should be trained on the communicating and working with the farmers on rationalized burning.
- EEAA should launch an awareness and communication campaigns to the framers on the adverse impacts of waste burning and on the benefits of collecting the rice straw for proper disposal and treatment.
- EPAP II should continue to pilot the disposal the burning the agricultural waste in cement kilns as to obtain better information analysis and requirements that can be used for replication.

D. Charcoal Production

Approximately 14 million tons of wood residues from old trees, plantations, and agricultural trimmings are produced annually (EEAA, 2006). About 7.5 million tons are used as the feedstock for charcoal manufacturing in Egypt by means of traditional earth-pits also called open pits and the residual volume is used for wood furniture. About 942 possibly reaching 4,600 open pits exist in Egypt and release pollutants such as CO, CO_2, SO_x and PM_x. The charcoal carbonization processes are considered one of the contributors to the Black Cloud in Greater Cairo[27] and produces tar that, if unsafely discarded or reused, can pollute surface and ground waters.

The charcoal production is often unlicensed and completely disorganized in and north of Greater Cairo. New charcoal kiln standards were approved by the Egyptian Organization for Standardization and Quality, EEAA, and the Federation of Egyptian Industries. Therefore, three approved design options (double jacket metal kiln without a flare; double jacket metal kiln with flare; and brick kiln) are considered to convert the 232 open pits or 25 percent of Egypt's total pits when considering EEAA very conservative figure of 942 pits for GCMA and its environs (Table 7.4).

Table 7.4. Kiln Alternatives to Abate Charcoal Air Pollution, LE

Alternative Processes	**Wood Input**	**Finance per Unit**					**Kiln Needed**	**NPV over 20 years**		**IRR**		**Emission averted**		
		Open Pit	Kiln	Revenue	Cost	OMEX/ year		w/o CDM	with CDM	w/o CDM	with CDM	**CO_2**		**PM_{10}**
	Ton/year		LE 000'				#	LE million		%		Ton/year	LE/ton	LE/ton
Diesel (Solar)														
Metal Kiln w/o flare	480	96	144	95.6	141	64	942	81	93	22	24	37,156	2,503	2,661
Metal Kiln with flare	480	96	144	97.5	151	64	942	73	84	21	22	36,867	2,278	2,791
Brick Kilns	210	42	63	44.7	42	25	2,170	153	202	40	49	140,146	1,441	1,988
Natural Gas														
Metal Kiln w/o flare	480	96	144	95.4	196	51	942	133	155	24	26	60,068	2,580	3,206
Metal Kiln with flare	480	96	144	97.2	206	51	942	125	145	23	25	59,778	2,426	3,336

A financial analysis on three types of kilns was performed. It was found that the type of kilns whether fueled by diesel or by natural gas are financially viable with an IRR of 10-24 percent with the exception of the kiln fueled by diesel, which from the PM_{10} point of views is the most effective: LE 1,998 per ton of PM_{10} averted and 140,146 ton of CO_2 averted. However no consideration was taken for SOx and NOx emissions which could be high for kiln powered by diesel.

It was estimated that the total cost of the kilns that could be provided by the private sector amount varies between LE 71 million–LE 153 million (US$11.8 million–US$25.5 million), whereas the yearly OMEX per kiln amounts to LE 25,000, equivalent to US$416 (annex 4).

Key conclusions of this section

Based on the reduction of PM_{10} and SOx, the metal kiln without flare and fuelled by natural gas appears to be the most suitable environmentally and financially.

E. **Industrial Pollution Control**

In collaboration with the World Bank, EEAA and the National Bank of Egypt has successfully developed since 1997, a financing scheme for industrial air pollution abatement under EPAP I. Under EPAP II, the market based mechanism was scaled up and involved the financing and collaboration of the EIB, Japan's International Cooperation Agency, the AFD for an estimated level of funding of US$185 million equivalent. EPAP II is to help reduce industrial air pollution by providing attractive financing to industrial companies, in the hot spots areas of greater Cairo and Alexandria. EPAP II has allowed leveraging funds that could be borrowed by polluting companies through the National Bank of Egypt (NBE) and other participating commercial banks and be used for pollution abatement. If satisfactory implementation is

[27] JCEE (2009).

assessed by EEAA, beneficiary company repays 80 percent of the loan to the commercial bank (NBE or participating bank) - thus 20 percent can be considered as a performance based grant. This mechanism serves as a strong incentive for polluting companies to comply and meet their pollution targets. As of December 2011 the EPAP II active project pipeline totaled US$238 million, which exceeds the available funds by more than US$50 million. Furthermore, the EPAP II study on the use of alternate fuels in cement kilns indicated overall investment requirements exceeds US$230 million.

Results indicate that EPAP II has already achieved significant air pollution reduction from six sub-projects with an overall 93 percent reduction in particulates and 77 percent reduction in SO_2 in South Cairo area[28] which includes the three cement factories as well conversion of 176 mazout fired brick factories of Arab Abou Saad to natural gas[29] and for which the remedial cost of LE 17 per ton of PM_{10}averted is highly cost-effective. The reduction of ambient concentration of the total suspended articles (TSP) for all emission sources decreased from 1,840 ug/m^3 to 109 ug/m^3. This reduction in ambient TSP concentrations to minimize short term health episodes for the local population[30]. EPAP II has now introduced a systematic system of conducting cost benefit of all its subprojects and estimating the pollution loads as well the cost of TEP as well as the unit cost of abatement for TSP and SO_2. Such financial rigor is laudable and should be now introduced to all industrial pollution control projects irrespective of their funding sources.

Key conclusions of this section

As EPAP II will be closed in the next 18 months, MSEA has indicated in interest in designing a third phase of EPAP III. The results of this study should serve as a background for the EPAP III to include in its design:

- A Pollution Control for large enterprises but focusing primarily on the mining and chemical industries as explained in chapter 3.
- Pollution control for SMEs primarily in the Shoubrah El Kheima which the study showed to be a hot spot.
- Use of alternate fuels in the cement industry after completing a full feasibility study based on a pilot operation in EPAP II.
- Leverage financing for the private sector to scale up support towards the valorization of municipal waste in terms of the 4 Rs (Reduce, Re-use, Recycle, Recover), so that waste become an asset rather than a liability.
- Participate in the successful CNG switching program by extending it to micro-buses in the Cairo and Gizeh Areas.

7.4.3 Pillar 3: Adopting a Package of Price and Sector Policies in the Long Term

A. Price Policies

Pillar 3 entails the adoption of a series of price and sector policies in transport and energy that could be implementable whenever the economic and political situation would improve. Price reforms and sectoral measures are not mutually exclusive. Price readjustment would both reduce environmental impacts and reduce subsidy payments. Thus it is very likely to be cost-effective. Low energy prices are bad for the environment and in particular for air pollution: they lead to excess consumption, reduce the cost-

[28] EPAP II appraisal mission January-February 2012.
[29]REMIP (2007); and EPAP II (2009).
[30] EPAP II appraisal mission, January-February 2012.

effectiveness of energy efficiency measures and lower the financial incentives for fuel switching and have distorted technological choices for companies and household alike. These huge subsidies are costing the Treasury some LE 68 billion in financial terms (21 percent of the budget and 10.9 percent of GDP) and LE 142 billion in economic terms in 2010[31]. Subsidies are poorly targeted in Egypt as they benefit disproportionately the upper middle class and the rich (LE 47 per capita) rather than the lower middle class and the poor segment of the population (LE 19 per capita). The major beneficiary of subsidies is the residential and the industrial sector as shown in Table 7.5 and gas oil and LPG are the most subsidized fuels followed by gas oil.

Table 7.5. Approximate Amount of Egypt's Energy Subsidies in FY 2009/2010, LE billion

Item	Price (Average)	Financial Cost	Economic Cost	Subsidy (Financial)	Subsidy (Economic)
Electricity	LE/MWh	LE/MWh	LE/MWh	LE billion	LE billion
Industry	140-250	430-450	530-560	6.3	10.6
Agriculture	130-150	435-460	555-590	0.9	1.8
Commercial	240-300	435-460	555-590	0.7	1.5
Residential	157	480-520	575-625	10.4	15.7
Government	150-250	435-460	555-590	0.7	1.6
Other	100-350	440-520	530-625	2.9	4.8
Total				21.9	38.9
Natural Gas	LE/m^3	LE/m^3	LE/m^3	LE billion	LE billion
Power	0.25	0.45	0.55-0.85	5.9	13.4
Industry	0.3-0.6	0.45	0.60-0.90	1.2	2.8
Residential	0.25	0.45	0.65-0.95	0.7	1.3
Other	0.25-0.5	0.45	0.65-0.95	2.3	4.9
Total				10.0	22.4
Petroleum	LE/ton	LE/ton	LE/ton	LE billion	LE billion
LPG	225	1,840	4,350	9.7	19.8
Gasoline	1,750	2,430	5,280	5.6	16.7
Kerosene	1,320	2,430	5,280	0.8	1.5
Gas Oil	1,320	2,210	4,920	12.9	26.8
Fuel Oil	995	1,975	2,980	6.8	16.4
Total				35.7	81.1
Grand total				**67.6**	**142.4**

Source: Castel (2011).

The energy subsidy reform program of Egypt was launched in 2004 but was suspended in 2009. It increased the price of gasoline and diesel oil, and a gradual increase in the price of electricity at the rate of 5 percent per annum that took effect from 2005 to 2008 and was followed by a sharp increase of 30 percent of the price of natural gas and electricity that target energy intensive industries.

There is however a need for new energy price reforms that would be suitable to the present political and economic circumstances as the impact of these subsidies is having a significant effect on fiscal discipline and budgetary rigor. With half of the subsidies targeting petroleum products, this has led to an excessive energy consumption that has resulted in Egypt's switch from oil exporting to an oil importing country while also limiting the country's ability to export natural gas. Therefore, a new energy pricing strategy is indeed intertwined with wider government policies aimed at energy market liberalization, restructuring and reform.

[31] Castel (2012).

Removal of the subsidy will have a significant impact on the poor and therefore, a well designed social protection component should be considered and implemented before any removal of any subsidy. Moreover, the simulations of energy subsidy removal in Egypt[32] show that the elimination of energy subsidies would reduce the GDP growth rate and the household welfare at all levels of income distribution.[33] Nevertheless, a well thought subsidy scheme targeting the poorest two quintiles will improve both efficiencies and equity among the population as the poorest households allocate a large portion of their income towards energy products, being it electricity, kerosene, gas, LPG/CNG and mazout.

Price reforms should carefully be crafted to target the poor, benchmark the magnitude of price increase and speed up price adjustment. However, an extensive public relations campaign is needed prior to the removing of subsidies by underlining the social inequity of subsidies and the raising of prices. The media should have special programs to emphasize the social inequity of subsidies and making sure that the poor understand that they are not the main beneficiaries of the current system. Phasing out these subsidies could reduce economic distortions, release some of the stress on the environment and improve social equity while freeing up scarce public resources and implement a cash transfer policy targeting the poor in a time of budgetary constraints where the country is currently recording a double-digit fiscal deficit, increasing debt and shrinking foreign reserves.

Key conclusions of this section

If price reform strategies cannot be comprehensive, then targeting transport fuels appears to be a sensible compromise. There is a dual gain in avoided subsidy and avoided damage. Such a strategy has some other advantages, namely that there is relatively little substitution of other fuels in transport, so leakages into other fuels not subject to price reform would be small. The most likely substitution would be an enhanced used of natural gas in transport, which is in any case a policy with much to recommend it. Moreover, natural gas is fairly abundant in Egypt and electricity as a product of natural gas is also easily available. There is some justification in focusing price reform on fuels that are locally scarcer.

B. Sector Policies

EEAA has proposed two different scenarios that include a package of targets that should result in reducing PM_{10} and $PM_{2.5}$ concentration to acceptable levels. As stated in previous chapters, the PM_{10} and $PM_{2.5}$ concentrations remain high but could partly be reduced during the period 2010-2020 if the measures provided in the strategy can be achieved. By reducing PM_{10} and $PM_{2.5}$ to 112 and 65 μ/m^3 annual mean respectively by 2020, which are about 5 and 6 times respectively higher than the WHO guidelines, but are considered to be an upper limit for GCMA in view the high concentration of geological dusts, there will be health and economic benefits to be accrued as shown in Figure 7.4.

The Inter-ministerial committee established for this study has proposed two scenarios that include a package of targets indicators to be achieved. These are described in Table 7.6.

Table 7.6. Proposed Greater Cairo Pollution Abatement Scenarios by the Government

Projection Scenario	Projection Indicator	Applicable Source Categories and Indicator Values

[32] CAPMAS (2004).
[33] Castel (2011).

Projection Scenario	Projection Indicator	Applicable Source Categories and Indicator Values
<u>Baseline scenario</u>: (Autonomous development)	Technology improvement (Estimated fuel efficiency improvement of 1%/year):	1 - Fuel combustion (with exception of Charcoal production) 2010→2015: - 5 % 2010→2020: - 10 %
	Road transport • No replacement of existing vehicles by vehicles with lower exhaust emissions • Additional vehicles with cleaner engines than existing vehicles	1.A.3 – Transport - Road Transport (Combustion)'
	Unchanged (amongst others) • Sulfur contents of the fuels • Field burning of agricultural wastes	
<u>Scenario 1</u>: (Existing and envisioned environmental policy)	Energy security policy "*Utilization of sustainable, renewable and clean energy resources to achieve 20% of electricity demand from it by the year 2020*". It is assumed that this will be achieved without atmospheric emissions (e.g., wind, solar, hydropower).	1.A.1.a Electricity production 2010→2015: - 10% 2010→2020: - 20%
	Energy security policy "*Maximize energy efficiency to reduce consumption by 20 % by the year 2022*" This corresponds approx. with a fuel efficiency improvement of 1%/year	1 - Fuel combustion (with exception of Charcoal production) 2010→2015: - 5 % 2010→2020: - 10 %
	Field burning of agricultural wastes "*Recycling of rice straw and other agricultural waste*"	4F – Field burning 2010→2015: - 25 % 2010→2020: - 50 %
	Transport: Programs and projects of the environmental policy include vehicle exhaust testing, replacement of old taxis, replacement of two stroke motorcycles by four stroke ones and expansion of natural gas in vehicles.	1.A.3 – Transport Road Transport (Combustion)' 2015: 5% replacement of the 2010 fleet 2020: 15% replacement of the 2010 fleet
	Unchanged: Sulfur contents of the fuels • The policy summary document mentions low sulfur fuel as but doesn't state maximum sulfur content for the internal Egyptian fuel market. "*Improving the specification of petroleum products and reduce the sulfur content to access the international standards as well as the harmful exhaust emissions which to compete in world export markets and export high-quality Egyptian products, which include implementation of a number of important projects for the production of high octane gasoline*"	

Projection Scenario	Projection Indicator	Applicable Source Categories and Indicator Values
<u>Scenario 2</u>: (Additional environmental policy)	Transport • Partial replacement of existing vehicles (emission factors typical EU-15 fleet in 1995) • Additional vehicles 2000-2020 calculated as average emission factor complying with Euro 5 standard (this standard entered into force in January 2000)	1.A.3 – Transport (combustion) • *Refer to separate section* '1.A.3 - Road transport (combustion)' 2015: 5% replacement of the 2010 fleet 2020: 15% replacement of the 2010 fleet
	Low sulfur fuel • Gasoline (S content from 500 ppm to 10 ppm) • Diesel (S content from 4,000 ppm (10 g/kg) to 10 ppm) • Heavy fuel oil (S content from 2.5% to 1%) Low industrial sulfur technology (by using desulfurization and/or low sulfur fuels in industry)	1.A.3 – Road transport (combustion) • Gasoline (SO_2 from 1 g/kg in 2010 to 80 mg/kg in 2020) • Diesel (SO_2 from 20 g/kg in 2010 to 16 mg/kg in 2020) 1.A.1 Energy sector and 1.A.2 Industry (combustion) • – Fuel Combustion and 2 - Industrial Processes'
	Cleaner industrial technology, achieved by a variety of mitigating measures, selecting less polluting processes or end-of-pipe techniques for example: • Low NOx burners • Controlling fugitive emission • Fabric filters instead of or additional to cyclones and electric precipitators	1.A.1 – Energy industries (combustion) 1.A.2 – Manufacturing industry and construction (combustion) 1.A.4 – Fuel combustion in commercial, institutional, residential and agricultural sectors 2 – Industrial processes (non-combustion) • The mean value of the emission factor range is selected instead of the maximum value: Refer to separate section '1.A – Fuel Combustion and 2 - Industrial Processes'

A benefit assessment was conducted on each of these two scenarios that showed the following:

(a) At a minimum, the air quality concentration for PM_{10} and $PM_{2.5}$ would reach 112 µg/m^3 and 62 µg/m^3 respectively.
(b) There will be a net gain ranging from 55,000 to 178,000 DALY averted over the 2010-2020 periods for scenario 1 and scenario 2 respectively or a reduction of the DALY lost per 1,000 inhabitants: from 8.2 to 7.5 and 6.6 respectively by 2020 as a result of a lower exposure of the Cairenes to particulate matters.
(c) The burden of air pollution in GCMA relative to GDP would be maintained within the 1 percent mark.

The cumulative social benefits in terms of health benefits averted cost attributable to the air-related burden in GCMA as shown in Table 7.4 will range between LE 5 and 18 billion for scenario 1 and 2 respectively over the 2010-2020 periods in 2009 prices or a net present value LE 3 billion and LE 12 billion, respectively, with an annualized LE 0.3 billion and LE 1.1 billion, respectively, over the period.

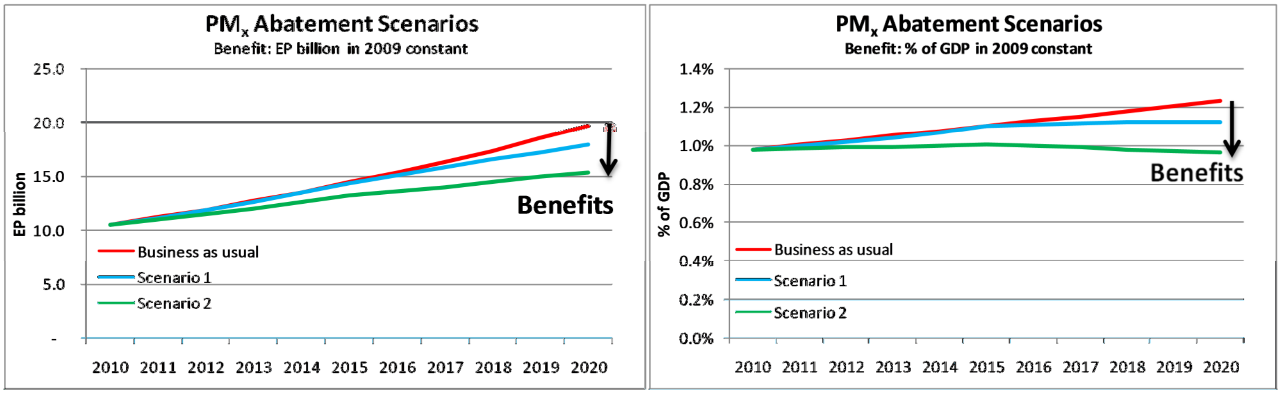


Figure 7.4. Greater Cairo Air Remedial Cost per Scenario

The current strategy seems to maintain the air pollution at almost 2010 (scenario 2) levels. However this may not be enough as the intention is to decrease the air pollution level below the 2010 level in Table 7.7.

Table 7.7. Air Pollutant Projection and Benefit by Scenario, 2010-2020

Item	**Unit**	**2010**	**2015**	**2020**
Pollutant (Mean annual)				
Scenario 1				
$PM_{2.5}$	µg/m^3	76	72	69
PM_{10}	µg/m^3	141	144	132
Scenario 2				
$PM_{2.5}$	µg/m^3	76	71	65
PM_{10}	µg/m^3	141	131	112
Benefit				
Scenario 1				
Burden of Disease averted	000' DALY	0	2	16
Burden of Disease averted/1,000 inhabitants	DALY/1,000	8.2	8.1	7.5
Net gains	LE Billion	0.0	0.1	1.8
% of GDP	%	0.98%	1.10%	1.12%
Scenario 2				
Burden of Disease averted	000' DALY	0	14	38
Burden of Disease averted/1,000 inhabitants	DALY/1,000	8.2	7.6	6.6
Net gains	LE Billion	0.0	1.3	4.3
% of GDP	%	0.98%	1.00%	0.96%

It is therefore recommended that a third scenario be included that would build on scenario 2 and target additional cost-effective interventions especially with regards to transport, domestic and agricultural waste, charcoal production, unpaved roads and building construction/destruction, and other industrial processes as shown in explained in pillar 2. Although scenario 3 will produce additional social benefits, it still needs to be packaged over the short to medium term to derive the net benefits. The specific measures considered under Scenario 3 are illustrated in Table 7.8.

Table 7.8. Additional Scenario 3 to Increase Pollution Abatement in Greater Cairo

Projection Scenario	Projection Indicator	Applicable Source Categories and Indicator Values
Scenario 3: (Additional environmental policy)	**Same as Scenario 2 with:** Transport Implementing the most cost-effective interventions in terms of reducing PMx and associated emissions, which include fine tuning for minivans, buses and trucks and switching from gas to CNG for low disposable income old car owners	**Same as Scenario 2 with:** 2015: accelerating the replacement of the 2010 fleet by more than 5% 2020: accelerating the replacement of the 2010 fleet by more than 15%
	Domestic Waste Implement the SWM New Plan in Greater Cairo that was formulated in 2010 without WTE	Consider the most cost-effective interventions for the full waste chain to reduce PMx and related emissions: collection, segregation and landfilling.
	Agricultural waste Devise alternatives to target landlocked parcels (± 60%) north of GCMA where rice straw and other staple residue burning is still being performed	Consider the most cost-effective interventions that reduce PMx and related emissions while minimizing EEAA subsidies
	Charcoal burning Enforce the ban of open pits in and around GCMA	Consider the most cost-effective interventions that reduce PMx, CO_2 and related emissions
	Unpaved Roads, Construction and Destruction Assess the roads that need to be paved Develop and enforce building construction and destruction guidelines	Decision would be based on traffic flows and population and density Control onsite emissions of dust and other pollutants through prevention, suppression and containment
	Industry Ongoing pollution abatement funded by concessional loans through EPAP II	Heavy polluters soliciting EPAP II and EPAPA III funding

7.5 Action Plan

An Action Plan was prepared for the implementation of the main sectoral policies described above aiming at improving the air quality situation. This Action Plan will have to be developed further, and changed where required, since it can only be implemented within a coherent framework of Egypt's environmental, energy and economic policies, which need to be defined and adopted by the government. Therefore, the Action Plan, as presented in this report, should be considered as a basis for the ongoing discussion with the government, which in any case must be continued for the further implementation of work that has been initiated by this report. The Action Plan also indicates entities which should be involved in, or responsible for, implementing and monitoring of specific activities. An overview of the action plan is attached.

Executing agencies named in the Action Plan are generally the Ministry responsible for the sector to which the policy is related. However, there will be a few instances where the measure will be cross-cutting across more than one ministry. For example, a policy of reducing subsidy on gasoline may directly relate to the Ministry of Petroleum, but will also have relevance to the Ministry of Finance because of its repercussions for the state finances and budget. It is thus proposed to set up a Task Force for each component policy with members drawn from the concerned ministries and other bodies, but functioning under one particular ministry so that the accountability is fixed. The Task Force should also have a member from the implementing agency to provide insights into what kind of mechanism is required to actually put the policy in place. But since the overall objective of this report is to the air quality in GCMA, EEAA should be the one overall executing agency responsible for overseeing and monitoring the action plan is also recommended. At a later stage, whenever the decision of the government will be to undertake substantial policy reforms, the Sustainable Development Committee, which is responsible for the state of environment in the country should be responsible for overseeing the Action Plan (Table 7.9) with the EEAA/Policy Support Group acting as a secretariat for monitoring, evaluating and coordinating the policy options executed and implemented by various agencies.

Table 7.9 Proposed Action Plan

Pillar	Component	Sub-Components	Proposed Actions	Responsibility	Priority	Proposed Timing
1	Building Institutions	-Improving the Institutional Framework	-Establishing a subcommittee identify and approve actions that would help identify, anticipate air quality issues	EEAA Board of Directors	1	October-November 2012
			Establish a Policy Support Group (PSG) for setting objectives and monitoring air quality targets and compliance	Air quality Department / Central Department Central Department for Environment Inspection and Environment Compliance and the General Department of Industrial Improvement	1	January 2013
		-Development and Implementation of air quality management system	Manage emissions from both point sources and non-point sources	Regional Branches Offices (RBO)s of Cairo and Giza	1	January 2013-June 2013
			Restrict the occurrence of urban expansion, industrial or commercial activities within specific areas in which air quality concentrations are the highest on PM_{10}	Governorates of Cairo and Giza and PSG	2	January 2014
			Establish a decision making mechanism for determining when an air quality issue is significant	EEAA Air Quality Department/RBOs	1	July 2013-October 2013
			Determine the role of the local government, industry and the public for problem solving within the hotspot area.	Governorates of Cairo and Giza/Federation of Egyptian Industries (FEI)	2	March 2014
		Stringent air quality standards	Revise the national standards for PM_{10}, $PM_{2.5}$, SOx and NOx in the executive regulations of Law 9 of 2009	SGP and EEAA board of Directors	1	November-December 2013
			Prepare the necessary fleet fuel efficiency and fuel quality standards and comparable to European Standards using Euro 3, Euro 4 and even Euro 5. Particular emphasis would be on fuel efficiency in two and four stroke motorcycles, mini and micro-buses, heavy truck	Ministry of Petroleum/Ministry of Interior, Egyptian Standards Organization/EEAA	1	July-September 2013
			Reach agreement with the private sector which either import vehicles or assemble vehicles to comply with the fuel efficiency and fuel quality	Ministry of Petroleum/ Ministry of Industry, Ministry of Interior, Federation of Egyptian Industries	2	January 2015
			Design an incentive system to enable the buyers of mini buses, trucks and passengers vehicles alter their decision in order to purchase efficient vehicles	EEAA/ Ministry of Finance	1	August 2013

Pillar	Component	Sub-Components	Proposed Actions	Responsibility	Priority	Proposed Timing
			Implement a mandatory vehicle emissions testing program to cover the three governorates in a transparent manner.	Ministry of the Interior/EEAA	2	August 2014- December 2014
		Improving public awareness of air quality	Design a communication strategy on air quality	EEAA Department of Communication/ National TV / Radio station/ National Press and NGOs	1	June 2013
			Develop educations materials for school children on health impacts and improve air quality	EEAA Department of Communication/ Ministry of Education/NGOs	2	July 2014
			Finance TV clips , and radio messages on health benefits of clean air and behavioral change requirements	EEAA Department of Communication/ National TV / Radio/Press/NGOs	1	September 2013 and thereafter
2	Targeting Effective Investments	Vehicle Emission Control	Fine-tune old motorcycles, especially two-stroke motorbikes, through more effective testing before considering an incentive schemes to encourage a trade in with four-stroke motorbikes	Ministry of Interior/ Ministry of Transport/ Governorates of Cairo and Giza	1	January 2014, and thereafter
			Fine tune buses and trucks through emission testing every three years	Ministry of Finance/Ministry of Transport and Governorates of Giza and Cairo	2	January 2015 and thereafter
			Implement the second phase aims at assisting taxi-owners in replacing a further 21,250 taxis to switch from gasoline to CNG	EEAA/Ministry of Finance	1	July 2013 to July 2015
			Purchase New CNG buses	Ministry of Transport/ Ministry of Finance	2	January 2014-January 2016
		Open Waste Burning from Municipal Waste	Revise the New Government Plan for MSW without WTE	Ministry of Local Development/EEAA Department of Waste Governorates of Cairo and Giza	1	July 2013
			Revise gradually the cost recovery after the improvement of municipal collection and services	Ministry of Finance/Ministry of Local Development/EEAA Department of Waste	2	July 2014
			In-depth financial and economic analysis is needed to determine the best waste alternatives	EEAA Department of Waste and Governorates	1	January 2013
		Open Waste Burning from Agricultural Waste	Commission a study to find ways to determine ways to bring rice straws in landlocked lots to access points to be collected to process compost and/	Ministry of Agriculture/ EEAA Department of Waste and Governorates	1	July 2013

Pillar	Component	Sub-Components	Proposed Actions	Responsibility	Priority	Proposed Timing
			Reach agreement with the Ministry of Agriculture that its extension staff be involved with the farmers in rationalizing burning and provide training	Ministry of Agriculture/ EEAA Department of Waste and Governorates	1	August 2013-October 2013
			Launch a communication and awareness campaigns on rationalized burning	EEAA Environmental Awareness Department/ National TV and Radio/Press/NGOs	2	January 2014 and thereafter
			Pilot the disposal the burning the agricultural waste in cement kilns as to obtain better information analysis and requirements that can be used	EPAP II/Cement factories	1	January-December 2013
		Charcoal Production	Provide technical support to the Owners of charcoal production to purchasing metal kiln without flare and fuelled by natural gas	EEAA Department of Industrial Environment charcoal production owners	1	January 2014-April 2014
			Provide concessionary loans to owners of charcoal production from the Environment Protection Fund to purchase metal kiln without flare and fuelled by natural gas	Environment Protection Fund/EEAA Department of Industrial Environment	2	July 2014-December 2015
		Industrial Pollution Control	Use the findings of the Cairo air report to help design EPAP III, namely pollution control for mining and chemical industries, Pollution control for SMEs primarily in the Shoubrah El Kheima, use of alternate fuels in the cement industry, scale up support to the 4R in MSW, and CNG switching program for micro buses	EEAA Department of Industrial Environment/National Banks	1	January 2013-July 2013
3	Pricing and Sector Policies	Pricing Policies	Conduct a detailed study on all aspects and impacts of Price Readjustment;	Inter-Ministerial Committee chaired by the Minister of Finance	1	January 2014-December 2014
			Consider a limited price readjustment program could have major impacts if it concentrated on fuels with high environmental impacts: principal among these are mazout (fuel oil) and gas oil (diesel);	Inter-Ministerial Committee chaired by the Minister of Finance	2	July 2015-July 2016
		Sector Policies	Revise the sector policies package proposed by the Cairo Air Pollution Committee b y adding a scenario 3 which includes scenario 2 as well as the sector policies in pillar 2	Cairo Air pollution Committee/ Policy Support Group (PSG)	1	July 2014

Annex 1. Emission Estimation Approach for the Base Year 2010

Atmospheric emissions are usually estimated as a function of a rate of activity (activity data) combined with an emission rate specific for the activity (emission factor). Activity data include, for example, data sets of energy consumption/conversion, industrial production, population, land use patterns, and transportation. Emission factors represent the emissions that are associated with the activity. Emission factors should match with the activity data in terms of "activity definition" and be specific for a time period.

A.I.1 Activity data

The Egyptian Environmental Affairs Agency (EEAA) is involved in the project by providing primary data, by assistance to the national consultant who collected most of the data, and by providing assistance to the World Bank team during all phases of the project. The modeling is based on data gathered during the period April – June 2011 covering:

- Fuel consumption, production, and activity data
- Digital maps to define the boundaries of GC area and all pollution sources.
- Projections data of industrial growth, population growth, changes in land use patterns, energy and Transportation demand to prepare the scenarios for 2015, 2020.
- Provision of Ambient Air Quality data from monitoring networks for ($PM_{2.5}$, PM_{10}, NOx, SO_2).
- Past studies regarding emission inventories and air quality.

The data originates from EEAA publications such as the State of the Environment 2009 report, and from data submitted by ministries and institutions including the Ministry of State for Environmental Affairs, the Ministry of Petroleum, the Ministry of Trade and Industry, the Ministry of Transportation, the Ministry of Civil Aviation, the Ministry of Agriculture, the Ministry of Health and Population, the Ministry of Electricity and Energy, and the Central Agency for Public Mobilization and Statistics (CAPMAS).

A.1.2 Emission factors

In essence an emission inventory is always an approximation as the details on technology and operational modes of the activities are not known. The selected approach consists of using typical emission factors that are geared to available activity data level. Local emission factors have been used when available. For the other activities, the main source of emission factors is the EMEP/EEA air pollutant emission inventory guidebook – 2009, available from the European Environment Agency (EEA) website[34]. The EMEP/EEA air pollutant emission inventory guidebook (formerly referred to as the EMEP CORINAIR emission inventory guidebook) provides guidance on estimating emissions from both anthropogenic and natural emission sources. It is designed to facilitate reporting of emission inventories by countries to the UNECE Convention on Long-range Transboundary Air Pollution and the EU National Emission Ceilings Directive. The EEA publishes the Guidebook, with the UNECE's Task Force on Emission Inventories and Projections having responsibility for the technical content of the chapters.

The EMEP/EEA air pollutant emission inventory guidebook – 2009 has been selected as the main reference for the methodology and the emission factors. The guidebook offers a practical way to estimate emissions in line with international reporting requirements (UN FCCC and LRTAP) and has multiple

[34] http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009

tiers of calculation methodology geared to the available information. Tier 1 methodology has been used to calculate the sector totals. Tier 2 methodology can be applied when detailed information on the actual processes is available. Furthermore the guidebook offers not just one emission factor number but also indicates a 95 percent confidence interval and full background information. The former enables to reflect improvements in technology.

The factors are a compilation of European and international references (incl. US-EPA) and represent different levels of technology as the situation between the various regions in EMEP countries varies. In principle, these factors are suitable for activities in Egypt as it concerns the same processes but the abatement level may differ. When using emission factors of the EMEP/EEA guidebook, mean and upper (95 percent confidence interval) values have been selected. The actual selection is specified per activity in the following section. Based on the comparison with the monitoring results, the mean values have been selected for NOx emission factors except for transport, upper values have been selected for PM_{10} and $PM_{2.5}$ emission factors. SO_2 emission factors are based on the sulfur content of the fuel in most cases. The selection of emission factors is also discussed in the sensitivity analysis chapter.

The following sections present the emission estimation approach for the base year 2010.

A.1.3 Spatial distribution

The spatial distribution of the estimated emissions is modeled along:

a) Point sources where the location of stationary sources is known; and
b) Area sources where emissions are generated by a multitude of sources or the location of the sources is unknown.

Areas are defined in the GIS maps. A limited set of areas have been used for the spatial distribution:

a) Number of people in an area;
b) Industrial zones (surface); and
c) Agricultural area.

A.1.4 Source Category 1- Fuel Combustion

The source classification has separate categories for combustion processes and non-combustion processes. For example the NOx emissions from fuel combusted emission of nitric acid factories are reported under 1.A.2 whereas the NOx emissions from the nitric acid process are reported under 2.B.2. The advantage of this approach is that the inventory can be based on the (national) fuel mass balance, which is accurate compared to the estimating the industry average situation.

A.1.4.1 . Source Category 1.A.1 – Energy Sector Fuel Combustion

Both a top-down emission estimation approach and a bottom-up approach have been used. The top-down approach refers to the fuel type specific national fuel consumption data. The bottom-up approach refers to the fuel consumption of individual power plants.

Sector	Activity Data	Calculation/Assumption	Emission Factors
1 A 1 a - Public electricity generation	• Capacity, production and consumption of 7 Power plants [Annual report of Egyptian Electricity Holding Co]; base year = 2008-2009 • National fuel consumption of the public electricity sector [Ministry of Petroleum]; base year = 2009-2010 • Spatial distribution to point sources (EEAA GIS map)	• The fuel consumption of the individual power plants has been broken down per fuel type (basically natural gas and mazout/fuel oil) using the national ratio. • Assuming 2.5 % S in heavy fuel oil (verbal communication of Ministry of Petroleum; June 2011)	Emission inventory guidebook 2009, namely activity 1.A.1 – Energy industries – Table 3-5 for gases (mean value for NOx and SOx; upper value for PM), Table 3-7 for heavy fuel oil and Table 3-8 for other liquid fuels (both tables: mean value for NOx, mean SOx value corrected for S-content; upper value for PM)
1 A 1 b – Mineral oil refining	• National fuel consumption of the industry sector [Ministry of Petroleum]; base year = 2009-2010 • Spatial distribution to point sources for the refinery Cairo Oil Refining Company (north of Cairo)	• Ratio of 20% used for the Cairo area versus national total • Assuming 2.5% S in heavy fuel oil (verbal communication of Ministry of Petroleum; June 2011)	Emission inventory guidebook 2009, namely activity 1.A.1 – Energy industries – table 4-3/-7 for gases (mean value for NOx and SOx; upper value for PM), 4-5 for heavy fuel oil (mean value for NOx, mean SOx value corrected for S-content; upper value for PM); 4-6 for diesel (mean value for NOx, upper value for SOx (considering S-content in diesel); upper value for PM)
1 A 1 c - Manufacture of Solid Fuels and Other Energy Industries	• Production estimation per governorate by EEAA (base year = 2010) • Spatial distribution to agricultural areas	• PM = 100% PM10 • Not in operation during September, October, November	REMIP; study of Dr. Eibid*
1 A 1 d - Oil and gas extraction	Assumed that there are no large scale oil and gas extraction plants in/near Cairo	Not applicable	Not applicable

** The AP42 document of the US EPA (chapter 10 Section 07) and the TCP/CRO/3101 (A) Development of a sustainable charcoal industry, environmental aspects of charcoal production in Croatia; FAO 2008 were also considered but were deemed less typical for the Cairo situation.*

A.1.4.2 . Source Category 1.A.2 - Manufacturing Industries and Construction Fuel Combustion

The activities essentially cover combustion activities in industry. There are many industrial facilities where combustion activities essentially relate to the use of fuels in conventional boilers, furnace, gas turbine, engine or other combustion devices. The combustion emissions of these industrial facilities are estimated using one methodology.

Sector	Activity Data	Calculation/Assumption	Emission Factors
1 A 2 a - Iron and steel	• National fuel consumption of the industry sector per fuel type [Ministry of Petroleum]; base year = 2009-2010 • Energy consumption of iron and steel sector [IDA; 2009] • Spatial distribution to point sources (foundries, EEAA GIS map)	-	Emission inventory guidebook 2009 Section 1.A.2 –Manufacturing industries and construction - Table 3-3 for gases (mean value for NOx and SOx; upper value for PM), and table 3-4 for liquid fuels (mean value for NOx; upper value for SOx and PM)
1 A 2 b – Nonferrous metals	• National fuel consumption of the industry sector per fuel type [Ministry of Petroleum]; base year = 2009-2010 • Energy consumption of copper sector [IDA; 2009] • Spatial distribution to point sources (foundries, EEAA GIS map)	• The fuel consumption has been broken down per fuel type (mainly natural gas, mazout/fuel oil and diesel) using the national ratio.	Emission inventory guidebook 2009 Section 1.A.2 –Manufacturing industries and construction - Table 3-3 for gases (mean value for NOx and SOx; upper value for PM), and table 3-4 for liquid fuels (mean value for NOx; upper value for SOx and PM)
1 A 2 c – Chemicals	• National fuel consumption of the industry sector per fuel type [Ministry of Petroleum]; base year = 2009-2010 • Energy consumption of chemicals /pharmaceuticals. / fertilizers sectors [IDA; 2009] • Spatial distribution according to industrial zones)	• The fuel consumption of the industrial sectors has been broken down per fuel type (mainly natural gas, mazout/fuel oil and diesel) using the national ratio (except for the fertilizer industry where actual numbers have been used)	Emission inventory guidebook 2009 Section 1.A.2 –Manufacturing industries and construction - Table 3-3 for gases (mean value for NOx and SOx; upper value for PM), and table 3-4 for liquid fuels (mean value for NOx; upper value for SOx and PM)

Sector	Activity Data	Calculation/Assumption	Emission Factors
1 A 2 d – Pulp, paper and print	• National fuel consumption of the industry sector per fuel type [Ministry of Petroleum]; base year = 2009-2010 • Energy consumption of pulp &paper sector [IDA; 2009] • Spatial distribution to point sources (EPAP factories, EEAA GIS map)	• The fuel consumption of the industrial sectors has been broken down per fuel type (mainly natural gas, mazout/fuel oil and diesel) using the national ratio.	Emission inventory guidebook 2009 Section 1.A.2 –Manufacturing industries and construction - Table 3-3 for gases (mean value for NOx and SOx; upper value for PM), and table 3-4 for liquid fuels (mean value for NOx; upper value for SOx and PM)
1 A 2 e – Food processing, beverages and tobacco	• National fuel consumption of the industry sector per fuel type [Ministry of Petroleum]; base year = 2009-2010 • Energy consumption of food sector [IDA; 2009] • Spatial distribution to point sources (EPAP factories, EEAA GIS map)	• The fuel consumption of the industrial sectors has been broken down per fuel type (mainly natural gas, mazout/fuel oil and diesel) using the national ratio.	Emission inventory guidebook 2009 Section 1.A.2 –Manufacturing industries and construction - Table 3-3 for gases (mean value for NOx and SOx; upper value for PM), and table 3-4 for liquid fuels (mean value for NOx; upper value for SOx and PM)
1 A 2 f – Other manufacture (cement)	• Energy consumption of cement sector [IDA; 2009] • Spatial distribution to point sources (cement factories; EEAA GIS map)		Emission inventory guidebook 2009 – Section 1.A.2 –Manufacturing industries and construction - Table 3-24 (mean value for NOx; half of upper value for SOx; note that all pollutants expect PM are allocated to combustion in cement manufacture); for PM refer to 2.A.1
1 A 2 f – Other manufacture (textile, glass, bricks)	• Energy consumption of the sectors of textile, of glass and of bricks [IDA; 2009] • Spatial distribution to point sources (EPAP factories; EEAA GIS map)	The fuel consumption of the industrial sectors has been broken down per fuel type (mainly natural gas, mazout/fuel oil and diesel) using the national ratio.	Emission inventory guidebook 2009 Section 1.A.2 –Manufacturing industries and construction - Table 3-3 for gases (mean value for NOx and SOx; upper value for PM), and table 3-4 for liquid fuels (mean value for NOx; upper value for SOx and PM)

A.1.4.23. Source Category 1.A 3 – Transport

Sector	Activity Data	Calculation/Assumption	Emission Factors
1 A 3 a - Passenger cars, light-duty trucks, heavy-duty vehicles including buses and motor cycles	• National fuel consumption of the transportation sectors per fuel type [Ministry of Petroleum]; base year = 2009-2010 • Transport fuel consumption 2010 for international aviation and domestic air transport [Ministry of Civil Aviation] • Vehicles 2009 per Governorate [CAPMAS] • Fuel Consumption in GC 2009 for three governorates [Prof.Dr.Hindawi Saleh]. • Spatial distribution according to population density (EEAA GIS map)	The calculated fuel consumption as reported in reference "Fuel Consumption in GC 2009 [Prof.Dr.Hindawi Saleh]" has been used.	Emission inventory guidebook 2009 – Section "1.A.3.b.i, 1.A.3.b.ii, 1.A.3.b.iii, 1.A.3.b.iv - Passenger cars, light-duty trucks, heavy-duty vehicles including buses and motor cycles" - Table 3-6 for NOx and PM (upper values). For NOx of passenger cars with diesel engines, the UNEP emission factor for "old diesel cars" has been used. Sulfur content and SOx emission presented in section 0
1.A.3.b.vi - Road vehicle tyre and brake wear 1.A.3.b.vii - Road surface wear	• National fuel consumption of the transportation sectors per fuel type [Ministry of Petroleum]; base year = 2009-2010 • Vehicles 2009 per Governorate [CAPMAS] • Fuel Consumption in GC 2009 for three governorates [Prof.Dr.Hindawi Saleh]. • Spatial distribution according to population density (EEAA GIS map)	• Mileage (kilometers driven) calculated using typical fuel consumption figures (Emission inventory guidebook 2009, Section "1.A.3.b.i, 1.A.3.b.ii, 1.A.3.b.iii, 1.A.3.b.iv - Passenger cars, light-duty trucks, heavy-duty vehicles including buses and motor cycles" - – table 3-13).	Emission inventory guidebook 2009 – Section "1.A.3.b.vi Road vehicle tyre and brake wear (upper value) and 1.A.3.b.vii Road surface wear" – Tables 3-1 and 3-2 (upper value)

Sector	Activity Data	Calculation/Assumption	Emission Factors
1 A 3 a - Passenger cars, light-duty trucks, heavy-duty vehicles including buses and motor cycles	• National fuel consumption of the transportation sectors per fuel type [Ministry of Petroleum]; base year = 2009-2010 • Transport fuel consumption 2010 for international aviation and domestic air transport [Ministry of Civil Aviation] • Vehicles 2009 per Governorate [CAPMAS] • Fuel Consumption in GC 2009 for three governorates [Prof.Dr.Hindawi Saleh]. • Spatial distribution according to population density (EEAA GIS map)	The calculated fuel consumption as reported in reference Saleh (2009) has been used.	Emission inventory guidebook 2009 – Section "1.A.3.b.i, 1.A.3.b.ii, 1.A.3.b.iii, 1.A.3.b.iv - Passenger cars, light-duty trucks, heavy-duty vehicles including buses and motor cycles" - Table 3-6 for NOx and PM, table 3-12 (column 1996 base fuel) for sulfur content.
1.A.3.b.vi - Road vehicle tyre and brake wear 1.A.3.b.vii - Road surface wear	• National fuel consumption of the transportation sectors per fuel type [Ministry of Petroleum]; base year = 2009-2010 • Vehicles 2009 per Governorate [CAPMAS] • Fuel Consumption in GC 2009 for three governorates [Prof.Dr.Hindawi Saleh]. • Spatial distribution according to population density (EEAA GIS map)	• Mileage (kilometers driven) calculated using typical fuel consumption figures (Emission inventory guidebook 2009, Section "1.A.3.b.i, 1.A.3.b.ii, 1.A.3.b.iii, 1.A.3.b.iv - Passenger cars, light-duty trucks, heavy-duty vehicles including buses and motor cycles" - – table 3-13).	Emission inventory guidebook 2009 – Section "1.A.3.b.vi Road vehicle tyre and brake wear and 1.A.3.b.vii Road surface wear" – Tables 3-1 and 3-2.

A.1.5. REMIP Study

Mobile Emission Source Inventory Survey; Draft Final Report; Submitted by: Cairo University Research Team, Mechanical Power Department; Faculty of Engineering, Cairo University; Submitted to: JICA Expert Team for the Regional Environmental Management Improvement Project (REMIP); February 2007.

The REMIP study provides a solid base on road transport, presenting a road classification and coding system, traffic volume and main characteristics per road section, including coordinates. It had been the intention to use the REMIP data but unfortunately it was not possible. The codes used in tables with the traffic volume (tables 3a & 3b) do not correspond with the codes used in the road section table 1a, which has the coordinates. For example [10201154 – B2 Rodh El Farg] is mentioned in the first row of table 3a (traffic volume) but this code 10101154 is not listed in table 1a (road sections with coordinates). The corresponding database tables (mentioned in the executive summary) has been requested but have not been made available. The consequence is that the spatial distribution of the traffic emissions had to be approximated.

A.1.6. Emission Factors

EEAA proposed to use the UNEP emission factor set "Tool kit text book" (titled "Clean up Your Fleet Textbook"; available at http://www.unep.org/tnt-unep/toolkit/; undated). The UNEP set is based on measurements of Nairobi vehicles. The UNEP factor methodology requires more detailed information on the engine types than is available. The EMEP tier 1 methodology gives emission factors for a vehicle fleet with mixed engine types, based on fuel consumption. The EMEP emission factor set presents a typical EU-15 fleet in 1995 and covers a mix of with controlled and uncontrolled vehicles. The UNEP/EMEP factors have been compared based on some additional assumptions for the UNEP set. The impact of the emission factor set has been analyzed in the sensitivity analysis. The UNEP / EMEP comparison reveals that the resulting emissions are comparable when using the upper values of the EMEP emission factor range. One NOx emission factor of the UNEP set has been used along with the EMEP tier 1 emission factors.

The most detailed EMEP emission estimation methodology (tier 2 and tier 3) uses emission factor expressed as g/km, similar to the units used in emission regulation, for example the Euro emission standards (along with a test cycle) and also US EPA legislation (both standards are used in other parts of the world). As this methodology requires very detailed information on the driving conditions and as this is not available for Greater Cairo, the simpler methodology (tier 1) has been used.

The conversion from fuel consumption to mileage is necessary for calculation of the PM emissions caused by wearing of roads and vehicle (tires) as these emission factors are expressed per km. The calculation is based on the typical fuel consumption figures presented in Emission inventory guidebook 2009.

A.1.6.1 Source Category 1.A.4 – Fuel Consumption from Other Sectors

Sector	Activity Data	Calculation/Assumption	Emission Factors
1.A.4.a. - Commercial	• National fuel consumption of the Residential & Commercial sector, of Tourism sector and of Roads & Contracting [Ministry of Petroleum]; base year = 2009-2010 • Spatial distribution according to population per district (EEAA GIS map)	• Ratio of 30% used for the Cairo area versus national total • Fuel consumption assumed 50% residential and 50% commercial	Emission inventory guidebook 2009 – Section "1.A.4.a.i, 1.A.4.b.i, 1.A.4.c.i, 1.A.5.a - Small combustion" – Tables 3-8 for gases and 3-9 for liquid fuels.
1.A.4.b - Residential	• National fuel consumption of the residential & commercial sector [Ministry of Petroleum]; base year = 2009-2010 • Production estimation per governorate by EEAA (base year = 2010) • Spatial distribution according to population per district (EEAA GIS map)	• Ratio of 30% used for the Cairo area versus national total • Fuel consumption assumed 50% residential and 50% commercial • Cairo charcoal production = Cairo charcoal consumption	Emission inventory guidebook 2009 – Section "1.A.4.a.i, 1.A.4.b.i, 1.A.4.c.i, 1.A.5.a - Small combustion" – Tables 3-4 for gases, 3-5 for liquid fuels, and 3-14 for charcoal.
1.A.4.c - Agriculture, Forestry and Fishing	• National fuel consumption of Agriculture & Irrigation [Ministry of Petroleum]; base year = 2009-2010 • Spatial distribution to agricultural areas (EEAA GIS map)	• Ratio of 30% used for the Cairo area versus national total	Emission inventory guidebook 2009 – Section "1.A.4.a.i, 1.A.4.b.i, 1.A.4.c.i, 1.A.5.a - Small combustion" – Tables 3-8 for gases and 3-9 for liquid fuels.

A.1.7. Sulfur Content

The calculations of the SOx emissions from fuel combustion are based on the sulfur content of the fuels. Unfortunately, the actual average sulfur content is not known. However, the maximum sulfur content of the fuel types has been specified by communication of the Ministry of Petroleum (June 2011).

- Fuel oil (mazout): 2.5 % sulfur, i.e. 25 kg S/ton
- Diesel: 1% (10,000 ppm) sulfur, i.e. 10 kg S/ton
- Gasoline: 0.05% (500 ppm) sulfur, i.e. 0.5 kg S/ton.

The EEAA estimates that the market average value of the sulfur diesel content is 4,000 ppm or less (communication of February 2012). The situation for a specific industrial plant may differ from the market average. For example, the sulfur content of the fuel oil in Mostrod refinery amounts to approximately 2.6-2.8 percent S (source: Ministry of Petroleum). Sulfur content numbers of low sulfur fuels as for example natural gas are not available but are less important as the associated SOx emission are insignificant compared to the SOx emissions of the "high sulfur fuels" (fuel oil, diesel and gasoline). The molecular weight of sulfur (32 g/mol) is half of the one of SO_2 (64 g/mol), i.e. the SO_2 emission factor equals two times the sulfur content value, assuming complete conversion.

Taking the above into consideration, the selected values for the sulfur content or SOx emission factors are presented in the following table.

Fuel	**Reference**	**Sulfur Content**	[ppm] or [g/ton]	**Default* SOx Emission Factor**
Fuel oil (mazout)	Max. allowed content (Ministry of Petroleum)	2.5%	25000	*
Diesel	Estimated max. market average (EEAA)	0.4%	4000	20 kg/ton
Gasoline	Max. allowed content (Ministry of Petroleum)	0.05%	500	1 kg/ton
Natural gas	Emission inventory guidebook 2009	0.01 g/m^3		0.3 g/GJ
LPG	Assumption	negligible		negligible

* There are various processes where not all the sulfur in the fuel is emitted as SOx to the atmosphere. The emission factors that are specified in the Emission inventory guidebook 2009 have been used as the basis but adjusted for the above sulfur contents. For example the handbook gives SOx emission factors of heavy oil based on 1 percent sulfur content. These factors have been multiplied by 2.5 to adjust for 2.5 percent sulfur of the Egyptian heavy fuel.

Source Category 2 - Industrial Processes

This section covers the process emissions only. The combustion related emissions are covered by source category 1.A.2.

Sector	Activity Data	Calculation/Assumption	Emission Factors
2.a.1 Cement production	• Cement production of Cairo Governorate [IDA and EEAA]; base year = 2010 • Spatial distribution to point sources (cement factories; EEAA GIS map)	-	Emission inventory guidebook 2009, Section 2.A.1 Cement production - Table 3-1 for PM (upper value)
2.a.2 Lime production	• Lime production of Cairo Governorate [IDA]; base year = 2009 • Spatial distribution to point sources (cement factories; EEAA GIS map)	-	Emission inventory guidebook 2009, Section 2.A.2 Line production - Table 3-3 for PM (upper value)
2.a.3 Limestone and dolomite use	• Limestone production of Cairo Governorate [IDA]; base year = 2009 • Spatial distribution to point sources (cement factories; EEAA GIS map)	• Emissions of NOx/SO_2/PM from this source are not significant.	Not applicable
2.a.4 Soda ash production and use	• Soda ash production of Cairo Governorate [IDA]; base year = 2009 • Spatial distribution according to industrial zones	-	Emission inventory guidebook 2009, Section 2.A.4 Soda ash production and use - Table 3-1 for PM (50% and 25 % upper TSP value for respectively PM_{10} and $PM_{2.5}$)
2.a.5 Asphalt roofing	• Asphalt roofing production of Cairo Governorate [IDA]; base year = 2009 • Spatial distribution according to industrial zones	-	Emission inventory guidebook 2009, Section 2.A.5 Asphalt roofing - Table 3-1 for PM (50% and 25 % upper TSP value for respectively PM_{10} and $PM_{2.5}$)
2.A.7.b Construction and demolition	• Surface area of the urbanized areas (EEAA GIS maps) • Spatial distribution according to urbanized areas (EEAA GIS maps)	• Assuming that 5% of populated Cairo area is under construction, consisting of 2% for renovation (based on a building lifetime of 50 years) and 3% for expansion; based on GC inhabitants growth).	Emission inventory guidebook 2009, Section 2.A.7.b Construction and demolition - Table 3-1 for PM (upper values)

2.b.1 Ammonia production	• National ammonia production [IDA]; base year = 2009 • Spatial distribution according to industrial zones	.	Emission inventory guidebook 2009, Section 2.B Chemical industry - Table 3-1 for NOx (mean value)
2.b.2 Nitric acid production	• Nitric acid production of Cairo Governorate [IDA]; base year = 2009 • Spatial distribution according to industrial zones	-	Emission inventory guidebook 2009, Section 2.B Chemical industry - Table 3-2 for NOx (mean value)
2.b.3 Sulfuric acid production	• Sulfuric acid production of Cairo Governorate [IDA]; base year = 2009 • Spatial distribution according to industrial zones	-	Emission inventory guidebook 2009, Section 2.B Chemical industry - Table 3-21 for SOx (mean value)
2.c.1 Iron and steel production	• Iron & steel production of Cairo Governorate [IDA]; base year = 2009 • Spatial distribution to point sources (foundries; EEAA GIS map)	-	Emission inventory guidebook 2009, Section - Table 3-1 for PM (upper values)
2.c.3 Aluminum production		There is no primary aluminium production in Greater Cairo	Emission inventory guidebook 2009, Section 2.C.3 Aluminium production – Table 3-1 (mean value for NOx and SOx; upper value for PM)
2.d.1 Pulp and paper	• Paper production of Cairo Governorate [IDA]; base year = 2009 • Spatial distribution according to industrial zones	-	Emission inventory guidebook 2009, Section 2.D.1 Pulp and paper – Table 3-1 (mean value for NOx and SOx; upper value for PM)
2.d.2 Food and drink	• Food and drink production per governorate (Cairo, Helwan, 6 of October, Qalyubia and Giza) [IDA]; base year = 2009 • Spatial distribution to point sources (EPAP; EEAA GIS map)	Assuming no significant PM/NOx/SO_2 process emissions	Not applicable

The Cairo CMB Source Apportionment Study identified the following industrial processes:

a) Lead smelter
b) Copper foundry
c) Cement plant
d) Iron production

Production data on cement and iron plants has been provided, whereas no data lead and copper smelters was provided. It is assumed that the latter are no longer operational in the greater Cairo area.

The emissions of the cement production have been calculated with default emission factors, consisting of:

- Fuel related emissions: (NOx and SOx)
- Not fuel related emissions: particulate matter (PM10, PM2.5).

Source Category 4 – Agriculture

Sector	Activity Data	Calculation/Assumption	Emission Factors
4 A/B – Livestock	• Number of animals 2009 per governorate [CAPMAS] • Spatial distribution according to agricultural areas (EEAA GIS Map)	-	Emission factors as per ministerial guideline of the Netherlands (May 2010; PM10 and livestock).
4 F – Field burning of agricultural residues	• Field burning 2009 per governorate) [Ministry of local development; EEAA] • Spatial distribution according to agricultural areas (EEAA GIS Map)	-	Egypt State of the Environment 2009, table 1-8 for TSP + Emission inventory guidebook 2009, (Activity 4.F – Field burning of agricultural wastes – table 3-6 Burning rice) for the break-down of TSP into PM10 and PM2.5 fraction.

The livestock emission factors are taken from ministerial guideline of the Netherlands (May 2010; PM10 and livestock):

- Cows: 148 g PM10 per animal per year (used for cows, buffalo, camels, horses, asses, donkeys, sheep and goats)
- Chickens: 23 g PM10 per animal per year (used for poultry)

Monitoring results in the Netherlands revealed that 18 percent of PM_{10} emitted consists of $PM_{2.5}$.

It is assumed that the field burning numbers refer to rice straw only. The production numbers are copied from a table of EEAA sent on 13 April 2011 [References: Ministry of Local Development and EEAA]. The column title is "*rice straw*", and the table title is "*Field Burning of Agricultural Residues 2008/2009*". Most of the rice straw field burning occurs upwind in the Delta area. These emissions are not covered in the emission inventory of Greater Cairo but the contribution of the rice straw burning to the PM air pollution is included in the iso-concentration contours (courtesy of the EEAA).

Source Category 6 C – Waste Incineration

Sector	Activity Data	Calculation/Assumption	Emission Factors
6 C – Waste incineration	• Waste incineration 2009 per governorate (not being field burning nor WTE facilities) [Ministry of local development; EEAA] • Spatial distribution according to population density for (Cairo and Giza) and to specific landfill sites (Helwan, 6 October and Qalyubia)	-	Emission inventory guidebook 2009, Activity 6.C.e – Small scale waste incineration – table 3-1 (upper values).

Source Category 7 – Natural Processes and Other Sources

The Cairo CMB Source Apportionment Study identified several natural PM sources:

- Geological erosion sources: dust from El-Zamalek soil, Helwan soil, Kaha soil and pure lime ($CaCO_3$)
- Sea salt.

Also pollution from regions outside the Cairo area create a "background concentration". The contribution of these sources is accounted for as a background concentration level, i.e. the emission sources as such are not quantified.

Annex 2. Valuation Method

Source: Doumani (2011)

Background

Air pollution, which is caused by industrial and mining processes, energy production, various modes of transport, domestic energy use, other activities as well as natural causes (sand storms) is attributable to common but harmful pollutants such as notably ozone (O_3), fine respirable particulate matter ($PM_{2.5}$ and PM_{10}), carbon monoxide (CO), sulfur monoxide and dioxide (SO_x), nitrogen monoxide and dioxide (NO_x) and lead, as well as volatile organic compounds (VOC). However, up to 98 percent of the health benefits attributed to the US 1990 Clean Air Act, 1970-90 came from reductions in PM and lead as the other compounds represented only 2 percent (Cropper, 2003). Moreover, while effects of short-term and long term exposures to high levels of outdoor air pollution are usually emphasized (Pope et al. 1995, 2002 and 2009) a study of the five criteria pollutants in the United States showed that long-term chronic exposure to lower concentrations of air pollutants can also affect human health (Kyle et al., 2002). Also, elevated levels of SO_2 and NO_x could have adverse effects as they can react with other substances in the atmosphere to form particulates, e.g., SO_4^{2-}. For the case of O_3 and VOC, short exposure to high levels could have serious health effects but WHO and EPA revoked the yearly exposure guidelines.

The methodology adopted for Greater Cairo focuses on the PM_{10}, $PM_{2.5}$ and lead as the other compounds are below WHO thresholds. Epidemiological evidence suggests that there may be a link between ozone exposures and premature mortality, however possible confounding with PM-related mortality precludes its inclusion in the PM analysis. In the valuation, WHO air pollution guidelines (WHO website: www.who.int) are considered.

The DALY Metric

The Disability-adjusted life years (DALY), which is a metric that measures the decrement or increment in health state, was used to determine the burden of air pollution in Greater Cairo in health terms. Hence, the mortality and morbidity derived in Table A2.1 are denominated in DALY lost to quantify the health effects associated with the reduction or increase of the level of pollutants. The analysis will assign a value on the DALY lost (see below).

The DALY is a non-utilitarian metric that measures the burden of disease and expresses years life lost to premature death and years lived with a disability of specified and normalized severity (0 to 1) and duration (1 to 365 days). The DALY is *one lost year of healthy life* and could be interpreted in two different ways. A *DALY lost* stands for the magnitude of the burden of disease; and a *DALY averted* stands for the magnitude of the burden of disease to be reduced through a policy choice, project or intervention. The DALY life expectancy is set at 80 years for males and 82.5 years for females and the DALY [3,1] is discounted at 3 percent and includes the age weights whereby a year of healthy life lived at younger and older ages was weighted lower than the other ages, which remain controversial: the discount rate is considered a social discount rate to reflect people preferences with regards to a future disease or condition, e.g., smoking kills but young people keep on smoking which means that they put less weight on their future health than on their actual health, nevertheless, DALY lost could be calculated without the social discount and the age weights, and is usually represented as follows: DALY [0,0]. Hence DALY lost associated with premature death varies with age and is illustrated in Table A2.1 (METAP, 2009; and Murray and Lopez, 1996). In the current analysis, the DALY [3,1] was considered. For more information on the severities and duration of the various diseases to derive DALY lost, see Murray and Lopez (1996) and WHO website: www.who.int.

Table A2.1. Life Expectancy and DALY Lost at selected ages by Gender

Age	Life expectancy		DALY lost at selected ages discounted at 3%	
	Male	Female	Male	Female
At Birth	80.0	82.5	33.0	33.0
5 years	75.4	78.0	36.5	36.7
15 years	65.4	68.0	36.8	37.0
30 years	50.5	53.3	29.6	29.9
45 years	35.8	38.7	20.2	20.7

Source: Murray and Lopez (1996).

Dose-Response

The valuation will use the exposure-based evidence from international literature by using the relative risk functions provided by Ostro et al. (2004) and Pope et al. (1995,2002 and 2009). The impacts of PM_{10} and lead on morbidity are based on dose response coefficients from Ostro (1994) and Akeson et al. (1999) and are illustrated in Table A2.2:

- adult mortality related to cardiopulmonary diseases and lung cancer caused by long-term exposure to $PM_{2.5}$;
- Children under 5 year mortality related to respiratory diseases caused by short-term exposure to PM_{10};
- all-age morbidity related to exposure to PM_{10}, such as chronic bronchitis, hospital admissions of patients with respiratory problems, emergency room visits, restricted activity Days (RAD), lower respiratory infections in children, and general respiratory symptoms.
- adult mortality related to heart attack related to exposure to Pb;
- adult morbidity related to hypertension related to exposure to Pb; and
- Children under 5 year losses of IQ points.

An important question is whether the effects of short term and long term exposures can be aggregated when estimating the damages associated with air pollution. The general answer is yes, if the exposures affect different health endpoints. For example, in computing total health damages, it is certainly appropriate to add cases of acute respiratory illness associated with short term exposures to PM to cases of chronic bronchitis associated with long term exposures to PM.

The relationship between PM_{10} air pollution and short term premature mortality on children under 5 is usually assumed to be semi-logarithmic that may be applied to estimate the relative risk of mortality from concentration levels of PM_{10}:

Relative Risk =

(1) $E(\text{deaths}) = \exp[\beta(\text{pollution}) - (\text{compound threshold})]$,

(2) $(\Delta\text{deaths})/\text{deaths} = \beta(\Delta\text{pollution})$.

Equivalently, ($\beta\Delta$pollution) is the percentage change in deaths associated with a given change in pollution. This implies that a given change in pollution (e.g., 10 micrograms per cubic meter or $\mu g/m^3$ of PM_{10}) has the same percentage impact regardless of the level of pollution.

The relationship between $PM_{2.5}$ air pollution and long term premature mortality on adults greater than 30 years is usually assumed to be log-linear that may be applied to estimate the relative risk of mortality from concentration levels of $PM_{2.5}$:

$$\text{Relative Risk} = [(X + 1)/(X_0 + 1)]^{\beta}$$

where X is annual concentration of $PM_{2.5}$; and X_0 is a threshold level below which it may be assumed that the relative risk of mortality from $PM_{2.5}$ is 1.0 (no mortality effect from $PM_{2.5}$). The β coefficient is 0.1551 for cardiopulmonary mortality and 0.2322 for lung cancer mortality.

The attributable fractions (AF) assess the proportion of cases in a population attributable to certain risk factors. One of the most frequently applied approaches calculating the AF is the Levin formula, which requires only the relative risk estimate (RR) and the prevalence of the risk factor (p):

$$AF = p*(RR-1)/1+p*(RR-1)$$

where p is derived from WHO's Burden of Disease prevalence of risk factors and RR is derived from the above formulas.

In case of Egypt, death prevalence for: Acute Respiratory Infection is 0.0398 percent; lung cancer is 0.0089 percent; and cardiopulmonary disease is 0.5754 percent (WHO Burden of Disease database website: www.who.int/healthinfo/global_burden_disease/en/index.html).

End Points Used

The morbidity health endpoints considered are chronic bronchitis, hospital admissions of patients with respiratory problems, emergency room visits, restricted activity days, lower respiratory infections in children, and general respiratory symptoms. While this list is not exhaustive, it captures the health endpoints that are likely to have the largest monetary impact on total damages. Case in point is the chronic bronchitis coefficient used in the 2002 Egypt COED was three times higher than the one used in the current analysis as the latter is based on more recent epidemiological evidence.

Table A2.2 summarizes the impact of the common air pollutants on other health endpoints, including the incidence (number of new cases) of chronic bronchitis, respiratory hospital admissions, respiratory restricted activity days and sub-clinical symptoms (itchy, watery eyes, runny nose). Estimates of the effects of air pollution on the incidence of chronic illness come from cross-sectional studies. Most of the remaining impacts rely on time series variation in air pollution to measure its impact on health.

Table A2.2. Dose Response Functions with the Main Criteria Pollutants: Central Estimates

Annual Health Effects and Pollutant standards	Age Group or % reduction	Effects of 1 μg/m^3 annual average ambient concentration			
		PM_{10}	$PM_{2.5}$	Pb	SO_2
PM_{10} until reaching 20 μg/m^3					
Premature mortality	Under 5 years	0.084			
Chronic bronchitis	100,000 of >15 years	0.87			
Hospital admissions	100,000 of >15 years	1.2			
Emergency room visits	100,000 of >15 years	23.5			
Restricted Activity Days (RAD)	100,000 of >15 years	5,750			
Acute Lower Respiratory Infection	100,000 of Under 5 years	169			
Respiratory symptoms	100,000 of >15 years	18,300			
$PM_{2.5}$ until reaching 10 μg/m^3					
Premature mortality	% reduction		0.8		
Pb until reaching 0.5 to 1 μg/m^3					
Premature mortality	Per 100,000 adult males >45 years			35	
IQ Point Loss (points)	Per 1 Under 5 years			0.98	
Hypertension cases	Per 100,000 adult males >15 years			7,260	
Doctor's Visits: ½ the cases	Per 100,000 adult males >15 years			3,630	
RAD: 1 day	Per 100,000 adult males >15 years			3,630	
Non-fatal heart attack cases	Per 100,000 adult males >45 years			34	
Hospital admissions: 3 days	Per 100,000 adult males >45 years			17	
Emergency room visits: 1 day	Per 100,000 adult males >45 years			17	
RAD: 4 days	Per 100,000 adult males >45 years			136	
SO_2 until reaching 50 μg/m^3					
Premature mortality	% reduction				0.048
Respiratory symptoms	100,000 of Under 5 years				0.0018
Chest discomfort	100,000 of >15 years				0.01

Source: Adapted from Ostro (1994); Pope et al. (1995); Pope et al. (2002); WHO (2005); and Pope et al. (2009).

It should be noted that, while the impact of a change in pollution concentrations is usually measured in terms of a percentage change in the health endpoint of concern this is not always the case. When the impact is measured per person (for each person in the exposed population) care must be taken to compare the size of the estimated effect to the baseline number of cases of the illness to check that results are reasonable.

Valuation

Valuing mortality remains controversial. Still the human capital approach (HCA) and the value of statistical life (VSL, which is an expression of preferences for reducing risks of death in monetary terms) were used as a lower and a higher bound, respectively, for premature mortality cases. Most importantly, these values are the social cost of premature death and are considered in terms of welfare economics which is a branch of economics that uses microeconomic techniques (stated or revealed preferences) to valuate economic well-being.

The HCA, which is considered the lower bound value, is the net present value of the foregone income from mortality from age 20 to 65 years. For simplification purposes, the GDP per capita is applied per DALY lost. The VSL, which is considered the upper bound value, adapts values derived internationally by using a benefit transfer method. In this particular case, the VSL meta-analysis figure of US$3.5 million in 2000 is provided by Viscusi and Adly (2003) and transferred to Egypt. The VSL is divided by 20 DALY lost to determine the value per DALY lost.

Valuing morbidity, one could use either Cost of Illness estimates or estimates of willingness to pay to avoid morbidity transferred from international studies, with adjustment for income. In the current case, illness costs were derived from the World Bank Egypt COED (2002), calibrated for year 1999 and projected to 2009 and 2020. The GDP nominal growth rate is used to adjust the various costs over the 1999-2009 periods and the 2009-2020 periods (Table A2.3 and Table A2.4). It is important to mention that the figures are supposed to be real costs irrespective of the subsidized share by the public sector.

Table A2.3. Cost of Illness Used in the Valuation

		1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
±% GDP growth nominal			11%	5%	6%	10%	16%	11%	15%	21%	20%	16%
Hospitilization	LE/day	470	519	548	579	638	741	822	943	1,138	1,368	1,586
Emerg. Visit	LE/visit	78	87	91	97	106	124	137	157	190	228	265
Doctor Visit	LE/visit	39	43	46	48	53	62	69	79	95	114	132
RADs	LE/day	22	24	26	27	30	35	39	44	54	65	75
HCA low	LE/DALY Lost	4,467	4,847	5,015	5,198	5,619	6,409	6,980	7,859	9,303	10,985	12,513
VSL high	LE/DALY Lost	17,588	19,446	20,510	21,665	23,872	27,749	30,791	35,319	42,585	51,209	59,385

Note: The benefit transfer used the Purchasing power parity (PPP) for the income differential because nominal exchange rates do not always reflect international differences in relative prices hence PPP rates allow a standard comparison of real price levels between countries, just as conventional price indexes allow comparison ofreal values over time; the income elasticity is assumed to be conservatively set at 1, which means that the percentage responsiveness of quantity demanded is exactly equal to the percentage change in income. The PPP$ conversion factor or international dollar is used for the GDP/capita, which

is the number of units of a country's currency required to buy the same amount of goods and services in the domestic market as a U.S. dollar would buy in the United States.
Source: World Bank (2002); Viscusi and Adly (2003); and Doumani (2011).

Table A2.4. Cost of Illness Used in the Projection

		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
±% GDP real growth			4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Hospi.	LE/day	1,586	1,650	1,716	1,784	1,856	1,930	2,007	2,087	2,171	2,258	2,348	2,442
Emerg. Visit	LE/visit	265	275	286	298	310	322	335	348	362	377	392	408
Doctor Visit	LE/visit	132	138	143	149	155	161	168	174	181	188	196	204
RADs	LE/day	75	78	81	84	88	91	95	98	102	106	111	115
HCA low	LE/DALY Lost	12,513	13,014	13,534	14,076	14,639	15,224	15,833	16,467	17,125	17,810	18,523	19,264
VSL high	LE/DALY Lost	59,385	61,760	64,231	66,800	69,472	72,251	75,141	78,147	81,273	84,523	87,904	91,421

Source: World Bank (2002); Viscusi and Adly (2003); and Doumani (2011).

Annex 3. Summary of Air Pollution Reduction Measures in Some Major Cities

Sector	Measurements	Effectiveness	Cost	Cost	Coordination cost	Term			Country experience			
						Short	Mid	Long	Manila	Jakarta	Bangkok	Mumbai
Transport	**Traffic Management Systems to reduce congestion**											
	Installing traffic signals, introducing one-way roads and improving parking facilities, and coordinating different transportation modes, such as introducing separate bus lanes Construction and improvement of mass-transit systems (Introduction underground rail system, Light rail transport systems (streetcars), Bus Rapid Transit System (BRTS))	environmental benefits, such as increased urban efficiency and improved real estate values, are larger but environmental benefits may only become visible over a long period of time **Manila**: The BRT project in the Philippines will require $350 million in funding for the total 50 kilometers	The investment costs of introducing mass transportation are larger than introduction of technical devices for pollution control	△	H			x	x			x
	Implementing an inspection and maintenance (I/M) scheme	It would reduce tail-pipe emissions of PM10, VOC, and CO by one-third. **Jakarta**: Results from voluntary I&M program in Jakarta showed substantial reductions of CO (±50%), HC (±35%), and opacity (±45%) emissions **Manila:** Reduced mortality 316; reduced RSD 8 milloin; Benefits P1.1 billion; Reduction of CO, VOC; 4,000 tons PM10 avoided annually	Maintenance costs are expected to be offset by improved fuel efficiency	◎	L		x		x	x	x	x
	Addressing polluting vehicles (high use and diesel vehicles)	emission reduction of 1,000 tons of PM10 **Jakarta**: Reduced mortality 163; reduced RSD 4 million; avoided health costs Rp23.7 billion	Varied depending on implementation	○	L		x		x	x	x	
	Phase-out of old vehicles		Depend on the scale of program	○	M		x					x
	A restricted-access policy: restricting the use of vehicles, curbing parking in specific zones	A few cities, including Athens and Mexico City, are attempting to control episodic pollution during stagnant weather by restricting the use of vehicles on those days. For example, only vehicles with odd license numbers are allowed on the road on certain days, alternating with those with even license numbers.	Relatively low	◎	M	x						
	A restricted-access policy: road-pricing systems or levying toll at the entry of specific zones	**Singapore**: 14 years of direct road pricing through Area Licensing Schemes have significantly reduced congestion and helped to control the growth in vehicle use in central Singapore. An initial reduction in morning peak traffic was considerably greater, at 70%, than intended. The reduction in traffic has settled down to about 44%, with an increase of 22% in traffic speeds.	Initial investment is required but expect to be offset by collection of fees	○	M		x					

Sector	Measurements	Effectiveness	Cost	Cost	Coordination cost	Term			Country experience			
						Short	Mid	Long	Manila	Jakarta	Bangkok	Mumbai
Transport	**Emission reducing devices**											
	Application of three-way (closed-loop) catalytic converters	Catalytic converter can lead to a 90% reduction in tail-pipe emissions of CO, NOx and VOC. They must be used in conjunction with unleaded gasoline. After 1993, all cars must be installed with catalytic converters in	Extra purchasing costs of a car equipped with a three-way catalyst, and a fuel control system is up to US$400 per car (pre tax)	○	L		x		x	x	x	
	Application of oxidative catalytic converters (oxidation catalysts)	Catalytic converter can lead to a 90% reduction in tail-pipe emissions of CO, Nox and VOC. They must be used in conjunction with unleaded gasoline	Extra purchasing cost of vehicles equipped with these open-loop control systems (oxidation catalysts) is US$200 per car or motorcycle	◎	L		x					
	Carbon canister (carbon filter)	80% of evaporation emissions	Each canister adds US$100 to the cost. Some of this cost is compensated by savings from reduced fuel loss	◎	L	x						
	Shift two-stroke motorcyles to four-stroke	Over 80% of Thai motorcycle production have shifted to 4-stroke engines	The 4-stroke motorcycles are less polluting, have better fuel efficiency, and are priced similarly to the 2-stroke ones	◎	L		x		x		x	
	Adoption of clean vehicle emissions standards to promote above technologies	Varied depending on enforcement		◎	H			x	x	x	x	x

Sector	Measurements	Effectiveness	Cost	Cost	Coordination cost	Term: Short	Term: Mid	Term: Long	Country experience: Manila	Country experience: Jakarta	Country experience: Bangkok	Country experience: Mumbai
Transport	**Improving fuel quality**											
	Reduction of sulfur content of diesel fuel	Proportional to the decrease of sulfur content. In Thailand, the benzene content of gasoline is limited to less than 3.5% by volume and the aromatic content is set to be lower than 35% by volume. For diesel fuel, sulfur content is reduced from 1.0 to 0.5% by weight.	Depend on local fuel-market conditions, and on initial and required sulfur content. Some of the additional cost is compensated by benefits from longer lasting exhaust systems	◎	L					x	x	x
	Banning lead in gasoline	100% reduction	Depend on local fuel-market conditions	◎	L		x			x	x	x
	Using better quality e.g., more volatile, diesel fuel	Depends on a range of other variables, such as tuning and maintenance of motors. Increasing cetane number and adding detergents would result in 10% reduction of PM10 <u>**Jakarta:**</u> Reduced mortality 41; reduced RSD 1 milloin; avoided health costs Rp5.9	Low. Depend on local fuel-market conditions	◎	L		x		x	x	x	
	Fuel switching to CNG (compressed natural gas)	90% reduction in PM10	Relate to technical alteration of engines and fuel systems, increased inspection and maintenance, and an infrastructure for the supply of CNG. These costs maybe partly offset by low CNG costs	◎	L		x			x		x
	Fuel switching to NG, LPG	LPG does not contain lead and sulfur (order of magnitude of emissions reduction is 25%) <u>**Manila**</u>: Reduced mortality up to 600; reduced RSD up to 15 milloin; benefit P550 million; reduction of SO2 emissions; Jeepney/UV using gasoline avoided 2,000 tons PM10 annually	Depend on local fuel-market conditions. Obstacles include the severely limited number of natural-gas stations, the relatively high initial cost of installing engines specifically designed for natural gas and of modifying existing petrol and diesel	◎	L		x	x	x		x	
	Improving quality of lubricating oil (the use of "low-smoke" or "smokeless" lubricating oil)	It is assumed that the use of a better lubrication oil would cut the emissions in half (Jakarta)	The price of such oil (marketed in Western Europe) is double the price of lubricating oil currently used in South East Asia	○	L	x				x		

Sector	Measurements	Effectiveness	Cost	Cost	Coordination cost	Term			Country experience			
						Short	Mid	Long	Manila	Jakarta	Bangkok	Mumbai
Transport	Reinforcing the "anti-smoke belching program"	50% reduction **Manila**: 2,000 tons PM10 avoided at a cost of P2.5 million. Mortality avoided 158; RDS avoided 4 million; Benefits P550 million	Depend on the scale of program. Cost of annual inspection per jeepney/utility vehicle was P200	○	L	x			x			
	Road Dust Control											
	Sweeping, cleaning and washing of roads	Depend on the scale of program	Depend on the scale of program	○	L	x	x				x	
	Road side Inspection	Varied depending on enforcement. Roadside inspection for smoky vehicles in Bangkok is carried out every day by four agencies	Depend on the scale of program. Roadside inspection for smoky vehicles in Bangkok is carried out every day by four agencies.	○	L	x					x	
Power/ Industry	**End of pipe technologies to control particulate emissions in industries and power plants**											
	Electrostatic filters	Up to 99.9% reduction. Residual concentration of TSP in waste gases are less than 50 mg/M3	Energy consumption: 0.3 - k Wh/1,000m3. Investments order of magnitude larger than cyclones	○	L	x			x			
	Fabric filters	Up to 99% reduction	Typical investments range from Dfl 25 to 5 (per cubic meter), with flow rates varying between 1,000 to 100,000m3 /hour (excluding ducting costs)	○	L	x			x			
	Cyclones	Up to 100% reduction (depending on particle size distribution)	Equipment relatively simple (no moving parts). Requires fan. Consumption of energy: 0.25- 1.5 kWh/1000m3. Indication of investments (without ducts and construction): US$500-1000 per 1000m3/h	◎	L	x			x			
	Wet scrubbers	Up to 100% reduction	Costs are variable and generally high	○	L	x						
	Increasing stack height	Only reduces ambient concentrations, not emissions	Depend on various factors and local construction costs	○	L	x						

Sector	Measurements	Effectiveness	Cost	Cost	Coordination cost	Term			Country experience			
						Short	Mid	Long	Manila	Jakarta	Bangkok	Mumbai
Power/ Industry	**Regulatory**											
	Environmental Impact Assessment	Varied depending on enforcement. In Thailand, enforcing agency has the authority to revoke a factory's operating license if the standards set are not being followed. In addition to providing penalties for a company operating a factory in violation of stipulated requirements, the company's directors, managers, and operators of the factory may also be individually liable for damages and criminal violations.		○	M		x				x	x
	Emission Standards	Varied depending on enforcement	Low	◎	H			x	x	x	x	x
	Monitoring Requirements	Varied depending on enforcement		○	H		x				x	
	Integrated Area Management	Groups of various industries are located in industrial estates or complexes	The initial investment will be expensive but there will be cost sharing among enterprises	△	H			x			x	x
	Energy Efficiency											
	Improve thermal insulation, mechanical draft etc, improve EE of kilns		The costs are expected to off set by saved energy	○	L		x					
	Cleaner production											
	Promoting cleaner fuels		Depend on local fuel-market conditions	○	L	x			x			
	Promoting renewable energies	Up to 100% reduction	Generally expensive	△	L			x				
	Replacement of coal and biomass with electricity if consistent supply is available	Up to 100% reduction	Relatively expensive	○	L		x					

Annex 4. Intervention Cost Effectiveness to reduce PMx

Agricultural Waste

Under the ongoing EEAA-backed scheme that started 7 years ago, an ongoing activity subsidizes entrepreneurs up to LE 82 per ton of rice straws to produce compost or about US$13.9 million to US$18.6 million per year based on 30–40 percent coverage. EEAA makes sure that the rice straw residues are turned into compost (Table A4.1).

Table A4.1: EEAA-backed Scheme Waste Generation and Lower and Upper Bound PM_{10} Emission, 2011

Lot Access	Area	Rice Straw	Rice Straw	PM_{10} Emission	PM_{10} Load	PM_{10} Reduced	CO_2 Emission	CO_2 Load	CO_2 Reduced	Subsidized Disposal Cost: EEAA	Total Disposal Cost	Cost/PM_{10} reduced
	Feddan	Ton / Feddan	Ton million	Kg/ton	Tons	Tons	Kg/ton	Ton million	Ton million	LE Cost/ton	LE million	LE/ton
Lower Bound												
Good	510,000	5	2.6	8	20,400	20,400	900	2.3	2.3	82	209.1	4,299
Medium	170,000	5	0.9	8	6,800	6,800	900	0.8	0.8	82	69.7	4,299
Poor	1,020,000	5	5.1	8	40,800		900	4.6			-	
Total	1,700,000		8.5		68,000	27,200		7.7	3.1		278.8	4,299
Upper Bound												
Good	510,000	2	1.0	31	31,620	31,620	900	0.9	0.9	82	83.6	2,775
Medium	170,000	2	0.3	31	10,540	10,540	900	0.3	0.3	82	27.9	2,775
Poor	1,020,000	2	2.0	31	63,240		900	1.8			-	
Total	1,700,000		3.4		105,400	42,160		3.1	1.2		111.5	2,775

Note: Cost effectiveness figures derived from Tables A4.3 and A4.5 below.

Source: Doumani (2011).

This scheme targets easy (30 percent) to medium (10 percent) access lots as access to the remaining landlocked lots is difficult unless farmers are incentivized to transport the rice straws to an access point. Fodder and biogas pilots proved to be less viable than the compost alternative (see METAP below). A lower and upper bound was considered for PM_{10} emissions: 8 kg of PM_{10} per ton by higher rice straw per feddan of 5 as reported in El Seoud (2010); and 31 kg per ton but lower rice straw per feddan of 2 as reported in Broader (2011). PM_{10} emissions range between 68,000 tons and 105,400 tons respectively for the entire country with a cost-effectiveness of LE 4,299 and 2,775 per ton of PM_{10} averted respectively (Table A4.1).

Under METAP, GTZ International Services conducted astudy in 2006 that identified the priority Governorates of Sharkia, Gharbia, Qaliobeya, Kafr El-Sheikh and Dakhlaya where the burning of the rice straw residues constituted the major cause of black smoke over Greater Cairo during fall. The largest amount of unused crop residue is rice straw with significant quantities of cotton stalks and small quantities of other residues remained also unused.

Financial and economic analysis has therefore been undertaken under the overall assumption that each option would be implemented by the private sector:

- Option 1: Composting of crop residues with manure at a dedicated site serving several communities.
- Option 2: Composting of crop residues with the organic component of municipal solid waste at a municipal solid waste treatment location.

- Option 3 (i): Adding ammonia to crop residues to create fodder.
- Option 3 (ii): Adding urea to crop residues to create fodder.
- Option 3 (iii): Adding "el mufid" to crop residues to create fodder.[35]

Financial analysis identifies that Option 1 has a Net Present Value (NPV) of LE 228,482 over a 10 year period, and an Internal Rate of Return (IRR) of 15 percent. Economic analysis identifies that Option 1 has a NPV of LE 900,370 over a 10 year period and an IRR of 25 percent. Other options have a negative NPV and a negative IRR. Analysis identifies opportunities for revenues to be obtained under the Clean Development Mechanism (CDM) of the Kyoto Protocol; revenues could potentially flow to Option 1 and, to a lesser extent, Option 2.

Under EPAP II, a recent study conducted by Broader (2011) looked at the alternative of using the agricultural waste residue to be used as a burning fuel by the cement companies with a 10 percent replacement rate that would gradually reach 30 percent: Lafarge, Cemex, Suez Cement Company and Ameriya Cement. The cement kiln is a safe and secure disposal route for combustible wastes as ash becomes part of the cement product.

As cement company prerequisites, the financial analysis was conducted over a 3 year period, which meant that the investment was to be recouped over 3 years. A minimum agricultural waste capacity amounting to 3.3 million tons per year in 2009 to reach 4.4 million tons per year in 2012 was needed to consider the agricultural waste as an alternative fuel. A total agricultural waste residue was estimated at 15 million tons with rice straw amounting to 5 million tons per year. The transport routes and therefore costs were optimized to transport (200 km on average) the residue to the closest cement company. Most financial analyses took advantage of the CDM. The average cost of transferring agricultural waste from farm gate to cement kiln amounted to LE 250 for bulk straw and LE 270 for shredded straw. At that rate, none of the alternatives was viable unless gas price subsidy was partially removed to bring the gas price closer to international prices.

For the COED mitigation, three alternatives are considered.

Option 1: In the short run, Option 1 has a dual purpose: determine ways to bring rice straws in landlocked lots to access points to be collected to process compost and/or refuse derived fuel (study); and controlled burning of about 2 million tons of rice straws in the landlocked lots is suggested over 1 to 2 years (Table A4.1) while options 2 and/or 3 are under implementation. Currently, the residual amount of about 1.4 million is either recycled by farmers or processed into compost by the EEAA-backed scheme. The controlled burning campaign should not last more than 2 years and awareness and coordination cost is estimated at US$5.5 million per year (Table A4.2) for a total area of 1 million feddans. A mix of public servants and NGOs could be mobilized for the campaign in addition to radio and TV campaigns. Nevertheless, Option 1 neither reduces PM_{10} nor CO_2 emissions but reduces the load intensity of PM_{10} and black smoke during fall over Greater Cairo and therefore could spare a great number of cardiopulmonary morbidity and mortality and reduce cost of illness.

[35] El mufid is a mixture of urea, molasses and salts.

Table A4.2: Awareness Campaign for Rice Straw Controlled Burning, LE and US$

	Number	Unit	Unit Cost	LE 2012	US$ 2012
Staff/NGO	500	Number	30,000	15,000,000	2,500,000
Staff/NGO Transport Compensation per Km	5,000,000	Km	0.10	750,000	125,000
Coordination Equipment and Misc.	Lump sum			5,000,000	833,333
Radio and TV adds	Lump sum			12,000,000	2,000,000
Landlocked lot access study	Lump sum			120,000	20,000
Total				32,870,000	5,478,333

Source: Doumani (2011).

Option 2: Replicate the EEAA-backed scheme to be devolved to the private sector and the land provided by the government otherwise the project is not viable. The METAP (2006) input was used although the production capacity is very low with 20,000 tons of fertilizers produced of which only 8,000 tons of rice straws. Hence, **the project investment cost (CAPEX) of US$0.6 million should be replicated 200 to 300 times** if the residual rice straws that are still being burnt should be considered. A number of additional key assumptions have been considered for the financial analysis (Table A4.3):

- The financial analysis is carried out over the 2012-2022 periods or 11 years.
- All designs and construction are performed over 1 year starting 2012.
- A real discount rate of 5 percent per annum is used and the cash flow will be reinvested at 10 percent for the financial analysis.
- Revenues and benefits are not increased in the original financial analysis but are increased for the sensitivity analysis.
- The right-of-way including the price of land is considered nil and is supposed to be provided by the government.
- Revenues are derived from the actual market price of LE 300 in 2012 prices (LE 275 in 2005 prices) per ton of organic fertilizer.
- CDM was considered under this option.
- Revenue and dynamic fee are farm gate prices.

Table A4.3: Dataset for Agricultural Waste Option 2

	Cost LE 2005	Quantity	Unit	LE 2005	US$ 2012
CAPEX					
Civil works (CW)	350,000	1		350,000	63,671
Equipment	2,410,000	1		2,410,000	438,418
Direct CAPEX	2,760,000			2,760,000	502,088
Site Organization (10% of Directs)		7.0%			
Engineering, Design and Site Supervision		15.0%			
Commissioning Costs (5% of Direct Costs)		5.0%			103,344
Contingencies (10% of Total Works)		10.0%			
Contractors Fees (15 % of Total Works)		15.0%			
Insurance (3% of Total Works)		3.0%			
Total direct and indirect CAPEX					605,433
OMEX					
Engineer	12,000	1		12,000	2,183
Accountant	12,000	1		12,000	2,183
Labourers	4,200	9		37,800	6,876
Electricity	25,000	1		25,000	4,548
Fuel	10	20,000	Tons of compost	200,000	36,383
Water	4	20,000	Tons of compost	80,000	14,553
Transport	70	20,000	Tons of compost	1,400,000	254,682
Monitoring	5,000	1		5,000	910
Overhead	10,000	1		10,000	1,819
Maintenance CW	10,500	3%	% of Civil Work	10,500	1,910
Maintenance Equipment	241,000	10%	% of Equip.	241,000	43,842
Agricultural Waste	70	8,000	Tons	560,000	101,873
Manure	30	12,000	Tons	360,000	65,490
Land lease	Provided by the government				
Total OMEX per year				2,953,300	537,253
Timelife: 11 years					
Revenues					
Fertilizer sales	275	20,000	Tons/year	5,490,119	998,740
CO_2 averted from rice straw burning		8,000		428,800	71,467
Total revenues per year				5,918,919	1,070,207

Note: Based on 0.8 ton of CO_2 averted from averted rice straw burning with an LE 67/ton of CO_2.

Source: Doumani (2011).

Option 3: Replicate agricultural waste to cement kiln (Broader, 2011) but over 11 instead of 3 year periods. Broader (2011) input was used although the production capacity is relatively low with 100,000 tons per kiln of which **only 75,000 tons of rice straws**. If further kilns are to be added we assume that a further 50 percent will be the extra capital requirement. Hence, **the project investment cost of US$10.9 million including the recycling facility should be replicated 10 to 15 times** if the residual rice straws that are still being burnt should be considered. The capital cost, which includes design, permitting, equipment, cavils, buildings, erection and commissioning, also considers the de-baling equipment. Also, the **cost of the material recycling facility is included in the analysis whereas the transport is not** otherwise the project is not viable without a heavy subsidy or an increase of the gas prices by 50 percent (Broader, 2011).

Table A4.4: Dataset for Agricultural Waste Option 3

	Cost EP 2011	Quantity	Unit	EP 2012	US$ 2012
CAPEX					
Civil works (CW)	10,225,000	1		10,327,250	1,721,208
Equipment	14,606,000	1		14,752,060	2,458,677
Material recycling facility	35,000,000			35,350,000	5,891,667
Indirect CAPEX				5,089,288	848,214
Total CAPEX				65,518,598	10,919,766
OMEX					
Land lease	Provided by the Government				
Total OMEX per year				3,725,620	620,937
Timelife: 11 years					
Revenues					
Fuel cost saving				7,117,000	1,186,167
CO_2 averted from process				3,960,000	660,000
CO_2 averted from rice straw burning		75,000		4,020,000	670,000
Total revenues				15,097,000	2,516,167

Note: Based on 0.8 ton of CO_2 averted from averted rice straw burning with an LE 67/ton of CO_2.

Source: Doumani (2011).

A number of additional key assumptions have been considered for the financial analysis (Table A4.4):

- The material recycling facility to process 100,000 tons of refuse derived fuel including rice straws will necessitate an investment amounting to LE 35 million.
- Not included in the analysis is the transport of the bailed refuse derived fuel estimated between LE 200 and LE 300 per ton delivered to the cement factory gate.
- Not included in the analysis is the cost savings associated with the diversion of waste to be landfilled in terms of volume averted and the selling of recyclables obtained at the material recycling facility.
- The financial analysis is carried out over the 2012–22 period or 11 years.
- All designs and construction are performed over 1 year starting 2012.
- A real discount rate of 5 percent per annum is used and the cash flow will be reinvested at 10 percent for the financial analysis.
- The material recycling facility to process 100,000 tons of refuse derived fuel including rice straws will necessitate an investment amounting to LE 35 million.

- Revenues and benefits are not increased in the original financial analysis but are increased for the sensitivity analysis.
- The right-of-way including the price of land for the material recycling facility is considered nil and is supposed to be provided by the government. The land at the cement plant is provided by the cement company.
- CDM was considered under this option in terms of averted CO_2 through the avoided rice straw burning and the switch from gas to biomass for the cement kiln.
- Revenue and dynamic fee are farm gate prices.

Summary Rice Straw

Table A4.5 summarizes the results of the 3 options:

Option 1. One (US$5.5 million per year) to two years are needed to implement a controlled burning under Option 1 to reduce the PM_{10} loads during fall and reduce the black smoke over Cairo while a study will be commissioned to find ways to bring the rice straws from landlocked lots to an access point. Moreover, the study will look at ways to enforcing the areas planted with rice as actual areas (1.7 million feddans) exceed the officially approved areas (1.3 million feddans in 2011) while the excess rice production (39 percent more than the local needs) is a cash crop being exported. However, this excess is expected to be curtailed by 2030 to reach rice self-sufficiency according to the Ministry of Agriculture new strategy to the detriment of notably wheat, corn and sugar beet plantation.

Option 2 seems the most viable although marginal as the project is no longer viable when the sensitivity analysis is performed. Nevertheless, Option 2 considers the transportation cost in the financial analysis which is not the case under Option 3. The land needed to set up the units needs to be provided by the government. Fertilizer processing should be a priority in the Governorates of Sharkia, Gharbia, Qaliobeya, Kafr El-Sheikh and Dakhlaya that generate 1.2 million tons of rice straws in 2010 and where the burning of the residues that are not covered by the EEAA-backed scheme constitute the major cause of black smoke over Greater Cairo during fall. Moreover, this option is much less efficient at reducing both PM_{10} and CO_2 (LE 2,775 per ton of PM_{10} averted and LE 178 per ton of CO_2 averted) than Option 3.

Option 3 is viable and efficient when CDM is considered and transportation costs are not. However, the latter could range from LE 200 to 300 per ton and the current EEAA subsidy of LE 82 is not sufficient to cover these costs. The caloric value of one ton of rice straw is equivalent to 13.8 GJ and the full dynamic fee (CAPEX and OMEX) reaches LE 18 per ton or LE 1.3 per GJ without transportation whereas the gas is priced at LE 16 per GJ, which shows an important opportunity when transportation costs are not considered. Moreover, this option is much more efficient at reducing both PM_{10} and CO_2 (LE 458 per ton of PM_{10} averted and LE 30 per ton of CO_2 averted) than Option 2. If this option were to be considered, a jump start of this economic segment is needed that: either necessitate the increase of the current EEAA subsidy of LE 82 to LE 250 to cover transportation costs, which would amount to about US$85 million per year on top of the US$15 million already covered under the current EEAA-backed scheme, and the set up a compensation scheme to cover the difference of the payback period from 3 years as initially requested by the cement companies to 11 years (US$1.5 million per unit in interest payment with a 7 percent rate or a total of US$18.6 million for 12.5 units); or increase the price of gas by 50 percent to make the project financially viable especially since most of the energy subsidy still benefits industries including cement industries and the richest household quintiles: a smart fuel subsidy targeting only the poor (1, 2 and possibly 3 quintiles) could free up some public funds that could be reallocated towards smart subsidies such as the biomass chain of transport (Table A4.6). Currently, Option 3 is only financially viable when cement companies have mazout-fired kilns that could be switched to refuse derived fuel as the CO_2 emission differential is higher than switching from gas and therefore CERs are higher, e.g., the Cemex Company has applied in 2006 for over 400,000 CERs per year to substituting mazout with biomass.

Table A4.5: Financial Analysis Summary of the 3 Rice Straw Options, US$ million

Key Financial Indicator with an 11 Year Investment Period	**Option 1 Controlled Burning**	**Option 2 Fertilizers**	**Option 3 Cement Fuel Substitution to Biomass**
CAPEX per Unit or Year (US$ million)	5.5	0.6	10.9
Requirements to cover the rice straw residues that are still burnt	**1 to 2 years** Short term intervention	**200 to 300 units** But priority investments should target 5 governorates to the north of Cairo	**10 to 15 units** But priority investments should target governorates to the north of Cairo
Total Midpoint CAPEX Needed (US$ million)	**Up to 11**	**90**	**128**
+ Total EEAA estimated actual and *suggested* subsidy (US$ million)	**15**	**15**	**15 + 85**
+ Subsidy (Option 3: 7% interest for the extension of the pay back period)		**Land for Fert. Units**	**1.5 x 12.5 =18.6**
Or increase the gas prices of LE 16.06 per GJ by:			**50% = LE 32.1/GJ**
Financial Analysis per Unit based on the following capacity (tons)	NA	20,000	100,000
NPV at 5% (US$ million)	5.2	0.01	5.8
IRR at 5%	NA	5%	14%
Modified IRR at 5% and 10%	NA	8%	12%
PV Benefit/Cost Ratio	NA	1.1	1.5
CAPEX Dynamic Fee/ton of rice straws at 5% (US$)	NA	1	16
OMEX Dynamic Fee/ton of rice straws at 5% (US$)	NA	10	2
Total CAPEX & OMEX Dynamic Fee/ton of rice straws at 5% (US$)	NA	11	18
Project Viability	**NA**	**Yes**	**Yes**
Sensitivity Analysis: CAPEX and OMEX increased by 1%	NA	No	Yes
Sensitivity Analysis: Revenues decreased by 1%	NA	No	Yes
Dynamic Cost per ton of lower bound PM_{10} emission averted at 5% (US$)	0	4,299	458
Dynamic Cost per ton of upper bound PM_{10} emission averted at 5% (US$)	0	2,775	
PM_{10} lower bound emission averted (tons/year)	0	253	3,675
PM_{10} upper bound emission averted (tons/year)	0	392	
Dynamic Cost per ton of CO_2 emission averted at 5% (US$)	0	6,118	30
CO_2 emission averted (tons/year)	0	178	59,850

Note: PM_{10} and CO_2 emissions from refuse derived fueltransport are not considered in the financial analysis but should be considered in an economic analysis.
Source: Doumani (2011).

Table A4.6 Absolute Transfers from Oil and Gas Subsidies, by Household Consumption Quintile, 2004

Product	**Quintile 1**	**Quintile 2**	**Quintile 3**	**Quintile 4**	**Quintile 5**	**Overall**
	LE per month per capita					
Kerosene	2.51	1.97	1.49	1.25	0.74	1.61
Natural gas	0.12	0.31	0.49	0.75	3.13	0.96
Gasoline	0.02	0.05	0.18	0.28	7.53	1.59
LPG	6.23	8.22	9.32	10.68	10.89	9.13
All 4 products	8.88	10.55	11.48	12.96	22.29	13.29

Source: CAPMAS (2004).

Domestic Waste

Only 65 percent of solid waste generated in Greater Cairo is collected, transported and disposed in 2011. The problem manifests itself in large accumulations of waste in residential areas, and open self igniting dumpsites which increases the emission of air pollutants namely PM_x and CO_2.

Collection and sweeping is entrusted to either public or private service providers with a significant difference in the cost per ton collected and service effectiveness by Governorate and within Governorate. Table A4.7 illustrates the waste generation by Governorate and the collection deficit and additional cost needed to fulfill this shortcoming. Based on average actual collection cost in each Governorate, the total additional amount needed to bridge the gap is about US$49 million per year provided that contracts with private firms are renegotiated under the same terms as most contracts expire in 2011 and 2012. Nevertheless, the negotiations between the government and the private service providers is being exacerbated by a number of problems in terms of on one hand unpaid arrears by the government and on the other hand ineffectiveness by the companies in fulfilling the terms of the original contracts due to social resistance and poorly performed capacity needs assessment at the onset.

Table A4.7 Greater Cairo Collection and Cost of Collection Gap

	Service Provision	Generation		Collection Coverage	Deficit		Cost/Ton	Yearly Additional Collection Cost
		Ton/day	%	%	Ton/day	%	US$	US$ million/year
Cairo	Mixed	11,290	46	70	3,387	39	20.5	25.3
Helwan	Mixed	2,800	12	70	840	10	27.5	8.4
Giza	Mixed	4,200	17	60	1,680	20	9.7	6.0
6th of October	Mixed	2,500	10	70	750	9	20.5	5.6
Qaliobiya	Public	3,500	14	45	1,925	22	4.5	3.1
Total		24,290	100		8,582	100		48.8

Note: Actual collection cost for Cairo, Helwan and Giza. For Qaliobiya, the public service cost derived from Giza was used whereas Cairo's mixed service cost was used for 6th of October.

Source: Doumani (2011).

A SWM strategy for Greater Cairo was formulated in 2010 and a reduction of small open dumps in Cairo is sought, which would reduce haphazard flaring in Greater Cairo.The Ministry of State for Environmental Affairs, in coordination with Ministry of Local Development, has prepared a plan to replace uncontrolled dumpsites, the prevailing disposal mechanism in most Governorates, with sanitary landfills. The first phases of the plan is to be implemented for Greater Cairo Region comprising the governorates of Cairo, Giza and Helwan but excludes 6th of October and Qaliobiya which has the lowest collection coverage among the 5 Governorates (Table A4.7). Hence, with the first and second phases of the plan, 11 percent of the non-collected waste in 6th of October and Qaliobiya will remain a potential for haphazard flaring in Greater Cairo if the collection and processing are not duly addressed.

In particular, the new plan is to engage the private sector in raising the necessary investments to replace the existing dumpsites. The new plan calls in its first and second phases for the:

- expansion and creation of 18 transfer stations of which some will be used for pre-segregation by scavengers;

- building of two WTE plants that will produce electricity, reduce air pollution including CO_2 emissions;
- the setting up of one sorting and composting facilities with recycling capabilities and the 15 Mayo landfill will be closed down in 2014 and transformed into a pre-segregation station for scavengers; and
- Four integrated sorting/composting/recycling/sanitary landfills including leachate treatment and gas collection, and one segregation station.

Table A4.8 Greater Cairo Summary New Plan based on 2011 Figures

	Pre-Segregation	**Transfer Station**		**Distance**	**WTE**		**Segregation**		**Segregagtion and Landfilling**			
	Ton/day	#	Ton/day	Km	#	Ton/day	#	Ton/day	#	Ton/day	Location	Area Km^2
Cairo East	617	6	3,415	55					1	3,415	Ain Sukhna	588
Cairo West and North	714	7	3,947	28-57					1	3,947	Bilbeis Road	294
Cairo South	341	1	1,887	37					1	1,887	Kraymat in 2014	504
Helwan		4	2,800	10-41	1	990	1	on demand		1,810		
Giza		5	4,200	29-63	1	2,000	1	800	1	1,400	Soldier Planet	504
Total	**1,672**	**23**	**16,249**		**2**	**2,990**	**2**		**4**	**12,459**		**1,890**

Source: Doumani (2011).
Note: Residual waste from segregation and WTE is transferred to the landfill. Under the New Plan, the Cairo West and North included Cairo South, which was separated in the table. Two transfer stations in Helwan for construction debris are not reported in the table.

The Governorate of Cairo has 9 transfer stations, 2 recycling plants, 4 composting plants (running at 52 percent capacity of 1,590 ton/day), 2 dumps and 3 landfills. The new plan calls for the creation of: 9 transfer stations and closing down 4 old transfer stations; 2 segregation/recycling/ composting plants (Ain Sukhna and Bilbeis Road) that will be integrated with 2 landfills and one segregation/recycling/composting plant that will be integrated with 1 landfill in Kraymat that will serve both Governorates of Cairo and Helwan at Kraymat, and will start operating in 2014.

The Governorate of Helwan has no transfer stations, 2 dumps and one integrated compost (capacity 1,600 ton/day)/recycling/dump site at 15 Mayo jointly owned and utilized by the Governorates of Cairo and Helwan. The new plan calls for the creation of: 7 transfer stations that will use the 15 Mayo dump until its planned closing and shifting the remaining waste of 1,810 tons/day to the new composting/recycling/landfilling site in Kraymat in 2014; 3 transfer stations for construction debris; the transformation of 15th of May into a pre-segregation station to be used by scavengers; and a WTE plant (990 tons/day based on 2011 generation figures).

The Governorate of Giza has 5 transfer stations, 2 composting plants (running at 65 percent capacity of 480 ton/day) and a dump site at Shabramant. The new plan calls for the: expansion of 3 and setting up 2 new transfer stations; the creation of one 800 ton/day segregation station (238 feddans) on the Cairo Fayoum Road; a WTE plant (2 x 1,000 tons/day based on 2011 generation figures) on the Cairo Fayoum Road; and an integrated compost/recycling/landfilling site at the Soldier Planet area.

Quantification Process

Transfer Stations in Cairo, Helwan and Giza

Transfer stations were calibrated to cover waste generation for 20 years after which capacity should be gradually increased. The breakdown of the transfer station number and capacity is illustrated in Table A4.9 and reaches 13,300 ton/day installed capacity.

Table A4.9 Greater Cairo Transfer Station Typology, 2014-2033, Ton/day

	Partial Waste Generation in 2011	Suggested Transfer Capacity by Type	Additional Transfer Stations Needed	Transfer Station Capacity Needed
	Ton/day	Ton/day	#	Ton/day
Cairo East	877	1,000	1	1,000
	508	750	5	3,750
Cairo West and North	756	1,000	2	2,000
Cairo South	1,887	Already exists	0	0
	340	400	3	1,200
Helwan	1,300	1,600	1	1,600
	200	250	3	750
Giza	800	1,000	1	1,000
	700	1,000	2	2,000
Total			**18**	**13,300**

Note: Waste generation growth is equal to the population growth of 2.27 percent and does consider that an increase in income will generate the same amount of waste with a different breakdown though. Waste generation using already existing transfer stations is not included.

Source: Doumani (2011).

WTE in Helwan and Giza

WTE plants were calibrated to cover waste generation for 20 years after which an expansion plan will be needed. The breakdown of the WTE capacity is illustrated in Table A4.10 and reaches 6,000 ton/day installed capacity.

Table A4.10 Greater Cairo WTE Typology, 2014–33, Ton/day

	Partial Waste Generation in 2011	Suggested WTE Capacity by Type	WTE Plant Number Needed	WTE Capacity Needed
	Ton/day	Ton/day	#	Ton/day
Helwan	990	2,000	1	2,000
Giza	2,000	2,000	2	4,000
Total	**2,990**		**3**	**6,000**

Source: AEB website: <www.afvalenergiebedrijf.nl>; and Doumani (2011).

Segregation and Landfilling for Cairo, Helwan and Giza

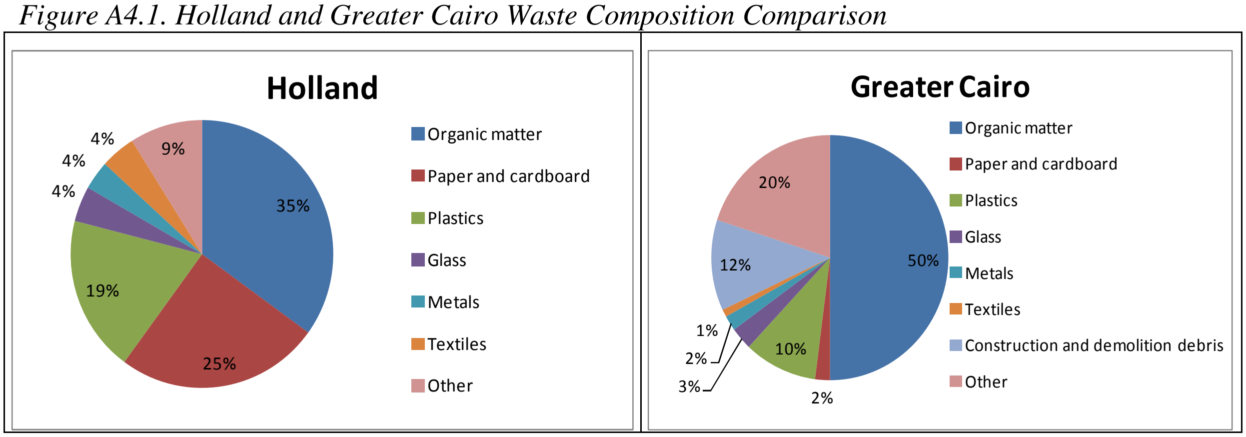
Segregation and landfilling were calibrated to cover waste generation for 20 years after which an expansion plan will be needed. The breakdown of the segregation and landfilling capacity is illustrated in Table A4.11 and reaches 16,800 ton/day installed capacity with a landfilling based on three scenarios that are function of the segregation effectiveness: Scenario 1 considers 15 percent recycling and 40 percent composting which brings the waste to be landfilled to 5,946 ton/day; Scenario 2 considers 12 percent recycling and 30 percent composting which brings the waste to be landfilled to 9,810 ton/day; or Scenario 3 considers 8 percent recycling and 20 percent composting which brings the amount to be landfilled to 12,162 ton/day.

Table A4.11 Greater Cairo Segregation and Landfilling Typology, 2014-2033, Ton/day

	Partial Waste Generation in 2011	**Suggested Segregation Capacity**	**Segregation Plant Needed**	**Segregation Capacity Needed**	**Landfilling Capacity Needed: 3 Scenarios**		
					S1: At 15% R - 40% C	S2: At 12% R - 30% C	S3: At 8% R - 20% C
	Ton/day	Ton/day	#	Ton/day	Ton/day	Ton/day	Ton/day
Cairo East	3,415	4,300	1	4,300	1,505	2,494	3,096
Cairo West and North	3,947	5,000	1	5,000	1,750	2,900	3,600
Cairo South	1,887	2,300	1	2,300	805	1,334	1,656
Helwan	1,810	2,300		2,300	805	1,334	1,656
Giza	1,400	1,800	1	1,800	630	1,044	1,296
	800	1,000	1	1,000	350	580	720
WTE					66	66	66
Total	**12,459**		**5**	**16,700**	**5,911**	**9,752**	**12,090**

Source: AEB website: <www.afvalenergiebedrijf.nl>; and Doumani (2011).
Note: Pre-segregated waste is not included in the table. R stands for recycling and C for composting. WTE is assumed to generate 2 percent residual waste according to the latest technology.

Figure A4.1. Holland and Greater Cairo Waste Composition Comparison



Note: it is unclear whether the waste composition in Cairo reflects before or after scavenging operation statistics.

Source: AEB website: <www.afvalenergiebedrijf.nl>; and Doumani (2011).

In summary, with a daily flow of 17,290 tons of waste per day in Cairo, Helwan and Giza in 2011, the needed capacity for the first phases of the new strategy is: 13,300 tons/day for transfer stations; 6,000 tons/day for WTE; 16,700 tons/day for segregation to derive recycling materials and produce compost; and a range between 5,911 and 12,090 tons/day to be landfilled including the residual amount generated from the WTE operations. The three landfilling scenarios emanates from both the segregation and composting effectiveness and the uncertainty regarding the waste composition in Greater Cairo as it is unclear whether the figures reflect before or after scavenging operation statistics. Also, it is unclear whether the current waste composition in Greater Cairo will not require additional fuel to compensate for low calorific values (plastic and paper are essential combustible agents in the process and represents only 10% and 2 percent respectively in Greater Cairo) as Greater Cairo's waste generates 1,500 calories/Kg according to EEAA. Figure A4.1 compares waste composition in Holland, where one of the most up to date WTE plant is operational, and Greater Cairo: the composition differences are significant.

The pre-segregated waste of 1,672 tons/day in 2011 is not included in these figures as well as sludge that could eventually be used as a fuel for WTE operations and other wastes that could be discarded at the landfills.

Financial Analysis

A number of key assumptions have been considered for the financial analysis:

- The financial analysis is carried out over the 2012-2033 periods or 22 years.
- All designs and construction are performed over 2 years starting 2012.
- A real discount rate of 5 percent per annum is used and the cash flow will be reinvested at 10 percent for the financial analysis.
- The right-of-way including the price of land for the transfer, segregation, WTE and landfill is considered nil and is supposed to be provided by the government.
- Dynamic fees are calculated.
- No profit margin, depreciation and interest payment are accounted for.
- The Kraymat integrated site is considered to be operational in 2014.
- The rehabilitation of the 15 Mayo dump into a segregation station for scavengers is not considered in the analysis.
- Indirect CAPEX include site organization (2 percent of directs), engineering, design and site supervision (3 percent of direct costs), contingencies (10 percent of total works), contractors fees (10 percent of total works) and insurance (3 percent of total works).
- Carbon funding is only sought for the WTE and not composting. Carbon capture in landfills is assumed to be minimal after composting and therefore was not considered.
- Composting revenues in terms of compost selling and carbon credit could reduce the overall operation cost but were not considered in the analysis.
- Recycling through segregation and WTE could generate revenues and reduce the overall operation cost but was not considered in the analysis.
- Recycling processing plants are not included in the analysis.
- Transfer stations that needed expansion were considered as new stations to be built in the analysis.

Collection/Sweeping Gap Cost and Transfer Cost in Cairo, Helwan and Giza

For the New Strategy, the dynamic waste fee per ton transported over 20 years for the collection/sweeping gap and all transportation from transfer stations to the new WTE plants and integrated landfills was calculated and is illustrated in Table A4.12. In Cairo, Helwan and Giza, the collection/sweeping dynamic waste fee for the uncollected waste reaches US$20.4 per ton and the transportation dynamic waste fee from the transfer stations reaches US$6.3 per ton. In other words, under the new strategy, about US$27 is needed per ton in constant terms for the waste collection/sweeping gap and transfer based on a constant cost of US$0.14/km over the 20 years. To gauge sensitivity, a 33 percent increase of collection and transfer transportation dynamic fee will bring the cost to US$36 per kilometer for the three governorates.

Table A4.12 Greater Cairo New Plan Dynamic Fee for Collection and Transfer, 2014–33, US$/ton

	Dynamic Fee for Uncollected Waste over 20 years		**Dynamic Fee from Transfer Stations for all Generated Waste over 20 years**	
	Based on current cost per Governorate	Cost increase by 33%	Based on actual Dynamic Fee of US$0.14/Km	Based on an increase of Dynamic Fee to US$0.20/Km
	US$/Ton	US$/Ton	US$/Ton	US$/Ton
Cairo East			7.9	11.0
Cairo West and North	20.5	27.3	8.0	11.2
Cairo South			5.3	7.4
Helwan	27.5	36.6	4.3	6.0
Giza	9.7	12.9	5.8	8.1
For 1 Segregation plant and 2 WTE plants			2.9	4.0
Subtotal 3 Governorates	**20.4**	**27.1**	**6.3**	**8.9**
6th of October	20.5	27.3		
Qaliobiya	4.5	6.0		
Total	**15.5**	**20.6**		

Note: Waste generation growth is equal to the population growth of 2.27 percent and does not consider that an increase in income will generate the same amount of waste with a different breakdown though. Transportation cost of US$0.14/km is kept constant over the 20 years. Transfer generation and cost from Cairo South and Helwan are included beginning 2014. Helwan WTE residue and Giza segregation/WTE residue transportation cost are based on 20 km from the premises to the landfills with 850 tons/day from segregation and 66 tons/day from WTE residues.

Source: Doumani (2011).

Transfer Stations

The construction of the new transfer stations is expected to improve the productivity and cost-efficiency of the collection in Greater Cairo hence reducing the collection cost and freeing up some collection truck time per day. In the USA for instance, transfer stations are justified when landfill locations exceed 35 Km from collection points (USEPA website: <www.epa.gov>) and most Greater Cairo landfills are farther than 35 Km. The capital expenditures (CAPEX) include the cost of transfer trucks and the maintenance and operation expenditures (OMEX) include the OMEX of the transfer station and the maintenance of the trucks as truck operations are considered under transportation (A4.12). The total CAPEX reaches US$460.5 million (Table A4.13).

Table A4.13 Greater Cairo New Plan Transfer Station CAPEX, 2012-2031, US$ million

	Suggested Transfer Capacity by Type	Yearly Suggested Transfer Capacity by Type	Transfer Stations Needed	Transfer Station CAPEX per unit	Transfer Station Total CAPEX
	Ton/day	Ton/year	#	US$ million	US$ million
Cairo East	1,000	350,000-400,000	1	32.7	32.7
	750	250,000-300,000	5	26.1	130.7
Cairo West and North	1,000	350,000-400,000	2	32.7	65.4
Cairo South					
	400	150,000-200,000	3	15.7	47.1
Helwan	1,600	550,000-600,000	1	49.0	49.0
	250	75,000-100,000	3	12.5	37.6
Giza	1,000	350,000-400,000	1	32.7	32.7
	1,000	350,000-400,000	2	32.7	65.4
Total			**18**		**460.5**

Source: Doumani (2011).

Waste to Energy

The newest generation of WTE allows to: use waste as a *supposedly* clean renewable energy fuel to generate electricity (new generation with at least 30 percent efficiency); optimize land use by reducing the use for landfills (as low as 1 to 2 percent residual landfilling of total waste); maximize the use of recyclables by turning the waste into recycled-grade metal, gypsum and salt (iron, non ferrous, precious metals, limestone bricks and concrete for construction); and drastically reduce the carbon footprint when compared to a landfill (-547 kg of CO_2 per ton of waste) or a dump (-1,195 kg of CO_2 per ton of waste). It is important to note that the plant should be located within a 500 meter radius away from inhabited areas. Moreover, the smoke depollution system usually accounts for 30 to 50 percent of the cost of a whole WTE unit and its operations and maintenance (O&M) account for about 40 percent with dioxin being the most dangerous and complicated compound to abate and its real impact needs to be addressed in an Environmental Impact Assessment. Three 800,000 ton/day capacity would partially cover the needs of Greater Cairo's SWM New Plan over the next 20 years and would cost US$1.8 billion.

Table A4.14 Greater Cairo WTE CAPEX, 2012-2031, US$ million

	Suggested WTE Capacity by Type	Yearly Suggested WTE Capacity by Type	WTE Plant Number Needed	WTE Total CAPEX
	Ton/day	Ton/year	#	US$ million
Helwan	2,000	800,000	1	586
Giza	4,000	800,000	2	1,172
Total			**3**	**1,758**

Source: AEB website: <www.afvalenergiebedrijf.nl>; and World Bank CEA Lebanon (2011): <www.worldbank.org>.

Segregation and Composting

The total CAPEX for source segregation reaches US$460.8 million and includes biofilters (Table A4.15) and the segregation efficiency will determine the volumes to be landfilled.

Table A4.15 Greater Cairo Segregation CAPEX, 2012-2031, US$ million

	Suggested Segregation Capacity	**Segregation Plant Needed**	**Yearly Segregation Capacity Needed**	**Segregation Total CAPEX**
	Ton/day	#	Ton/year	US$ million
Cairo East	4,300	1	160,000,000	160
Cairo West and North	5,000	1	190,000,000	190
Cairo South	2,300	1	180,000,000	180
Helwan	2,300			
Giza	1,800	1	70,000,000	70
	1,000	1	40,000,000	40
Total		**5**		**640**

Source: Doumani (2011).

Landfilling

The calculation for the landfilling is based on a 30 meter depth and relative waste density reduction effectiveness from 0.3 ton/m^3 as reported by EEAA to 0.8 ton/m^3, 0.7 ton/m^3 and 0.6 ton/m^3 for scenarios 1, 2 and 3 respectively after composting and sorting. Gently sloping base are considered to reduce base and drainage costs. Land cost is not included in the landfill CAPEX that varies between US$8.1 million and US$22.1 million according to the retained scenario. Carbon funding is not considered as most carbon savings will accrue during the WTE and composting processes.

Table A4.16 Greater Cairo Landfilling CAPEX by Scenario, 2012-2033, US$ million

	Segregation Capacity Needed	**Landfilling Capacity Needed: 3 Scenarios**			**Landfilling CAPEX Needed: 3 Scenarios**		
		S1: At 15% R - 40% C	S2: At 12% R - 30% C	S3: At 8% R - 20% C	S1: At 15% R - 40% C	S2: At 12% R - 30% C	S3: At 8% R - 20% C
	Ton/day	Ton/day	Ton/day	Ton/day	US$ million	US$ million	US$ million
Cairo East	4,300	1,505	2,494	3,096	2.7	4.6	5.7
Cairo West and North	5,000	1,750	2,900	3,600	3.2	5.3	6.6
Cairo South Helwan	4,600	1,610	2,668	3,312	2.9	4.9	6.0
Giza	1,800	630	1,044	1,296	1.1	1.9	2.4
	1,000	350	580	720	0.6	1.1	1.3
WTE		66	66	66	0.1	0.1	0.1
Total	**16,700**	**5,911**	**9,752**	**12,090**	10.8	17.8	22.1

Source: Doumani (2011).
Note: Pre-segregated waste is not included in the table. R stands for recycling and C for composting. WTE is assumed to generate up to 2 percent residual waste according to the latest technology.

Summary of Capital Cost and Dynamic Fee

The CAPEX net of indirect cost (design, insurance, contingencies, etc.) for the SWM New Plan for Cairo, Helwan and Giza is estimated at US$2.9 billion over 20 years if we consider scenario 2 (12 percent recycling and 30 percent composting) for landfilling.

The CAPEX including indirect cost (design, insurance, contingencies, etc.) for the SWM New Plan for Cairo, Helwan and Giza is estimated at US$3.4 billion over 20 years if we consider scenario 2 (12 percent recycling and 30 percent composting). The WTE represents 62 percent of the total CAPEX and the cost recovery is the highest or US$205 per ton although every ton of waste processed in the WTE could generate up to US$85 worth of electricity and benefit from about US$1.7 of carbon funding bringing a total of US$86.7 of extra revenues.[36] Although all the recyclables could also add significant value to the benefit flow, they were not however taken into account in the analysis. Nevertheless, all these figures are based on the hypothesis that Greater Cairo's waste mix will only need little calibration to reach optimal capacity (Table A4.18).

Table A4.17 Greater Cairo New Plan CAPEX Summary, 2012-2033, US$ million

	Transfer Station	**WTE**	**Segregation**	**Landfill (Scenario 2)**	**Total**
	US$ million	US$ million	US$ million	US$ million	US$ million
Cairo East	32.7		160.0	4.6	**197.3**
Cairo West and North	196.1		190.0	5.3	**391.4**
Cairo South			180.0	5	**904.7**
Helwan	133.7	586.0			
Giza	98.1	1,172.0	110.0	2.9	**1,383.0**
Total	**460.5**	**1,758.0**	**640.0**	**17.8**	**2,876.3**

Note: All investment costs exclude land price. Existing transfer stations are not included in this table.

Source: Doumani (2011).

Table A4.18 Greater Cairo New Plan CAPEX and Dynamic Fee Summary, 2012-2033, US$ million

	Unit	**Collection Sweeping**	**Transfer Station**	**Transfer Transp.**	**WTE**	**Segregation**	**Landfill (Scen. 2)**	**Total with WTE**	**Total w/o WTE**
CAPEX with Indirect Cost	US$ million		548		2,104	766	107	2,205	1,320
OMEX	% CAPEX & ±%/year		3% & +2%/year		6% & +3%/year	3% & +2%/year	2% & +2%/year		
Dynamic Fee at 5%									
-CAPEX	US$/ton		12.9		116.2	7.6	2.3	129.4	23.0
-OMEX	US$/ton	20.4	4.6	6.3	89.2	3.6	5.4	129.9	40.0
-Total Cost Recovery	US$/ton	20.4	17.5	6.3	205.4	11.1	7.7	259.3	63.0

Note: All investment costs exclude land price. Existing transfer stations are not included in this table. Costs do not include the rehabilitation of the 15th of May dump.

Source: Doumani (2011).

The full cost recovery of the SWM New Plan for Cairo, when considering the Helwan and Giza WTE requires at least US$259.3 per ton of waste over the 2014-2033 years. However, the waste stream cost recovery without the WTE is more affordable with US$63 per ton from collection to landfilling.

Air Contaminants Emitted from Waste Burning

The air contaminants emitted from waste burning can include common air contaminants (CAC), total organic carbon (TOC) and CO_2 (Box A4.1).

[36] Based on US$0.1 kW/h and LE 67 per ton of carbon.

Box: A4.1 Air Contaminants and Green House Gases Emitted from Waste Burning

Waste burning air contaminants emissions can include:

- Common Air Contaminants (CAC);
  - carbon monoxide CO,
  - particulates (including soot, semi volatile organic compounds, & inorganic),
  - oxides of nitrogen (NO and NO_2), and
  - sulphur dioxide (SO_2).

Depending on the chemical composition, physical characteristics of the waste and the completeness of combustion (the combustion process) the emissions can also include:

- Total organic carbon (TOC) made up of:
  -volatile organic compounds (VOC such as benzenes, acetone aldehydes and ketones) Usually methane is not included in this category; and
  -semi volatile organic compounds (SVOC). These are compounds that are released as vapors but soon condense when cooled in the open air. These include poly aromatic hydrocarbons (PAH), which are products of incomplete combustion. At least seven of the many PAH are known carcinogens;
  -Dioxin, furans and chlorobenzenes. These, and the other chlorinated compounds shown below, are formed by the presence of chlorine such as in present in poly vinyl chloride (PVC), and to a lesser extent, in salt-laden drift wood as may be used for beach fires;
  -Polychlorinated biphenyls (PCBs);
  -Hydrochloric acid (HCl);
  -Hydrogen cyanide (HCN); and,
  -Metals (mercury, zinc).

There is also carbon dioxide (CO_2) which is not normally classed as an air contaminant, but is amajor greenhouse gas (GHG) if generated from a non-renewable source.

Source: cited in Doumani (2011).

Burning about 4.5 kg of municipal waste in the open is equivalent to burning about 200 tons in a modern well controlled incinerator. Hence, the gains are tremendous in terms of averted compounds emitted. For simplification purposes, we will use the emission factors illustrated in Table A4.19 and consider a conservative 80 percent reduction of the mass emitted to account for the waste composition.

Table A4.19 Emissions per Waste Burnt, Kg/ton

Source	**Citation**	**$PM_{2.5}$**	**PM_{10}**	**SO_x**	**NO_x**	**CO**	**TOC**	
							Methane	**Non-Methane**
		Kg of emissions per metric ton of waste burnt						
Municipal refuse	Beauchemin and Tam (2005)		8	0.5	3	42	6.5	15
Municipal refuse	USEPA (1997)	15.8	17.2					
Municipal refuse	Average used	15.8	16.2	0.5	3	42	6.5	15

Source: Cited in Doumani (2011).

If we consider the current Greater Cairo uncollected waste, improved SWM could reduce the various emission compounds as illustrated in Table A4.20. The reduction of PM_{10} according to the cost derived for the new Waste Strategy is 4.1 fold less expensive when the WTE is not considered: US$9,929 per ton of PM_{10} averted with WTE against US$2,215 per ton of PM_{10} averted without WTE. Most other compounds are efficiently.

Table A4.20 Cost Effectiveness for Reducing Emissions of Waste Burnt, Kg/ton

Source	Waste	$PM_{2.5}$	PM_{10}	SO_x	NO_x	CO	TOC Meth.	TOC Non-Meth.
Municipal refuse (Kg of emissions per metric ton of waste burnt)		15.8	16.2	0.5	3	42	6.5	15
Uncollected Waste								
Uncollected Waste: Cairo, Helwan and Giza (million ton/y)	2.2							
Uncollected Waste: 6th of October & Qaliobiya (million ton/y)	1.0							
Total Uncollected Waste: Greater Cairo (million ton/y)	3.1							
Total Compound Emissions								
Uncollected waste: Cairo, Helwan and Giza (ton/y)		34,066	34,928	1,078	6,468	90,554	14,014	32,341
Uncollected Waste: 6th of October and Qaliobiya (ton/y)		15,427	15,817	488	2,929	41,008	6,346	14,646
Total Uncollected Waste: Greater Cairo (ton/y)		49,492	50,745	1,566	9,397	131,562	20,361	46,986
Compound Emissions Averted								
Uncollected waste: Cairo, Helwan and Giza (ton/y)		27,253	27,942	862	5,175	72,443	11,211	25,873
Uncollected Waste: 6th of October and Qaliobiya (ton/y)		12,341	12,654	391	2,343	32,806	5,077	11,717
Total Uncollected Waste: Greater Cairo (ton/y)		39,594	40,596	1,253	7,518	105,250	16,289	37,589
Cost Effectiveness per ton of Compound Averted								
Uncollected waste with WTE: Greater Cairo (US$/ton)		1,625	9,929	Not efficient > 100,000				
Uncollected waste without WTE: Greater Cairo (US$/ton)		395	2,415	Not efficient > 100,000				

Note: Compound emission averted represent 80 percent of total compound emissions.

Source: cited in Doumani (2011).

Charcoal Production

Approximately 14 million tons of wood residues from old trees, plantations, and agricultural trimmings are produced annually (EEAA, 2006). About 7.5 million tons are used as the feedstock for charcoal manufacturing in Egypt by means of traditional earth-pits also called open pits and the residual volume is used for wood furniture. About 942 possibly reaching 4,600 open pits exist in Egypt and release pollutants such as CO, CO_2, SO_x and PM_x. The charcoal carbonization processes are considered one of the contributors to the black clouding in Greater Cairo[37] and produces tar that, if unsafely discarded or reused, can pollute surface and ground waters.

The production is unlicensed, fined by the government and completely disorganized in and north of Greater Cairo: Cairo (32 pits), Giza (32), Qaliobiya (168), El-Sharkiya, El-Gharbiya, El-Beheira, El-Manofia and El-Dakahleya Governorates (70 percent of total production). Most of the pits produce from 10 to 15 tons of charcoal per production cycle of 3 to 5 weeks depending on the size of the pit, wood quality, and the efficiency of carbonization process. The production cycle duration ranges from 3 to 5 weeks, thus the production rate ranges from 0.3 to 0.75 charcoal tons per day. Moreover, open pits can only operate 8 months per year due to government restrictions during the black cloud episode.

Although information of the charcoal production remains scarce, new charcoal kiln standards were approved by the Egyptian Organization for Standardization and Quality, EEAA, and the Federation of Egyptian Industries. Despite the provision of land in Sharkyia by EEA provided that produced adopt the charcoal kiln standards, producers are resisting abandoning the traditional and haphazard production.

Under the AMS III-K, regulating the process could reduce emissions of $CO_{2\text{-}e}$ through capturing and flaring methane or producing electricity and refueling carbonation gases. Refueling the carbonization

[37] JCEE/GTZ (2009).

gases in the charcoal kilns seems the most interesting alternative as it will help reduce methane (CH_4), carbon monoxide (CO), nitrogen oxides (NO_x), particulate matter (PM), tar, formaldehyde, phenols, hydrocarbons, and volatile organic compounds (VOCs).

The economic analysis conducted in JCEE/GTZ (2009) is based on 3 designs for the equivalent of 942 kilns that are either diesel-fueled or gas-fueled, namely: (i) double jacket metal kiln without a flare; (ii) double jacket metal kiln with flare; and (iii) brick kiln. The results are illustrated in Table A4.21. The diesel-fueled kiln is the most effective (140,146 ton of CO_2 averted) and the most efficient with LE 1,441 per ton of CO_2 averted. Through these new designs, PM_{10} emissions could be reduced between 4,500 and 6,700 kg (10 to 15 days respectively) for the traditional open pit to about 350 kg (over 2 days) for the improved process per ton of charcoal produced.[38] A midpoint of 5,700 kg of PM_{10} emission is considered for the open pit bringing the averted PM_{10} to 5,350 kg by introducing the improved process. It is important to mention that during the improved process, some compounds exceed the allowed threshold, which calls for preventive measures mainly in terms of occupational health:

- Metal Kiln without flare: CO ranges between 914 and 2,360 mg/m^3 per hour (average over 3 hours) against 500 mg/m^3 allowed;
- Metal Kiln with flare: CO reaches 2,360 mg/m^3 per hour (average over 3 hours) against 500 mg/m^3 allowed; and
- Brick Kilns: CO reaches 5,119 mg/m^3 against 500 allowed; and NOx reaches 347 mg/m^3 against 300 allowed.

Table A4.21: Kiln-Based Charcoal Alternative Production

Alternative Processes	Wood Input	Finance per Unit					Kiln Needed	NPV over 20 years		IRR		Emission averted		
		Open Pit	Kiln	Revenue	Cost	OMEX/ year		w/o CDM	with CDM	w/o CDM	with CDM	CO_2		PM_{10}
	Ton/year			LE 000'			#	LE million		%		Ton/year	LE/ton	LE/ton
Diesel (Sular)														
Metal Kiln w/o flare	480	96	144	95.6	141	64	942	81	93	22	24	37,156	2,503	2,661
Metal Kiln with flare	480	96	144	97.5	151	64	942	73	84	21	22	36,867	2,278	2,791
Brick Kilns	210	42	63	44.7	42	25	2,170	153	202	40	49	140,146	1,441	1,988
Natural Gas														
Metal Kiln w/o flare	480	96	144	95.4	196	51	942	133	155	24	26	60,068	2,580	3,206
Metal Kiln with flare	480	96	144	97.2	206	51	942	125	145	23	25	59,778	2,426	3,336

Source: cited inDoumani (2011).

In Cairo, Giza and Qaliobiya, 232 open pits (25 percent of Egypt's total pits if we consider the very conservative figure of 942 pits) are being used to produce charcoal according to EEAA (2009). The average production is estimated at 0.5 ton per day per open pit. Hence, the average production for the 3 Governorates of Cairo is estimated at 27,800 tons over 8 months emitting about 158,688 tons of PM_{10}. Hence, the PM_{10} averted amounts to a lower bound 148,944 tons but could reach 4 to 5 times this amount if the upper bound number of pits is considered: roughly 928 and 1,160 pits in Greater Cairo with 595,776 to 744,720 tons of PM_{10} averted. The cost per ton averted of PM_{10} ranges between LE 1,988 and LE 3,336.

[38] FAO (2008).

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