ECONOMIC AND SOCIAL COMMISSION FOR WESTERN ASIA

OPTIONS AND OPPORTUNITIES FOR GREENHOUSE GAS ABATEMENT IN THE ENERGY SECTOR OF ESCWA REGION

VOLUME I

TRANSPORT SECTOR

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ANNEXES

ABBREVIATIONS

CDM	Clean Development Mechanism
CFCs	Chlorofluorocarbons
CH_4	methane
CNG	compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
GCC	Gulf Cooperation Council
GDP	gross domestic product
GEF	Global Environment Facility
Gg	gigagram
GHG	greenhouse gas
HC	Hydrocarbon
HFC	hydrofluorocarbon
IPCC	Intergovernmental Panel on Climate Change
JI	Joint Implementation
kgoe	kilograms of oil equivalent
km	kilometres
km/h	kilometres per hour
LE	Egyptian pounds
m	metres
m^3	cubic metres
NMVOC	non-methane volatile organic carbon
NO_X	oxides of nitrogen
OECD	Organization for Economic Cooperation and Development
PCF	Prototype Carbon Fund
ppm	parts per million
psi	pounds per square inch
SEC	specific energy consumption
SO_X	oxides of sulphur
tj	terajoules
toe	tons of oil equivalent
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change

INTRODUCTION

Despite its vital role in the economic and social development in the region, the energy sector in the member States of the Economic and Social Commission for Western Asia (ESCWA)[1] has serious adverse environmental impacts. The energy sector of the ESCWA region is dominated by thermally generated electricity, the production of which releases large amounts of greenhouse gases (GHGs)[2] into the atmosphere and discharges large volumes of waste water into local waterways. The region's major energy-consuming sectors, particularly industry, discharge contaminated wastewater and the transport sector generates GHG emissions. Most importantly, though, energy consumption patterns in all sectors are unsustainable.[1] These characteristics determine the type and severity of local environmental problems and associated health problems, as well as global environmental issues such as global warming.

In 1999, the total primary energy consumption in the ESCWA region reached 247.6 million tons of oil equivalent (Mtoe), including about 141.0 Mtoe of petroleum products, 99.0 Mtoe of natural gas and about 7.0 Mtoe of hydro power and coal resources.[2] The transport sector was the major consumer of petroleum products, consuming about 54.4 Mtoe, or 43.6 per cent of the region's total, while the electric power sector consumed 24.16 Mtoe of petroleum products, or 19.0 per cent of the regional total, in addition to its consumption of natural gas. Being major consumers of energy and largely dependent on petroleum products and thermally generated electricity, both the transport and power sectors contribute large proportions of the region's GHG emissions. This problem is exacerbated by the fact that the energy consumption patterns in the ESCWA region are, in general, unsustainable. Average energy intensity in the region reached 0.522 kilograms of oil equivalent per dollar of gross domestic product (GDP) (kgoe/$) in 1999, or 1.6 times the world average (0.320 kgoe/$).[2]

Total carbon dioxide (CO_2) emissions from fuel combustion in the ESCWA region increased by an annual average 8 per cent from 102.4 million tons in 1973 to reach 687 million tons in 1999. The ratio of CO_2 emissions to GDP in the region in 1973 was just 0.3 kg/$, not quite a quarter of the world average and about a third of the Organization for Economic Cooperation and Development (OECD) average for the same year. This ratio has increased dramatically in the ESCWA region and now exceeds both the OECD and world averages. Although this ratio is influenced by many factors, it indicates that energy consumption in the ESCWA region is not sufficiently efficient.

The adverse environmental impacts of the GHGs produced by the transport and electric power sectors present a serious challenge to all stakeholders in issues relating to energy and the environment in the ESCWA region. Such groups and individuals need to find solutions that will limit the negative impacts of the transport and power sectors without affecting the contribution they make to national social and economic development. The 1992 United Nations Framework Convention on Climate Change (UNFCCC) and its 1997 Kyoto Protocol established initiatives to guide States in their efforts to reduce GHG emissions and slow the pace of climate change. These provisions include advice on the formulation and implementation of GHG abatement measures, the transfer of information between Parties, and the promotion of clean technologies, renewable resources and sustainable development. Most of the ESCWA member States, which are classified for the purposes of the Convention as developing countries, have signed the UNFCCC.

In line with its mandate to support economic and social development in the region, the ESCWA secretariat encourages efficiency in sectoral energy consumption. Accordingly, a study on ways to increase energy efficiency in ESCWA member States was conducted in 1997[34] in order to assess sectoral energy consumption patterns in the region. The study found that the residential, industrial and transport sectors accounted for the largest shares of energy consumed in the ESCWA region. A 1999 study on the harmonization of environmental standards in the energy sector of ESCWA member States[1] demonstrated an urgent need to review, update and harmonize environmental regulations and standards in the region's

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[1] The ESCWA member States are: Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, the Syrian Arab Republic, the United Arab Emirates and the Republic of Yemen.

[2] According to the United States Energy Information Administration, the transport-generated greenhouse gases include water vapour, carbon dioxide, methane, non-methane hydrocarbons, carbon monoxide, nitrous oxide, nitrogen oxides and ozone.

energy sector, especially the transport and power sectors.[1] Achieving this objective would have a positive impact on the mitigation of adverse environmental effects caused by energy use.

The transport and electric power generation sectors in the ESCWA region are major consumers of energy in general, and of petroleum products in particular, and are therefore major producers of GHG emissions. In recognition of the need to investigate options for preventing pollution and mitigating negative environmental impacts of energy use, and in response to the requirements of the UNFCCC and Kyoto Protocol, the ESCWA secretariat has included the preparation of this study in the work programme of the Energy Issues Section for the biennium of 2000-2001.

The main objectives of this study are: (a) to assess the levels of GHG emissions produced by the transport and electric power sectors in the ESCWA region; (b) to identify and evaluate options for GHG abatement; (c) to identify and assess potential constraints on the implementation of the proposed abatement options, (d) to recommend general implementation guidelines; and (e) to present case studies of GHG abatement efforts in Egypt and Lebanon. The study is published in two volumes. Volume I focuses on the transport sector, while volume II focuses on the electric power generation sector.

In Volume I, chapter I presents an overview of the transport sector including its structure, its energy consumption, the resultant GHG emissions and their effects on the environment. Chapter II reviews and identifies a number of options available in the ESCWA region for the reduction of transport-related GHGs. These options fall into four categories: advanced-technology vehicles; use of higher-quality transport fuels; policy and management measures; and environmental regulations and standards supported by the sharing of relevant information and experience from within the region. Chapter III presents the methodology and the criteria used to evaluate the options identified in chapter II in view of the present state of the transport sector in the ESCWA region and ranks them in order of priority. The chapter concludes with an overview of the possible challenges and constraints that may face its potential implementation in the region and proposes some guidelines to facilitate its realization.

Chapter IV is a case study of GHG abatement in the Egyptian transport sector. This case study can serve as a valuable resource for other ESCWA member States because Egypt has experience of a number of GHG abatement technologies and policies. Chapter V presents a case study of the GHG abatement opportunities in Lebanon as reflected in the national GHG inventory and other studies. Based on this case study, a number of implementation mechanisms are recommended. Finally, chapter VI summarizes the study, recommending a set of measures for the promotion of efficient energy use and for the reduction of the negative environmental impacts of transport activity

I. THE ESCWA TRANSPORT SECTOR: OVERVIEW, ENERGY CONSUMPTION AND GREENHOUSE GAS (GHG) EMISSIONS

The transport sector plays a major role in the economic and social development of the ESCWA member States. Demand in this sector in the ESCWA region is likely to increase faster than GDP, as a result of population movement from rural areas to cities, the movement of increasing quantities of goods within and between countries, and the fact that motor vehicle ownership is growing at a faster pace than road transport infrastructure in urban areas.[1] The transport sector has, however, had a significantly negative impact on the environment at both the local and global levels. Vehicles are the main source of urban air pollution, which has negative consequences for public health. Vehicle emissions of CO_2, oxides of nitrogen (NO_X) and hydrocarbons that react to form tropospheric ozone are also believed to contribute to global warming.

A. THE STRUCTURE OF THE TRANSPORT SECTOR IN THE ESCWA MEMBER STATES

There is considerable diversity in the structure of the transport sector in the various ESCWA member States, particularly in relation to the size of each country's national vehicle fleet, the relative penetration of various modes of transport, and the quality of infrastructure serving the sector.

1. *Volume and modes of transport*

(a) *Volume of road transport*

In 1997, the total volume of road transport in the ESCWA region reached about 14.451 million motor vehicles (excluding motorcycles), distributed as shown in table 1.[3]

TABLE 1. NUMBER AND TYPES OF VEHICLES IN THE ESCWA MEMBER STATES, 1997

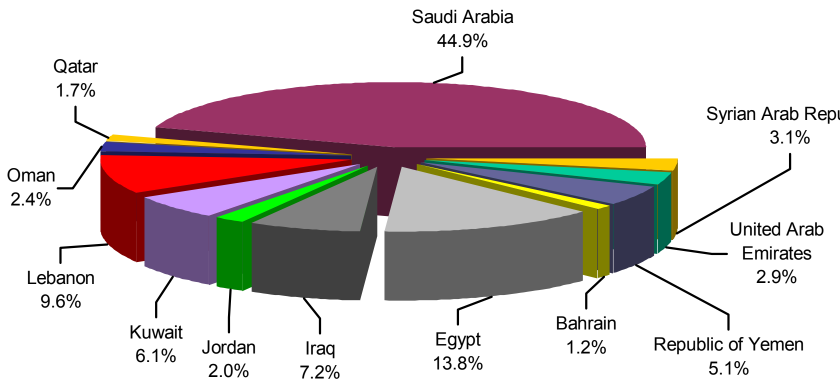
Country	Total number of vehicles (excluding motorcycles)	Distribution by mode *(Percentage)*			Average annual growth in vehicles, 1990–1997 *(Percentage)*	Share of ESCWA total *(Percentage)*	Population per vehicle	Population per passenger
		Passenger cars	Trucks (including light-duty trucks)	Buses				
Bahrain	175 547	81.3	15.5	3.1	5.3	1.2	3.2	3.9
Egypt	1 987 493	72.1	25.7	2.2	7.2	13.8	31.2	43.3
Iraq	1 036 712	66.0	28.8	5.2	0.3	7.2	19.4	29.4
Jordan	283 821	66.9	32.6	0.4	4.1	2.0	14.8	22.1
Kuwait	887 521	84.2	14.4	1.5	4.4	6.1	1.9	2.3
Lebanon	1 391 473	93.4	6.1	0.5	6.0	9.6	2.2	2.3
Oman	352 184	69.6	28.7	1.7	7.7	2.4	6.3	9.0
Qatar	243 831	67.6	31.8	0.6	6.3	1.7	2.2	3.3
Saudi Arabia	6 490 857	53.8	45.0	1.2	3.5	44.9	2.8	5.2
Syrian Arab Republic	441 428	31.4	60.1	8.5	8.9	3.1	32.2	102.6
United Arab Emirates	419 939	79.0	18.3	2.7	6.6	2.9	5.3	6.7
Republic of Yemen	740 189	43.5	55.8	0.7	9.7	5.1	20.3	46.7
Total ESCWA	14 450 995	63.6	34.6	1.8	4.7	100.0	10.0	15.7

Source: ESCWA, *Statistical Abstract of the ESCWA Region*, nineteenth issue, 1999.

Note: Figures may not add up to 100 per cent due to rounding.

Saudi Arabia and Egypt have the highest volumes of road transport of the ESCWA member States, with almost 6.491 and 1.987 million vehicles, respectively, representing 44.9 per cent and 13.8 per cent of all road transport in the region (see chart 1).

Chart 1. Distribution of motor vehicles in the ESCWA region in 1997



Source: ESCWA, *Statistical Abstract of the ESCWA Region*, nineteenth issue, 1999.

Note: Total is about 14.451 million vehicles.

Average annual growth in the volume of transport between 1990 and 1997 ranged from 0.3 per cent in Iraq to 9.7 per cent in the Republic of Yemen, with a regional average annual growth rate of 4.7 per cent. The ratio of population to vehicles ranged from as low as 1.9 persons per vehicle in Kuwait and 2.2 persons per vehicle in Lebanon and Qatar to as high as 31.2 and 32.2 persons per vehicle in Egypt and the Syrian Arab Republic, respectively.

(b) *Modes of transport*

Passenger cars, trucks (including light-duty trucks) and buses account for 63.6 per cent, 34.6 per cent and 1.8 per cent, respectively of the total number of vehicles in the ESCWA region (see table 1). Passenger cars are the dominant mode of transport in most of the ESCWA member States, accounting for between 53.8 per cent (in Saudi Arabia) and 93.4 per cent (in Lebanon) of national vehicle fleets. The Syrian Arab Republic (where passenger cars account for just 31.4 per cent of all vehicles) and the Republic of Yemen (with 43.5 per cent) are the exceptions; in these countries, trucks (including light-duty trucks) account for 60.1 percent and 55.8 per cent of all road vehicles, respectively.

In the Gulf Cooperation Council (GCC) countries[3], light-duty vehicles are the most common mode of transport. Maritime transport is also significant, oil tankers in particular. There are plans to extend rail transport in Saudi Arabia with the establishment of three more lines—adding 1,400 kilometres (km) of track—by 2005. Egypt (with 4,000 km of track) and Iraq have extensive rail capacity. The Syrian Arab Republic and Jordan, however, have only limited rail capacity.

(c) *Vehicle ownership*

The transport sector in the ESCWA region is characterized by high rates of private ownership of vehicles, in particular in Egypt and Lebanon. In Lebanon, 99 per cent of cars, 88 per cent of buses and 95 per cent of trucks are privately owned, while private ownership in Egypt accounts for 97 per cent of cars, 70 per cent of buses and 80 per cent of trucks.[4]

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[3] The States of the Gulf Cooperation Council are: Bahrain; Kuwait; Oman; Qatar; Saudi Arabia; and the United Arab Emirates.

[4] Responses to a questionnaire conducted by ESCWA in 1999.

2. *Road networks and congestion*

The total length of roads (sealed and unsealed) in the ESCWA member States in 1997 is estimated to have been about 346,000 km, and grew by an average 4.1 per cent a year for the period 1989–1997.[3] Roads in Saudi Arabia, Egypt, and the Syrian Arab Republic account for about 40 per cent, 17.5 per cent, and 12 per cent of this total, respectively. Roads in Bahrain, the United Arab Emirates and Kuwait represent 0.9 per cent, 1 per cent, and 1.4 per cent, respectively, of the total road length in the region.

Traffic congestion is a growing problem in the ESCWA region due to a large increase in the volume of traffic in recent years, in particular in cities with more than a million inhabitants such as Baghdad, Beirut, Cairo and Damascus. The growth in private car ownership generally reflects growth in income and travel. This has been the case in the GCC countries in particular, where more than one car per family unit is common and where people are highly dependent on private vehicles for travel. Subsidized gasoline prices in most ESCWA member States**,** low utilization of public transport (either as a result of a preference for private vehicle use or a lack of effective public transport) and an ageing, highly polluting vehicle fleet, all contribute to traffic congestion and higher levels of energy consumption, which compound pollution problems locally, as well as globally.

The widening congested roads has become an important part of urban planning in ESCWA member States. In Cairo, a network of flyovers and underpasses has been built, and the road network in Beirut has been substantially rehabilitated. In the GCC countries, new roads are being established—for example, a 36 km network of minor roads was formally inaugurated in Jebel Al-Akhdar in Oman in 1997, augmenting almost 500 km of existing dual carriageway.[4] As a result of the Gulf war, Kuwait, which has an excellent road network in populated areas, has deferred plans to build a causeway across Kuwait Bay.

B. TRANSPORT SECTOR ENERGY CONSUMPTION AND INDICATORS

The ESCWA region has tremendous fossil fuel resources. In 1999, oil reserves in the ESCWA region were estimated at 589.431 billion barrels, or 57 per cent of the world's total proven reserves. In 1998, the region produced an average of 18.3 million barrels per day. In 1999, the total primary energy consumption reached 247.6 Mtoe, and per capita energy consumption reached 1,558 kgoe. Although this regional figure is in the vicinity of the world average (1,451 kgoe), looking at the energy consumption patterns of the individual ESCWA member States reveals a great deal of diversity. Per capita consumption in 1999 ranged from about 210 kgoe in the Republic of Yemen to more than 14,800 kgoe in Qatar (more than 10 times the world average).[2, 5]

Average energy intensity for the region reached 0.522 kgoe/$ in 1999, or 1.6 times the world average (0.320 kgoe/$). At a national level, energy intensity ranged between 1.32 kgoe/$ in Bahrain to 0.295 kgoe/$ in Oman.[2] The high energy intensity in the region can be attributed to a combination of factors including: inefficient energy use; underpricing of fuel and electricity; the growing penetration of vehicle ownership and use; and increasing per capita income.

1. *Energy consumption in the transport sector*

(a) *Road transport fuel consumption*

The transport sector in the ESCWA region is a large-scale consumer of energy and depends heavily on petroleum products. Fuel consumption in the region's transport sector in 1997 was about 39.5 Mtoe, 73.3 per cent of which was gasoline and 26.7 per cent of which was diesel (see table 2).[3]

Saudi Arabia, Egypt and Iraq have the highest road transport fuel consumption of the ESCWA member States (see table 2). In terms of per capita consumption, however, the GCC countries—in particular, Kuwait, Qatar and Bahrain—are the heaviest users of fuel for road transport. Transport energy consumption ranges between 0.07 toe/capita in Egypt and 1.65 toe/capita in Kuwait. The regional average is 0.25 toe/capita, or 15.2 per cent of total per capita primary energy consumption. The consumption of road transport fuel increased by an average 4.8 per cent a year in the ESCWA region in the period 1994–1997; this growth rate is higher than that of primary energy consumption for the same period (4.2 per cent).[2, 6]

TABLE 2. ROAD TRANSPORT ENERGY INDICATORS FOR THE ESCWA MEMBER STATES, 1997

Country	Total primary energy consumption[a/] (*Thousands of toe*)	Road transport fuel consumption[b/] (*Thousands of toe*)	Gasoline/road transport fuel total (*Percentage*)	Diesel/road transport fuel total[c/] (*Percentage*)	Average annual growth for road transport fuel consumption 1994–1999 (*Percentage*)	Proportion of ESCWA road transport fuel consumption (*Percentage*)	Fuel (road transport): Share of total primary energy consumption (*Percentage*)	Fuel (road transport): toe/capita
Bahrain	8 042	535	72.7	27.3	5.2	1.4	6.7	0.87
Egypt	38 769	5 253	50.9	49.1	6.8	13.3	13.6	0.07
Iraq	25 068	4 506	71.2	28.8	0.2	11.42	18.0	0.22
Jordan	4 964	953	62.9	37.1	4.8	2.41	19.2	0.21
Kuwait	13 800	3 055	80.2	19.8	4.6	7.74	22.1	1.65
Lebanon	5 262	1 953	86.6	13.4	5.9	4.95	37.1	0.58
Oman	4 170	1 338	67.6	32.4	8.0	3.39	32.1	0.52
Qatar	7 893	897	63.4	36.6	6.4	2.27	11.4	1.44
Saudi Arabia	84 487	13 988	85.5	14.5	3.4	35.45	16.6	0.72
Syrian Arab Republic	12 857	2 556	48.3	51.7	8.1	6.48	19.9	0.15
United Arab Emirates	25 316	1 984	77.7	22.3	7.0	5.03	7.8	0.78
Republic of Yemen	3 475	2 445	68.8	31.2	9.5	6.20	70.4	0.14
ESCWA	234 103	39 463	73.3	26.7	4.8	100.0	16.9	0.25

Source: Compiled from various national and international sources.

Note: Figures may not add up to 100 per cent due to rounding.

a/ Figures for total primary energy consumption from Organization of Arab Petroleum Exporting Countries, *Annual Statistical Report*, 2000, p. 44 (figures were calculated using barrels of oil equivalent per day multiplied by 0.136, multiplied by 365 to give toe per year).

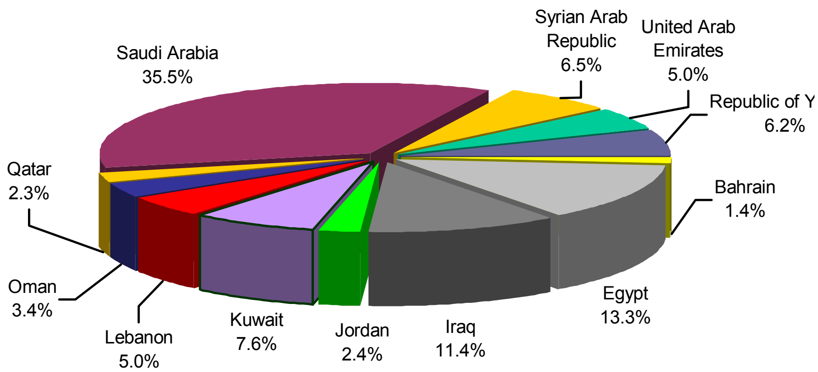
b/ Total road transport fuel consumption calculated as the sum of gasoline and diesel fuel consumption, based on 1994 values for gasoline consumption, adjusted according to the growth in motor vehicle numbers in each country published in ESCWA, *Statistical Abstract of the ESCWA Region*, nineteenth issue, 1999.

c/ Diesel values were calculated based on various national and international sources.

(b) *Impact of road transport on primary energy consumption*

The proportion of transport fuel in total primary energy consumption in the ESCWA region reached almost 16.9 per cent in 1997, and generally ranged between 6.7 per cent (in Bahrain) and 37.1 per cent (in Lebanon). The Republic of Yemen was a striking exception, with transport fuel accounting for 70.4 per cent of primary energy consumption (see table 2).

Chart 2. Distribution of road transport fuel consumption in the ESCWA member States in 1997



Source: Based on table 2.

Note: Total consumption of petroleum products in the ESCWA region for 1997 is about 39.5 Mtoe.

(c) *Energy demand in the transport sector*

A study by the World Energy Council in 1998 indicated that the worldwide total energy use for transportation would increase by more than 55 per cent between 1995 and 2020, averaging 1.8 growth of per cent a year.[7] A similar growth rate has been forecast for the ESCWA region's energy use for the same period (see table 3).[1]

TABLE 3. GROWTH IN TRANSPORT SECTOR ENERGY DEMAND IN THE ESCWA REGION, 1995–2020

	Light-duty vehicles	Aviation	Road freight	Rail	Total	Total energy demand for transport worldwide
1995						
Total *(Mtoe)*	4.0	2.5	27.5	0.5	34.5	1 918.0
Percentage of total	11.6	7.3	79.7	1.5	100.0	100.0
2020						
Total *(Mtoe)*	11.0	6.5	36.5	0.5	54.5	2 997.0
Percentage of total	20.2	11.2	67.0	0.9	100.0	100.0
Annual growth (*percentage*)	3.8	3.6	1.2	0.0	1.8	1.8

Source: ESCWA, "Towards harmonization of environmental standards in the energy sector of ESCWA member States", 1999, p. 58; figures for worldwide transport energy demand from World Energy Council, "Global transport and energy development: the scope for change", London, 1998, p. 14.

Note: Figures may not add up to 100 per cent due to rounding.

While the use of light-duty vehicles accounted for almost 49 per cent of world transport energy demand in 1995, it represented only 11.6 per cent of the total for the ESCWA region, and is expected to increase to slightly more than 20 per cent by 2020. This is a higher growth rate (3.8 per cent) than those forecast for other modes of transport (which range between zero growth and 3.6 per cent a year).

Road freight in the ESCWA region, which represented almost 80 per cent of total transport energy consumption in 1995, is expected to decline to 67 per cent by 2020. Aviation's share of energy consumption is expected to increase significantly, from 7.3 per cent of the region's total energy consumption in 1995 to 11.2 per cent in 2020 (see table 3).

2. *Energy consumption indicators for the transport sector*

Specific indicators used worldwide to assess transport sector energy consumption include:

(a) *Specific energy consumption*. Energy use per vehicle kilometre travelled per year is an indicator of how transport energy efficiency. Many factors could cause an increase in specific energy consumption including the use of vehicles with larger engines; the use of heavier vehicles; the use of less efficient types of fuel; or a change in driving conditions;

(b) *Intensity of gasoline consumption*. This indicator is expressed in kilograms of gasoline consumed per capita (kg/capita). Consumption of gasoline, the principal fuel for vehicles in the ESCWA region, has increased in the past 10 years to reach a total of 23,179 tons, reflecting the growing number of vehicles in the region. Gasoline consumption in the ESCWA member States ranges from 32 kg/capita in Egypt to as much as 980 kg/capita in Kuwait. The ESCWA member States in general, and the GCC countries in particular, have among the highest rates of gasoline consumption in the world (after the United States of America and Canada, where 1997 consumption rates were 1,284 kg/capita and 883 kg/capita, respectively).[5]

A major factor contributing to high gasoline consumption rates in the ESCWA member States is the relatively low cost of government-subsidized gasoline (both regular and premium). Low fuel costs have encouraged the use of larger motor vehicles for more frequent travel over longer distances, all of which results in increased GHG emissions.

C. TRANSPORT-RELATED GHG EMISSIONS AND THEIR ENVIRONMENTAL IMPACTS

Several ESCWA member States have become major consumers of energy since the mid-1940s as a result of: the development of the oil industry; rapid socio-economic development; and high rates of industrial and population growth. There has been a parallel increase in the number of vehicles in cities, which has resulted in more air pollution and water pollution, in particular in the region's densely populated cities.

This section provides a brief overview of the impacts of the transport sector on local natural resources and their significance for global warming, and highlights the relevant United Nations conventions and protocols. It also estimates levels of GHG emissions generated by the transport sector in the ESCWA region and their relevance for total energy sector emissions in the region as well as those of countries elsewhere.

1. *The environmental impacts of the transport sector*

(a) *Impacts on local natural resources*

Transport-related activities have wide-ranging and far-reaching environmental impacts, which include the following:

(i) *Air pollution*. All modes of transport produce emissions from the combustion and/or the evaporation of fuels. These emissions include carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NO_X), particulate matter, lead and CO_2, as well as chlorofluorocarbons (CFCs), which are released during vehicle manufacture and disposal. Factors that determine levels of transport energy use and related emissions include the following:

a. The level of demand for passenger transport (expressed in passenger kilometres travelled or a similar unit), and demand for freight transport (expressed in tons per kilometre travelled or a similar unit);

b. The performance of transport equipment in terms of fuel efficiency and emissions, which may in turn be determined by vehicle technology, fuel characteristics, maintenance of vehicles and equipment, age of equipment, and the behaviour of owners and operators.

The unabated increase in motorized transport and the concentration of vehicles in urban areas has seriously affected the air quality in several cities in the ESCWA region. It is expected, however, that provision of wide streets, reasonably fast-flowing traffic, well-developed traffic plans and automated traffic control, and the recent introduction of unleaded gasoline in most of the ESCWA member States will help to reduce the impact of vehicle-generated pollution. The pollutants emitted during transport activities have a variety of environmental impacts, *inter alia*, global warming, acid rain, chronic health problems and damage to vegetation (see annex I for more detail on the impacts of various modes of transport on natural resources).

(ii) *Water pollution*. Run-off of water from roads pollutes surface water and ground water, and natural waterways are often modified in the course of road building. The environmental impact of railroads is limited to the release of oil and grease from trains, and the leakage of creosote from track beds. Aviation-related environmental impacts mar arise from the construction of airports, which often involves modification of water-tables, the course of rivers and field drainage; and the contamination of nearby water sources by de-icing chemicals and degreasers. Maritime activity can create environmental problems through the discharge of ballast wash, the modification of water systems during port construction, canal cutting and dredging, sanitation discharges, and, in the event of an accident at sea, environmentally devastating oil spills.[1]

(iii) *Impact on land resources*. Land resources are affected by a number of transport-related activities, such as the development of infrastructure, the construction of terminals, the extraction of road-building materials, and the disposal of rubble from road works, road vehicles withdrawn from service, waste oil, tyres and batteries.

(b) *Global warming, pollution and congestion*

The transport sector contributes to global warming and tropospheric ozone pollution (smog) through the production of GHG emissions, in particular CO_2. GHG inventories in ESCWA member States have shown that the transport sector is the main contributor to GHG emissions in the region. Other effects of transport-related activities include local noise pollution and congestion, as well as a range of public health problems.

2. *Relevant United Nations conventions and protocols*

The last decade of the twentieth century witnessed the conclusion of two major international agreements aimed at reducing anthropogenic emissions of CO_2 and other GHGs, namely, the 1992 UNFCCC and the 1997 Kyoto Protocol.

The UNFCCC was adopted in May 1992 and in little more than a year had more than 160 signatories. It entered into force in March 1994. The ultimate objective of the UNFCCC, as stated in Article 2, is "to achieve stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system".

Several ESCWA member States have since initiated national GHG inventories; only four—Bahrain, Egypt, Jordan and Lebanon—have actually submitted their initial national communications, however. With the exceptions of Iraq and Palestine, all ESCWA members have ratified the UNFCCC.

In December 1997 the Kyoto Protocol was adopted at the third session of the Conference of the Parties to the UNFCCC. The Protocol establishes a legally binding obligation on Annex I countries[5] to reduce their

[5] Annex I of the UNFCCC, as amended on 11 December 1997, includes the following Parties: Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, the Czech Republic, Denmark, Estonia, the European Community, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein (included with Switzerland), Lithuania, Luxembourg, Monaco (included with France), the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, the Russian Federation, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, the United Kingdom of Great Britain and Northern Ireland and the United States of America.

emissions of six GHGs—carbon dioxide (CO_2), methane (CH_4), nitrogen dioxide (NO_2), carbon monoxide (CO), oxides of nitrogen (NO_X)and non-methane volatile organic compounds (NMVOC)—with an aggregate reduction during the commitment period 2008–2012 that brings levels to at least 5 per cent below those recorded in 1990. There are no such obligations on developing countries.[6]

3. *GHG emissions from fuel combustion in the ESCWA region*

Energy production and fuel combustion are the primary contributors to GHG emissions in the ESCWA region. In 1997, the transport sector (mainly road transport) used more than 32 per cent of all petroleum products consumed in the region; consequently, transport was a major source of GHG emissions.

(a) *ESCWA and the transport sector*

In 1990, emissions of CO_2 in the ESCWA region reached almost 456 million tons and had increased to almost 705 million tons by 1998.[8] Transport contributed 81.07 million tons of the 1990 total and 108.31 million tons in 1998, a 33.6 per cent increase (see table 4). Iraq and Saudi Arabia were the major individual contributors in 1998, producing 26.4 million tons and 29.9 million tons of CO_2, respectively, that year.

In 1998, the transport sector ranked third among sectors producing CO_2 from fuel combustion in the ESCWA region contributing 15.37 per cent of the regional total (see chart 3). Although industry produced 39.15 per cent of the regional total, emissions from transport represent a greater threat to public health, due to the particulate matter of transport emissions. The sectoral distribution of CO_2 emissions in the ESCWA member States in 1998 shows that the proportion of CO_2 emissions from the transport sector was highest in Yemen, followed by Iraq, Lebanon and Jordan. A possible explanation for this distribution may be the use of older, less efficient vehicles in these countries (see chart 4). Transport-related GHG emissions in the GCC countries were generally less than 10 per cent of national totals, with other sectors, mainly industry, accounting for greater proportions of CO_2 emissions.

(b) *GHG emissions per capita*

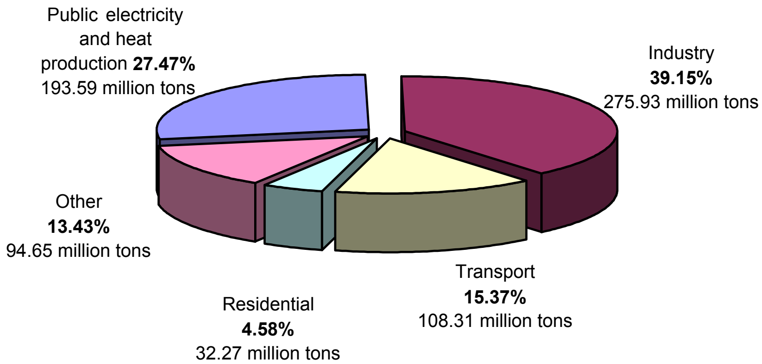
Fuel consumption and growth in per capita transport-related emissions vary widely among individual ESCWA member States. Major oil-producing States such as the GCC countries and Iraq have the highest per capita CO_2 emissions. Qatar had the highest level of emissions in 1998, followed by Kuwait, and the United Arab Emirates. Countries with limited or no oil resources, such as Egypt, the Syrian Arab Republic and the Republic of Yemen, recorded the lowest CO_2 emission rates. The high average annual growth rate in CO_2 emissions per capita in the period 1990–1998 in Lebanon and Kuwait could be the result of post-war recovery in those two countries, leading to high levels of energy consumption and hence increased emission rates.

Emissions of CO_2 from all fuel combustion in the entire ESCWA region reached 4.59 tons per capita in 1998, an increase of 24.73 per cent since 1990. Emissions of CO_2 from transport reached 0.706 tons per capita in 1998, or 15.37 per cent of total emissions from fuel combustion, compared with 17.78 per cent in 1990.

Estimated emissions of other GHGs produced by the ESCWA transport sector in 1997 are: 60,853 tons of CH_4; 9.82 million tons of CO; 962 tons of NO_2; 1.047 million tons of NO_X; and 1.85 million tons of NMVOC.[9]

[6] See annex II of this study for an outline of the objectives and status of each of these agreements and for a list of actions taken by ESCWA member States to meet their commitments under the UNFCCC and/or the Kyoto Protocol, as well as their present status in relation to the accumulation of GHGs.

Chart 3. Distribution by sector of CO_2 emissions from fuel combustion in the ESCWA region, 1998



Source: International Energy Agency, *CO_2 Emissions from Fuel Combustion 1971–1998*, 2000.

(c) *GHG emissions in the ESCWA region and levels worldwide*

The United States produces more GHGs than any other country, accounting for 23 per cent of emissions worldwide. China is the next most prolific producer of GHGs (accounting for 14 per cent of the world total) followed by the Russian Federation (which produces 8 per cent of the global total).[10] Poland, South Africa and Indonesia, at the other end of the scale, each generate 1 per cent of the world's GHG emissions. The ESCWA region's contribution to the world's GHG emissions is minimal when compared with that of other developing countries (such as China) or the industrial nations (such as the United States or Canada). OECD countries[7] collectively produced 60.4 per cent of the world's transport-generated CO_2, and Annex II Parties to the UNFCCC[8] contributed 56.3 per cent of the world total in 1998 (see table 5). The ESCWA region's share was just 2.1 per cent in 1998 (1.8 per cent in 1990 and 2.3 per cent in 1996).[8]

The main reason that the ESCWA region produces a small proportion of the world's transport-related GHG emissions is the fact that most of its member States lack extensive transport infrastructure and their motorization levels are lower than those in other parts of the world. This situation may change in coming years, however, because the ESCWA member States are now experiencing greater growth in transportation.

D. THE NEED FOR ACTION

In light of the above, it is apparent that the growth of the transport sector in the ESCWA member States could have serious environmental implications which. If left uncontrolled, such growth could cause further deterioration of the air quality in some of the region's already congested cities, with associated public health impacts. Immediate action should therefore be taken to improve energy efficiency in the transport sector and to reduce the environmental impacts—in particular, GHG emissions—of transport activity.

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7 The members of the OECD are: Australia; Austria; Belgium; Canada; the Czech Republic; Denmark; Finland; France; Germany; Greece; Hungary; Iceland; Ireland; Italy; Japan; Korea; Luxembourg; Mexico; the Netherlands; New Zealand; Norway; Poland; Portugal; Spain; Sweden; Switzerland; Turkey; the United Kingdom of Great Britain and Northern Ireland; and the United States of America.

8 Annex II of the UNFCCC includes the following Parties: Australia; Austria; Belgium; Canada; Denmark; the European Community; Finland; France; Germany; Greece; Iceland; Ireland; Italy; Japan; Liechtenstein (included with Switzerland); Luxembourg; Monaco (included with France); the Netherlands; New Zealand; Norway; Portugal; Spain; Sweden; Switzerland; Turkey; the United Kingdom of Great Britain and Northern Ireland; and the United States of America.

TABLE 4. TOTAL AND ROAD TRANSPORT CO_2 EMISSIONS IN THE ESCWA REGION

Country	1990					1998					Average annual growth (*Percentage*)
	Total fuel combustion		Road transport fuel		Transport share (*Percentage*)	Total fuel combustion		Road transport fuel		Transport share (*Percentage*)	
	Total CO_2 emissions (*Millions of tons*)[a/]	Total CO_2 emissions/capita (*Tons*)	CO_2 emissions from transport (*Millions of tons*)	Transport emissions/ capita (*Tons*)		Total CO_2 emissions (*Millions of tons*)[a/]	Total CO_2 emissions/ capita (*Tons*)	CO_2 emissions from transport (*Millions of tons*)	Transport emissions/ Capita (*Tons*)		
Bahrain	10.86	20.24	0.99	1.98	9.12	15.60	21.72	1.38	2.16	8.85	1.14
Egypt	73.34	1.57	13.19	0.25	18.04	93.81	1.72	16.75	0.27	17.86	1.00
Iraq	57.02	3.04	23.54	1.30	41.28	71.45	3.80	26.43	1.18	36.99	(1.15)
Jordan	9.09	2.95	2.66	0.84	29.26	13.64	2.94	3.19	0.70	23.39	(2.08)
Kuwait	19.98	9.86	2.62	1.23	13.11	66.56	20.12	6.21	3.32	9.33	21.24
Lebanon	6.39	1.76	1.84	0.51	28.80	15.04	3.57	4.40	1.05	29.26	13.26
Oman	10.68	6.35	1.67	1.02	15.64	17.23	7.72	2.47	1.09	14.34	0.86
Qatar	14.01	28.52	1.80	3.67	12.85	31.29	45.19	3.01	4.18	9.62	1.73
Saudi Arabia	175.92	10.15	20.44	1.29	11.62	257.16	13.05	29.90	1.49	11.63	1.89
Syrian Arab Republic	30.99	2.65	3.75	0.31	12.10	49.63	3.03	3.61	0.24	7.27	(2.96)
United Arab Emirates	41.37	22.76	4.82	2.62	11.65	64.82	23.98	6.37	2.34	9.83	(1.32)
Republic of Yemen	6.31	0.62	3.75	0.32	59.43	8.55	0.55	4.59	0.28	53.68	(1.55)
ESCWA total[b/]	455.96	3.69	81.07	0.66	17.78	704.78	4.60	108.31	0.71	15.37	

Source: International Energy Agency, *CO_2 Emissions from Fuel Combustion 1971–1998*, Paris, 2000, pp. 54–55.

Notes: ( ) indicates negative.

a/ Intergovernmental Panel on Climate Change (IPCC) sectoral approach for total CO_2 emissions.
b/ The population of the ESCWA region was 123.72 million in 1990 and 153.39 million in 1998.

TABLE 5. TRANSPORT-GENERATED CO_2 EMISSIONS BY COUNTRY GROUPING
(*Millions of tons*)

Country groupings	1990	Percentage of world total	1996	Percentage of world total	1998	Percentage of world total
World	4 524.5	100.0	4 604.6	100.0	5 294.5	100.0
UNFCCC Annex I Parties	-	-	3 243.1	70.4	3 199.3	60.4
UNFCCC Annex II Parties	2 571.3	56.8	3 042.6	66.1	2 982.4	56.3
UNFCCC Annex B Parties[a/]	-	-	3 197.2	69.4	3 158.8	59.7
OECD countries	2 737.7	60.5	3 279.9	71.2	3 198.6	60.4
European Union[b/]	698.5	15.4	851.8	18.5	805.3	15.2
ESCWA	81.1	1.8	106.2	2.3	108.3	2.1

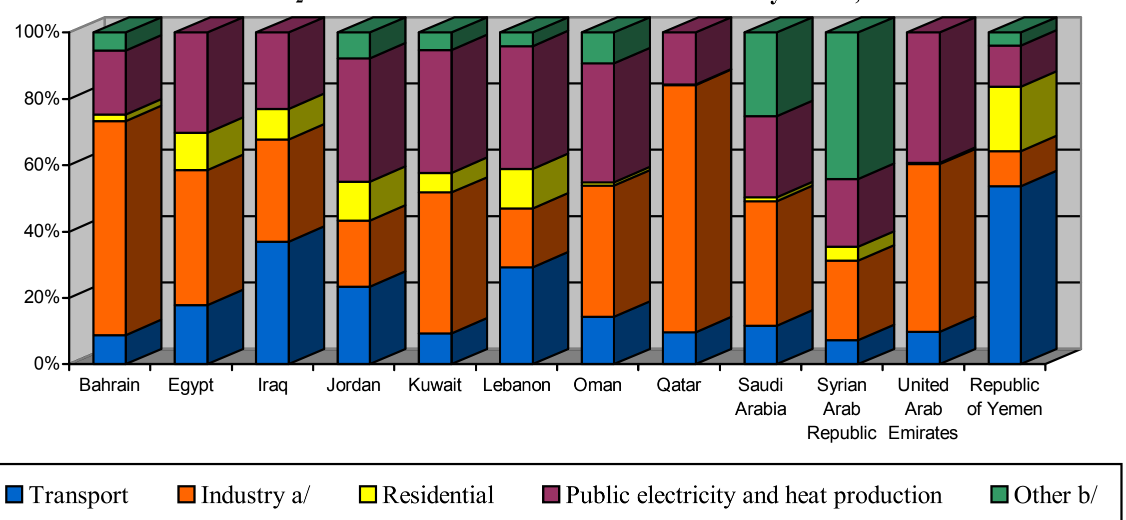
Source: International Energy Agency, *CO_2 Emissions from Fuel Combustion 1971–1998*, Paris 2000.

Note: A hyphen (-) indicates the item is not applicable.

a/ Annex B of the Kyoto Protocol to the UNFCCC includes the following Parties: Australia; Austria; Belarus; Belgium; Bulgaria; Canada; Croatia; the Czech Republic; Denmark; Estonia; the European Community; Finland; France; Germany; Greece; Hungary; Iceland; Ireland; Italy; Japan; Latvia; Liechtenstein; Lithuania; Luxembourg; Monaco; the Netherlands; New Zealand; Norway; Poland; Portugal; Romania; the Russian Federation; the Slovak Republic; Slovenia; Spain; Sweden; Switzerland; Ukraine; the United Kingdom of Great Britain and Northern Ireland; and the United States of America.

b/ The members of the European Union are: Austria; Belgium; Denmark; Finland; France; Germany; Greece; Ireland; Italy; Luxembourg; the Netherlands; Portugal; Spain; Sweden and the United Kingdom of Great Britain and Northern Ireland.

Chart 4. CO_2 emissions in the ESCWA member States by sector, 1998



Source: International Energy Agency, *CO_2 Emissions from Fuel Combustion 1971–1998*, Paris 2000.

a/ Industry includes manufacturing industries and construction, as well as other energy-consuming industries.
b/ Other includes unallocated automobile producers and other sectors (excluding residential).

Reducing GHG emissions in the transport sector poses great challenges, for which there are, unfortunately, no obvious answers or quick technical fixes. There is, however, a range of promising technologies available which, if supported by appropriate policies, may be capable of alleviating the GHG problem.

The ESCWA member States need to establish strategies to meet their national transportation needs while also addressing considerations of efficient energy use, environmental impacts and economic responsibility. Such strategies should include: plans for improving the efficiency of motorized vehicles; switching to alternative, "clean" fuels; introducing and/or improving telecommunications systems; maximizing the efficiency of existing transportation systems; and placing greater emphasis on the development and utilization of more energy-efficient and less environmentally damaging modes of transport (for example, mass transit systems and non-motorized transport). Emphasis must also be placed on comprehensive land-use planning in order to design effective, efficient transport systems that can handle future demands.

There are several options available by which it should be possible to mitigate the negative environmental impacts of transportation growth in the ESCWA region. The chapters to follow will present a selection of these options and provide an evaluation and ranking for each.

II. OPTIONS FOR THE ABATEMENT OF TRANSPORT-RELATED GHG EMISSIONS IN THE ESCWA REGION

Transportation systems the world over rely almost entirely on petroleum-based fuels. In 1997, road transport accounted for almost 32 per cent of all petroleum products consumed in the ESCWA member States. Transport is therefore responsible for a substantial proportion of gaseous pollutants, in particular, GHGs and particulate matter. With the tremendous, continuing growth of travel and traffic around the world, it is increasingly important that the relationship between transportation and the environment be monitored in order to identify, quantify and rank pollution prevention strategies that could be adopted in order to minimize the negative environmental impacts of transport activities.

This chapter provides an overview of the development status, characteristics and experience gained in various countries of a group of options for the mitigation of transport-related GHG emissions. These options are classified into four main categories: advanced-technology vehicles; higher quality transport fuels; policy and management measures; and environmental regulations and standards (see chart 5).

A. ADVANCED-TECHNOLOGY VEHICLES

Vehicles running on modern gasoline emit a complex mixture of air pollutants, many of which are toxic. A great deal of effort has been made to reduce automobile pollution—through the development of innovative emission-control technologies, the establishment of inspection and maintenance programmes, and the adoption of regulations and standards to control transport sector emissions. Each year, however, there are more cars on the road, travelling longer distances, and the pollution control measures taken thus far have proved insufficient to solve the air pollution problem, especially in mega-cities (with more than a million inhabitants).

Advanced-technology vehicles[9] are powered by energy sources other than conventional gasoline and diesel fuels. Promising alternatives include the following: (a) electric vehicles (powered by batteries, fuel cells or hybrid power sources); and (b) “clean-fuel” vehicles (running on compressed natural gas (CNG), methanol, ethanol, propane, or hydrogen).

1. *Electric vehicles*

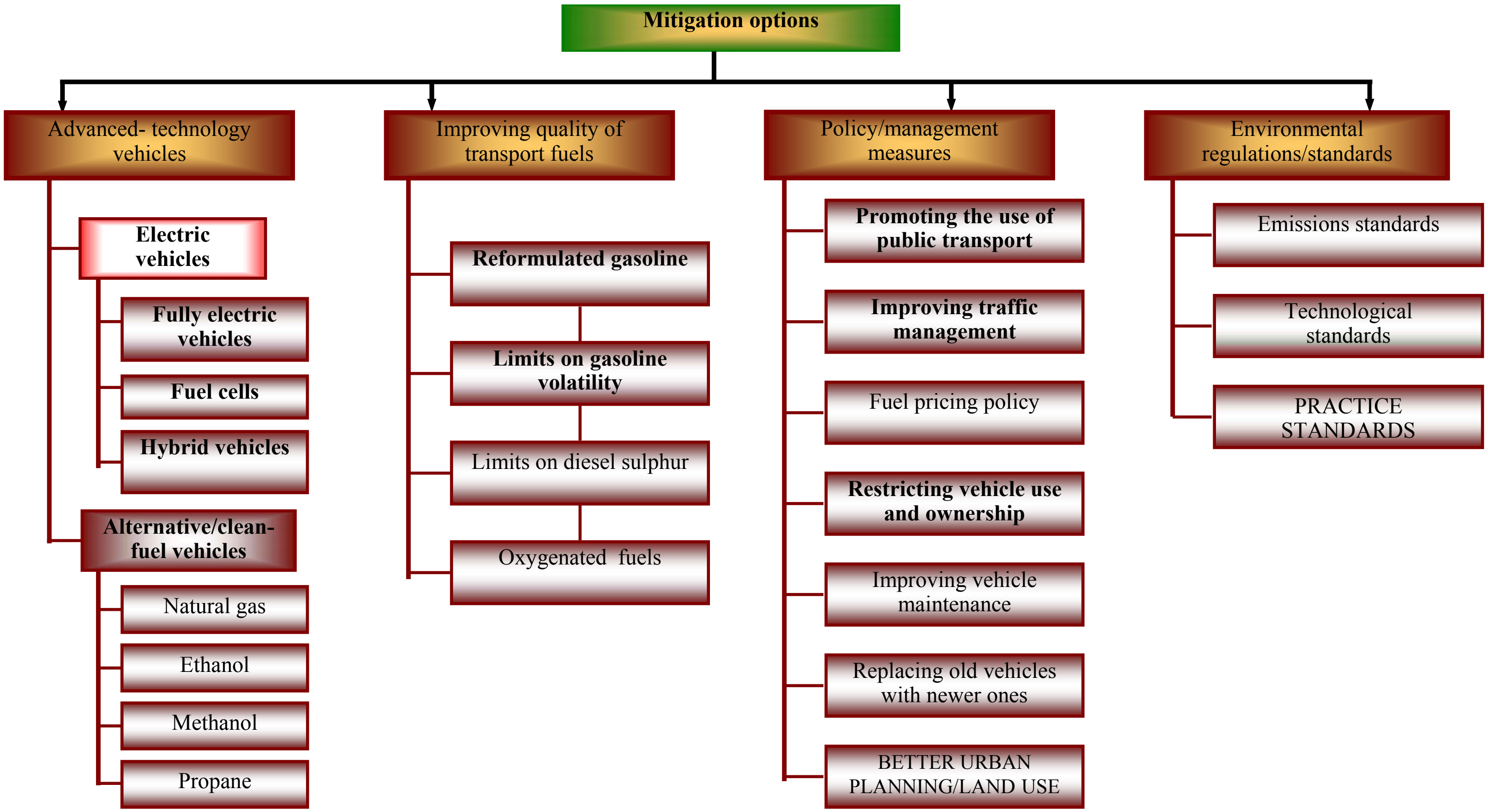
(a) *Fully electric vehicles*

Battery-powered vehicles give off virtually no pollution and offer one of the best options for reducing motor vehicle emissions in polluted cities. The environmental drawbacks of the types of electric vehicles presently in use, however, include the emissions from the power stations that generate the electricity for battery recharging, and the introduction of significant amounts of lead into the environment, regardless of best efforts to recycle lead-acid batteries. Other drawbacks include the fact that the driving range of electric vehicles is limited by the amount of power the battery can provide and that current batteries take hours to recharge. The cost of electric vehicles is high. [11]

Efficient emission controls can be installed and maintained more easily on an individual power plant that charges many electric vehicles than on millions of vehicles running on conventional fuels. Greater market penetration by electric vehicles will depend on improvements in battery charging rates, energy densities and power densities and market factors such as cost, consumer preference and the response of manufacturers to more stringent regulations for air quality. A Massachusetts Institute of Technology study on the future of electric passenger cars in the United States concluded that electric vehicles for road use remained in a highly experimental phase, that their reliability over a standard warranty period such as three years or 80,500 kilometres was unknown, and that cost-effective batteries able to run the desired range of electric vehicles were not yet available. A recently completed cost analysis, also by the Massachusetts Institute of Technology, concluded that mass-produced (100,000 units per year) electric vehicles would be 32 per cent more expensive than their fossil fuel-powered equivalents and that their batteries would add 7–23 per cent to the manufacturer’s retail price. With certain improvements, however, electric vehicles could achieve parity in cost and price with conventional fossil fuel-powered vehicles.

[9] Advanced-technology vehicles are factory-built vehicles that run on electricity or alternative fuels. The category also includes such future technologies as hybrid-electric and fuel cell-electric vehicles.

Chart 5. GHG mitigation options for the transport sector



In the United States, rapid progress is being made in the design of electric vehicles powered by high-energy-density batteries. Producing affordable electric vehicle batteries with less weight and more capacity remains the key to the market success of electric vehicles. The development of electric vehicle subsystems— including the development of infrastructure components for rapid charging and battery energy management subsystems—is progressing rapidly.

(b) *Fuel cell-electric vehicles*

A fuel cell is an electrochemical engine (with no moving parts) that combines hydrogen and air to produce electricity. Hydrogen can be produced inside the fuel cell itself from a fuel such as methane or natural gas, or by the electrolysis of water. Fuel cells can be used as an alternative to internal combustion engines, converting chemical energy directly into electricity without combustion, with considerably greater efficiency than that of internal combustion engines, and with very low emission levels. The limitations of batteries in electric vehicles in terms of range and durability can be avoided by the use of fuel cells.

In the United States, emphasis has been placed on the production of a smaller, lighter, low-cost fuel cell system. A proton exchange membrane fuel cell is the current technology of choice because it offers the potential for low-cost mass production, as well as higher power density for heavy vehicles with rapid start-up time. North American automobile industries have invested more than $1 billion to manufacture and market fuel cell technology. [12]

Fuel cell-powered cars easily outperform today's battery-powered electric vehicles. A key issue, however, is the cost of the fuel cell itself. Automobile industry experts estimate that for fuel cell-powered cars to be marketable, the cost of the fuel cell would need to be $100 to $150 per kilowatt of capacity. In contrast, conventional gasoline engines cost about $35 per horsepower, or about $50 per kilowatt.[13]

More than 50 companies worldwide are working on developing fuel cells and prototype fuel cell vehicles. It is estimated that by 2010, fuel cell buses could be competitively priced and could be used in the major cities of developing countries. With mass production, the price of fuel cell vehicles will be reduced but many challenges remain, not least of which is the determination of which power source to use—hydrogen, methanol, gasoline or some other fuel.

The United Nations Development Programme (UNDP) has initiated programmes to promote the use of hydrogen fuel cells in buses in Brazil, China, Egypt, India and Mexico—countries that contain many of the world's mega-cities. These programmes also receive funds through the Global Environment Facility (GEF).

(c) *Hybrid vehicles*

The range and performance of an electric vehicle can be considerably improved when a turbine or combustion engine is coupled in series or parallel with an electric power train to create a hybrid electric vehicle. Several major equipment manufacturers are putting hybrid vehicle models on the market, combining electric drives and internal combustion engines. Use of hybrid vehicle technology can compensate for many of the shortcomings of the fully electric vehicle, providing greater range, lower vehicle weight (as a result of lower battery weight), lower operating cost per kilometre and generally better road performance. The disadvantage of the hybrid vehicle is its complex power train and emissions from the internal combustion auxiliary power unit.[11]

Hybrid vehicle technology offers a viable way to improve fuel efficiency, especially in urban traffic, where vehicles must constantly stop and start. A lightweight, compact, high-power energy storage device such as a flywheel system or an ultracapacitor is a critical component enabling hybrid vehicle systems to balance the dynamic load profiles of the power train and to store and recover unused energy during braking and idling. With a hybrid configuration, the primary energy converter can be smaller than in a conventional vehicle and can operate at loads and speeds that optimize efficiency, independent of the vehicle's transient needs. Series and parallel hybrid systems are currently under operational testing in partnership programmes between the federal government, industries and regional consortia. [12]

2. *Alternative, or "clean-fuel" vehicles*

Some fuels, because of physical or chemical properties (for example, a low carbon content), create less pollution—and less CO_2 per unit of energy—than do gasoline or diesel. Such fuels are consequently known as "clean fuels" (see table 6). Use of clean fuels could help to slow the atmospheric build-up of CO_2, considered to be the most significant factor contributing to global warming.

TABLE 6. CO_2 PRODUCED PER UNIT OF ENERGY IN THE COMBUSTION OF SELECTED FUELS

	Natural gas	Liquefied petroleum gas	Gasoline	Diesel	Fuel oil	Coal
Tons of CO_2 produced per toe	2.34	2.63	2.98	3.09	3.23	3.94

Source: Organization for Energy Planning, *Energy in Egypt 1997/1998*.

Clean-fuel vehicles run on four main types of fuel—natural gas, ethanol, methanol and propane. Natural gas, which will be described in more detail below, are the most advanced and most widely used of the clean-fuel vehicles, which use the following fuels:

(a) *Ethanol*. Ethanol is the primary automotive fuel in Brazil and ethanol-gasoline blends (known as "gasohol") have been used in the United States for many years. Pure ethanol fuel offers excellent performance, emitting only low levels of hydrocarbons and toxic compounds. Ethanol can be produced domestically from corn or other crops, as well as from cellulosic materials such as wood or paper waste. Its use therefore has additional potential for limiting the accumulation of GHGs, because the renewable resources from which it can be made draw CO_2 out of the atmosphere as they grow. With current technology and price structures, ethanol is more expensive than gasoline. New technologies, however, offer the prospect of significantly reduced costs;

(b) *Methanol*. Methanol, like ethanol, is a high-performance liquid fuel that emits low levels of toxic and ozone-forming compounds. It can be produced from natural gas at prices comparable to those for gasoline and can also be produced from coal and wood. All major automobile manufacturers have produced cars that run on a blend of 85 per cent methanol and 15 per cent gasoline, known as M85. Cars that burn pure methanol, or M100, offer far greater advantages in terms of emissions and efficiency. Many automobile manufacturers have developed advanced M100 prototypes. Methanol has long been the fuel of choice for racing cars because of its superior performance and fire safety characteristics;

(c) *Propane*. Propane, or liquefied petroleum gas (LPG), is a by-product of petroleum refining and natural gas production. It burns more cleanly than gasoline but supply is limited. Propane-fuelled vehicles are already common in many parts of the world.

3. *CNG and liquefied natural gas vehicles*[*]

(a) *The technology*

The only major difference between a gasoline vehicle and a natural gas vehicle is the fuel system. Natural gas can be stored onboard a vehicle in pressurized, insulated tanks. Most natural gas vehicles at present use CNG. Liquefied natural gas is increasingly being investigated, however, because of its storage benefits. The viability of technology for transferring liquefied natural gas from a refuelling station to a vehicle, and for vaporizing the fuel as it enters an engine largely remains to be demonstrated, however.

[*] This section draws heavily on "Energy and Sustainable Development, Energy and Transport", Report of the Secretary-General, third session, New York, 23 March–3 April 1998. Item 4(d) of the provisional agenda (E/C./13/1998/6) and United States Environmental Protection Agency, Details of the Alternatively Fuelled Vehicles Project available at http://www.epa.gov/oaintrnt/intrnlp2/p2/opprtnty/altfuel.htm.

Natural gas is compressed to 3,000–3,600 pounds per square inch (psi) and is stored onboard the vehicle in cylinders installed in the rear, attached to the undercarriage, or on the roof. When the engine requires fuel, the gas leaves the cylinders, passes through a master manual shut-off valve and travels through a high-pressure fuel regulator located in the engine compartment. It is injected at atmospheric pressure through a specially designed natural gas mixer, where it is mixed with air. The gas then flows into the engine's combustion chamber and is ignited to create the power required to drive the vehicle. Special solenoid-operated valves prevent the gas from entering the engine when the vehicle is not running. Natural gas vehicles can be "fast filled" in five to six minutes using compressed gas stored in cascades of natural gas cylinders or they can be refuelled overnight in a "timed fill" process taking between five and eight hours. Many private fleet fuelling stations use a combination of fast fill and timed fill.

The use of gas-fuelled vehicles has grown rapidly, and it is estimated that there are now more than a million natural gas vehicles in the world and 3,951 fuelling stations in more than 46 countries; Argentina, Italy and the United States in particular have made considerable progress. Most gas-fuelled vehicles can run on either gas or gasoline. The widespread introduction of vehicles that run solely on natural gas would make an even greater contribution to reducing emissions of major pollutants such as CO_2, CO, NO_X, non-methane hydrocarbons and oxides of sulphur. These vehicles have a long-established record in Australia, Canada, Europe and New Zealand. There are approximately 579,000 natural gas-fuelled vehicles in Argentina, or 46.1 per cent of the world total (see chart 7), and more than 320,000 in Italy (25.5 per cent). The United States has more than 90,000 natural gas vehicles (7.2 per cent of the world total), Canada has nearly 40,000 gas-fuelled vehicles (1.6 per cent of the world total) and a network of 125 public fuelling stations (2.4 per cent of the worldwide total). Russia has more than 200,000 natural gas vehicles (2.4 per cent of the world total), with plans to convert a million vehicles by the end of this decade. Egypt has about 30,000 natural gas vehicles, 2.2 per cent of the worldwide fleet and 1.6 per cent of all natural gas fuelling stations in the world.[9]

The environmental and economic benefits of gas-fuelled vehicles are demonstrated by the data recorded by a taxi company in southern California, United States. Based on an annual driving cycle of 112,700 kilometres, it was calculated that a fleet of 104 natural gas-fuelled taxis would reduce pollution by more than 73 tons per year and reduce annual maintenance costs by $1,300 per vehicle; Fuel cost savings were calculated at $2,260 a year[10] for taxis driving 128,800 kilometres per year.[33]

(b) *Types of natural gas vehicles*

(i) *Bi-fuel vehicles*

A bi-fuel vehicle can run on either natural gas or gasoline. Many are designed to switch automatically to gasoline when the natural gas fuel tank is empty. These vehicles get the same or slightly fewer kilometres per equivalent litre of natural gas as do vehicles using gasoline only.

(ii) *Dual-fuel vehicles*

Dual-fuel vehicles run either on diesel fuel only, or diesel and natural gas simultaneously, with the combustion of the diesel serving to ignite the natural gas.

(iii) *Dedicated natural gas vehicles*

Dedicated natural gas-fuelled vehicles run on natural gas only. They may be gasoline-fuelled vehicles that have been converted to run on natural gas; most, however, are produced as dedicated natural gas vehicles by original equipment manufacturers in the light-duty vehicle market and by a host of manufacturers of trucks and buses in the medium- and heavy-duty vehicle markets.

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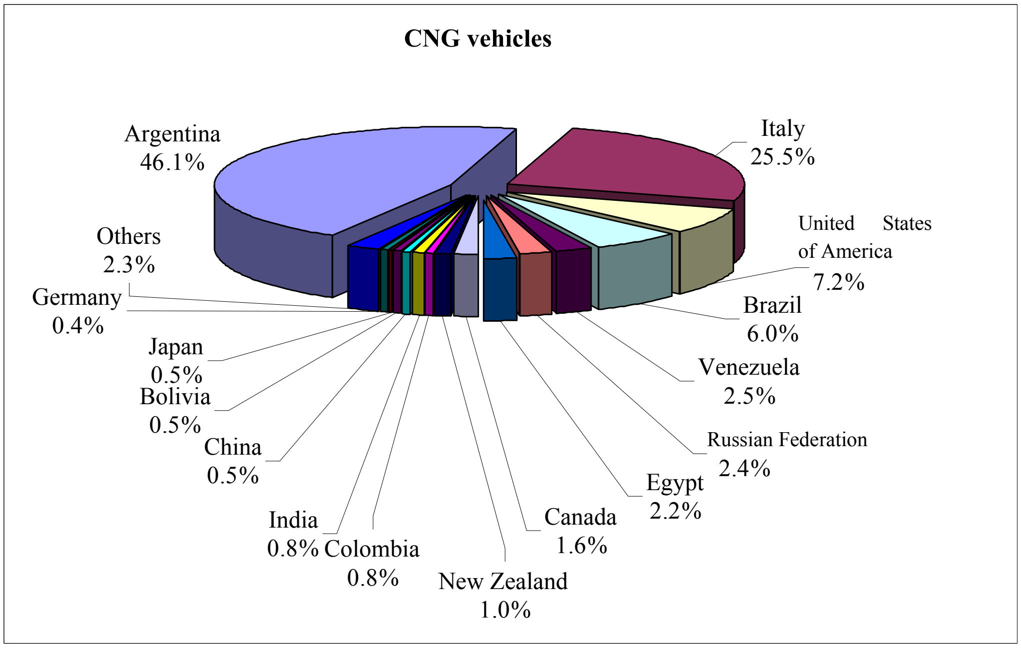
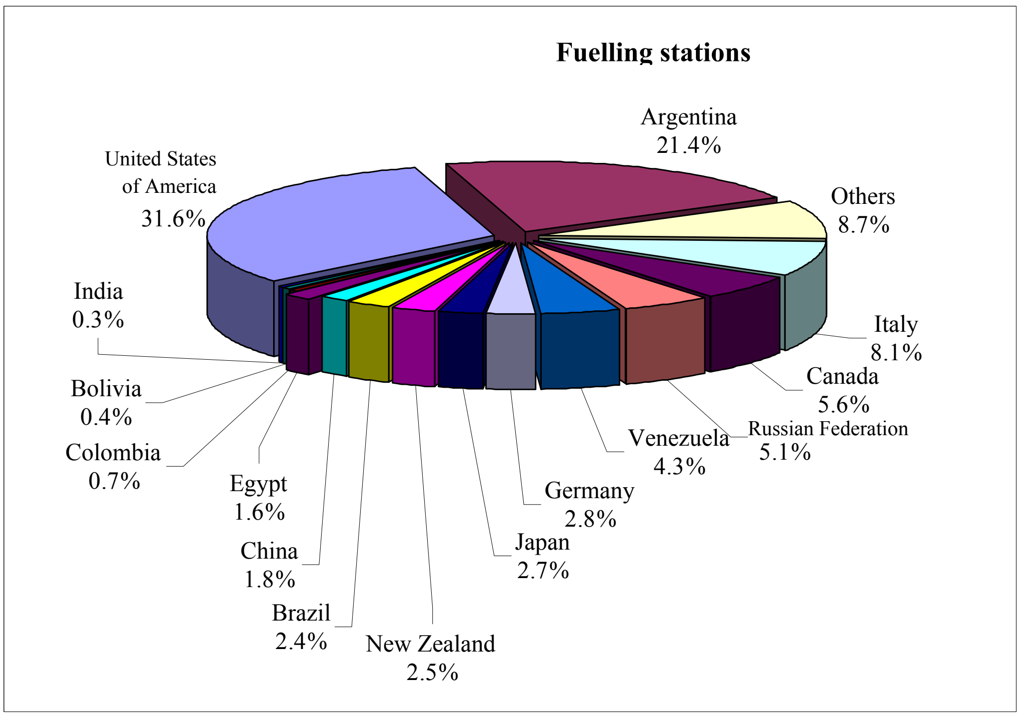
[10] The price difference in southern California between 4.55 litres of gasoline and equivalent of natural gas was 48 cents.

Chart 6. Distribution of CNG vehicles and fuelling stations worldwide





Source: Salah Kandil, "Options for GHG abatement in the ESCWA region: case study of Egypt", report prepared for ESCWA, 2000.

(c) *Benefits of natural gas fuel*

Natural gas fuel has several economic, social and environmental benefits, especially for countries that have natural gas resources.

(i) *Economic benefits*

On a litre-equivalent basis, natural gas costs an average of 15 to 40 per cent less than gasoline and diesel. Natural gas is also a clean-burning fuel, so vehicles using it require less maintenance than those using conventional fuels. Many owners of gas-fuelled vehicles report that oil changes are required only every 16,100–32,200 kilometres. Standard spark plugs in gas-fuelled vehicles last as long as 120,750 kilometres.[14] Given that fuel theft is an ongoing concern of fleet managers, natural gas has another advantage in that, unlike liquid fuels, it cannot be siphoned from a vehicle.

(ii) *Environmental benefits*

Because natural gas burns more cleanly, emissions of GHGs and toxins from natural gas-fuelled vehicles are much lower than those from gasoline-powered vehicles. Vehicles running on natural gas, for example, produce 70 per cent less CO than those running on gasoline. Non-methane organic emissions are 89 per cent lower from vehicles fuelled by natural gas and emissions of NO_X are 87 per cent lower. These values are affected by factors such as engine condition, the operating environment and fuel quality.

(iii) *Social benefits*

Promoting the use of alternative fuels and the vehicles that use them can benefit the economy at the local and national levels by creating jobs and commercial opportunities. Activities such as CNG vehicle conversions, the development of new technology, and the use of more domestically produced fuels and feedstock for fuel production all generate business growth and new profit opportunities. It has been estimated that in the United States, direct investment in the fabrication of vehicles that run on alternative fuels, the construction of fuelling stations and infrastructure, and the maintenance of vehicles and stations will have created 13,500 jobs by the end of 2000. Indirect investment is expected to have stimulated the creation of another 30,000 jobs in the same period.[14]

Natural gas is as safe for vehicle use as traditional fuels such as gasoline because CNG, unlike gasoline, dissipates into the atmosphere in the event of an accident. A survey of more than 8,000 vehicles that cumulatively travelled approximately 450 million kilometres in the period 1987–1990 in the United States found that the injury rate for vehicles fuelled by natural gas per vehicle mile travelled was 37 per cent lower than the rate for gasoline-powered vehicles in the survey and 34 per cent lower than the entire national fleet of registered gasoline-fuelled vehicles. No fatalities were recorded in association with the gas-fuelled vehicles in the survey, compared with less than 1.28 deaths per 100 million vehicle miles travelled associated with the gasoline-powered vehicles.[15]

(d) *Cost of conversion to natural gas*

In the United States, the typical cost to convert a light-duty gasoline-fuelled vehicle to run on natural gas ranges from $3,000 to $5,000. Converting larger vehicles, such as trucks and school buses, costs more. Dedicated natural gas-powered vehicles cost $3,500–$7,000 more than gasoline vehicles but economies of scale can be expected to reduce the price. The United States Department of Energy estimates that mass-produced gas-powered vehicles will cost approximately $800 more than comparable gasoline models.[14] It is important to note that conversion costs vary from one country to another, depending on factors such as the technology used and labour costs. Currently in Egypt, the cost of converting a passenger car from gasoline to natural gas is estimated to be about $1,500.

4. *Comparison of alternative fuels*

Vehicles running on alternative fuels produce less CO_2 and other pollutants than do conventionally-fuelled vehicles. They can therefore help to reduce smog problems and slow the pace of climate change. A key method of promoting the use of alternative fuels is to increase the availability and convenience of appropriate refuelling facilities.

It is estimated that by 2020, there will be a wider variety of vehicles using fuels other than gasoline or diesel. The current growth rate of alternative fuels is calculated to be 22 per cent for CNG, 50 per cent for liquefied natural gas and 95 per cent for reformulated gasoline (see table 7 for advantages and disadvantages of various clean fuels).[12]

TABLE 7. ADVANTAGES AND DISADVANTAGES OF SELECTED ALTERNATIVE FUELS

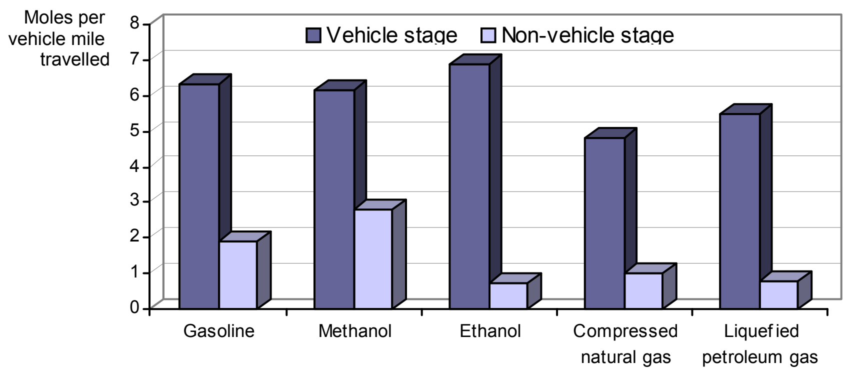
Fuel	Advantages	Disadvantages
Electricity	Potential for zero vehicle emissions; power plant emissions are easier to control than vehicle emissions; recharge can be done at night when power demand is low.	Current technology is limited; higher vehicle cost; lower vehicle range and performance than vehicles using conventional fuels; less convenient refuelling.
Ethanol	Excellent automotive fuel; very low emissions of ozone-forming hydrocarbons and toxic compounds; produced from renewable resources; can be produced domestically.	High fuel cost; lower vehicle range.
Methanol	Excellent automotive fuel; very low emissions of ozone-forming hydrocarbons and toxic compounds; can be produced from a variety of feedstocks and other renewable resources.	Fuel may initially need to be imported; lower vehicle range.
Natural gas (methane)	Very low emissions of ozone-forming hydrocarbons, toxic compounds, and CO; currently cheaper than gasoline; can be produced from a variety of feedstocks, and other renewable resources; excellent fuel, especially for fleet vehicles.	Higher vehicle cost; lower vehicle range; less convenient refuelling.
Propane	Currently cheaper than gasoline; currently the most widely available clean fuel; lower emissions of ozone-forming hydrocarbons and toxic compounds; excellent fuel, especially for fleet vehicles.	Limited supply; cost will rise with demand; no energy security or trade balance benefits.
Reformulated gasoline	Can be used in all vehicles without requiring modification of the vehicle or fuel distribution system; lower emissions of ozone-forming hydrocarbons, nitrogen oxides and toxic compounds.	Higher fuel cost; issues relating to fuel energy security and/or trade balance.

Source: United States Office of Transportation and Air Quality Web site http://www.epa.gov/otaq/.

Water vapour and CO_2 together account for more than 97 per cent of emissions from the combustion of both alternative and traditional transportation fuels.[16] CNG was found to produce the lowest levels of CO_2 across the total fuel cycle (which includes the production of the fuel, its transfer to a vehicle engine and its combustion) followed by liquefied petroleum gas (see chart 8). Methanol and gasoline, on the other hand, produce almost the same amount of CO_2 in the vehicle stage of the fuel cycle. Looking at emissions of GHGs other than CO_2, it was found that CNG produces higher levels of CH_4 during the vehicle stage of the fuel cycle than do the other alternative fuels. Ethanol produces the highest level of nitrous oxide emissions across the total fuel cycle.

The end-user portion of the fuel cycle (that is, the vehicle stage) accounts for at least 80 per cent of total fuel cycle CO_2 emissions for all of the fuels listed in chart 8 other than methanol (from natural gas). Efforts to reduce GHGs produced as a direct result of vehicle use are therefore justified.

Chart 7. CO_2 per vehicle mile travelled for selected fuels throughout the fuel cycle



Source: United States Department of Energy, Energy Information Administration, *Alternative to Traditional Transportation Fuels 1994*, vol. II, Washington, D.C., September 1996.

Note: The non-vehicle stage of the fuel cycle includes all fuel processes from resource recovery through energy transformation prior to end use.

CFCs and hydro fluorocarbons (HFCs), which are also transport-related GHGs, are not produced by fuel combustion; rather, they are used in motor vehicle air conditioners. Unlike CO_2 and CH_4, CFCs can have potent effects even if emitted in only small quantities.

B. Higher quality transport fuels[**]

The composition of vehicle emissions depends largely on the fuel being burned. Consequently, upgrading the quality of transport fuel can have great benefits for emission control programmes. The 1990 Clean Air Act in the United States, for example, established regulations and standards for fuels and fuel additives and for emissions from new motor vehicles and new engines.[11]

The most important processes for improving fuel quality include the following:

(a) *The use of reformulated gasoline*. Gasoline is made up of various hydrocarbon compounds including aromatics, olefins and benzene, all of which contribute to ozone-formation and toxic air pollution through evaporation and combustion. These compounds are present in smaller quantities in reformulated gasoline, resulting in fewer harmful emissions. Reformulated gasoline provides the same performance characteristics as conventional gasoline but produces less damaging emissions. There are hundreds of different formulations for making gasoline. The ingredients used to make reformulated gasoline are no different from those used to produce conventional gasoline. The only difference is the proportions in which the ingredients are used, in particular those ingredients that contribute to air pollution. The main advantages of reformulated gasoline include the following:

(i) Lower levels of pollutant compounds that contribute to air pollution. Using reformulated gasoline can reduce vehicle emissions of ozone-forming hydrocarbons and toxic compounds by 15–17 per cent;

[**] The following section draws heavily from United States Office of Transportation and Air Quality Web site http://www.epa.gov/otaq/.

[11] Details of the United States Clean Air Act can be found on the United States Environment Protection Agency Web site at www.epa.gov/oar/caa.

(ii) Lower volatility, meaning that reformulated gasoline does not evaporate as easily as conventional gasoline and therefore releases lower levels of ozone-forming hydrocarbons into the atmosphere;

(iii) The presence of oxygenates, or "chemical oxygen", which can achieve a 1–2 per cent improvement in fuel efficiency compared with conventional fuels (assuming that all other variables—such as weather conditions, driver behaviour and vehicle maintenance—are equal).

(b) *Limits on gasoline volatility*. Some toxic compounds in gasoline, such as benzene, released into the air when gasoline evaporates. Limits on gasoline volatility have therefore been imposed in some countries in order to control evaporative emissions of both hydrocarbons and toxic compounds;

(c) *Limits on sulphur in diesel fuel*. Lowering the sulphur content of diesel fuels reduces emissions of particulate matter and other toxic air pollutants produced by diesel-fuelled vehicles, in particular buses and trucks. In the combustion process, sulphur reacts with air forming sulphur dioxide (SO_2), high concentrations of which can cause respiratory problems and may aggravate existing respiratory and cardiovascular conditions. Emissions of SO_2 also contribute to acid deposition, or acid rain, which causes acidification of lakes and streams and can damage trees, crops, historic buildings and statues;

(d) *Oxygenated fuels*. Additional oxygen in fuel ensures that fuel is burned more completely. This, in turn, can reduce vehicle CO emissions by 10–20 per cent. Fuel additives such as ethanol tertiary butyl ether, a methanol derivative, supply the extra oxygen.

C. POLICY AND MANAGEMENT MEASURES

1. *Promoting the development and use of public transport*

While engineers continue to work on developing cleaner, more efficient vehicles, States and communities have a major role to play in slowing the growth of vehicle use. Use of public transit and ride-sharing not only reduce pollution, but also save money for commuters and Governments alike. Public transit is an efficient mode of transport, occupying much less road space and using less fuel per passenger than cars. Public transport therefore also creates less pollution on a per passenger basis. Using buses instead of passenger cars has been calculated to decrease emissions of CO_2, NO_X, CO, and HC by 3.6, 3.0, 19.2, and 10.2 times, respectively (see table 8).[19]

TABLE 8. UNITED KINGDOM: EMISSIONS FROM CARS AND BUSES IN BRITAIN, 1989
(*Grams per passenger per kilometre travelled*)

	Private car or taxi	Bus	Car/bus
CO_2	126.73	35	3.6
NO_X	1.16	0.39	3.0
CO	5.57	0.29	19.2
HC	0.61	0.06	10.2

Source: United Kingdom, Department of Transport, *Transport Statistics 1978–1988*, London, Her Majesty's Stationery Office, 1989.

In order to promote the use of public transport, ESCWA member States should make their public transport systems more efficient, more comfortable and more affordable. An attractive public transport system has a twofold advantage: it encourages vehicle owners to use public transport (at least during periods of peak traffic) and it provides the commuting masses with an affordable and efficient means of transportation.

Major steps to promote the use of public transport have either been taken or are under serious consideration in some of the major cities of the ESCWA region. In Cairo, for example, the construction of the underground (metro) system has eased traffic congestion considerably. In Damascus and Amman, plans for the construction of light rail systems are being assessed.[17]

It is important to accompany traffic restrictions with improvements to public transport. In Singapore, emphasis has been placed on the following:

(a) Making optimal use of existing roads;

(b) Promoting the use of public transport while restricting growth in automobile use and vehicle ownership (numbers of new “certificates of entitlement” are increased by just 3 per cent annually);

(c) Making public transport more attractive with pleasant stations, reliable services and user-friendly ticketing systems.

In Zurich, an ever-increasing portion of the city is gradually being incorporated into the “blue zone” in which parking (for everyone other than residents) is restricted to a maximum 90 minutes. Urban transport and commuter rail services, meanwhile, offer a viable alternative. In Egypt, the underground metro system went into operation 15 years ago, serving the most congested areas in Cairo, and there are plans for its extension.[12]

Large-scale transport offers environmental and economic benefits in the transportation of freight as well as the movement of people. The use of rail transport or ships instead of trucks to move freight magnifies those benefits. The specific energy consumption (SEC) (expressed in fuel/ton/km) for trucks in Egypt is 4.9–6.2 times that of trains (see table 9).[18]

TABLE 9. EGYPT: SPECIFIC ENERGY CONSUMPTION FOR DIESEL-FUELLED TRUCKS AND TRAINS

Transport mode	Diesel consumption (litres/1 000 tons/km)	SEC (truck)/SEC(train)
8 ton truck	20.6	5.4
15 ton truck	18.6	4.9
20 ton truck	19.6	5.1
25 ton truck	23.6	6.1
30 ton truck	23.7	6.2
1 000 ton train	3.8	1.0

Source: Organization for Energy Planning, *Energy in Egypt 1997/1998*

2. *Improving traffic management*

(a) *General improvements*

For most countries, but in particular, developing countries, technological improvements alone may not be sufficient to deliver significant reductions in land-transport generated GHG emissions. The benefits of improved technology may be undermined by growing demand for road transport. Improving traffic flows and circulation and providing better facilities and road infrastructure can result in greater fuel efficiency and, at the same time, reduce levels of traffic-related pollutants and noise.

Simulations of various traffic conditions illustrate the environmental advantages of more smoothly flowing urban traffic. A comparison of travel on an urban route in the early morning (5 a.m.) and during the afternoon rush hour (5 p.m.) showed that smooth-flowing morning traffic conditions produced better fuel efficiency (by 31 per cent) and reduced HC emissions by 54 per cent, CO by 52 per cent and NO_X by 2 per cent. It has also been established that driving on smooth road surfaces and maintaining a constant speed also deliver appreciable benefits in terms of fuel efficiency (see table 10 for effects of vehicle speed on emissions of various pollutants).[17]

TABLE 10. DRIVING CONDITIONS AND EXHAUST EMISSIONS

Mode of operation	HC (*Parts per million*)	CO (*Per cent in volume*)	NO_X (*Parts per million*)	H_2O (*Per cent in volume*)	CO_2 (*Per cent in volume*)	H_2 (*Per cent in volume*)
Idling	750	5.2	30	1.7	9.5	13.0
Cruising	300	0.8	1 500	0.2	12.5	13.1
Accelerating	400	5.2	3 000	1.2	10.2	13.2
Decelerating	4 000	4.2	60	1.7	9.5	13.0

Source: ESCWA, Proceedings of the Expert Group Meeting on Harmonization of Environmental Standards in the Energy Sector of ESCWA Member States, held in Cairo on 29 June–1 July 1999.

Another example illustrating the environmental advantages of more smoothly flowing urban traffic is provided by a field study conducted in Greater Cairo on two main traffic corridors (Sudan Street and Malek al-Saleh), where three traffic management options were tested. The first option involved redesigning traffic signal system; this is the cheapest solution, with almost no cost. The second option required the reorganization of on-street parking, clearing sidewalks, enhancing shared taxi movements and introducing simple geometric designs at certain intersections. The third option, which was the most costly, involved grade separations and a focus on public transport systems.

The results of this study, which are examined in detail in the case study of Egypt in chapter IV, indicated that the third option provided the greatest energy savings and CO reductions, with the shortest journey times and highest average speeds. The degree of improvement that can be achieved depends on the route and journey direction, as well as the traffic management plan that is implemented. The energy saving on the Sudan Street route, for example, ranged from 11.5 per cent to 15.2 per cent, with a reduction in CO emissions of 2.4–16.1 per cent. For the Malek al-Saleh route, energy savings ranged between 41.8 per cent and 45 per cent, while CO reductions were between 5.5 per cent and 22.6 per cent (see chapter IV).

The Cairo provides a graphic demonstration for policy makers, city engineers and managers of the vital importance of traffic management. Even small improvements achieved using low cost solutions on a certain corridor (as in the first two options), can produce massive benefits on an aggregate basis. Improving traffic management in urban areas is therefore the most cost-effective method of reducing transport-related air pollution.

(b) *Transport information and communications systems*

Transport information technology and intelligent transport systems, both of which were developed primarily in the United States and Germany, can produce significant improvements in traffic management, which in turn helps to limit air pollution. Transport information technology gives priority to buses and trains at traffic lights, helping to streamline the movement of public transport. It also monitors bus and train movements, allowing better control of services and the provision of real-time information on a system-wide or even nation-wide basis, via call centres or direct through the Internet.[12, 20]

Intelligent transport systems technology incorporates advanced transport communication systems. In vehicles, such systems can provide real-time traffic information that can be used to optimize efficiency in travel and freight transport. City intersections can be fully computerized to keep traffic flowing smoothly. Such intelligent traffic management infrastructure has enhanced the carrying capacity of many major roads.

3. *Transport fuel pricing policies*

Higher fuel prices encourage automobile buyers to choose cars that provide better fuel efficiency. They may do this either by compromising on size or other features in favour of fuel efficiency or by demanding technological improvements from suppliers so that they can have the features they want as well as lower specific consumption rates. Manufacturers will respond to such consumer demand if they believe fuel prices will remain high enough long enough to make it worth their while. Higher fuel prices may also discourage unnecessary use of vehicles in the long term by prompting structural changes (for example, lifestyle or urban planning decisions) that reduce the need for car travel. Such measures may be particularly effective in the ESCWA region, where fuel prices are presently subsidized in many countries The social impacts must, however, be taken into consideration when weighing up the advantages and disadvantages of using fuel pricing to inhibit vehicle use.

4. *Restricting the use and ownership of vehicles*

Cars and trucks today burn fuel 35 per cent more efficiently and emit 95 per cent less pollutants—excluding CO_2—than they did 30 years ago. Nonetheless, increasing vehicle use means that transport still has serious environmental impacts.[21] Restricting vehicle use is therefore an important option for GHG abatement, particularly in areas that are congested or subject to heavy traffic. This option not only promises a reduction in air pollution, but also reduces operating costs and the amount of vehicle maintenance required. Traffic authorities should also restrict vehicle ownership to levels that will prevent general congestion across an entire road network. One measure by which vehicle ownership can be restricted is the imposition of vehicle and fuel taxes.

Traffic authorities, in cooperation with other governmental bodies, should establish implementation mechanisms that are appropriate to country-specific circumstances and will not inadvertently aggravate the problems they were meant to solve, or create new ones. In Caracas, for example, use of private vehicles in the city centre was prohibited for one day of every week (the day being determined according to car registration number) in order to reduce pollution. This plan, which worked by assigning re was initially successful, and air quality improved. After some time, however, many households acquired additional vehicles with registration numbers that would permit them to drive in the city on days when their other vehicle was banned.

5. *Improving vehicle maintenance*

The efficiency with which fuel is burned is an important determinant of overall levels of GHG emissions. In many developing countries, however, vehicle efficiency is low and fuel consumption is high. Regular maintenance, inspection, and tuning can improve fuel combustion efficiency and deliver other benefits such reducing exhaust emissions, optimizing fuel efficiency, extending vehicle life, increasing vehicle resale value, and reducing running costs. It is not unusual, however, to find that more than 70 per cent of the light-duty vehicle fleet in a developing country does not receive regular maintenance or diagnostic testing, and has an average age of abut 15 years.[7] Inspection and maintenance programmes can be designed to suit local conditions. In general, though, the most technically advanced testing and repair programmes yield the greatest benefits, reducing air pollution by as much as 30 per cent in some cases.[15]

The results of a vehicle emissions testing, engine tuning and certification programme in Cairo in 1999 revealed that of 13,000 vehicles inspected, 66 per cent complied with national standards and 34 per cent needed tuning. In 1995, tests to determine the effect of inspecting and tuning 1,286 vehicles found that the average reduction in CO emissions was 62 per cent; HC emissions declined by 35 per cent and fuel consumption was reduced by 15 per cent. [9]

6. *Replacement of old vehicles with newer ones*

Wear and tear inevitably makes vehicles more polluting and less roadworthy over time. Older vehicles are more likely to break down on the road, causing congestion and posing a danger to other road users. It is recommended that Governments discourage people from keeping old vehicles and encourage the early replacement of such vehicles. In developing countries, however, this approach would impose a heavy economic burden, making implementation very difficult.

Many ESCWA member States have ageing vehicle fleets. In Egypt, for example, about 65 per cent of vehicles are 10 years old or older, and about 25 per cent of those vehicles are more than 20 years old. In the Syrian Arab Republic, about 60 per cent of passenger cars are at least 13 years old, and 24 per cent are 24 years old or older; 40 per cent of buses are at least 13 years old and 10 per cent are 24 years old or older, while 60 per cent of trucks are at least 13 years old, and 20 per cent are 24 years old or older.[17]

In order to encourage the replacement of the old, highly polluting, fleet of taxis operating in the major cities of Jordan, the Government there has granted taxi owners an exemption from taxes if they opt to replace their old vehicles with newer ones. Vehicles of better quality, with cleaner-running engines can therefore be introduced more quickly, with appreciable benefits for the environment.

7. *Better urban planning and land use*

Urban populations are increasing rapidly and motor vehicle ownership is growing at a faster pace than the availability of urban roads. At the same time, urban settlements are developing erratically, without adequate public transport infrastructure. This gives rise to three major transport related problems in the mega-cities of the developing world: congestion; pollution; and the need for long, costly commuting between home and work.

Urban planning can mitigate the detrimental of effects traffic has on air quality. An increase in urban settlement activity calls for a corresponding increase in transportation capacity. Systematic town planning can therefore play a major role in minimizing the number of daily vehicle trips required. Developing countries can benefit from the experiences of developed countries in this respect, avoiding mistakes that other countries have made and emulating their successes as they build or complete their transport infrastructure.

Communities should be designed in ways that promote sustainable transportation development and facilitate access. Good urban planning is a central factor in improving traffic conditions. It is observed almost everywhere that uncontrolled urban growth, in conjunction with increasing demand for mobility and communication, impedes efforts to improve traffic conditions. Controlling urban growth is therefore vitally important to the development of effective, efficient transportation systems and for the maximization of limited resources. It may ultimately be necessary to take efforts to reverse the present trend of rural-urban migration, in particular by improving conditions in rural areas.

D. ENVIRONMENTAL REGULATIONS AND STANDARDS RELATING TO TRANSPORT

Environmental standards in the transport sector differ markedly around the world as a result of the diversity of environmental conditions in various countries and the structure of each country's transport sector. Generally, environmental standards relating to the mitigation of transport-related GHG emissions can be classified into three categories as follows:[1]

1. *Emission performance standards*

This category aims to regulate transport fuel specifications and motor vehicle emissions. Such regulations have been adopted mainly in industrialized countries, where they have resulted in significant reductions in emissions of CO, NO_X and HC. In developing countries, little has been done so far in this regard. Performance standards include the following:

(a) Maximum emission levels and smoke standards;
(b) Fuel efficiency standards;
(c) Vehicle certification and testing regulations;
(d) Standards relating to refrigerant leakage;
(e) Vehicle durability standards;
(f) Maximum power-to-weight ratios;
(g) Fuel quality standards, setting limits on impurities;
(h) Limitations on fuel additives;
(i) Fuel volatility standards;
(j) Refuelling control regulations.

2. *Technology standards*

Technology standards apply essentially to new vehicles and clean-fuel vehicles. It will therefore be years before these standards will fully penetrate the global vehicle fleet. Technology standards can be classified as: standards for advanced-vehicle technology (electric vehicles and fuel-cell vehicles); natural gas vehicle technology standards; and standards for vehicle pollution control technologies.

3. *Standards relating to transport practices*

Standards in this category are established in order to moderate the growth of road traffic and the environmental impacts of transport activity. They include the following:

(a) Fuel pricing regulations favouring clean fuels;

(b) Regulations for retiring old and/or polluting cars (for example, the establishment of financial incentives);

(c) Regulations restricting the import of cars that are highly polluting and/or consume fuel at an excessive rate;

(d) Regulations restricting vehicle use and ownership;

(e) Regulations relating to road taxes;

(f) Traffic regulations;

(g) Vehicle taxes scaled according to emission levels;

(h) Regulations relating to driver instruction.[12]

Environmental laws and executive regulations in the ESCWA member States usually include articles prohibiting the use of machines, engines or vehicles that produce emissions exceeding set limits. In many cases, however, the regulations are either not yet sufficiently developed or enforced and/or the standards they set have not been adequately defined. The overview of GHG mitigation strategies presented in this chapter will therefore be used as the basis for the selection and evaluation of options that might be applied in the ESCWA region. Chapter III will present the methodology and criteria for ranking the options and assessing the challenges posed by each.

[12] Details of transport-related environmental standards in the United States, the European Union countries and the ESCWA member States can be found in ESCWA, “Towards harmonization of environmental standards in the energy sector of ESCWA member States” (E/ESCWA/ENR/1999/21).

III. GHG ABATEMENT OPTIONS: EVALUATION AND IMPLEMENTATION CHALLENGES

The abatement of transport-related GHG emissions is a particular challenge because of the unique role this sector plays in the personal, social and economic development of any community. Transport has many stakeholders, including private and commercial transport users, manufacturers of vehicles, suppliers of fuels, builders of roads, planners, and transport service providers. Strategies to reduce transport-related GHG emissions often challenge the interests of one or another of these groups and run the risk of failure unless they take account of stakeholder concerns and meet a population's transport needs.

The choice of strategy for mitigating GHG emissions for any country or region is guided mainly by existing economic and technical capabilities. This chapter deals with the selection, evaluation and ranking of a set of GHG abatement options for the transport sector in the ESCWA region. The sections to follow will define criteria for evaluation; explain the evaluation methodology; and rank the options in order of priority.

A. OPTIONS SELECTED FOR EVALUATION

Chapter II introduced a number of measures for reducing transport-related GHG emissions, detailing in each case the development status, characteristics and local experience with the measure in question. Each of the various options has its own optimum conditions for implementation. Within the ESCWA region, each member State likewise has its own particular circumstances, which determine how best it might handle the issue of transport-related GHG emissions. The selection of options to be evaluated in a country-specific context depends heavily on the degree to which the requirements of each option match local conditions.

1. *Prevailing conditions in the transport sector of the ESCWA region*

In most of the ESCWA member States there are a number of characteristics that are common to the each country's transport sector and which will have a bearing on the initial selection of GHG mitigation options to be considered. These common characteristics include the following:

(a) *The age of the national vehicle fleet*. Vehicles in most countries in the ESCWA region (the exception being the GCC countries) tend to be old, with high fuel consumption and low efficiency. It is not unusual to find that more than 70 per cent of the light-duty vehicle fleet in a developing country does not receive regular maintenance or diagnostic testing, and has an average age of about 15 years;[7]

(b) *The need for better traffic management*. This is a common feature in the ESCWA region; modification of traffic management systems is urgently needed, as is the introduction of a programme to increase public awareness of changing traffic conditions. In cities with particularly heavy traffic, such as Cairo, Baghdad and Damascus, there is also a need to update traffic regulations;

(c) *The limited penetration of public transport*. The most frequently used mode of transport in the ESCWA member States is private car, a situation that aggravates problems of congestion, travel delay and pollution;

(d) *The lack of relevant standards and regulations*. Environmental standards and regulations relating to the transport sector are either non-existent or not enforced;

(e) *Extensive natural gas resources*. The ESCWA region has enormous natural gas resources, local consumption of which can be encouraged, for economic and environmental reasons, by availability at reasonable prices;

(f) *Regional experience*. Several ESCWA member States have successfully taken measures to limit GHG emissions. Examples of such measures include the promotion of the use of public transport (as in the case of the underground metro train system in Cairo, Egypt) and the introduction of vehicles fuelled by CNG (which has also been implemented in Egypt).

2. *Selected mitigation options*

Based on the regional conditions outlined above and the list of options for mitigating GHG emissions presented in chapter II, the following seven options are expected to have great potential for replication in the ESCWA region:

(a) *Improving vehicle maintenance*. Programmes for vehicle inspection, engine tuning and general maintenance are expected to provide large reductions in emissions of GHGs and other pollutants. Improving vehicle maintenance has the additional benefit of extending a vehicle's lifespan, and is considered a cost-effective option for limiting GHG emissions;

(b) *Improving traffic management*. In many of the large cities in the ESCWA region, simple changes in traffic management have substantially improved the flow of traffic. Examples of such measures include the following:

(i) Converting two-way streets into one-way streets;

(ii) Changing the direction of traffic on major roads during peak traffic times to provide more lanes in the direction of heavy flows;

(iii) Redesigning systems of traffic signals;

(iv) Reorganizing on-street parking;

(v) Enhancing shared taxi movements.

Improving traffic management in urban areas is considered to be the most cost-effective way to reduce transport-related air pollution;

(c) *Promoting the use of public transport*. Increasing the use of public transport is a particularly promising option and such measures have already been implemented or are under serious consideration in several of the region's major cities. The construction of the underground rail system in Cairo, for example, has eased traffic congestion considerably in that city. Plans for light rail systems are also being considered for Damascus and Amman. The expectation is that if public transport systems improve, many people will opt to use public transport instead of private cars;

(d) *Improving urban planning and land use*. Optimizing traffic flows through good urban planning and land use has been shown to be a very effective way to reduce emissions of GHGs. This option also has the advantage of requiring only low levels of expenditure in developing countries, which are still in the process of building or completing their urban infrastructure. Communities and city planners should therefore ensure that they consider transport requirements during the urban planning process;

(e) *Restricting vehicle use and ownership*. In some cities in the ESCWA region where traffic congestion is severe, such as Cairo, placing restrictions on the use of private vehicles is expected to be one of the most important methods of reducing GHG emissions. Such measures are more likely to produce positive results if public transport systems improve. Restrictions on vehicle ownership, meanwhile, are expected to reduce GHG emissions in other countries, such as in the GCC countries;

(f) *Establishing and enforcing environmental standards and regulations*. The development and enforcement of appropriate environmental standards and regulations relating to transport-generated pollution are badly needed in the ESCWA region, where countries generally lack specific air pollution standards. The development and implementation of such standards and regulations is expected to carry relatively minor costs;

(g) *Introducing CNG technology*. CNG vehicle technology is expected to prove economically and environmentally attractive as a GHG reduction measure in the ESCWA region, which enjoys huge reserves of natural gas. There is greater economic benefit in maximizing local use of the region's natural gas than there is in exporting it. Because of the low carbon content of natural gas, the use of CNG vehicles as opposed to those running on gasoline, produces approximately 20 per cent reductions in CO_2 emissions. Seven years ago, Egypt became the first country in the region to adopt CNG vehicle technology. Since then, its fleet of natural gas-fuelled vehicles has grown to number about 30,000, making it the seventh-largest natural gas-powered vehicle fleet in the world.

B. SELECTION CRITERIA AND METHODOLOGY

1. *Defining and weighting criteria*

Seven criteria have been applied in the selection of options that might be applied in the ESCWA region, and have been designed within the following parameters:

(a) Consideration of the potential applications of each option;
(b) The features of each option;
(c) The degree to which options complement or conflict with one another;
(d) Where and when evaluation will take place.

Specific characteristics that will be considered include the technical features of each option, its development status, expected difficulties in its implementation, its effectiveness in reducing GHG emissions, the political and/or social implications of implementation, and the costs and benefits to be gained through its replication in other countries. The seven criteria used in the evaluation process are listed below, along with the weighting applied to each. They are the following:

(a) *Effectiveness in reducing GHG emissions*. Given that the primary goal is the reduction of GHG emissions, this is the most important criterion, and it therefore carries a weighting of 30 per cent;

(b) *Capital costs*. The importance of cost considerations, always high, is even higher in developing countries where the economy is relatively weak. Many of the options that will be evaluated require investment in such areas as the purchase of equipment and instruments, the establishment of infrastructure, the introduction of new technologies, and training. This criterion has been assigned a weighting of 25 per cent;

(c) *Operation and maintenance costs*. There are many and various costs involved with sustaining emission-reduction measures after initial implementation. It may be necessary to meet ongoing or periodic costs for labour or spare parts, for example. This criterion has been given a weighting of 10 per cent;

(d) *Implementation difficulties*. The difficulties encountered during implementation may be technical, administrative, financial, social and/or political. Such problems can cause delays, increase costs, or even prevent the completion of a project. In the implementation of measures to limit transport-related GHG emissions, it is expected that difficulties are more likely to arise when projects are undertaken by partnerships. This criterion has a weighting of 10 per cent;

(e) *Potential for replication*. Factors influencing the potential for replication in another country are found in the particularities of the various options as well as in the characteristics of the country in which they are being implemented. This criterion has been assigned a weighting of 10 per cent;

(f) *Non-environmental benefits*. Several of the options under consideration have the potential to deliver economic and social benefits (for example, job creation) in addition to reducing GHG emissions. This criterion has a 10 per cent weighting;

(g) *Sustainability*. Options that generate their own momentum or require little additional or ongoing investment are more likely to become self-sustaining. This criterion has been assigned a 5 per cent weighting.

TABLE 11. EVALUATION CRITERIA

Criteria	Weighting (*Percentage*)	Basis for scoring
Effectiveness in reducing GHG emissions	30	Score increases as the reductions achieved in GHG emissions increase.
Capital costs	25	Score increases as capital costs decline.
Operation and maintenance costs	10	Score increases as costs decline.
Implementation difficulties	10	Score increases as difficulties decrease.
Potential for replication	10	Score increases as potential for replication increases.
Non-environmental benefits	10	Score increases as non-environmental benefits increase.
Sustainability	5	Score increases as sustainability increases.

2. *Evaluation of options*

The GHG mitigation options identified in section A have been evaluated and the results and rationale by which they were determined are presented in tables 12–18.

TABLE 12. EVALUATION: IMPROVING VEHICLE MAINTENANCE

Criteria	Weighting (*Percentage*)	Unadjusted score	Rationale
Effectiveness in reducing GHG emissions	30	90	Improving vehicle maintenance and engine tuning greatly reduces emissions of GHGs and other pollutants. Engine tuning adjusts the air-to-fuel ratio, which increases the efficiency with which fuel is burned and therefore reduces fuel consumption and, consequently, pollution—by up to 30 per cent in some cases.[22] In many developing countries, as much as 70 per cent of the light-duty vehicle fleet does not receive regular maintenance or diagnostic testing.[7] The low levels of vehicle efficiency and high levels of vehicle use that characterize the transport sector in most of the ESCWA member States means that the benefits to be gained by implementing this option are particularly significant;
Capital costs	25	80	In order to establish a vehicle maintenance programme, capital is required for the installation of workshops and for the purchase of testing equipment (such as dynamometers, which measure force and power) and instruments for vehicle inspection and engine tuning. These items constitute a moderate capital outlay;
Operation and maintenance costs	10	50	The sustainability of this option depends on ongoing investment. To keep vehicles operating efficiently, and thereby maintaining returns in terms of lower GHG emissions, regular spending on labour, materials and spare parts will be required. This option can therefore be considered to involve high annual variable costs;
Implementation difficulties	10	73	A programme to improve vehicle maintenance may face technical, administrative, and/or financial difficulties. These have been rated as moderate.

TABLE 12 (*continued*)

Criteria	Weighting (*Percentage*)	Unadjusted score	Rationale
Potential for replication	10	78	The establishment of vehicle a maintenance programme can be easily replicated in the ESCWA region, and most countries already have some experience in this field. Egypt, for example, has a vehicle emissions-testing programme, which is just one component of the Cairo Air Improvement Project. The experience that Egypt has gained can help to accelerate replication throughout the region. While the expected replication level for this option is high, it should be noted that in some GCC countries most vehicles are modern and in good condition, making such measures unnecessary.
Non-environmental benefits	10	82	Proper maintenance, periodic inspection and engine tuning can reduce costs for items such as fuel and spare parts. Regular maintenance and tuning also increase a vehicle's resale value and extend its lifespan. Additionally, demand for vehicle servicing can generate employment. In terms of the non-environmental benefits it produces, this option therefore rates highly.
Sustainability	5	70	Sustainability in this case depends on financial, technical and regulatory support. Vehicle maintenance requires continual annual investment by vehicle owners, owners of workshops and the Government. The sustainability of this option is therefore rated as medium.

TABLE 13. EVALUATION: IMPROVING TRAFFIC MANAGEMENT

Criteria	Weighting (*Percentage*)	Unadjusted score	Rationale
Effectiveness in reducing GHG emissions	30	70	Improving traffic management reduces fuel consumption per passenger per kilometre travelled by reducing journey stoppage rates. Creating conditions that produce more smoothly flowing traffic reduces emissions of pollutants such as CO, HC and NOx. The effectiveness of this option for reduction of GHG emissions is rated as medium.
Capital costs	25	77	In order to improve traffic management, it is necessary to take such measures as introducing geometric modifications and reorganizing streets. Such measures require only low levels of capital expenditure.
Operation and maintenance costs	10	70	This option requires annual investment for the maintenance of modifications such as new traffic signals and parking places. These costs have been rated as medium.
Implementation difficulties	10	82	There are generally no technical or social difficulties arising from the implementation of this option. Administrative problems are expected, however, and therefore implementation difficulties are rated as low.
Potential for replication	10	80	This option does not rely on high levels of technology and therefore its replication potential is rated as high.
Non-environmental benefits	10	70	Improving traffic management will reduce the need for vehicle maintenance and expenditure for spare parts. It will also save time by reducing journey stoppage rates.
Sustainability	5	70	The sustainability of this option is rated as medium.

TABLE 14. EVALUATION: PROMOTING THE USE OF PUBLIC TRANSPORT

Criteria	Weighting (*Percentage*)	Unadjusted score	Rationale
Effectiveness in reducing GHG emissions	30	80	Public transport has two environmental advantages: (a) It produces lower levels of emissions per passenger/km than do private cars; and (b) vehicles for mass transit occupy much less road space per passenger than do cars, thereby helping to improve traffic conditions. In Britain, it has been shown that travel by private car produces 3.6 times as much CO_2 as travelling by bus, 3 times as much NO_x, 19.2 times as much CO, and 10.2 times as much HC.[19] In Egypt, transporting freight by truck is calculated to use 4.9-6.2 times as much fuel per ton/km as rail.[18] This option therefore rates highly for its effectiveness in reducing GHG emissions.
Capital costs	25	58	In order to implement this option, large vehicles, garages, workshops and stations are required, with a medium to high level of capital investment.
Operation and maintenance costs	10	66	Maintenance will be required for public transit vehicles, garages and property, at levels of annual expenditure that are rated as medium.
Implementation difficulties	10	70	No social difficulties are expected. Technical, administrative, and/or financial difficulties are likely, however and ultimately the implementation difficulties facing this option have been rated as medium to high.
Potential for replication	10	78	The replication potential for this option is approaching a high rating because most countries in the region already have experience in this field.
Non-environmental benefits	10	68	Greater use of public transport will have a positive on traffic management, and could also generate employment. The expansion of public transport will, however, dampen demand for taxis and minibuses. The non-environmental benefits for this option are therefore rated as medium.
Sustainability	5	82	Sustainability for this option is approaching high. After the initial effort to develop the required infrastructure, routine maintenance is generally all that is needed to achieve long-term sustainability.

TABLE 15. EVALUATION: BETTER URBAN PLANNING AND LAND USE

Criteria	Weighting (*Percentage*)	Unadjusted score	Rationale
Effectiveness in reducing GHG emissions	30	75	Better urban planning helps to reduce pollution by minimizing traffic congestion. The positive environmental impact of this option may decrease over time as the region's population increases. Generally, the effect of improving urban planning on reducing GHG emissions can be rated as medium.
Capital costs	25	64	Urban planning is a major national issue. It requires large-scale capital investment. Benefits may be gained indirectly, however, from projects with goals other than the reduction of GHG emissions. For example, a well-designed housing project implemented mainly to solve housing problems may indirectly aid the reduction of GHG emissions. Thus, the costs of urban planning directly attributable to efforts to reduce levels of GHGs may be rated as medium.

TABLE 15 (*continued*)

Criteria	Weighting (*Percentage*)	Unadjusted score	Rationale
Operation and maintenance costs	10	90	Modifications achieved through urban planning tend to be long lasting and may require only low levels of expenditure for maintenance. This option therefore rates highly in terms of operation and maintenance costs.
Implementation difficulties	10	53	Urban planning and housing projects generally face financial difficulties, and sometimes technical problems as well. Implementation difficulties are therefore rated as medium to high.
Potential for replication	10	70	Urban planning needs in the ESCWA member States vary greatly due to the wide variety of geographical and climatic conditions existing within the region. The replication potential of this option is therefore rated only as medium.
Non-environmental benefits	10	82	Urban planning projects create employment and help to remedy housing problems. This option is rated as high in terms of non-environmental benefits.
Sustainability	5	92	Urban planning is an ongoing project, and by its nature tends to be sustainable.

TABLE 16. EVALUATION: RESTRICTING VEHICLE USE AND OWNERSHIP

Criteria	Weighting (*Percentage*)	Unadjusted score	Rationale
Effectiveness in reducing GHG emissions	30	70	Restricting vehicle use reduces fuel consumption and air pollution. In California, a programme to restrict vehicle use was shown to produce significant annual reductions of CO_2 emissions.[21] This option's impact on GHG reduction is rated as medium.
Capital costs	25	90	Restricting vehicle use and ownership requires little capital outlay.
Operation and maintenance costs	10	92	This option centres on legislative activity. It is therefore rated as having low operation and maintenance costs.
Implementation difficulties	10	60	There may be social difficulties involved with the implementation of this option due to public resistance. Administrative difficulties are also expected. The difficulty rating for this option is therefore in the medium range.
Potential for replication	10	60	The successful implementation of this option in the ESCWA region will depend on the particular social, economical, and political situation in each member State. Its replication potential is rated as medium.
Non-environmental benefits	10	68	Restricting vehicle use will reduce vehicle operating costs and will slow the depreciation of a vehicle's value. It will also help to promote the use of public transport. Non-environmental benefits are rated as approaching medium.
Sustainability	5	55	The sustainability of this option appears weak in view of the high degree of support required from Governments, and the anticipated public resistance, particularly to restrictions on car ownership, which may be circumvented.

TABLE 17. EVALUATION: ENVIRONMENTAL STANDARDS AND REGULATIONS

Criteria	Weight (*Percentage*)	Unweighted score	Rationale
Effectiveness in reducing GHG emissions	30	60	The enactment of environmental standards and regulations for the transport sector will compel vehicle owners to maintain their cars. This, in turn, will promote GHG abatement. This option's rating for effectiveness in reducing GHG emissions approaches medium.
Capital costs	25	90	Capital costs for this option are expected to be low.
Operation and maintenance costs	10	90	Operation and maintenance costs for this option are considered low.
Implementation difficulties	10	55	There may be public resistance to the establishment of environmental regulations. The implementation of this option also requires the cooperation of many participants such as ministries of environment and interior. Medium to high administration difficulties are therefore anticipated.
Potential for replication	10	62	As with the previous option, the development of environmental standards and regulations will depend on circumstances in individual member States. Its replication potential is rated as close to medium.
Non-environmental benefits	10	62	Indirect benefits may include support for programmes to improve the maintenance and inspection of vehicles. This option's non-environmental benefits are rated between low and medium.
Sustainability	5	55	This option's sustainability is considered weak because regulations must be updated periodically. Additionally, the cost to the public of compliance with the regulations may prove prohibitive.

TABLE 18. EVALUATION: INTRODUCTION OF CNG VEHICLE TECHNOLOGY

Criteria	Weighting (*Percentage*)	Unadjusted score	Rationale
Effectiveness in reducing GHG emissions	30	95	Natural gas has a lower carbon content than gasoline or diesel. Using natural gas to fuel vehicles therefore reduces emissions of CO_2 and HC.[23] Vehicles fuelled by natural gas also emit much lower levels of CO, NMVOC, and NO_X than do gasoline-powered vehicles.[14] This option will therefore be very effective in reducing GHG emissions and is rated highly.
Capital costs	25	48	Considerable capital expenditure is required for the implementation of this option. Investment is required to establish infrastructure (such as a network of gas pipelines, fuelling stations and service centres) and to fund the conversion of vehicles from gasoline or diesel.
Operation and maintenance costs	10	85	Operation and maintenance costs for converted vehicles, CNG fuel stations and the supply network are also high but this option is ultimately self-sustaining (that is, revenue generated is expected to cover these costs and more).
Implementation difficulties	10	70	Difficulties facing the implementation of this option include high investment requirements as well as technical and administrative problems. The experience that Egypt has gained with natural gas vehicle technology could, however, help to overcome those difficulties.

TABLE 18 (*continued*)

Criteria	Weighting (*Percentage*)	Unadjusted score	Rationale
Potential for replication	10	76	Replication of this option is expected to be high because of the large reserves of natural gas in the countries of the ESCWA region (with the exception of Jordan, Lebanon and the Republic of Yemen). It should be possible to repeat the success experienced in Egypt if appropriate pilot projects and training programmes are implemented.
Non-environmental benefits	10	96	Introducing CNG technology will create employment to meet the anticipated demand for fuelling stations and converted vehicles. A report published by the National Defense Council Foundation in the United States estimated that direct investment in the construction and maintenance of natural gas-powered vehicles and related infrastructure would create 13,500 jobs during the first phase of the market's development (ending in 2000). Indirect investment was expected to stimulate the creation of another 30,000 jobs.[14] In Egypt, two companies producing natural gas vehicles have been established so far and more are expected to enter the market in coming years.
Sustainability	5	94	Once the infrastructure required (for example, a network of gas pipelines, fuel stations, and converted vehicles) has been established, this option should be relatively easily sustained for the long term.

3. *Determination of rankings*

Based on the considerations listed above, each option has been scored against each of the criteria and those scores have been adjusted in line with the weightings assigned to each criterion. The sum of the weighted scores gives the final rating for the option, which is characterized as high (a final score of 76-100), medium (51-75) or low (0-50). The results (presented in order of priority in table 19) indicate that improving vehicle maintenance was the highest-rating option, with a final score of 78.8 (out of a possible 100), followed by the introduction of CNG technology (with a score of 77.9). Restricting vehicle use and ownership, and improving traffic management ranked third and fourth, scoring 74.3 and 74.0, respectively.

C. CHALLENGES FACING THE IMPLEMENTATION OF THE RECOMMENDED OPTIONS

In spite of the importance of adopting the recommended GHG mitigation options and expediting their implementation, many challenges remain, including the following:

(a) The lack of adequate financial resources;

(b) The limited nature of existing national and/or regional GHG abatement strategies;

(c) The lack of existing strategies, policies and regulations, and the limited enforcement of those that do exist;

(d) The need for capacity-building in relation to GHG abatement in the ESCWA region;

(e) The low priority that GHG reduction is accorded by policy makers;

(f) The lack of adequate public awareness of environmental issues.

TABLE 19. EVALUATION OF OPTIONS

Option (*In order of priority*)		Effectiveness in reducing GHG emissions (*30 per cent*)	Capital cost (*25 per cent*)	Operation and maintenance costs (*10 per cent*)	Implementation difficulties (*10 per cent*)	Potential for replication (*10 per cent*)	Non-environmental benefits (*10 per cent*)	Sustainability (*5 per cent*)	Final (adjusted) score[a/]
Improving vehicle maintenance	Grade	H	M	L	M	H	H	M	H
	Unadjusted score	90	80	50	73	78	82	70	78.8
Introducing CNG vehicle technology	Grade	H	L	H	M	H	H	H	H
	Unadjusted score	95	48	85	70.0	76	96	94	77.9
Restricting use and ownership of private vehicles	Grade	M	H	H	M	M	M	M	M
	Unadjusted score	70	90	92	60	60	68	55	74.30
Improving traffic management	Grade	M	H	M	H	H	M	M	M
	Unadjusted score	70	77	70	82	80	70	70	74
Better urban planning and land use	Grade	M	M	H	M	M	H	H	M
	Unadjusted score	75	64	90	53	70	82	96	72.8
Promoting the use of public transport	Grade	H	M	M	M	H	M	H	M
	Unadjusted score	80	58	66	70	78	68	82	76.8
Developing environmental standards and regulations	Grade	M	H	H	M	M	M	M	M
	Unadjusted score	60	90	90	55	62	62	55	70.20

Notes: L indicates a low score of 0-50; M indicates a medium score of 51-75; H indicates a high score of 76-100.

a/ Final score after weighting is the sum of the weighted score for each criterion.

A more detailed examination of several of the challenges identified above follows, along with proposed general guidelines that might be followed in order to overcome or minimize these challenges.

1. *Addressing the lack of financial resources*

The lack of financial resources is a major barrier to the implementation of GHG mitigation options in most of ESCWA countries. The existence of a range of pressing developmental needs means that other projects are given higher priority for funding. This problem could be resolved in part by making GHG mitigation technologies more commercially attractive through the reduction of capital investment risk and uncertainty.

External funding for GHG mitigation projects could be accessed via mechanisms created to assist developing countries to pursue the goals of the UNFCCC and the Kyoto Protocol. Such funding mechanisms include the Global Environment Facility; Joint Implementation; the Clean Development Mechanism; and the Prototype Carbon Fund.

(a) The Global Environment Facility (GEF) provides funding for country-driven projects that support sustainable development Projects in a number of ESCWA member States have benefited from GEF funding, including projects to reduce GHG emissions from the transport sector (see table 20). Bahrain has also received financial assistance from the GEF for the preparation of its first national communication to the UNFCCC;

(b) Joint Implementation represents a market-based mechanism by which countries can work towards achieving the objectives of the UNFCCC. This approach offers project participants an opportunity to reduce global GHG emissions in a cost-effective, mutually beneficial manner. Joint Implementation would be of particular benefit to developing countries and economies in transition, as well as to investors. For this mechanism to advance, however, obstacles such as the lack of funding available for pilot projects, will need to be eliminated;

(c) The Clean Development Mechanism, created under Article 12 of the Kyoto Protocol,[35] promotes the establishment of mutually beneficial project partnerships through which industrialized countries may meet part of their GHG emissions-reduction commitments by investing in low-cost, clean development projects in developing countries;

(d) The Prototype Carbon Fund, established by the World Bank in March 2000, is a fund whose contributors include both governments and the private sector, and through which finances are channelled to projects to reduce GHG emissions. The fund allows contributors to spread their contributions across a diversified portfolio of GHG reduction projects, providing greater assurance that investments will produce returns in terms of emission reductions. Contributors receive recognition for the reductions they have helped to achieve in other countries. These reductions can then be counted toward their own emissions reduction commitments. Another benefit of the Prototype Carbon Fund is that it reduces the costs associated with project identification, development and monitoring, as well as the verification of emission reductions.[24, 29]

2. *Developing strategies, policies and regulations*

Sound policies and legislation make a major contribution to the successful implementation of GHG mitigation options. Concerns about the environmental damage caused by transport-sector activities have forced many governments to develop polices and enact legislation that aim to reduce GHG emissions. Transport-related policies indicated in national communications from ESCWA member States to the UNFCCC are classified into the following three classes or types:

(a) *Economic incentives to influence vehicle design, purchase and use*. Most countries already levy taxes on vehicles and fuel, and in many instances vehicle taxes vary according to vehicle size, weight, engine size and/or fuel efficiency;

TABLE 20. GEF-FUNDED EMISSIONS-REDUCTION PROJECTS IN ESCWA MEMBER STATES

Country	Project	Project description	GEF allocation (*Thousands of dollars*)	Project type
Egypt	Building Capacity for Greenhouse Gas Inventory and Action Plans in Response to UNFCCC Communications Obligations	This project promotes technical assistance and builds capacity in Egypt to respond to the UNFCCC through the enhancement of institutional networks, development of GHG inventory assessments, training of personnel, establishment of policy dialogues, evaluation of climate change mitigation initiatives, review of climate change impacts and project proposal development.	748.60	EA[a/]
	Integrated System for Zero or Reduced Emission Fuel Cell Bus Operation in Cairo	This project aims to continue the investigation of the technical and commercial feasibility of fuel cell technology in the Egyptian setting, specifically focusing on determining the optimum total integrated fuel cell systems for application in Cairo's urban ground transport sector.	324.00	PDF-B[b/]
Lebanon	Building Capacity for Greenhouse Gas Inventory and Action Plans in Response to UNFCCC Communications Obligations	The project builds Lebanon's capacity to fulfil its communication requirements to the UNFCCC and to respond to the objectives of the Convention on a continuing basis. This will be achieved through the development of a GHG inventory, the assessment of GHG mitigation options (technical or policy-specific) the assessment of vulnerability and adaptation options, and the presentation of Lebanon's first national communication to the UNFCCC.	290.00	EA
Syrian Arab Republic	Urban Transport Project	This pilot project is a component of the Republic of Syria's National Environment Action Plan, which focuses on the integration of global environmental concerns. The aim of the project is to increase the efficiency of the Republic of Syria's hydrocarbon sector by improving the handling of associated gas and by demonstrating options for its productive use in the transport sector. The project will lay the groundwork for a progressive reduction in transport-related GHG emissions, and identify measures that must be taken in order to accelerate the adoption of new vehicle technologies including CNG vehicles.	750.00	
Republic of Yemen	Enabling Yemen to Prepare its First National Communication to the UNFCCC	The project will enable the Government of Yemen to prepare its first national communication in accordance with Article 12 of the UNFCCC.	195.71	EA

Source: United Nations Development Programme Web site: http://www.undp.org/gef/portf/ozone.html.

a/ Enabling activities.
b/ PDF = Project Development Facility (includes PDF-A, PDF-B, and PDF-C).

(b) *Regulations, standards and voluntary agreements for vehicle fuel efficiency*. The common approach is for manufacturers to enter into voluntary agreements to meet Government targets;

(c) *Local measures to influence behaviour*. Such measures include adoption of traffic control mechanisms and efforts to promote greater use of public transport.

While some laws and policies relating to transport-related GHG emissions do exist, most of the ESCWA member States do not have fully developed strategies to address the GHG problem. Most of these countries do not even enforce the limited environmental laws and regulations they already have. The challenge for many countries in the region is to develop a clear institutional framework for the implementation of environmental regulations and standards. The legal framework is necessary to ensure that regulatory measures are implemented. A lack of awareness among policy makers and a lack of sufficient pressure from environmental advocates among the public and concerned non-governmental organizations can be considered the main barriers to the establishment of an appropriate legal framework.

There are, however, many existing measures that could be more aggressively pursued in relation to the transport sector. Regardless of whether those measures employ regulations or incentives to achieve their aims, institutions are needed to monitor the performance of the sector. In the ESCWA region, transport systems are generally under the control of Governments and the enforcement of regulations is loose and ineffective. It is therefore necessary to establish and facilitate the required enforcement and monitoring institutions.

3. *Addressing the need for capacity building*

Capacity building in relation to the monitoring of the GHG situation in the ESCWA region and the reduction of transport-related GHG emissions could take many forms, such as technical studies (inventories, reviews of national policies, studies on vulnerability and adaptation), strengthening executive structures, personnel training, and environmental awareness programmes aimed at the public and decision makers. Capacity building activities depend on the availability of financial resources and on Government polices and programmes relating to the reduction of GHG emissions. Most of the ESCWA member States have fallen behind in this respect. A few countries, such as Egypt and Jordan, have made some progress by developing links with outside organizations.[25] Responsibility for capacity building ultimately rests with the ESCWA member States themselves. If lack of financial resources is the problem, funds could be obtained through mechanisms such as the CDM or Joint Implementation.

4. *Addressing the low priority accorded GHG abatement by policy makers*

In most of the ESCWA member States, the reduction of GHG emissions is not explicitly emphasized or included in national development plans. Greenhouse gas mitigation options would likely receive more attention if they were integrated with national development and environment plans and goals. Also, all stakeholders in a particular GHG abatement policy should be included in the policy development process so that the result is a more realistic policy with a better chance of successful implementation.

5. *Increasing public awareness of environmental issues*

Public awareness is vital to the success of any strategy to reduce GHG emissions. Educating and informing the public at all levels ensures widespread understanding of the environmental risks posed by unabated GHG emissions and of the need for action to reduce these risks. The public will thus become partners who share responsibility for any strategy that is adopted. Building public awareness of environmental issues has the additional advantage of generating political support for the enactment of appropriate legislation and the allocation of funding.

Increasing public awareness is particularly important in the ESCWA member States, whose nationals enjoy heavily subsidized public utilities and/or tax structures that promote private vehicle ownership. Greater public awareness of the problems caused by GHG emissions may help to change attitudes about vehicle ownership and use. Governments and concerned non-governmental organizations should, using all available means, conduct public awareness programmes focusing on environmental issues.

D. STEPS TOWARDS IMPLEMENTATION OF THE RECOMMENDED OPTIONS

In view of the challenges involved in implementing the GHG abatement options presented in this study, it is apparent that further fine-tuning would be of benefit. This process could be supported by the ESCWA secretariat through a series of regional expert group meetings that included discussions on the following issues:

(a) Implementation of the options proposed in this study from the viewpoint of individual ESCWA member States' capabilities and constraints. Such discussions would help to ensure that the views of all stakeholders were represented, increasing the likelihood that the relevant GHG emissions reduction strategies would be implemented successfully;

(b) The review and assessment of ESCWA member States' current national GHG management and control strategies, where they exist, for all energy sectors and in particular the transport sector;

(c) Efforts to develop and establish strategies and plans for mitigating GHG emissions in the event that a country has no such strategies;

(d) A review of existing policies and legislation and/or the development of new policies and the enactment of new laws to support the recommended strategies for the abatement of GHG emissions. Without an appropriate legal framework, it simply may not be possible to implement some of the recommended strategies;

(e) The facilitation of efforts to mobilize local, regional and international funds for financing high-priority GHG abatement projects in the ESCWA member States;

(f) The identification of areas in which capacity building is required relating to reducing GHG emissions and soliciting support from regional or international institutions;

(g) The organization and staging of national and regional environmental awareness campaigns to increase support among the public and decision makers, and to promote broader popular participation in the control and mitigation of the environmental and health risks associated with GHG emissions;

(h) The promotion of possibilities for regional cooperation in any or all of the activities listed above.

IV. CASE STUDY OF EGYPT***

Since 1993, the Government of Egypt has worked towards completing an assessment of the level of GHG emissions produced nationally and identifying ways in which that level might be reduced. A national air quality management programme, including a component focusing on controlling transport-related emissions, was established under Environment Law No. 4 of 1994. Information on a number of GHG mitigation options is available in Egypt and could be used by other countries in the development of their own GHG control programmes.

This chapter presents data on levels of GHG emissions in the Egyptian transport sector and reviews the development and implementation of strategies to control and reduce those emissions. The chapter also identifies and ranks a number of options for GHG abatement in Egypt's transport sector and presents a preliminary evaluation of the highest-ranked option.

A. THE STRUCTURE OF THE TRANSPORT SECTOR IN EGYPT

1. *Volume and modes of transport*

The number of vehicles registered in Egypt reached almost 3.02 million in 1999, of which about 47 per cent were registered in the governorates of Cairo, Kalyoubia and Giza (which together constitute the Cairo metropolitan area). Private cars represent 43.3 per cent of the total number of vehicles in Egypt. Taxis account for 9.9 per cent of the total, trucks represent 19.9 per cent, buses represent 1.6 per cent and motorcycles represent 16.1 per cent (see table 21 and chart 9). The total number of vehicles grew by 5.4 per cent a year in the period 1998–1999. The fastest-growing categories were: private cars, trucks, and buses, with annual growth rates of 6.8 per cent, 6.8 per cent, and 5.0 per cent, respectively.[3]

Significant features of the Cairo vehicle fleet include the following:

(a) There are essentially no diesel-powered passenger cars because these have been prohibited by law;

(b) Almost all trucks and buses use diesel fuel;

(c) Passenger cars are expected to constitute the fastest-growing category over the next few years. The number of public buses has not been expanding at a significant rate due to capital constraints and the growth of the underground metro rail system.

The total road length in Egypt in 1997 was about 59,723 km, representing 17.26 per cent of the total road length in all ESCWA member States. Most roads in Egypt are sealed (45,384 km), and the length of unsealed road is estimated to be 14,339 km. The annual growth rate of road length in Egypt in the period 1989–1997 averaged about 4.5 per cent. The growth rate for roads was therefore lower than that for vehicles over the same period.

2. *Volume of movement*

The volume of transport is expressed as passengers per kilometre travelled or, for freight, tons per kilometre travelled. Most passenger and freight movements use road transport, which represented 61 per cent of passenger travel in 1996/97, rail travel accounting for the other 39 per cent (see table 22 and chart 10). The volume of passenger movements in Egypt grew from 112,507 million passengers/km in 1989/90 to 151,246 million passengers/km in 1996/97, averaging 4.9 per cent growth annually. Growth rates for the volume of passenger movements by rail and road for the same period averaged 6.3 per cent and 4.1 per cent, respectively. Road transport also accounts for most of the freight movement in Egypt (83 per cent of the total in 1996/97), whereas rail and water represented only about 11 and 6 per cent, respectively. The volume

*** This chapter draws heavily upon Salah Kandil, "Options for GHG abatement in the ESCWA region: case study of Egypt", a report prepared for ESCWA, 2000.

of freight movement grew from 28,688 million tons/km in 1989/90 to 38,525 million tons/km in 1996/97, averaging 4.9 per cent growth annually. Average annual growth rates for the movement of freight by rail and water were 5 per cent and 2.2 per cent, respectively.

TABLE 21. EGYPT: NUMBER OF VEHICLES, 1998 AND 1999

	Private car	Taxi	Bus[a/]	Truck[b/]	Motorcycle	With custom numbers	Public sector	Government	Governorate	Other[c/]	Total
1998	1 225 479	291 600	45 149	563 370	460 898	124 109	49 670	53 264	26 931	23 920	2 864 390
Percentage of 1998 total	42.8	10.2	1.6	19.7	16.1	4.3	1.7	1.9	0.9	0.8	100.0
1999	1 308 318	299 353	47 424	601 526	485 209	112 809	58 816	54 861	27 059	24 607	3 019 982
Percentage of 1999 total	43.3	9.9	1.6	19.9	16.1	3.7	2.0	1.8	0.9	0.8	100.0
Average annual growth (%)	6.8	2.7	5.0	6.8	5.3	(9.1)	18.4	3.0	0.5	2.9	5.4

Salah Kandil, "Options for GHG abatement in the transport sector in the ESCWA region: case study of Egypt", report prepared for ESCWA, May 2000.

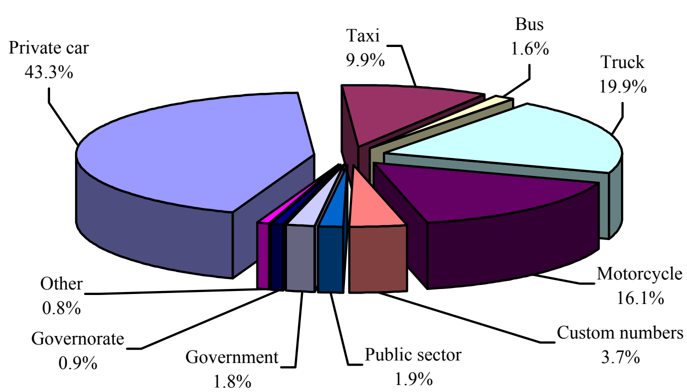
Note: ( ) indicates negative.

a/ Includes public buses, private buses, tourist buses, and school buses.

b/ Includes tractors.

c/ Includes caravans, diplomatic vehicles, commercial vehicles and temporary registrations.

Chart 8. Distribution of vehicles by category in Egypt, 1999



Source: Based on table 21.

B. ENERGY CONSUMPTION IN THE TRANSPORT SECTOR

1. *Sectoral distribution of energy consumption*

The total consumption of petroleum products in Egypt in reached 23.078 Mtoe in 1998/99, of which 38.3 per cent was used for transportation, 24.6 per cent for industry, 18.8 per cent for electricity, 14.5 per cent for residential and commercial purposes, 3.5 per cent for petroleum, and 0.4 per cent for agriculture (see table 23).[9]

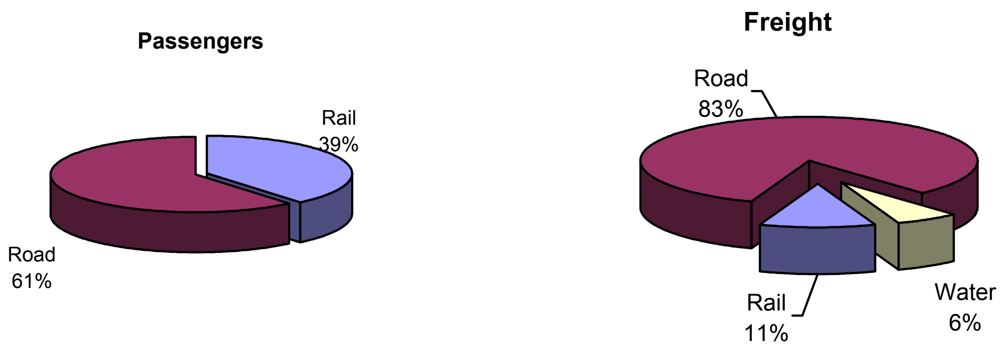
TABLE 22. EGYPT: VOLUME OF PASSENGERS AND FREIGHT, 1989/90–1996/97

	Rail		Road		Total	Rail		Road		Water		Total
	Millions of passengers/km	Percentage of total	Millions of passengers/km	Percentage of total		Millions of tons/km	Percentage of total	Millions of tons/km	Percentage of total	Millions of tons/km	Percentage of total	
1989/90	40 584	36	71 923	64	112 507	3 144	11	23 543	82	2 001	7	28 688
1990/91	43 449	37	74 649	63	118 098	3 186	11	24 866	83	1 877	6	29 929
1991/92	46 517	38	77 494	62	124 011	3 229	10	26 261	84	1 761	6	31 251
1992/93	48 456	38	78 625	62	127 081	3 141	10	26 584	84	1 881	6	31 606
1993/94	50 706	38	81 875	62	132 581	3 621	11	27 433	82	2 262	7	33 316
1994/95	52 838	38	85 496	62	138 334	4 073	12	28 761	82	2 354	7	35 188
1995/96	55 750	38	89 690	62	145 440	4 500	12	30 310	81	2 449	7	37 259
1996/97	58 520	39	92 726	61	151 246	4 405	11	31 815	83	2 305	6	38 525
Average annual growth	6.3%		4.1%		4.9%	5.7%		5.0%		2.2%		4.9%

Source: Salah Kandil, "Options for GHG abatement in the transport sector in the ESCWA region: case study of Egypt", a report prepared for ESCWA, May 2000.

Note: Figures may not add up to 100 per cent due to rounding.

Chart 9. Volume of movement of passengers and freight in Egypt by mode, 1996/97



Source: Based on table 22.

TABLE 23. EGYPT: CONSUMPTION OF PETROLEUM PRODUCTS BY SECTOR, 1998/99
(*Millions of tons of oil equivalent*)

	Industry	Transport	Agriculture	Residential and commercial	Electricity	Petroleum	Total
Consumption (Mtoe)	5.674	8.845	0.088	3.338	4.337	0.796	23.078
Percentage of total	24.6	38.3	0.4	14.5	18.8	3.5	100

Note: Figures may not add up to 100 per cent due to rounding.

2. *Energy consumption in the transport sector*

The consumption of petroleum products in the transport sector increased from 6.25 Mtoe in 1993/94 to 8.85 Mtoe in 1998/99 with average annual growth of 7.2 per cent (see table 24). In 1998/99, total gasoline consumption by the transport sector was 2.205 Mtoe (25.8 per cent), gas oil 4.917 Mtoe (57.5 per cent), fuel oil 0.738 Mtoe (8.6 per cent), and kerosene 0.418 Mtoe (4.9 per cent) (see table 25). Road transport was the major consumer of petroleum products, accounting for about 94.9 per cent. Rail transport accounts for about 3.5 per cent of the sector's total consumption of petroleum products, while water transport represents about 1.6 per cent of consumption (see chart 10).

TABLE 24. EGYPT: CONSUMPTION OF PETROLEUM PRODUCTS IN THE TRANSPORT SECTOR, 1993/94 – 1998/99

	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99
Total (Mtoe)	16.94	17.71	19.42	20.05	22.50	23.08
Transport (Mtoe)	6.25	6.52	7.11	7.35	7.99	8.85
Transport share of total (%)	36.9	36.8	36.6	36.7	35.5	38.3
Growth (%)	-	4.3	9.1	3.4	8.7	10.8
Average annual growth	7.2%					

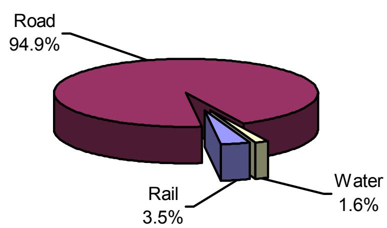
Note: A hyphen (-) indicates that the item is not applicable.

TABLE 25. EGYPT: CONSUMPTION OF PETROLEUM PRODUCTS BY MODE OF TRANSPORT, 1998/1999
(*Millions of tons of oil equivalent*)

Mode of transport	Gasoline	Kerosene	Gas oil	Fuel oil	Other[a/]	Total
Road	2.198	0.395	4.584	0.685	0.252	8.114
Rail	0.005	0.020	0.250	0.003	0.022	0.300
Water	0.002	0.003	0.083	0.050	0.002	0.140
Total	2.205	0.418	4.917	0.738	0.276	8.554
Percentage of total energy consumption	25.8	4.9	57.5	8.6	3.2	100

a/ Includes lubricants, asphalt and other products.

Chart 10. Consumption of petroleum products in Egypt by mode of transport, 1998/1999



Source: Based on table 25

Projections of growth in transport sector energy consumption have been calculated using a special mathematical model adopted for Egyptian conditions that takes into account growth rates for population, GDP, and movements of passengers and freight.[26] The average growth in transport-related energy consumption is therefore expected to be about 4.6 per cent a year for the period 1999/2000–2004/2005, and 6.4 per cent a year for the period 2004/2005–2014/2015. Therefore, the total energy consumption of the transport sector is expected to be about 11.4 Mtoe in 2004/2005, 14.6 Mtoe in 2009/2010, and 18.6 Mtoe in 2014/2015 (see table 26).

TABLE 26. ENERGY CONSUMPTION BY MODE OF TRANSPORT, 1989/90–2014/15
(*Millions of tons of oil equivalent*)

Mode of transport	1989/99	1999/2000	2004/05 [a/]	2009/10 [a/]	2014/15 [a/]
Road	8.390	8.776	10.795	13.817	17.685
Rail	0.310	0.325	0.399	0.511	0.654
Water	0.145	0.151	0.186	0.238	0.305
Total	8.845	9.252	11.380	14.566	18.644

Source: Organisation for Energy Planning, "Energy planning in the transport sector on a national level", 1997.

a/ Projections.

C. GHG EMISSIONS BY MODE OF TRANSPORT

GHG emissions are calculated using data for energy consumption and emission factors, which are expressed as kilograms per unit of energy (see table 27 for transport sector emission factors). GHG emissions for various modes of transport are thereby projected until 2104/15 (see table 28 and chart 11). Unsurprisingly, given that it is the major consumer of energy within the transport sector, road transport produces the most of the GHG emissions in Egypt, accounting for about 95 per cent of all transport-related emissions of CO_2, N_2O, and NO_x, and about 98 per cent of CH_4, CO, and NMVOC.

TABLE 27. GHG EMISSION FACTORS FOR THE TRANSPORT SECTOR

Fuel type	CO_2 (*Ton/ton*)	CH_4 (*Kilograms per terajoule*)	N_2O (*Kilograms per terajoule*)	NO_x (*Kilograms per terajoule*)	CO (*Kilograms per terajoule*)	NMVHC (*Kilograms per terajoule*)
Gasoline	3.1046	50	0.6	600	8 000	1 500
Gas oil	3.2093	5	0.6	800	1 000	200
Other products	2.9473	2	0.6	200	10	5

Source: IPCC Guidelines, 1996.

Note: Figures may not add up to 100 per cent due to rounding.

Rail and water transport produce only small proportions of transport-related GHG emissions, ranging from 0.4 per cent to 3.8 per cent. Based on projected energy consumption, GHG emissions for road, rail, and water transport have been projected until 2014/2015 (see table 28 and chart 11). Transport-related emissions of CO_2 are expected to rise from 28,323,851 tons in 1999/2000 to 57,079,130 tons in 2014/15, while CH_4 emissions are expected to rise from 6,600 tons to 13,301 tons; N_2O emissions are expected to increase from 240 tons to 483 tons; NO_X from 260,221 tons to 524,406 tons, CO from 1,082,327 tons to 2,181,139 tons and NMVOC from 206,004 tons to 415,145 tons. The increase in total GHG emissions amounts to 110 per cent, which corresponds with the projected increase in transport-related energy consumption to 2014/2015.

TABLE 28. EGYPT: GHG EMISSIONS BY MODE OF TRANSPORT, 1998/99–2014/15
(*Tons*)

	1998/1999	1999/2000	2004/2005[a/]	2009/2010[a/]	2014/2015[a/]	Share of total (1998/99)
Road						
CO_2	25 678 085	26 859 277	33 036 910	42 287 245	54 127 674	94.8%
CH_4	6 211	6 497	7 991	10 229	13 093	98.4%
N_2O	217	227	280	358	458	94.9%
NO_X	235 852	246 701	303 443	388 407	497 160	94.8%
CO	1 017 238	1 064 031	1 308 758	1 675 210	2 144 269	98.3%
NMVOC	193 466	202 365	248 909	318 604	407 813	98.2%
Rail						
CO_2	956 573	1 000 575	1 230 707	1 575 305	2 016 391	3.5%
CH_4	71	75	92	117	150	1.1%
N_2O	8	8	10	13	17	3.5%
NO_X	9 456	9 890	12 165	15 572	19 932	3.8%
CO	13 025	13 624	16 758	21 450	27 456	1.3%
NMVOC	2 588	2 707	3 329	4 262	5 455	1.3%
Water						
CO_2	443 594	463 999	570 719	730 520	935 066	1.6%
CH_4	28	29	36	46	58	0.4%
N_2O	4	4	5	6	8	1.6%
NO_X	3 470	3 630	4 464	5 714	7 315	1.4%
CO	4 466	4 671	5 746	7 355	9 414	0.4%
NMVOC	891	932	1 146	1 467	1 878	0.5%
Total						
CO_2	27 078 251	28 323 851	34 838 336	44 593 070	57 079 130	100%
CH_4	6 310	6 600	8 118	10 391	13 301	100%
N_2O	229	240	295	377	483	100%
NO_X	248 778	260 221	320 072	409 693	524 406	100%
CO	1 034 729	1 082 327	1 331 262	1 704 015	2 181 139	100%
NMVOC	196 944	206 004	253 384	324 332	415 145	100%

Source: Salah Kandil, "Options for GHG abatement in the transport sector in the ESCWA region: case study of Egypt", report prepared for ESCWA, May 2000.

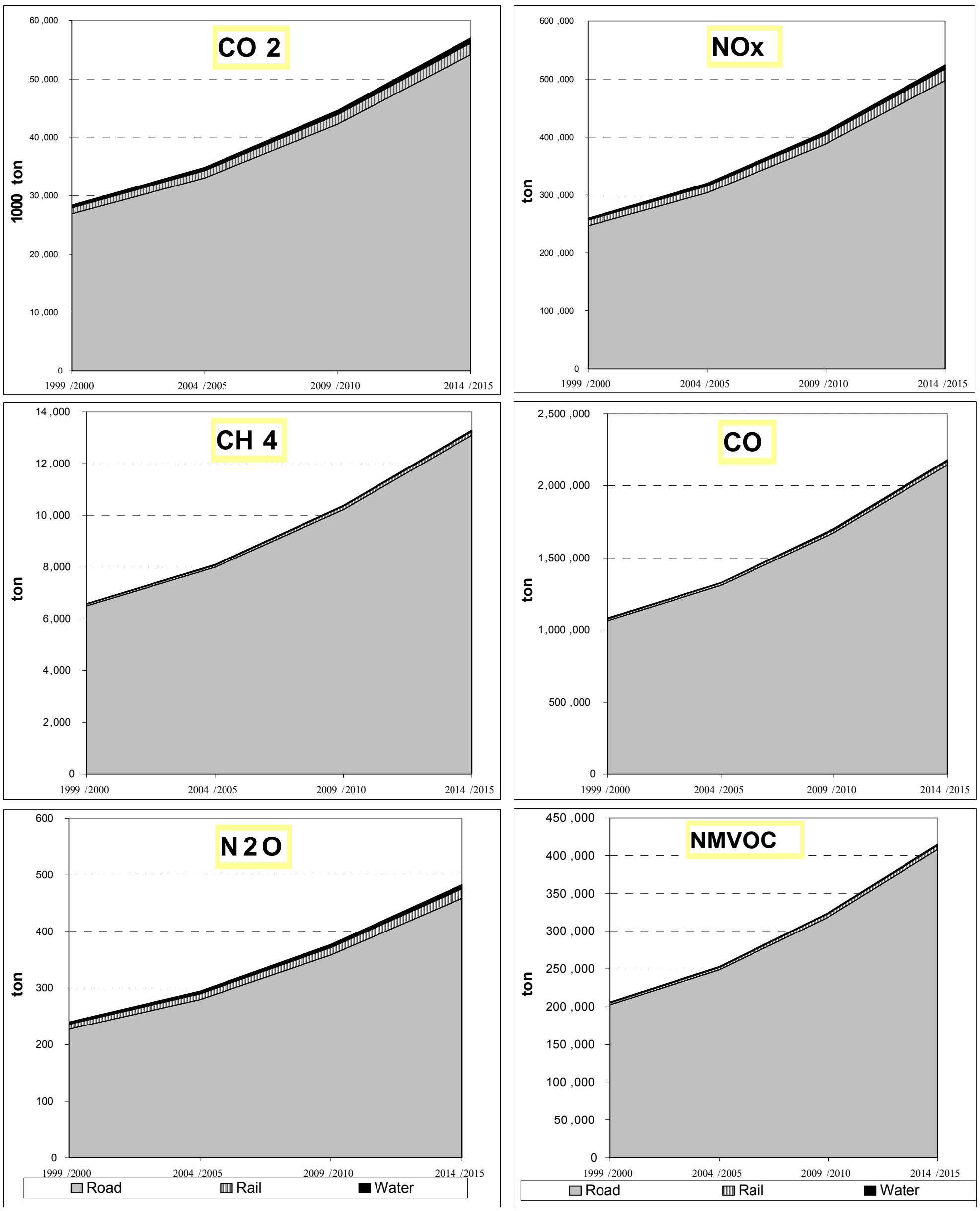
a/ Projections.

D. TECHNOLOGICAL OPTIONS FOR REDUCING TRANSPORT-RELATED GHG EMISSIONS IN EGYPT

1. *Conversion of vehicles to run on CNG*

The Ministry of Petroleum of the Government of Egypt conducted a trial of CNG vehicle technology in Cairo in 1992 and later encouraged two oil companies operating in Egypt, the Belayim Petroleum Company (known as Petrobel) and the Gulf of Suez Petroleum Company (known as Gupco), to apply this technology on their fleets. Two more companies carrying out CNG vehicle conversions, GasTec and NGV-CarGas, were established.

Chart 11. GHG emissions by mode of transport in Egypt, 1999/2000–2014/15



Source: Based on table 28.

In 1997, the Cairo Air Improvement Project commenced, funded by the United States Agency for International Development. The promotion of CNG vehicle technology is the major element of this programme, which is due to be completed in 2002. The aim of the project is to expand the use of CNG in public municipal bus fleets, in particular those of the Cairo Transport Authority and Greater Cairo Bus Company. The results of this project are presented in greater detail below.

(a) *The Petrobel and Gupco projects*

Petrobel's trial of natural gas vehicle technology began with just one bus in November 1992, which served the following purposes:

(a) It introduced new technology and promoted its use in vehicles;

(b) It demonstrated the viability of a natural gas vehicle programme in Egypt;

(c) It tested available equipment for its suitability for Egyptian conditions;

(d) It built up local expertise in natural gas vehicle technology;

(e) It promoted an understanding of the standards, regulations and incentives that would be required to sustain a viable natural gas vehicle industry in Egypt;

(f) It increased public awareness of natural gas technology;

(g) It drew attention to the environmental benefits of the natural gas vehicle programme. Petrobel then implemented a pilot project in which four diesel-powered buses were converted to run on natural gas by replacing the diesel components with a spark ignition combustion natural gas system. The performance of that prototype, in particular in terms of operation and ease of maintenance, encouraged Petrobel to convert 30 more buses and 200 light-duty trucks and passenger vehicles to operate with bi-fuel systems that use gasoline and CNG. The fuel and maintenance costs for the buses converted to run on CNG were just 65 per cent of comparable costs for their diesel-powered counterpart.

Test results showed that converting conventional light-duty trucks and passenger cars to run on natural gas fuel provided great benefits in terms of reducing GHG emissions (see tables 29 and 30).[26, 27]

TABLE 29. COMPARISON OF SELECTED EMISSIONS FROM GASOLINE AND CNG

	Gasoline	CNG
Light-duty truck operating at 1 000 rpm		
CO (%)	3.97	0.11
HC (parts per million)	260	63
Light-duty truck operating at 3 000 rpm		
CO (%)	3.39	0.31
HC (parts per million)	148	47
Passenger car operating at 900 rpm		
CO (%)	5.93	0.19
HC (parts per million)	1 147	45
Passenger car operating at 3 000 rpm		
CO (%)	6.84	0.05
HC (parts per million)	259	10

Source: Organisation for Energy Planning, "Energy planning in the transport sector on a national level", 1997.

TABLE 30. EMISSION REDUCTIONS ACHIEVED THROUGH CNG CONVERSION

Emissions	Reduction after conversion from gasoline fuel *(Percentage)*	Reduction after conversion from diesel fuel *(Percentage)*
NO_X	39	90
CO	97	96
Non-methane HC	75	99

Source: Hatem Khairy, "Petrobel's experience in using natural gas as a fuel for transportation in Egypt", December, 1999.

Gupco began its feasibility study of CNG vehicle technology in the early 1990s, and in September 1993 the company conducted a pilot project using two vehicles powered by natural gas. This project was followed by the conversion of 147 vehicles to a bi-fuel system using CNG and gasoline. The results, both economic and environmental, were encouraging. The period in which the conversion kit (which cost $850-$1,300) could be expected to pay for itself was less than one year.[13] Fuel costs for CNG per 100 km were less than one third of the cost for gasoline. Maintenance costs for the CNG-powered vehicle were also reduced, while its engine life was extended. Results from emissions tests showed that unburned hydrocarbons from CNG were just 36 parts per million compared with 140 parts per million for gasoline, a reduction of 74 per cent.

(b) *GasTec and NGV-CarGas*

The Egyptian International Gas Technology Company (GasTec) was established four years ago under Investment Law No. 230 of 1989 for the following purposes:

(a) To design, establish and own CNG centres and systems;

(b) To convert vehicles to operate on CNG;

(c) To prepare general recommendations for safety and technical specifications applicable to the use of CNG vehicle technology in accordance with Egyptian laws and regulations;

(d) To promote CNG to the public as a clean fuel;

(e) To promote the use of natural gas reserves in Egypt.

GasTec now owns 17 vehicle fuelling stations and has 10 more stations under construction. The company also owns 12 conversion centres and three more are being established. All of the fuelling stations and conversion centres comply with the Egyptian performance code. By 2000, GasTec had converted 11,968 vehicles to run on natural gas, representing about 44 per cent of the entire CNG-fuelled fleet in Egypt, most of which are taxis (see table 31). Its daily sales of natural gas increased from 80,900 cubic metres in 1998 to 168,000 cubic metres in 2000, representing average annual growth of 54 per cent.

The Natural Gas Vehicle Company (known as NGV-CarGas) was formed by Gas Misr Company, AMOCO Company, and Enppi, with the following objectives:

(a) To develop the CNG vehicle industry in Egypt, which includes establishing and operating CNG fuelling stations (public or private) and vehicle conversion centres;

(b) To convert various vehicle types, models, and capacities to operate on the bi-fuel system (combining either gasoline and CNG or diesel and CNG) or a dedicated NG system;

(c) To perform all maintenance and repairs required for the natural gas system and supply customers with spare parts.

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13 This calculation is based on an average 100 km/day distance travelled.

TABLE 31. EGYPT: CNG-FUELLED VEHICLES, 1998 AND 2000

Conversion company	Bus		Private		Taxi		Light-duty trucks		Total	
	1998	2000	1998	2000	1998	2000	1998	2000	1998	2000
NGV-CarGas	334	837	829	1 879	4 515	11 953	113	268	5790	14 937
GasTec	511	1 598	632	1 567	3 236	8 403	122	400	4501	11 968
Petrobel	3	30	62	112	0	0	67	150	132	292
Gupco	4	4	91	91	0	0	121	122	216	217
Total	852	2 469	1 614	3 649	7 751	20 356	423	940	10 640	27 414
Share of CNG-fuelled vehicles in Egypt (%)	8	9	15	13	73	74	4	3	100	100
Average annual increase (%)	94.9		63.0		81.3		61.1		78.8	

Note: Figures may not add up to 100 per cent due to rounding.

By 2000, NGV-CarGas had converted 14,937 vehicles, representing about 55 per cent of the total CNG-fuelled vehicle fleet in Egypt. NGV-CarGas owns 21 natural gas refuelling stations which are located throughout Egypt, and the company has 11 more stations under construction. Its daily gas sales increased from 72,500 cubic metres in 1998 to 202,800 cubic metres in 2000, an average annual increase of 90 per cent.

The total number of CNG-powered vehicles in Egypt increased from 10,640 in 1998 to 27,414 in 2000, an average annual growth rate of about 79 per cent. Taxis made up 74.3 per cent of that total and private cars accounted for 13.3 per cent, while buses and light-duty trucks represented 9.0 per cent and 3.4 per cent, respectively. The total number of CNG fuelling stations increased from 21 in 1998 to 43 in 2000, averaging about 52 per cent annual growth; there are about 21 additional fuelling stations under construction. Total annual gas sales have increased from 56 million cubic metres in 1998 to 135.3 million cubic metres in 2000, an average annual increase of about 71 per cent. The total number of CNG-fuelled vehicles in Egypt represents about 2.2 per cent of all such vehicles worldwide and makes Egypt's the seventh-largest national CNG vehicle fleet in the world.

(c) *Cairo Air Improvement Project and CNG programme*

The Cairo Air Improvement Project is implemented by the Egyptian Environmental Affairs Agency in partnership with the Ministry of Petroleum and the Organization for Energy Planning.[28] The project includes activities that have an immediate impact on reducing vehicle emissions, particulate matter and lead, while also setting the stage for a long-term effort to reduce GHG emissions and improve air quality. It does this by demonstrating and testing alternative technologies, increasing public awareness of environmental issues, and providing training.

The CNG vehicle programme is the most important component of the Cairo Air Improvement Project and a pilot programme has been implemented to demonstrate the technical and financial feasibility of converting the bus fleets of the Cairo Transport Authority and the Greater Cairo Bus Company to run on CNG. The project began in 1998 with a small test fleet of five CNG-fuelled buses which has been expanded to more than 50 vehicles (the bodies of which were built in Egypt). Almost all of these buses are now in operation. Two garages have been established for CNG refuelling and servicing and the Cairo Air Improvement Project has procured equipment for testing emissions and performance of CNG-fuelled and diesel-powered buses. The two most important items of equipment are the gas analyser for emissions testing and the chassis dynamometer, used to evaluate vehicle performance. CNG vehicle standards are being established by the Egyptian Organization for Standardization and Quality Control and the CNG programme is due to be completed in 2002.

2. *Introducing hydrogen as a transport fuel*

Many Egyptian institutions have undertaken research on fuel cell technology, in particular testing catalysts for increasing the production of hydrogen ions, developing more efficient Proton Exchange Membranes, and a Direct Methanol Fuel Cell operating at low temperatures and using liquid fuel to produce hydrogen. Egypt's experience with fuel cell technology makes the country well placed to adopt fuel cell technology and hydrogen fuel on a large scale.

(a) *Fuel cell bus demonstration project*

In 2001, Egypt took its GHG mitigation efforts in a new direction, beginning with a five-year demonstration project in Cairo of eight buses powered by hydrogen fuel cells.[28] The project is jointly funded by the Global Environment Facility, the Government of Egypt and bus manufacturers. The main goal of the project, from the Egyptian perspective, is the transfer of an efficient, advanced technology that utilizes energy resources that are readily available in Egypt.

The project involves a feasibility study conducted in two parts. The first part centres on the small-scale trial of eight buses which will go into operation mid-2002. The second part will be the full-scale commercial deployment in Cairo of public buses powered by fuel cells. It is expected that most of the Cairo Transport Authority's bus fleet (about 3,600 buses), will use hydrogen and fuel cell technology within the coming 15-20 years.

(b) *Constraints facing the adoption of fuel cell technology*

Plans to use fuel cell technology in the Cairo Transport Authority's buses have been evaluated economically, environmentally and technologically against the operation of the existing diesel-fuelled bus fleet. The main barrier to the adoption of fuel cell technology is its high cost. For example, the cost of the eight fuel cell buses to be purchased for the trial project is 10 times higher than that of comparable diesel buses. With the assistance of the Global Environment Facility, it is planned to add 20 more fuel cell buses in 2006, by which time the cost of such buses is expected to have declined to within two or three times that of their diesel-powered counterparts. By 2008 or 2009 the cost of a bus powered by fuel cells is expected to cost just 10-30 per cent more than a diesel-fuelled bus. Incentives to create demand for fuel cell buses, and therefore for bus manufactures to produce them, could also be provided by increasing the price of diesel fuel, imposing tighter vehicle emission standards, or creating a tax on pollutant emissions.

3. *Electrification of railways*

Rail plays a vital role in passenger transport in Egypt. Its share of total passenger transport in 1996/97 was about 39 per cent, and the line between Cairo and Alexandria has the highest passenger density of any line in the Egyptian rail network.[18]

Most of the rail system in Egypt operates on gas oil. In 1999, however, a preliminary study on the feasibility of railway electrification was carried out, using the Cairo-Alexandria line as a test case. The anticipated environmental and economic benefits of electrification include the following:

(a) *Fuel savings*. Assuming that the project is operational by 2007, it is expected that electrification will reduce consumption of gas oil by 26,605 tons per year (natural gas is to be used to fuel electricity generation) in addition to 17,596 tons gas oil saved as a result of an anticipated shift from road transport to railway. Thus the total anticipated reduction in consumption of gas oil in 2007 as a result of the project is 44,201 tons. Further projections indicate that by 2012 the electrified rail system should provide savings of 49,408 tons of gas oil, with 52,199 tons saved in 2017 and 61,239 tons in 2030 (see table 32 for the corresponding reductions of GHG emissions);

(b) *Lower costs for operation and maintenance*. The electrification of the Cairo–Alexandria railway is expected to reduce maintenance costs by about 50 per cent, while expenditure on oil and lubricants is expected to be reduced by about 70 per cent. The electrification project is also expected to extend the productive life of rolling stock and therefore the rate of depreciation. Locomotive availability is expected to increase by 75–90 per cent, and the productivity of rolling stock is expected to increase by about 25 per cent. The transfer of existing diesel locomotives and power units to other rail lines is calculated to generate extra revenue on those lines, and further extra revenue is expected from passenger travel, as travellers increasingly opt for train travel over buses and taxis. The electrified rail service is also expected to reduce travel time;

(c) *Economic feasibility*. Analyses indicate that the electrification project should provide a financial return of about 9 per cent, and an economic return of about 17 per cent. The simple payback period has been calculated to be about 10 years.

TABLE 32. PROJECTED REDUCTIONS IN ENERGY USE AND GHG EMISSIONS AFTER ELECTRIFICATION OF THE CAIRO–ALEXANDRIA RAILWAY

	Reduction in energy use		Reduction in GHG emissions (*Tons*)					
Year	Tons of gas oil	Terajoules (Tj)	CO_2	CH_4	N_2O	NO_X	CO	NMVOC
2007	44 201	1 937	142 150	9.9	1.2	1 578	1 937	395
2012	49 408	2 205	158 896	11.0	1.3	1 764	2 205	441
2017	52 199	2 330	167 872	11.6	1.4	1 864	2 330	466
2030	61 239	2 733	196 945	13.7	1.6	2 187	2 733	547

E. MEASURES AND POLICIES ADOPTED TO REDUCE TRANSPORT-RELATED GHG EMISSIONS IN EGYPT

1. *Improving vehicle maintenance and engine tuning*

(a) *Vehicle emissions testing and engine tuning programme*

A vehicle emissions testing, engine tuning and certification programme was established in Cairo in order to improve vehicle fuel efficiency and to reduce GHG emissions.[9] It was determined that the programme would require the development of a testing network that covered the Greater Cairo traffic departments, and the improvement of engine tuning capabilities that would be required by vehicles failing emission testing.

The programme comprises two main elements. The first element is a “rapid-start” programme, which works to increase public awareness of the importance of periodic vehicle inspections. This is achieved by issuing an open invitation to vehicle owners to take advantage of a free vehicle inspection. The second element of the programme is a testing programme, in which several sites for emissions testing have been selected in the Cairo area. There are now 26 service stations conducting emissions tests and 50,000 vehicles of various types have been tested.

In 1995, 1,286 vehicles were inspected and tuned, and the test results from this sample group showed that as a result of tuning, CO emissions were reduced on average by 62 per cent; emissions of HC decreased by 35 per cent and fuel consumption decreased by 15 per cent. In inspections of 13,000 vehicles conducted in February and April 1999, it was found that emissions of HC and CO generally exceeded Egyptian environmental standards by 12 per cent and 17 per cent, respectively. A total of 66 per cent of the cars inspected were found to comply with national standards, while 34 per cent needed tuning.

(b) *Potential for replicating the programme*

Taking the results of the testing program detailed above as representing the condition of the entire national vehicle fleet, it can be assumed that there are more than 500,000 gasoline-fuelled vehicles and 200,000 additional diesel-fuelled vehicles in Egypt that require maintenance. If it is assumed that gasoline consumption per vehicle is about 10 litres per day, and that a vehicle works for 300 days of the year, the 15 per cent fuel saving that can be achieved through engine tuning would amount to about 0.27 tons per year for a gasoline-fuelled vehicle. For diesel vehicles (assuming fuel consumption is about 35 litres per day per vehicle, and that vehicles work for 300 days per year), the 15 per cent fuel saving achieved through engine tuning would amount to about 1.15 tons per year (see table 33).

TABLE 33. EFFECTS OF ENGINE TUNING ON FUEL CONSUMPTION AND GHG EMISSIONS

Fuel type	Fuel consumption per vehicle[a/] *(Tons/year)*	Fuel saving per vehicle[b/] *(Tons/year)*	Reduction in GHG emissions per vehicle (*Tons/year*)					
			CO_2	CH_4	N_2O	NO_X	CO	NMVOC
Gasoline	1.80	0.270	0.838	0.00062	0.000007	0.007	0.100	0.019
Diesel	7.65	1.1475	3.690	0.00026	0.000031	0.041	0.051	0.010

a/ Based on consumption of 10 litres per day and 300 working days per year for gasoline vehicles and 35 litres per day and 300 working days per year for diesel vehicles.

b/ Based on a 15 per cent reduction in consumption.

Tuning 100,000 gasoline vehicles would therefore be expected to reduce fuel consumption by about 27,000 tons per year, and to reduce emissions of CO_2 by 83,824 tons/year; CH_4 emissions would be reduced by 62 tons/year, N_2O by 0.75 tons/year, NO_x by 748 tons/year, CO by 9,975 tons/year, and NMVOC by 1,870 tons/year. If 50,000 diesel-powered vehicles were tuned, fuel savings would reach 57,375 tons of gas oil per year, and CO_2 would be reduced by 184,518 tons/year. Reductions of CH_4 would total 13 tons/year; reductions of N_2O would be 1.54 tons/year; NO_x would be reduced by 2,049 tons/year; CO by 2,561 tons/year; and NMVOC by 512 tons/year.

If the programme was continued until 500,000 gasoline vehicles and 200,000 diesel vehicles had been tuned, fuel savings could reach 364,500 tons/year. Emissions of CO_2 could be reduced by about 1.157 million tons/year; CH_4 emissions could be reduced by 363 tons/year; N_2O, by 9.89 ton/year; NO_x, by 11,935 tons/year; CO by 60,120 tons/year; and NMVOC by 11,401 tons/year (see table 34).

TABLE 34. EGYPT: PROJECTED RESULTS OF REPLICATING EGYPT'S VEHICLE TUNING PROGRAMME

Vehicle type	Fuel consumption per vehicle (*Tons/year*)[a/]	Fuel saving per vehicle (*Tons/year*)[b/]	GHG reduction per vehicle (*Tons/year*)					
			CO_2	CH_4	N_2O	NO_X	CO	NMVOC
Gasoline								
100 000	180 000	27 000	83 824	62	0.75	748	9 975	1 870
200 000	360 000	54 000	167 648	125	1.50	1 496	19 951	3 741
300 000	540 000	81 000	251 473	187	2.24	2 244	29 926	5 611
400 000	720 000	108 000	335 297	249	2.99	2 993	39 902	7 482
500 000	900 000	135 000	419 121	312	3.74	3 741	49 877	9 352
Diesel								
50 000	382 500	57 375	184 518	13	1.54	2 049	2 561	512
100 000	765 000	114 750	369 036	26	3.07	4 097	5 122	1 024
150 000	1 147 500	172 125	553 554	38	4.61	6 146	7 683	1 537
200 000	1 530 000	229 500	738 072	51	6.15	8 195	10 243	2 049
Total[c/]	2 430 000	364 500	1 157 193	363	9.89	11 936	60 120	11 401

a/ Based on consumption of 10 litres per day and 300 working days per year for gasoline vehicles and 35 litres per day and 300 working days per year for diesel vehicles.

b/ Based on a 15 per cent reduction in consumption.

c/ Based on 500,000 gasoline vehicles and 200,000 diesel vehicles.

(c) *Limiting motorcycle emissions*

In 1998, there were about 460,000 motorcycles in Egypt, of which 173,000 were in the Greater Cairo area. The engine size of most of these motorcycles was 350 cubic centimetres, and about 95 per cent had two-stroke engines. Problems with motorcycle emissions are a result of both their quantity and the concentration of pollutants they contain. Motorcycles' two-stroke engines emit, on average, 7,000–8,000 parts per million (ppm) of HC, and this figure may, in extreme cases, reach as much as 20,000 ppm. By comparison, a typical passenger car emits less than 1,000 ppm of HC, and a well-tuned car emits less than 400 ppm. The fact that motorcycles use an oil-and-gasoline mixture as fuel (and their owners do not accurately measure the quantities) means that the quantity of exhaust emissions from motorcycles can be even greater. Studies conducted in Taiwan have shown that HC emissions for two-stroke motorcycles reach approximately 10 grams per kilometre travelled (g/km), which is 10 times higher than levels of HC emissions produced by a four-stroke engine. Emissions of particulate matter from two-stroke motorcycles reached 0.28g/km, which is between 5 and 10 times higher than emissions from a four-stroke engine. Based on these figures, and assuming that a motorcycle travels (on average) 12,000 km each year, motorcycles could be adding about 16,000 tons of HC and 700 tons of particulate matter each year to the emissions polluting Cairo's air.

Recognising that motorcycle emissions constitute a significant problem, the Cairo Air Improvement Project began a study in July 1999, the recommendations of which included the collection of emissions data and the establishment of emissions standards and environmental regulations relating to pollution from motorcycles.

2. *Public transport*

Energy consumption for public transport in Egypt is lower than it is for private cars or taxis (see table 35). The difference is magnified in relation to travel within cities (as opposed to intercity travel), where traffic tends to be more congested and where public buses carry large numbers of passengers. For intracity travel, electricity-powered modes of transport such as the metro or tram have the lowest energy consumption per passenger/km (see table 36). The underground metro has the lowest energy intensity of all. The Cairo tram is 2.4 times more energy intensive (Wh/passenger/km) than the underground metro; the new Cairo metro is 5.3 times more energy intensive, and the Alexandria tram is 1.7 times more energy intensive than Cairo's underground metro.

TABLE 35. ENERGY INTENSITY OF SELECTED VEHICLES

Mode of transport (and fuel)	Intercity travel		Intracity transport	
	Fuel consumption (*Litres/person km*)	Intensity	Fuel consumption (*Litres/person km*)	Intensity
Private car (gasoline)	0.0429	5.80	0.0508	7.05
Taxi (gasoline)	0.0289	3.91	0.0513	7.13
Microbus (gas oil)	0.0152	2.05	0.0171	2.37
Public bus (gas oil)	0.0074	1.00	0.0072	1.00
Private bus (gas oil)	0.0074	1.00	0.0092	1.28
Train (gas oil)	0.0074	0.63	0.0105	1.46

TABLE 36. ENERGY INTENSITY OF INNER-CITY ELECTRIC TRANSPORTATION

Transport Mode	Average load (*Passengers*)	Energy intensity (*Wh per passenger per kilometre*)	Energy intensity/energy intensity of the underground metro
Cairo			
Tram	141	24.44	2.43
New Cairo metro	233	53.27	5.29
Underground metro	4562	10.07	1.00
Alexandria			
City tram	189	16.6	1.65
Al-Raml tram	527	16.12	1.60

Source: Organization for Energy Planning, "Energy planning in transport at the national level in Egypt", 1997.

3. *Traffic management*

In every urban area in the world, the achievement of more smoothly flowing traffic flow is a key method by which it is possible to achieve better fuel economy and, at the same time, limit emissions of pollutants and noise. A field study was carried out to investigate how various changes to traffic management would effect vehicular fuel consumption and levels of air pollution in the Greater Cairo area. This study was conducted on two major traffic corridors in Greater Cairo, namely Sudan Street and Malek al-Saleh. The following traffic management options were tested on each corridor:

(a) *Alternative I*: *Redesigning traffic signals*. This was the cheapest solution, with virtually no cost;

(b) *Alternative II*: *Eliminating obstructions to traffic*. This option involves organizing on-street parking, clearing sidewalks, enhancing shared taxi movements and introducing simple geometric designs at selected intersections;

(c) *Alternative III*: *Grade separations and public transport solutions.* This was the highest-cost option.

These options were assessed against a set of indicators as shown in table 37. The degree of improvement varied depending on the corridor, the journey direction, and the alternative being implemented. Energy savings on Sudan Street ranged between 11.5 per cent and 15.2 per cent; CO emissions were reduced by 2.4–16.1 per cent. On Malek al-Saleh, energy savings ranged from 41.8 per cent to 45 per cent, and CO was reduced by 5.5–22.6 per cent. On both corridors, however, alternative III produced the greatest energy savings and reductions of CO emissions, in addition to the lowest journey times and highest average speeds.

TABLE 37. EGYPT: RESULTS OF CAIRO TRAFFIC MANAGEMENT FIELD STUDY

	Travelling from Faysal to Al-Ketkat				Travelling from Al-Ketkat to Faysal			
Sudan Street	Present case	Alternative I	Alternative II	Alternative III	Present case	Alternative I	Alternative II	Alternative III
Delay time (minutes/vehicle)	264.8	234.7	192.2	156.7	212.9	182.9	155.76	125.7
Average speed (km/h)	28.9	32.6	36.4	39.4	32.9	34.4	36.1	37.8
Journey time (minutes)	17:48	17:14	15:48	15:01	15:36	16:30	15:55	15:28
Noise level (decibels)	78.8	79.3	79.5	79.2	78.8	78.9	79.5	79.2
Fuel consumption (litres/vehicle)	1.51	1.33	1.30	1.28	1.48	1.31	1.30	1.29
Reduction in fuel consumption (%)	--	11.9	13.9	15.2	--	11.5	12.2	12.8
CO emissions (g/km)	31.0	29.0	28.0	26.0	29.0	28.3	28.0	26.5
Reduction in CO emissions (%)	--	6.5	9.7	16.1	--	2.4	3.5	8.6
	Travelling from Magra al-Ouon to Giza				Travelling from Giza to Magra al-Ouon			
Malek al-Saleh	Present case	Alternative I	Alternative II	Alternative III	Present case	Alternative I	Alternative II	Alternative III
Delay time minutes/ vehicle)	181.2	72.9	69.4	68.8	262.5	79.5	69.4	68.8
Average speed (km/h)	22.6	24.9	26.1	26.7	29.3	34.7	39.6	42.9
Journey time (minutes)	9:23	9:24	9:07	8:57	7:15	7:35	7:05	6:45
Noise level (decibels)	81.5	81.4	81.4	81.4	81.5	81.4	81.4	81.4
Fuel consumption (litre/vehicle)	1.34	0.78	0.77	0.76	1.31	0.74	0.73	0.72
Reduction in fuel consumption (%)	--	41.8	42.5	43.	--	44.5	44.3	45.0
CO emissions (g/km)	36.0	34.0	32.0	31.8	31.0	28.3	25.8	24.0
Reduction in CO emissions (%)	--	5.5	11.1	11.7	--	8.7	16.8	22.6

Source: Organization for Energy Planning. "The impact of traffic management on fuel consumption and the environment in the transport sector in urban areas", Cairo, Cairo University, January 1996.

The results of this study highlight the importance of traffic management. Even if only a small improvement in traffic flow can be achieved on a single corridor, the aggregate effect can be huge. In a large city such as Greater Cairo, which has several traffic corridors that are congested for at least 10-14 hours a day for about 10 months of the year, the collective benefits of traffic improvements can be magnified enormously. Even if the limited availability of resources meant that only low-cost solutions, such as alternatives I and II, could be implemented, the benefits that could still be achieved—starting with reductions in energy consumption and air pollution—are significant.

4. *Urban planning and land use*

The number of inhabitants in major Egyptian cities such as Cairo and Alexandria is increasing rapidly, as is the related demand for transport and communications. Good urban planning can therefore make an important contribution to the abatement of GHG emissions while also facilitating transport sector activity and making the best possible use of limited resources, including available space.

5. *Use of unleaded gasoline*

In October 1996, the Ministry of Petroleum in the Government of Egypt began to supply unleaded gasoline to fuelling stations in Greater Cairo. Since then, the distribution of unleaded gasoline has been extended to fuelling stations all over Egypt, which take delivery of more than 2 million tons of unleaded fuel per year. This amount represents about 90 per cent of all gasoline used in vehicles. A joint study was carried out by the Ministry of Petroleum in partnership with the High Studies and Research Institute at Alexandria University to investigate the environmental benefits of using unleaded gasoline in Cairo. The findings of the study revealed that since the introduction of unleaded gasoline, levels of lead found in the air and soil had been significantly reduced**.** Airborne lead levels were reduced in Ramsis, Attaba and Giza Square by 79 per cent, 88 per cent and 70 per cent, respectively. Lead levels in the soil were reduced in the same locations by 70 per cent, 82 per cent and 88 per cent, respectively.

6. *Air quality monitoring*

Air quality monitoring is necessary in order to measure and analyse the effect of efforts to improve air quality. The Cairo Air Improvement Project operates a network of 36 ambient air quality monitoring stations which cover areas of heavy traffic, industrial activity and residential use in Greater Cairo. These monitoring stations provide reliable data on levels of particulate matter and airborne lead, identifying locations where pollutant levels exceed the limits set by Environment Law No.4 of 1994.[28]

7. *Restricting vehicle use and ownership*

The Greater Cairo area alone accounts for about 62 per cent (811,100) of all private cars in Egypt; Alexandria accounts for another 17 per cent (224,700). The volume of passenger movement by road in Egypt has increased by an average 4.1 per cent/year over the period 1989/90–1996/97. Restricting vehicle use and ownership is therefore essential—in particular in Greater Cairo and Alexandria.

8. *Enforcement of GHG mitigation standards and regulations*

The most important standards and regulations in Egypt dealing with transport-related GHG emissions are the following:[1]

(a) *Presidential Decree No. 864 of 1969*. This decree established the Supreme Committee to prevent air pollution, chaired by the Minister of Health. Its mandate is to study sources of air pollution, to formulate general policies for preventing air pollution, and to set air quality standards;

(b) *Law No. 66 of 1973*. Amended by Law No. 210 of 1980, Law No. 20 of 1983, Decree No. 291 of 1974 and Decree No. 407 of 1983 of the Minister of Interior. This law deals with traffic and, in chapter V, with traffic rules preventing excessive vehicle exhaust emissions;

(c) *Article 35 of Environment Law No. 4 of 1994*. This Article stipulates that establishments must endeavour to prevent emissions or leakage of air pollutants at or above the maximum limits allowed;

(d) *Article 36 of Environment Law No. 4 of 1994*. This Article deals with vehicle emission standards. It prohibits the use of machines, engines or vehicles with exhaust emissions that exceed the following limits:

(i) For vehicles currently in service, the limit for CO emissions is 7 per cent in volume at 600-900 rpm. For HC emissions, the limit is 1000 ppm, at 600-900 rpm. Smoke emissions must not exceed 65 per cent opacity or the equivalent in other units, at minimum acceleration;

(ii) For new vehicles licensed since 1999, the limit for CO is 4.5 per cent in volume at 600-900 rpm. For HC, the limit is 900 ppm at 600-900 rpm. Smoke must not exceed 50 per cent opacity or the equivalent in other units, at maximum acceleration.

(e) *Vehicle certification and testing regulations*. The Ministry of State for Environment enforces these regulations by making vehicle emissions testing a prerequisite for the renewal of vehicle licences. The procedure to be followed begins with a mandatory technical inspection, including emissions testing. If the vehicle meets the standards set in Environment Law No. 4 of 1994, it receives its certification. If the vehicle fails to meet the required standards, the necessary maintenance must be performed and the inspection repeated until the vehicle meets the appropriate standards;

(f) *Standards relating to fuel additives.* The Ministry of Petroleum promotes the use of unleaded gasoline as part of its efforts to improve air quality in Greater Cairo. Unleaded gasoline now accounts for about 90 per cent of all gasoline used in vehicles in Egypt. Plans also exist to restrict the use of leaded gasoline in the near future;

(g) *Technology standards*. To ensure the safe application of natural gas vehicle technology in Egypt, the following measures have been taken:

(i) *The establishment of CNG codes*. In 1995, the Ministry of Petroleum issued two codes of practice relating to the use of natural gas in transport. The first code details standards for the construction of natural gas fuelling stations; the second deals with the design and construction of natural gas vehicles systems;

(ii) *CNG standards*. The National Standards Committee in Egypt is currently establishing Egyptian CNG standards, which are classified into three categories. Category A standards apply to the installation and safe performance of vehicles fuelled by natural gas. These standards apply to newly produced CNG vehicle components constructed entirely of new parts and material suitable for service pressures as specified by the manufacturer for use in internal combustion engines. These standards apply to either dedicated natural gas vehicles or vehicles converted to run on natural gas alone, or with bi-fuel or dual-fuel engines.

Category B standards set out minimum requirements for serially produced lightweight refillable gas cylinders. The cylinders to which these standards apply are intended only for the on-board storage of high-pressure CNG as a fuel for automotive vehicles, to which the cylinders are to be fixed. The cylinders may be of any steel, aluminium or non-metallic material, design or method of manufacture suitable for the specified service conditions. This standard does not cover metal liners or cylinders of stainless steels or of welded construction.

Category C standards deal with the CNG refuelling stations and their safe operation, and will be based on a code prepared by the Ministry of Petroleum.

(h) *Fuel pricing regulations*. The Ministry of Petroleum uses fuel pricing policy to promote the use of clean fuels. The price of CNG in Egypt is less than half the price of gasoline. This price difference promotes the use of the cleaner natural gas vehicle technology;

(i) *Traffic regulations*. A decree issued by the Traffic Department of the Ministry of Interior in 2000 made it necessary for the drivers of buses from outside the Greater Cairo area to obtain permission before entering that area. Failure to comply results in the imposition of a fine.

F. RANKING GHG ABATEMENT OPTIONS FOR THE TRANSPORT SECTOR IN EGYPT

1. *Selecting mitigation options*

Considerations for the selection and ranking of GHG abatement options for Egypt closely resemble those taken into account when arriving at the recommendations for the region (see chapter III). A number of features distinguish the Egyptian situation, however, and all options must therefore be considered in the national context, taking into account the following factors:

(a) The vehicle fleet in Egypt is relatively old and inefficient, and most vehicles do not receive regular maintenance or diagnostic testing;

(b) The traffic system in Greater Cairo and Alexandria is generally in need of improvement;

(c) The Cairo underground metro rail system has proved a good example of how public transport can help to control GHG emissions. Its reliability, efficiency and low cost have encouraged people from various socio-economic backgrounds to use for public transport instead of private cars;

(d) CNG is a proven technology in Egypt. The existence of well-established infrastructure, huge reserves of natural gas, and a solid base of CNG vehicle experience make this technology an essential GHG mitigation option for application in the Egyptian transport sector and probably in other ESCWA countries as well.

Given these country-specific factors, four options are expected to take priority in Egypt's efforts to control and reduce transport-related GHG emissions. They are the following:

(a) Improving vehicle maintenance and engine tuning;
(b) Improving traffic management;
(c) Promoting the use of public transport;
(d) Conversion to CNG vehicle technology.

2. *Evaluating the options*

Using the same criteria and weightings as were applied in the evaluation of GHG abatement options for the ESCWA region (see chapter III), the four options selected for consideration in the Egyptian context are evaluated and ranked below.

TABLE 38. EVALUATION: IMPROVING VEHICLE MAINTENANCE

Criteria	Weighting (*Percentage*)	Unadjusted score	Rationale
Effectiveness in reducing greenhouse gas emissions	30	80	Improving engine tuning has been shown to improve fuel efficiency by about 15 per cent. Low levels of vehicle efficiency currently existing in Egypt (as in most ESCWA member States) mean that there is an opportunity to achieve significant reductions of GHG emissions by implementing this option.
Capital cost	25	75	The sustainability of this option depends on ongoing investment. In order to keep vehicles operating efficiently, regular spending on labour, materials and spare parts is required. This option can therefore be considered to involve high annual variable costs;
Operation and maintenance costs	10	45	Labour, materials and spare parts are required to maintain vehicles and keep them in efficient working order. A considerable annual investment is therefore needed to assure the sustainability of this option.

TABLE 38 (*continued*)

Criteria	Weighting (*Percentage*)	Unadjusted score	Rationale
Implementation difficulties	10	70	A programme to improve vehicle maintenance may face technical, administrative, and/or financial difficulties. These have been rated as moderate.
Potential for replication	10	80	Egypt has already established a vehicle emissions testing programme and Egyptian experience will be a valuable resource for the replication of such programmes in other countries.
Non-environmental benefits	10	80	Proper maintenance, periodic inspection and engine tuning can reduce costs for items such as fuel and spare parts. Regular maintenance also increases a vehicle's resale value and extends its lifespan. Additionally, demand for vehicle servicing can generate employment. In terms of non-environmental benefits, then, this option rates highly.
Sustainability	5	70	The sustainability of this option depends on financial, technical and regulatory support. Vehicle maintenance requires continual annual investment. It will also be necessary to expand the maintenance programme in line with the growing number of vehicles.

TABLE 39. EVALUATION: IMPROVING TRAFFIC MANAGEMENT

Criteria	Weighting (*Percentage*)	Unadjusted score	Rationale
Effectiveness in reducing greenhouse gas emissions	30	90	In some corridors in Cairo, improving traffic management can reduce fuel consumption by more than 40 per cent.
Capital cost	25	90	Modifications to traffic management such as introducing one-way street systems and reorganizing on-street parking require low capital expenditure.
Operation and maintenance costs	10	70	Optimizing the traffic system is an ongoing activity, requiring low to medium annual investment to maintain the modifications that are introduced (such as traffic signals).
Implementation difficulties	10	75	Generally, this option is almost free from technical and financial difficulties. In Cairo, however, modifying the traffic system is useful only to a point, because traffic in Cairo is, in general, excessively heavy.
Potential for replication	10	85	This option does not rely on high levels of technology and therefore its replication potential is rated as high.
Non-environmental benefits	10	65	Improving traffic management will produce savings on vehicle maintenance costs and expenditure on spare parts. It will also save time by reducing journey stoppage rates.
Sustainability	5	65	Continual modification of traffic regulations, efforts to keep the public aware of changes, and effective management are necessary if traffic systems are to maintain optimal performance and achieve sustainability.

TABLE 40. EVALUATION: PROMOTING THE USE OF PUBLIC TRANSPORT

Criteria	Weighting (*Percentage*)	Unadjusted score	Rationale
Effectiveness in reducing greenhouse gas emissions	30	80	In Egypt, energy consumed per passenger/km for intercity travel by private car or microbus is between 2 and 5.8 times higher than for public bus travel. For intracity travel, public transport is between 2.4 and 7.1 times more energy efficient per passenger/km. Transferring passenger transport to large vehicles is expected to have a high degree of impact on GHG emission rates.
Capital cost	25	50	Promoting public transport requires a high level of capital expenditure for the acquisition of a fleet of large vehicles and the establishment of garages, workshops, and stations.
Operation and maintenance costs	10	60	Ongoing maintenance of vehicles and infrastructure is required, with costs that are rated as medium.
Implementation difficulties	10	70	No social difficulties are anticipated. Technical, administrative, and/or financial difficulties are possible, however.
Potential for replication	10	75	The replication potential for this option has been rated as high because Egypt, like most countries in the region, already has experience in this field.
Non-environmental benefits	10	65	Greater use of public transport will have a positive on traffic management, and could also help to generate employment. The expansion of public transport services will, however, dampen demand for taxis and minibuses. The non-environmental benefits for this option are therefore rated as medium.
Sustainability	5	85	The sustainability of this option is considered high; it requires high levels of infrastructure, but once established, such infrastructure promotes self-sustainability for the long term.

TABLE 41. EVALUATION: ADOPTING CNG VEHICLE TECHNOLOGY

Criteria	Weighting (*Percentage*)	Unadjusted score	Rationale
Effectiveness in reducing greenhouse gas emissions	30	95	According to tests carried out in Egypt, conversion from gasoline fuel to CNG reduces emissions of NO_X by 39 per cent; of CO by 97 per cent; and of NMVOC by 75 per cent. Conversion from gas oil to CNG decreases NO_X emissions by 90 per cent; CO emissions by 96 per cent; and NMVOC by per cent. The introduction of CNG vehicle technology is therefore a very effective option for GHG abatement.
Capital cost	25	85	CNG technology requires high capital expenditure on the construction of infrastructure. Egypt has already established its CNG infrastructure.
Operation and maintenance costs	10	90	Operation and maintenance costs for the vehicles and refuelling stations required for this option are high but anticipated revenues should cover these expenses so that the project is ultimately self-sustaining.

TABLE 41 (*continued*)

Criteria	Weighting (*Percentage*)	Unadjusted score	Rationale
Implementation difficulties	10	95	CNG technology was first introduced in Egypt nine years ago. There are now more than 27,000 CNG vehicles operating there, so, most of the implementation difficulties have already been dealt with.
Potential for replication	10	85	Replication of this option is expected to be high because of the large reserves of natural gas in the countries of the ESCWA region (with the exception of Jordan, Lebanon and the Republic of Yemen). It should be possible to repeat the success achieved in Egypt elsewhere in the region if appropriate pilot projects and training programmes are implemented.
Non-environmental benefits	10	95	Introducing CNG technology creates employment opportunities. In Egypt, two companies have been established to convert conventionally fuelled vehicles to run on CNG and it is expected that more will enter the market over time. In terms of non-environmental benefits, this option therefore rats highly.
Sustainability	5	95	The infrastructure required for this option is already highly developed in Egypt, which has a natural gas network, fuel stations, and a large number of CNG vehicles. Egypt also has huge natural gas reserves. The sustainability of Egypt's CNG vehicle programme is therefore rated as high.

3. *Ranking the options*

The rankings of these options have been calculated using the same method as was applied in chapter III. The evaluation of the four GHG mitigation options selected for application in the transport sector in Egypt indicated that switching to CNG technology rated highest overall, with a final, adjusted score of 91 (out of a possible 100), followed by improving traffic management (with a final score of 82). Improving vehicle maintenance ranked third (with a final score of 74), and the promotion of public transport ranked fourth (with a final score of 68).

TABLE 42. OPTION EVALUATION SHEET

Option (*In order of priority*)		Effectiveness in reducing emissions of GHGs (*30 per cent*)	Capital costs (*25 per cent*)	Operation and maintenance costs (*10 per cent*)	Implementation difficulties (*10 per cent*)	Potential for replication (*10 per cent*)	Non-environmental benefits (*10 per cent*)	Sustainability (*5 per cent*)	Final (adjusted) score
Introduction of CNG vehicle technology	Grade	H	H[a/]	H[b/]	H	H	H	H	H
	Unadjusted score	95	85	90	95	85	95	95	91
Improving traffic management	Grade	H	H	M	H	H	M	M	H
	Unadjusted score	90	90	70	75	85	65	65	82
Improving vehicle maintenance	Grade	H	M	L	M	H	H	M	M
	Unadjusted score	80	75	45	70	80	80	70	74
Promoting use of public transport	Grade	H	L	M	M	M	M	H	M
	Unadjusted score	80	50	60	70	75	65	85	68

Notes: L indicates a low score of 0-50; M indicates a medium score of 51-75; H indicates a high score of 76-100.

a/ CNG infrastructure has already been established in Egypt, reducing the need for capital investment.

b/ The CNG option is self-sustaining because it generates revenues that cover operation and maintenance costs.

G. EXPERIENCE WITH CNG VEHICLES IN EGYPT

The adoption of CNG vehicle technology has been therefore demonstrated to be a viable option by which the transport sector in Egypt might address the problem of GHG emissions. A more detailed examination of Egypt's experience with CNG vehicles is presented below. A large amount of data has been collected throughout almost 10 years of working with CNG vehicle technology in Egypt, where there are now about 27,414 CNG vehicles operating.[9]

1. *Performance and cost data*

(a) *Costs*. The average cost of converting a conventionally fuelled vehicle to run on natural gas in Egypt is about LE 5,000 ($1,300). The cost of gasoline is LE 1.00/litre ($0.26/litre), whereas a comparable quantity of natural gas (1 cubic metre) costs LE 0.45 ($0.12). Fuel and maintenance costs for buses converted to run on CNG represented just 65 per cent of corresponding costs for comparable diesel-powered buses. Owners of CNG-fuelled vehicles in Egypt have reported that oil changes were required only every 16,100-32,200 kilometres and that standard spark plugs could last as long as 120,750 kilometres;

(b) *Fuel consumption and GHG emissions*. The average annual fuel consumption for a gasoline vehicle is calculated (based on an assumed daily fuel consumption of 10 litres per day for 300 working days per year) to be 1.8 tons/year. For a diesel vehicle, the calculation is based on fuel consumption of 35 litres per day for 300 working days per year, and amounts to 7.65 tons/year. Emissions of CO_2 are calculated on the basis of the emission factors presented in table 27. Emissions of NO_X, CO, and NMVOC have been calculated using measurements recorded by Petrobel, which indicate that conversion from gasoline to CNG fuel reduces emissions of NO_X by 39 percent, CO by 39 per cent and NMVOC by 75 per cent. Conversion from gas oil to CNG fuel reduces emissions of NO_X, by 90 per cent, CO by 96 per cent, and NMVOC by 99 per cent (see table 43).

2. *Payback periods for CNG conversion*

The payback period is the main indicator of the economic viability of converting vehicles to run on CNG fuel. The length of the payback period depends on the following:

(a) The conversion cost (including equipment, materials and labour);

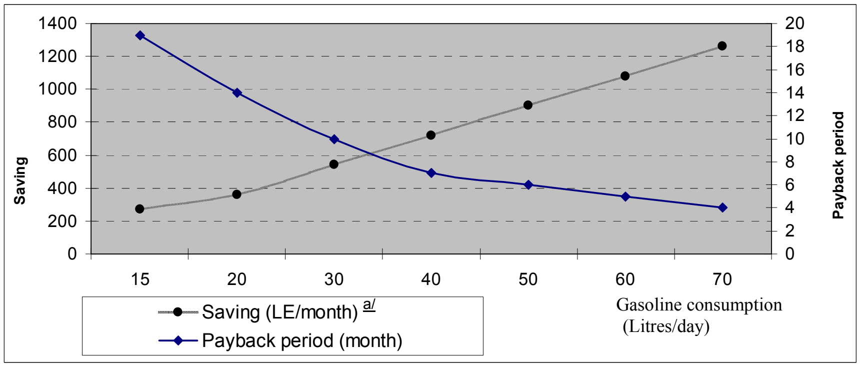
(b) The reduction in fuel costs after conversion;

(c) The average annual distance travelled;

(d) The fuel efficiency of the vehicle.

The fuel savings achieved by converting to CNG fuel increase as fuel consumption increases, while the payback period decreases correspondingly (see chart 12). At a consumption rate of 15 litres of fuel a day, the payback period is calculated to be 19 months. This period is reduced to just four months for a vehicle using 70 litres of fuel per day. The economic benefits of converting vehicles to run on CNG are therefore clear, in particular for vehicles that travel long distances. Further economic savings can be gained from conversion because of the fact that natural gas is a clean-burning fuel, which reduces the amount of vehicle maintenance required.

Chart 12. Fuel consumption and CNG conversion payback periods in Egypt



a/ Calculations based on conversion cost of LE 5,000, gasoline price of LE 1/litre and natural gas price of LE 0.45/m^3

3. *Potential GHG reductions*

(a) *Egypt*

In order to calculate the potential effect on GHG emissions of CNG conversion in Egypt, it is assumed that 25 per cent of the country's gasoline vehicles and 15 per cent of diesel vehicles will be converted to run on CNG.[14] The conversion programme for gasoline-fuelled vehicles could be implemented in five stages, with 5 per cent of the total converted in each stage. For diesel vehicles, only three stages would be required (again, with 5 per cent of the total converted in each stage). This would make the number of vehicles converted in each stage 80,000 for gasoline and 35,000 for diesel (see table 43).

The extrapolation of data on emissions reductions from CNG conversions in Egypt indicates that for every 80,000 gasoline vehicles converted, the annual reduction in emissions of CO_2 would be 75,385 tons. For NO_X the reduction would be 1,556 tons; for CO, 51,606 tons; and for NMVOC, 7,481 tons (see table 43). Every 35,000 diesel vehicles converted would reduce emissions of CO_2 by 191,324 tons. The reduction in emissions of NO_X would total 8,604 tons a year. Reductions of CO and NMVOC would total 11,473 tons and 2,366 tons, respectively. The combined reduction in annual emissions for 25 per cent of gasoline vehicles and 15 per cent of diesel vehicles would be: 950,948 tons (about 20 per cent) for CO_2; 33,594 tons (69 per cent) for NO_X; 292,450 tons (97 per cent) for CO; and 44,506 tons (78 per cent) for NMVOC. Emissions of CH_4, however, are expected to increase after CNG conversion because CH_4 is the main component of natural gas.

(b) *The ESCWA region*

The use of CNG vehicle technology in the ESCWA region is expected to provide considerable economic and environmental benefits. Given that the region has huge reserves of natural gas—and that it is more profitable to utilize these resources locally than it is to export them—CNG conversion is a particularly attractive option. The experience that Egypt has gained as the first country in the ESCWA region to apply CNG vehicle technology will be of benefit to other ESCWA member States that decide to implement similar programmes.

[14] The conversion of diesel vehicles requires more work and is more expensive than the conversion of a comparable gasoline-fuelled vehicle, hence the assumption that a lower percentage of diesel-fuelled vehicles will be converted.

TABLE 43. GHG REDUCTIONS AS A RESULT OF CNG CONVERSION IN EGYPT
(*Tons per year*)

Vehicles converted to CNG	Average fuel consumption (*Tons/year*)[a/]	CO_2			NO_X			CO			NMVOC		
		Before conversion	After conversion	Reduction	Before conversion	After conversion	Reduction	Before conversion	After conversion	Reduction	Before conversion	After conversion	Reduction
Gasoline													
80 000	144 000	447 062	371 677	75 385	3 990	2 434	1 556	53 202	1 596	51 606	9 975	2 494	7 482
160 000	288 000	894 125	743 334	150 791	7 980	4 868	3 112	106 405	3 192	103 213	19 951	4 988	14 963
240 000	432 000	1 341 187	1 115 001	226 186	11 971	7 302	4 669	159 607	4 788	154 819	29 926	7 482	22 444
320 000	576 000	1 788 250	1 486 668	301 582	15 961	9 736	6 225	212 809	6 384	206 425	39 902	9 975	19 927
400 000	720 000	2 235 312	1 858 334	376 978	19 951	12 170	7 781	266 012	7 980	258 032	49 877	12 469	37 408
Reduction		16.9%			39.0%			97.0%			75.0%		
Diesel													
35 000	267 750	859 210	667 886	191 324	9 560	956	8 604	11 951	478	11 473	2 390	24	2 366
70 000	535 500	1 718 420	1 335 773	382 647	19 121	1 912	17 209	23 901	956	22 945	4 780	48	4 732
105 000	803 250	2 577 629	2 003 659	573 970	28 681	2 868	25 813	35 852	1 434	34 418	7 170	72	7 099
Reduction		22.3%			90.0%			96.0%			99.0%		
Gasoline and diesel 505 000	1 532 250	4 812 941	3 861 993	950 948	48 632	15 038	33 594	301 864	9 414	292 450	57 047	12 541	44 507
Reduction		19.76%			69.08%			96.88%			78.02%		

a/ Based on fuel consumption of 10 litres per day and 300 working days per year for gasoline vehicles and 35 litres per day and 300 working days per year for diesel vehicles.

TABLE 44. POTENTIAL REDUCTIONS IN GHG EMISSIONS THROUGH CNG CONVERSION IN ESCWA MEMBER STATES

Country	Fuel type	Vehicles converted to CNG		Average annual fuel consumption (*Tons*)	Reduction (*Tons*)			
		Number	Percentage[a/]		CO_2	NO_X	CO	NMVOC
Bahrain	Gasoline	35 964	25	64 249	33 639	694	23 025	3 338
	Diesel	4 916	15	37 606	26 872	1 209	1 611	332
Egypt	Gasoline	400 000	25	720 000	376 978	7 781	258 031	37 408
	Diesel	105 000	15	803 250	573 970	25 813	34 418	7 099
Iraq	Gasoline	171 132	25	308 037	161 282	3 329	110 393	16 044
	Diesel	52 828	15	404 133	288 777	12 987	17 316	3 571
Jordan	Gasoline	47 499	25	85 497	44 765	924	30 640	4 442
	Diesel	14 074	15	107 666	76 934	3 460	4 613	951
Kuwait	Gasoline	186 760	25	336 168	176 011	3 633	120 475	17 466
	Diesel	21 072	15	161 201	115 188	5 180	6 907	1 425
Lebanon	Gasoline	324 850	25	584 729	306 152	6 319	209 553	30 380
	Diesel	13 811	15	105 656	75 498	3 395	4 527	934
Oman	Gasoline	61 283	25	110 310	57 756	1 192	39 533	5 731
	Diesel	16 058	15	122 841	87 777	3 948	5 264	1 086
Qatar	Gasoline	41 180	25	74 124	38 810	810	26 564	3 851
	Diesel	11 867	15	90 780	64 868	2 917	3 890	802
Saudi Arabia	Gasoline	873 020	25	1 571 436	822 773	16 982	563 167	81 645
	Diesel	449 816	15	3 441 095	2 458 869	110 583	147 444	30 410
Syrian Arab Republic	Gasoline	34 615	25	62 307	32 623	673	22 329	3 237
	Diesel	45 445	15	347 656	248 421	11 172	14 896	3 072
United Arab Emirates	Gasoline	82 938	25	149 288	78 164	1 613	53 502	7 756
	Diesel	13 228	15	101 195	72 310	3 252	4 336	894
Republic of Yemen	Gasoline	80 507	25	144 912	75 873	1 556	51 933	7 529
	Diesel	62 724	15	479 841	342 875	15 420	20 560	4 241
ESCWA	Gasoline	2 339 748	25	4 211 057	2 204 826	45 506	1 509 145	218 827
	Diesel	810 839	15	6 202 920	4 432 359	199 336	265 782	54 818
ESCWA total (gasoline and diesel)		3 150 587	21%	10 413 977	6 637 185	244 842	1 774 927	273 644
					20.1%	72.4%	96.8%	78.8%

a/ For illustration it is assumed that the same percentage of vehicles would be converted in each country. In reality the percentage would differ according to the circumstances in each country.

V. CASE STUDY OF LEBANON

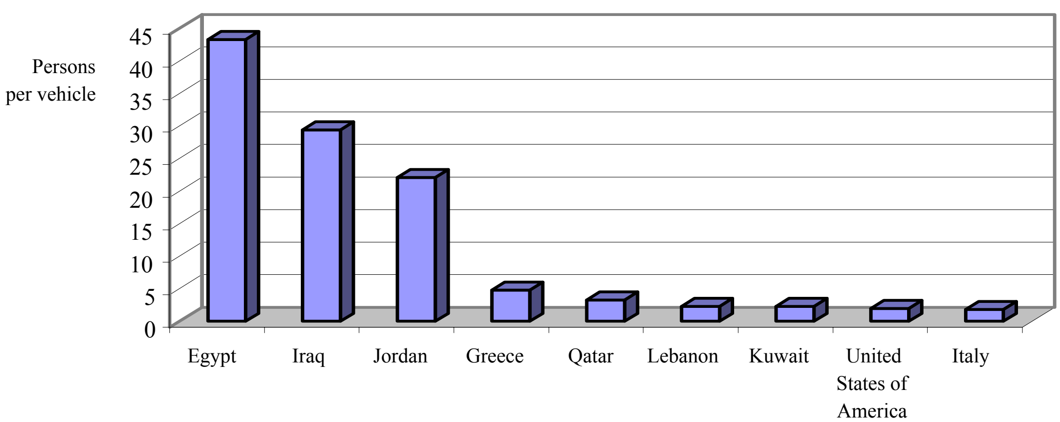
In 1995 Lebanon ratified the UNFCCC and has since developed a GHG inventory in accordance with the revised guidelines of the Intergovernmental Panel on Climate Change.[31] The results of the inventory indicated that the energy sector contributed 85 per cent of all CO_2 emissions in Lebanon. The transport sector was shown to be a major contributor, because rates of car ownership in Lebanon are closer to those recorded in industrialized nations than to rates in many other ESCWA member States. Part of the reason for this may be found in the civil disturbances that took place in Lebanon, which seriously damaged the transport sector infrastructure and forced people to depend on private vehicles for personal travel and business. Taking these factors into account, this chapter provides an overview of the transport sector in Lebanon, introduces a number of GHG mitigation strategies that could be implemented in Lebanon and evaluates each.

A. THE STRUCTURE OF THE TRANSPORT SECTOR IN LEBANON

1. *The structure of the transport sector*

In 1994, the base year for Lebanon's GHG inventory, the Lebanese transport sector constituted a fleet of about 1.2 million registered vehicles. It was estimated that more than 70 per cent of the vehicles were more than 15 years old, and tended to be poorly maintained. There was about one vehicle for every three people in 1994. By 1997, the national vehicle fleet had increased to 1,391,473 vehicles and the car ownership rate reached one vehicle for 2.3 people, one of the highest rates in the region and in the world (see chart 13). In addition to the GHG emissions problems these vehicles create, transport is causing serious local air pollution problems in Lebanon, in particular in major cities and areas of permanent traffic congestion.[3, 32]

Chart 13. Vehicle ownership rates in selected countries



Without a regular vehicle inspection and maintenance programme, there are no annual benchmarks against which vehicle performance can be measured over time. The authorities in Lebanon are therefore unable to update existing records or to ensure vehicles comply with emission standards.

2. *Energy consumption within the transport sector*

In 1997 in Lebanon, fuel consumption for road transport was 1.953 Mtoe. Most of this was gasoline (86.6 per cent of the total) or diesel (13.4 per cent).[3]

In the past decade, the price of transport fuel in Lebanon has increased as a result of additional taxes gradually imposed by the Government. It should be noted, however, that these increases have had only limited effect on fuel consumption because of the lack of alternative means of transport and the fact that, even with the extra taxes, fuel in Lebanon is still cheap compared with average income. Another factor likely to contribute to continuing high levels of fuel consumption in Lebanon is the modern road network, especially in the Greater Beirut area, which encourages people to live in the city's less expensive outskirts, from where they must spend longer commuting to the city centre.

In the past three years, Lebanon has suffered from excessive vehicle exhaust emissions, which are a result of the uncontrolled use of low-quality diesel fuel for small passenger taxis. By the end of 2000, only about 18 per cent of vehicles in Lebanon were using unleaded fuel. Catalytic converters are still regarded as luxury items in Lebanon and are therefore subject to higher import taxes.

In 2001, the Lebanese Parliament approved new regulations including an immediate ban on the import of small buses (carrying up to 22 passengers) that use diesel fuel. This measure is to be followed in a year by a complete ban on the use of such buses and the import of used diesel engines. These bans will be accompanied by mechanisms for financial compensation. The new regulations also include an adjustment to fuel pricing so that unleaded fuel becomes 10 per cent cheaper than leaded gasoline from January 2002. Bans on the importation of leaded fuel will be introduced in July 2002, which is also when the annual inspection and maintenance programme that was cancelled in 1997 is due to be reinstated.

B. ASSESSMENT OF GHG ABATEMENT MEASURES IN LEBANON

1. *Identification of options*

Several studies on transport-related environmental problems have been conducted in Lebanon in an attempt to identify the most feasible solutions.[32] Based on the findings of these studies a range of measures has been recommended including the following technological and policy-based options.

(a) *Improving the condition of the national vehicle fleet*. Levels of transport-related GHG emissions are, in general, determined by a number of factors including fuel type, the condition of a vehicle, its fuel consumption rate, distances travelled and time spent travelling. Lebanon, being a car-importing country, has no direct control on the design of vehicles, but it can impose controls on the specifications of imported vehicles. A more effective short-term measure is to encourage the importation of newer cars in order to reduce the average age of the national vehicle fleet. The re-instatement of the inspection and maintenance programme is also expected to bring about a significant improvement in the overall condition of the national vehicle fleet, with consequent reductions in GHG emissions of 10–15 per cent. The quality of imported transport fuels must also be controlled;

(b) *Improving urban traffic management*. Most urban regions in Lebanon, especially in the Greater Beirut area, are subject to extremely heavy traffic, causing long delays and extending travelling time. Studies have shown that the average speed on 75 per cent of streets in the Greater Beirut area is less than 20 km/h. When compared to average speeds in major cities worldwide (40–50 km/h), this translates into an average delay of about 70 per cent, and a corresponding increase in GHG emissions. The main reasons for the problem in Beirut in particular are the lack of modern traffic management and parking systems, and the low level of utilization of public transport. Improving traffic management systems and providing an efficient and reliable public transport are therefore expected to produce 40–50 per cent reductions in vehicle emissions;

(c) *Promoting the use of cleaner fuels*. Options such as the use of alternative fuels and vehicle technologies are regarded as medium- and long-term strategies. The development of hybrid electric vehicles with high energy efficiency and greatly reduced levels of GHG emissions is particularly promising. Fuel consumption for hybrid electric vehicles in urban areas is about 64 per cent of consumption by conventional vehicles driving in similar conditions (see table 45). The unit price of hybrid electric vehicles is almost 25 per cent more than the equivalent gasoline-fuelled vehicle;

(d) *Promoting the use of mass transport*. Mass transport is an effective way to address ever-increasing transport needs. Long-term projections (to 2015) for transport demand indicate that the number of journeys by motor vehcile in the Greater Beirut area will probably increase from 1.5 million a day in 1994 to

5 million a day by 2015. To cope with this tremendous increase, two alternative strategies have been considered. The first strategy focuses on the development of a large-scale rail freight system. The alternative approach is to work around existing trends by planning for intensive use of private vehicles with further development of the road network (see table 46).

TABLE 45. FUEL CONSUMPTION FOR SELECTED DRIVING ENVIRONMENTS
(*Litres per 100 kilometres*)

Driving environment	Standard conventionally-fuelled 1 500 cc car	Hybrid electric vehicle
Urban	7.6	4.9
Highway	6.5	4.4

Source: D. Hermance and S. Sasaki "Hybrid electric vehicles take on the streets," *IEEE Spectrum*, November 1998.

TABLE 46. ALTERNATIVE PASSENGER TRANSPORT STRATEGIES FOR THE GREATER BEIRUT AREA

	Mass transit	Private vehicles
Average speed for morning peak traffic	22 km/h	18 km/h
Average trip duration	34 minutes	40 minutes
Mass transport market share (%)	33	16
Small vehicle share (%)	67	84
Investment in roads	$4 850 million	$5 650 million
Investment in railway-metro network (millions of dollars)	$3 160 million	$540 million
Investment in bus network (millions of dollars)	$70 million	$320 million
Total investment (millions of dollars)	$8 080 million	$6 510 million

Source: Lebanon, Ministry of Environment, Lebanon's first national communication under the UNFCCC, 1997.

The projected share of small vehicles (private cars and taxis) in 2015, should the mass transit strategy be implemented, is 67 per cent, whereas the strategy involving the development of the road network is expected to produce a higher share—84 per cent. The increase in average speeds from 18 km/h to 22 km/h brought about by the implementation of the mass transit strategy produces an improvement in fuel efficiency of about 30 km per 20 litres of gasoline, which should also reduce GHG emissions.

The mass transit strategy is based on the development of a heavy rail network consisting of six lines. At full implementation, the system would require about 30 trains (of four carriages each), with each train covering approximately 90,000 km per year. These trains would be powered by electricity, using a third-rail electrification system.

2. *Assessment of the options*

The following three measures have been adopted for the Lebanese transport sector:

(a) Introduce hybrid electric vehicle technology, without use of incentives. It is expected that hybrid electric vehicles would, in this case, constitute just 1 per cent of the national vehicle fleet by 2015;

(b) Introduce hybrid electric vehicles and apply appropriate incentives—for example, waiving registration fees. It is expected that the share of hybrid electric vehicles in the national fleet by 2015 could be increased to 10 per cent by the adoption of incentives;

(c) Promote the use of electric trains for freight and passenger transport. The "cost" of such a scheme, which would be phased in over a period of 10 years, is calculated to be about $1.57 billion.

These three measures are compared in table 47, which presents the costs, savings and reductions of selected GHGs expected from each option. The benefit-to-cost ratio indicates the feasibility of the measure; without taking into account the social costs of pollution, a mitigation option with benefit-to-cost ratio greater than one is regarded feasible and profitable. This analysis indicates that the use of mass transit—in particular, rail freight—is the most attractive option. It provides a relatively high benefit-to-cost ratio that ranges from 2.38 to 4.21, depending on the national interest rate used in the calculation.

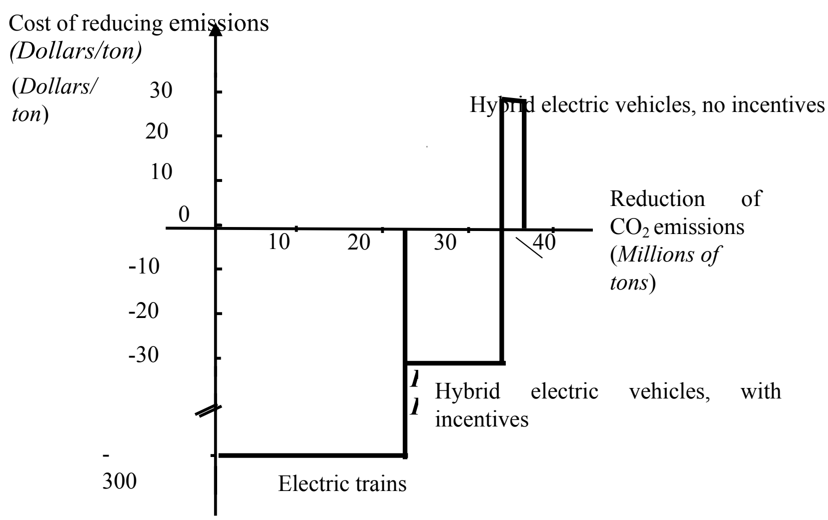
TABLE 47. COST COMPARISON OF GHG ABATEMENT OPTIONS FOR LEBANON, 1994
(*Millions of dollars*)

Scenario	Interest rate (*Percentage*)	Savings (*Millions of dollars*)	Costs (*Millions of dollars*)	Benefit-to-cost ratio	Cost of reducing GHG emissions (*Dollars per ton*)		
					CO_2	CO	$N0_x$
Hybrid electric vehicles without incentive	5	975	990	0.9848	40	120	3100
	10	261	265	0.987	30	190	4 880
	15	90.6	92.4	0.988	20	100	2 600
Hybrid electric vehicles with incentive	5	9 970	9 840	1.01	(86.58)	(420)	(10 800)
	10	2 666	2 629	1.01	(28.4)	(136)	(3 550)
	15	930	918	1.01	(26.8)	(130)	(3 350)
Freight transport by electric train	5	12 160	2 890	4.21	(390)	(1 860)	(48 380)
	10	3 063	981	3.12	(300)	(1 450)	(37 720)
	15	1 046	439	2.38	(130)	(600)	(15 620)

Source: Lebanon, Ministry of Environment, Lebanon's first national communication under the UNFCCC, 1997.

Notes: Parentheses ( ) indicate negative; dollars are 1994 dollars.

Chart 14. Cost and emissions reductions of selected GHG abatement measures in Lebanon



Source: ESCWA, "Opportunities for GHGs abatement in the Lebanese transport sector." A Background paper presented at the Expert Group Meeting on Energy for Sustainable Development in ESCWA Member States: The Efficient Use of Energy and Greenhouse Gas Abatement, held in Beirut on 8–11 October 2001.

Several ESCWA member States, such as Egypt and the Syrian Arab Republic, have established rail networks throughout their territories. In other countries, considerable benefit could be gained by developing national rail systems in order to relieve some of the burden on their roads.

While the introduction of an electrified rail system may be the best strategy for reducing transport-related GHGs in Lebanon, other measures—such as the Government's recent restrictions on the use of diesel fuel and the introduction of financial incentives for the use of unleaded gasoline—could, if sustained, prove effective in controlling GHG emissions;

The promotion of natural gas as an alternative fuel is another viable option in Lebanon in the long term, once natural gas becomes available to the electric power and transport sectors via the international gas network between Egypt, the Syrian Arab Republic, Lebanon and other countries, which is in the early stages of implementation.

C. RECOMMENDATIONS AND CHALLENGES FOR GHG ABATEMENT [32]

The following areas of focus are recommended for transport-related GHG abatement projects in Lebanon:

(a) *Improving the condition of the national vehicle fleet*. Three measures are recommended in this catetory. The first is the introduction of financial incentives for the adoption of new, more efficient technologies such as hybrid electric vehicles. Consultations with local car dealers gives reason to believe that waiving Government-imposed car-registration fees would be an effective incentive. The second measure is the passage of legislation relating to fuel and vehicle importation, including bans on the importation of older vehicles and the use of industrial diesel for transport fuel. The third measure that could be taken to improve the condition of vehicles in Lebanon is the reinstatement of the technical inspection and maintenance programme. Approval for this measure and the diesel ban have already been granted by the Government of Lebanon;

(b) *Upgrading traffic management systems*. The modernization of the traffic management systems in urbanized areas could be achieved by redesigning, reschedluling and relocating traffic signals and improving the road network. Improvements in the availablity and regulation of parking would also help to streamline traffic flows and reduce GHG emissions, as would zoning restrictions that discouraged people from driving into heavily built-up areas, in particular in the Greater Beirut area. A corresponding modernization of urban planning and building codes would increase the impact of these measures;

(c) *Promoting the use of public transport*. The development of a rail system for freight and passenger transport has been shown to be the optimal strategy for reducing transport-related GHG emissions in Lebanon. Expert studies have already been conducted investigating the feasibility of this measure, and would provide a good starting point for its implementation. The existing public transport system could be improved in terms of its reliability and it could be promoted more actively in order to increase public acceptance of using mass transit.

The taxation system could also be better utilized to provide financial incentives that would increase the impact of all the measures detailed above. The September 2001 decicion to make unleaded fuel 10 per cent cheaper than leaded fuel supports this argument; within four weeks of the decision taking effect, the proportion of unleaded fuel sold in Lebanon increased from about 20 per cent to 70 per cent of the market.

There are, however, several barriers that must be overcome in order to implement strategies to reduce transport-related GHG emissions in Lebanon. There is, for example, a shortage of knowledge among the public and decision makers regarding cleaner, more efficient technologies. There is also a shortage of data relating to patterns of end-use energy consumption in all sectors of the economy in Lebanon. There is likewise insufficient awareness of and documentation relating to the economic, environmental and social implications of existing technologies and trends. Finally, economic and financial barriers exist as a result of a lack of dedicated financing programmes or special incentives for the promotion of clean, renewable energy systems. This issue must be addressed through appropriate planning and financing.

VI. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

The present study has identified a range of methods by which transport-related emissions of GHGs might be controlled and ultimately reduced. Several options that are considered particularly relevant to the circumstances of ESCWA member States have been selected and evaluated, and ranked in order of priority. The options found to provide the best returns in terms of reducing emissions encourage and facilitate greater energy efficiency in the transport sector; the use of cleaner fuels; and a more sustainable approach to transport management. Reductions in GHG emissions, which constitute the prime objective of the UNFCC and the Kyoto Protocol, have additional environmental and health benefits at the local and the global levels. The main issues addressed in the study are reviewed in brief below.

1. *The ESCWA transport sector and GHG abatement options*

(a) *The ESCWA transport sector*. The transport sector in the ESCWA region is extremely energy-intensive and is a major contributor to regional GHG emissions. In 1997, the 14,450,995 vehicles operating in the ESCWA member States consumed about 39.46 Mtoe, or 16.85 per cent of the region's total primary energy consumption. In 1998, the transport sector produced 108.3 million tons of CO_2, or 15.37 per cent of all CO_2 produced by the energy sector. Clearly, there is a need for immediate, effective action to reduce transport-related emissions of GHGs in the ESCWA region. In view of the international GHG mitigation initiatives established by the UNFCCC and the Kyoto Protocol, it is important that ESCWA member States each identify the options that will be given priority in their national contexts;

(b) *GHG abatement options*. Methods of reducing GHG emissions tend to fall into the following four categories:

(i) Advanced technology vehicles and alternative fuels, including electric and clean-fuel vehicles;

(ii) Improving transport fuel quality;

(iii) Policy and traffic management measures;

(iv) Adopting appropriate environmental regulations and standards.

Details relating to the current development status, costs and existing use of various GHG reduction methods can be found in the body of the study.

(c) *Evaluation, ranking and constraints on implementation of GHG reduction methods*. Seven options were identified and their feasibility examined with reference to the particular circumstances of the ESCWA region. All seven options were evaluated against the following criteria:

(i) Effectiveness in reducing GHG emissions;
(ii) Capital costs;
(iii) Operation and maintenance costs;
(iv) Implementation difficulties;
(v) Potential for replication;
(vi) Non-environmental benefits;
(vii) Sustainability.

The rankings that were calculated for the seven options are as follows:

(a) Improving vehicle maintenance;
(b) Introducing CNG vehicle technology;
(c) Restricting vehicle ownership and use;
(d) Improving traffic management;

(e) Better urban planning;
(f) Promoting the use of public transport;
(g) Developing and enforcing environmental standards and regulations.

A range of potential obstacles to the implementation of this list of options was identified, including: the need for appropriate infrastructure; the lack of adequate financial resources; the lack of appropriate institutions to carry out implementation; the lack of existing policies dealing with environmental and transport management issues; and insufficient public awareness of environmental issues. Recommendations were made for dealing with these constraints.

2. *Case study of Egypt*

Since 1993, Egypt has worked to assess national levels of GHG emissions and to identify means by which they might be reduced. Environment Law No. 4 of 1994 and its executive regulations established standards for air quality, and a national air quality management programme, with a strong focus on reducing vehicle emissions, was initiated. The information gathered through Egypt's experience of a number of GHG mitigation measures can be of great benefit to other ESCWA member States as they begin to develop their own strategies for controlling transport-related GHG emissions.

In particular, Egypt has considerable experience in the introduction of natural gas vehicle technology, and is conducting trials of fuel cell buses. In Cairo, an air quality project has been established, promoting higher levels of vehicle maintenance and, as already stated, environmental standards and regulations have been established. The most feasible options for the reduction of transport-related GHG emissions in Egypt—which were not markedly different from those recommended for the region as a whole—were identified and ranked as follows:

(a) Converting vehicles to run on CNG;
(b) Improving traffic management;
(c) Improving vehicle maintenance and engine tuning;
(d) Promoting the use of public transport.

More detailed investigation of the anticipated reductions in GHG emissions that could be gained through the implementation of the highest-ranking option—the conversion of vehicles to run on CNG—established that this was a particularly viable option for Egypt and for many other ESCWA member States (subject to the availability of natural gas).

3. *Case study of Lebanon*

Taking into account the results of the GHG inventory and other studies carried out in Lebanon, it was determined that the establishment of an electrified heavy rail system was the optimal method for mitigating GHG emissions there. Other, less capital-intensive options that could also be pursued included encouraging the use of cleaner technologies and fuels, and reinstating the vehicle inspection programme that operated in the past. Improving traffic management would also produce reductions in GHG emissions, as would the further development of the existing public transport system. Experience in Lebanon has demonstrated that the use of financial incentives can be a very useful way of maximizing the effectiveness of any GHG abatement measures that are implemented.

B. CONCLUSIONS

The transport sector is one of the most energy-intensive sectors in the ESCWA region. Emissions of GHGs and other pollutants have adverse environmental impacts at both the local and global levels and transport-related emissions also have negative impacts on public health at the local level.

Population growth in the ESCWA region brings with it increasing numbers of vehicles on the region's roads. These vehicles tend to be concentrated in the already congested urban areas and if their numbers continue to grow unchecked, they will ultimately create pollution crises in the region's major cities.

Currently, transport pollution is not receiving the attention it deserves in the ESCWA region, for a number of reasons, *inter alia*: insufficient awareness of the magnitude of the pollution problem; limited awareness of and knowledge about ways to reduce GHG emissions; limited access to country-specific information about environmental and transport issues; the high cost of some of the available measures for improving energy efficiency and reducing pollution; and the limited capability of local energy and environmental support services.

Governments in the ESCWA region will need to take the lead in reducing the negative environmental impacts of the transport sector. They can do this by developing and implementing transport sector energy policies that promote greater energy efficiency and the use of alternative or clean fuels. They should develop markets for cleaner transport fuels and technologies, and support public transport.

Several GHG mitigation measures have been evaluated and ranked in order of their feasibility for implementation in the ESCWA region. The seven priority options that were thus identified represent a range of technologies and regulatory measures. They are, ranked in order of priority, the following:

(a) Improving vehicle maintenance;
(b) Introducing CNG vehicle technology;
(c) Restricting the use and ownership of private vehicles;
(d) Improving traffic management;
(e) Better urban planning and land use;
(f) Promoting the use of public transport;
(g) Developing environmental standards and regulations.

This list can be adapted to meet country-specific requirements. Each ESCWA Member State could therefore select the options most appropriate to its economic, social and political circumstances. The selection process should also include consideration of the time required for the implementation of each option. The following measures, however, should receive special attention:

(a) Setting and working towards energy efficiency targets for national vehicle fleets. These targets should be both attainable and effective;

(b) Integrating urban development and transportation planning, with an emphasis on promoting mass transit and other relatively "clean" modes of transport. In this way, Governments can achieve greater accessibility within urban environments while mitigating the adverse impacts of motorized transport;

(c) Removing or reducing government subsidies on fuel (where they exist) and introducing or reformulating taxation and user costs for vehicle use and ownership. The lifetime costs for a vehicle should reflect the environmental costs associated with its use in order to encourage the use of public transport and non-motorized modes of transport;

(d) Establishing and enforcing meaningful pollution prevention standards and setting up associated inspection and maintenance programmes for all modes of transport.

The successful implementation of GHG abatement strategies depends heavily on the development of partnerships between businesses, communities and environmental activists, with all parties investing time, talent, and resources.

A number of challenges and constraints could hamper the implementation of the recommended options, *inter alia*: the scarcity of financial resources; the limited level of existing national and/or regional strategies for GHG abatement; the lack or limited enforcement of existing regulations; the need for capacity building relating to abatement of GHG emissions; the low priority accorded environmental issues by policy makers; and an insufficient level of environmental awareness among the general population.

If GHG mitigation strategies are to be effectively implemented, it is necessary to take into account the concerns of all stakeholders and to balance these with the requirements of the transport sector. Stakeholders include private and commercial transport users, vehicle manufacturers, fuel suppliers, road planners and builders, and various services providers.

The experience gained by Egypt in various methods of controlling transport-related GHG emissions can serve as a valuable resource for other ESCWA member States as they develop their own strategies. The CNG vehicle conversion programme could prove to be a particularly viable option in many ESCWA member States with large reserves of natural gas.

In Lebanon, while the use of electric trains was found to be the best option for mitigating transport-related GHG emissions, the sustained implementation of additional measures—such as encouraging the use of unleaded gasoline and banning the use of diesel fuel—will have a great impact on levels of GHG emissions. Despite the fact that Lebanon does not have large reserves of natural gas, CNG vehicle conversion may also become a viable option there when the planned gas pipeline network linking Lebanon and other countries comes to fruition.

C. General recommendations

In view of the challenges and constraints outlined above, the implementation of the GHG abatement options presented in this study should be preceded by a number of activities—at the national and/or regional levels—that will improve their chances of success.

1. *Recommended action at the national level*

(a) The ESCWA member States should work to establish national strategies and strengthen existing measures to integrate efforts to improve transport-sector energy efficiency and pollution control. These issues should be considered together during transport planning as well as within general national energy planning;

(b) Governments in the region must develop and implement policies that encourage better transport efficiency and the use of alternative fuels;

(c) Policies and legislation that will support the above strategies must be developed and implemented. The existence of an appropriate legal framework makes the implementation of such strategies more effective;

(d) Efforts should be made to secure funding to finance the recommended GHG abatement options in the ESCWA member States. External funding should be sought from regional and international organizations, as well as from wealthier countries, in order to make up for any lack of national resources;

(e) It is important that the degree of capacity building required in the ESCWA member States relating to the monitoring and control of GHG emissions should be identified. Support, if and when required, should be solicited from established regional or international institutions;

(f) Individuals should make an effort to cultivate more energy-efficient transport habits.

2. *Recommended action at the regional level*

(a) Conduct regional expert meetings to discuss—in view of the capabilities and constraints existing in each member State—the options that have been recommended in this study, and the potential for regional cooperation. Such meetings could significantly increase the effectiveness of action taken to reduce GHG emissions and would provide a forum in which the views of all stakeholders could be presented;

(b) Investigate and facilitate regional cooperation where possible;

(c) Design and carry out national and regional campaigns to increase support and participation by the public and decision makers in efforts to limit the adverse environmental impacts and health risks associated with vehicle emissions;

(d) Coordinate efforts to review, update and harmonize regulations and standards relevant to the energy used and pollution generated by the transport sector at the national and regional levels. These efforts are vital for the establishment of sustainable energy consumption patterns and for the control of pollution in the region;

(e) Work to remedy deficiencies in the existence and availability of information relating to transport sector energy use and the environment in the region. In particular, information regarding vehicle ownership and use, energy consumption, driving conditions and pollution emissions are of vital importance in the formulation of sound policies and effective long-term strategies to reduce the negative environmental impacts of the transport sector;

(f) The ESCWA secretariat should continue its efforts to facilitate the exchange of information and coordination and cooperation among its member States in relation to energy efficiency in the transport sector and the evaluation of the results of GHG reduction projects implemented in the region.

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Annex I

THE ENVIRONMENTAL IMPACTS OF THE TRANSPORT SECTOR

Despite the vital importance of transport sector to the economic and social development of any country, this energy-intensive sector can have extremely negative environmental impacts. The various chemical contaminants that are emitted by transport-related activities can adversely affect humans and the natural environment alike. Health problems arising from transport emissions may include respiratory disease and heart disorders, and exposure to carcinogenic substances. Environmental problems include rising sea levels as a result of global warming and the disruption of the water cycle.

A. THE SECTOR'S ENVIRONMENT AND HEALTH IMPACTS

1. *Environmental impacts*

All modes of transportation have some environmental impacts. The extent and severity of those effects vary, however, depending on the mode of transport and the environment in which it operates. Of the various modes of transport, road transport is the main contributor to urban air pollution and congestion. Aviation causes local noise pollution and gases it emits into the stratosphere contribute to the depletion of the ozone layer. Maritime transport causes environmental damage is through the spillage of oil and other contaminants, whereas rail transport creates noise pollution and the fossil fuels burned to power trains contribute to air pollution.

POTENTIAL ENVIRONMENTAL IMPACTS BY MODE OF TRANSPORTATION

Mode of transport and operating environment	Impacts on air quality	Impacts on water resources	Impacts on land resources	Other impacts
Road				
Motor vehicles operating on urban streets and highways	Engine and evaporative emissions of CO, CH, NO_X, particulate matter and lead; emissions of CO_2 from fossil fuel combustion, CFCs released during vehicle manufacture and disposal.	Surface and groundwater pollution from runoff (lubricants, coolants, vehicle deposits); modification of water systems during road building.	Land taken for infrastructure; extraction of road building materials; abandoned rubble from road works; disposal of road vehicles withdrawn from service, waste oil, tyres and batteries.	Local noise; congestion.
Rail				
Trains (freight, intercity passenger and transit rail services running on railway tracks	Engine and evaporative emissions of CO, CH, NO_X and particulate matter; emissions of CO_2 from fossil fuel combustion, CFCs released during vehicle manufacture and disposal.	Pollution from leakage of oil and grease from trains, and creosote from track beds.	Land taken for rights-of-way and terminals; dereliction of obsolete facilities; abandoned lines, equipment and stock.	Local noise.

POTENTIAL ENVIRONMENTAL IMPACTS BY MODE OF TRANSPORTATION (*continued*)

Mode of transport and operating environment	Impacts on air quality	Impacts on water resources	Impacts on land resources	Other impacts
Aviation				
Aircraft, operating from airports	Engine and evaporative emissions of CO, CH, NO_X, particulate matter and lead; emissions of CO_2 from fossil fuel combustion, CFCs released during aircraft manufacture and disposal.	Modification of water tables, river courses and field drainage by airport construction; chemicals to prevent ice formation and degreasers used on runways can enter watercourses.	Land taken for infrastructure; dereliction of obsolete facilities; aircraft withdrawn from service; buffer zones for noise abatement.	Local noise.
Maritime				
Marine vessels operating from port facilities and on canals	Engine and evaporative emissions of CO, CH, NO_x, particulate matter and lead; emissions of CO_2 from fossil fuel combustion, CFCs released during vessel manufacture and disposal.	Pollution through the discharge of ballast water or sanitation devices; oil spills; modification of water systems during port construction and canal cutting and dredging.	Land taken for infrastructure; dereliction of obsolete port facilities and canals and vessels and craft withdrawn from service; disposal on land of dredged material.	Plastic and other wastes disposed of at sea.

Source: Global Transport and Energy Development. World Energy Council, 1988.

2. *Impacts on health*

In addition to their environmental impacts, many of the pollutants emitted by the transport sector, in particular by motor vehicles, have serious health impacts.

HEALTH IMPACTS OF SELECTED VEHICLE EMISSIONS

Substance	Source	World Health Organization limits	Health impacts	Environmental effects
Carbon monoxide	90 per cent of total world emissions of CO comes from the transport sector in general, and 65 per cent comes from motor vehicles.	100 mg/m^3 over 15 minutes (86 ppm) or 10 mg/m^3 over eight hours (8.6 ppm).	Fatal in large doses; aggravates heart disorders; can affect the central nervous system; impairs oxygen-carrying capacity of blood, resulting in impaired perception, slowed reflexes and drowsiness.	Contributes to global warming by removing hydroxyl radicals from the air.

HEALTH IMPACTS OF SELECTED VEHICLE EMISSIONS (*continued*)

Substance	Source	World Health Organization limits	Health impacts	Environmental effects
Nitrogen oxide	47 per cent of total world emissions of NO_2 comes from motor vehicles.	400 mg/m^3 over one hour (208 parts per billion) 150 mg/m^3 over 24 hours (68 parts per billion).	Irritation of respiratory tract; reduced lung function; and increased susceptibility to viral infections.	Acid rain; indirect contribution to global warming through the formation of ground-level ozone (smog).
Ozone	Interaction of hydrocarbons and nitrogen oxides in the presence of sunlight.	150-200 mg/m^3 over one hour (75-110 parts per billion).	Eye, nose and throat irritation; poses a risk to asthmatics, children and those involved in heavy exercise.	Damage to vegetation and crops; contributes to global warning; remains in soil, from where it reaches the food chain; can also be inhaled directly into the blood stream.
Lead	Gasoline additive.	0.5-1.0 mg/m^3 over one year.	Extremely toxic; affects nervous system and blood; can impair mental development of children; causes hypertension.	
Hydrocarbons	Up to 50 per cent of total world emissions of HC comes from vehicle emissions (excluding methane).	No general limit specified.	Drowsiness; eye irritation; coughing.	Indirect contribution to global warming through the formation of ground-level ozone (smog).
Benzene	Vehicle emissions; evaporative gasoline losses; cigarette smoking.	The World Health Organization recognizes no safe level.	Carcinogenic.	None identified to date.
Polyaromatic hydrocarbons	Mainly emitted from diesel fuel.		Carcinogenic.	
Carbon dioxide	Vehicle emissions.		None.	The most abundant greenhouse gas.

Source: Global Transport and Energy Development. World Energy Council, 1988.

B. REGIONAL IMPACTS

Evidence supports the argument that concentrations of GHGs (such as CO_2) emitted from the transport sector (and other sectors) are increasing in the atmosphere and accelerating global warming. Changes in regional climates as a result of factors such as vehicle emissions are also evident. The magnitude of regional effects remains uncertain, however. This is mainly due to the limitations of the available model for predicting climate change on a scale at which environmental impacts could be reliably estimated.

Indications of the impacts of climate change in the ESCWA member States—most of which are classified as arid or semi-arid areas—have been reported in various IPCC reports, in the national communications of ESCWA member States submitted under the UNFCCC, and in climate change studies presented at workshops held in the region in recent years. According to the assessment of the IPCC in 1997, the impacts are likely to be felt in the following areas:

(a) *Ecosystem*. Little change in vegetation models is expected; deserts will remain deserts. Semi-arid areas may experience more significant change in terms of the type and distribution of vegetation. Small increases in precipitation are expected but these will be counteracted by increases in temperature and evaporation rates. Grasslands and water resources will be the most vulnerable to climate change;

(b) *Hydrology and water resources*. Most countries in the region already suffer from a water deficit and this problems is expected to become more serious as a result of climate change;

(c) *Food production*. Problems associated with land degradation and the deterioration of water quality currently restrict agricultural productivity in the ESCWA region. This may threaten the food security in some countries;

(d) *Human health*. Climate change could lead to an increase in heat stress that may affect comfort levels. There is also a possibility that climate change could cause increased incidence of some diseases;

(e) *Rising sea level*. The anticipated rise in sea level, mainly as a result of polar ice melting, may threaten some coastal zones in the ESCWA region.

More specific impacts reported by some ESCWA member States are presented below.

IMPACTS OF CLIMATE CHANGE IN SELECTED ESCWA MEMBER STATES

Country	Environmental impacts
Egypt	The average night-time minimum temperature has increased by about 0.5^{o}C. This will result in higher evaporation rates and makes the Nile River, which is the source of 97 per cent of Egypt's water, more sensitive to further temperature changes. The average daytime maximum temperature has declined slightly (by about 0.1^{o}C). Rainfall rates have increased over the north coast and declined in the south. Solar radiation has declined as a result of increased turbidity (smog). Relative humidity has increased.
Lebanon	A growing water deficit and an increase in ground water salinity have been recorded along the coastal region as a result of seawater intrusion. The rainfall rate has changed over the past two decades. River systems are becoming more fragile as a result of lower levels of rainfall, in addition to other factors such as excessive exploitation of water resources and increasing levels of pollution. Increased water temperatures may also lead to a reduction in riverbank vegetation. Areas at altitudes of more than 1,500 metres are the most vulnerable to climate change.
Syrian Arab Republic	Water salinity has increased, mainly as a result of the rising sea level. This has exacerbated the existing processes of desertification. Water availability has declined as a result of increased evaporation and increasing demand.
United Arab Emirates	The availability of ground water has declined, while its salinity has increased.

Source: Compiled from various national and international sources.

Annex II

CLIMATE CHANGE AND INTERNATIONAL MITIGATION INITIATIVES

Climate change, also referred to as global warming or the greenhouse effect, as defined by the UNFCCC, is "a phenomenon attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which, in addition to natural climate variability, is observed over comparable time periods". The main anthropogenic GHGs that persist in the atmosphere are: carbon dioxide, methane, nitrous oxides, chlorofluorocarbons, hydrofluorocarbons and sulphur hexafluoride. There are several other gases with a shorter lifespan that also have an impact on global warming, including: ozone; carbon monoxide; non-methane volatile organic compounds; aerosols and water vapour.

Currently, global warming is regarded as a major threat, particularly to the environment, upon which all life ultimately depends. Consequently, a concerted international effort is being made to identify and implement measures that will control emissions of GHGs and minimize their associated environmental impacts. The major international agreements on climate change are described below.

A. FRAMEWORK CONVENTIONS AND PROTOCOLS FOR GHG REDUCTION

The last decade of the twentieth century witnessed the conclusion of two major international agreements that aimed to achieve reductions in anthropogenic emissions of CO_2 and other GHGs. These are the 1992 UNFCCC, and its 1997 Kyoto Protocol.

The UNFCCC was adopted in May 1992 and in little more than a year, had more than 160 signatories. It entered into force in March 1994. The ultimate objective of the UNFCCC, as stated in Article 2, is "to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system".

As a first step towards this goal, parties to the Convention agreed to adopt policies and measures to mitigate GHG emissions and to facilitate their removal from the atmosphere through the use of sinks. The developed countries and economies in transition (known as Annex I Parties) in particular were urged to reduce their GHG emissions to 1990 levels by 2000. Annex II Parties (developed countries only) also assumed an obligation to provide financial, technical and technological assistance relating to GHG abatement to developing countries. All Parties, including the developing countries, are to prepare and periodically update inventories of their national GHG emissions and sinks, and to produce national communications on their climate change policies and measures.

In December 1997, the Kyoto Protocol was adopted at the third session of the Conference of the Parties to the UNFCCC. The Protocol establishes a legally binding obligation on Annex I countries to reduce their emissions of six greenhouse gases (CO_2, CH_4, N_2O, CO, NO_X and NMVOC) with the aggregate reduction for the commitment period 2008–2012 to bring levels to at least 5 per cent below those recorded in1990. There are no such obligations on developing countries.

Countries whose economies are in the process of transition were generally assigned targets that were higher than their existing levels of GHG emissions, in order to accommodate their anticipated economic growth. The Protocol lists a variety of actions that could help Parties meet their emissions targets, with an emphasis on modifying energy consumption. Parties are not obliged to follow these suggestions, however. Policy recommendations include: enhancing energy efficiency; promoting research and development, in particular relating to the exploitation of renewable energy sources; and measures designed to limit transport-related emissions. Some of the most innovative elements of the Protocol include: provisions for Joint Implementation of emissions abatement projects through which emission reduction units may be traded; a Clean Development Mechanism that allows developed nations to meet part of their emissions reduction obligations by investing in GHG abatement projects in developing countries; and emissions trading between nations.

More than 180 nations have ratified the UNFCCC. Apart from Iraq, all of the ESCWA member States have ratified the treaty. Jordan was the first to do so, in November 1993, and the most recent ratification was by Qatar, in April 1996. All ESCWA members that are parties to the Convention have been classified as developing countries.

RATIFICATION OF THE UNFCCC BY ESCWA MEMBER STATES

Country	Signed	Ratified	Entered into force
Bahrain	8 June 1992	28 December 1994	28 March 1995
Egypt	9 June 1992	5 December 1994	5 March 1995
Iraq	-	-	-
Jordan	11 June 1992	12 November 1993	21 March 1994
Kuwait	-	28 December 1994	28 March 1995
Lebanon	12 June 1992	15 December 1994	15 March 1995
Oman	12 November 1992	8 February 1995	9 May 95
Qatar	-	18 April 1996	17 July 1996
Saudi Arabia	-	28 December 1994	28 March 1995
Syrian Arab Republic	-	4 January 96	3 April 1996
United Arab Emirates	-	29 December 1995	28 March 1996
Republic of Yemen	12 June 1992	21 February 1996	21 May 1996

Source: http://www.unfccc.org/resource/docs.

The Kyoto Protocol has been signed by more than 94 states. Egypt is the only ESCWA member State so far to have signed the Protocol (in March 1999).

B. NATIONAL COMMUNICATION IN MEMBER COUNTRIES

Climate change initiatives in most ESCWA countries are designed in accordance with the IPCC guidelines, and national communications are generally implemented in cooperation with United Nations Environment Programme, and funded by the Global Environment Facility. A number of the ESCWA member States have initiated national GHG inventories; only four countries—namely, Egypt, Jordan, Lebanon, and Bahrain—have submitted an initial national communication to the UNFCC. Problems that might explain the delay in the submission of national communications include a lack of relevant expertise and guidance and the corresponding need for capacity building.

NATIONAL COMMUNICATIONS OF ESCWA MEMBER STATES TO THE UNFCCC

Country	Base year	Year of initial national communication	Submission date	CO_2 assessment for base year *(Gg)*	CH_4 assessment for base year *(Gg)*
Bahrain	1994	1998	May 2001	16 508	139.9
Egypt	1990	1995	19 July 1999	75 260	5.949
Jordan	1994	1997	6 March 1997	13 390	403.8
Lebanon	1994	1999	2 November 1999	13 803	52.4
Oman	1990	1994	Ongoing	-	-

Source: http://www.unfccc.org/resource/docs.

Note: A hyphen (-) indicates the item is not applicable.

Many ESCWA member States have established special bodies or units to develop their initial national communications and to provide annual updates on GHG inventories, as indicated below.

NATIONAL BODIES DEALING WITH CLIMATE CHANGE IN ESCWA MEMBER STATES

Country	Body
Bahrain	National Climate Change Committee consisting of the following ministries: Housing Municipalities and Environment; Foreign Affairs; Oil and Industry; Transportation; Finance and National Economy; and Works and Agriculture.
Egypt	National Climate Change Committee consisting of the Environmental Affairs Agency; the Energy Planning Agency; the Ministry of Petroleum; and the Ministry of Transport.
Jordan	General Corporation for Environment Protection.
Lebanon	Ministry of Environment.
Oman	The Ministry of Transport and Housing and the Ministry of Electricity and Water.

Source: http://www.unfccc.org/resource/docs.