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NATIONAL GREENHOUSE GAS INVENTORY REPORT AND MITIGATION ANALYSIS FOR THE TRANSPORT SECTOR IN LEBANON

2015 MINISTRY OF ENVIRONMENT

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National Greenhouse Gas Inventory Report and Mitigation Analysis for the Transport Sector in Lebanon

May 2015

This document should be referenced as:

MoE/UNDP/GEF (2015). National Greenhouse Gas Inventory Report and Mitigation Analysis for the Transport Sector in Lebanon. Beirut, Lebanon.

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National Greenhouse Gas Inventory Report and Mitigation Analysis for the Transport Sector in Lebanon

Reference projects

Enabling Activities for the Preparation of Lebanon's Third National Communication to the UNFCCC

Lebanon's First Biennial Update Report

Executed by

Ministry of Environment

Funded by

Global Environment Facility

Implemented by

United Nations Development Programme, Lebanon

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Foreword

Ministry of Environment

Through the publications of Lebanon's Initial and Second National Communications to the United Nations Framework Convention on Climate Change, and the Technology Needs Assessment for Climate Change, the Ministry of Environment drew the large climate change picture in the country. The picture shed the light on a number of climate change matters: Lebanon's contribution to global greenhouse gas emissions, the sectoral share of national emissions, the socio-economic and environmental risks that the country faces as a result of climate change, and the potential actions that could and should be undertaken to fight climate change both in terms of mitigation and adaptation.

Through these series of focused studies on various sectors (energy, forestry, waste, agriculture, industry, finance and transport), the Ministry of Environment is digging deeper into the analysis to identify strengths, weaknesses, threats and opportunities to climate friendly socio-economic development within each sector.

The technical findings presented in this report (National Greenhouse Gas Inventory Report and Mitigation Analysis for the Transport Sector) will support policy makers in making informed decisions. The findings will also help academics in orienting their research towards bridging research gaps. Finally, they will increase public awareness on climate change and its relation to each sector. In addition, the present technical work complements the strategic work of the National Climate Change Coordination Unit. This unit has been bringing together representatives from public, private and non-governmental institutions to merge efforts and promote comprehensive planning approach to optimize climate action.

We are committed to be a part of the global fight against climate change. And one of the important tools to do so is improving our national knowledge on the matter and building our development and environmental policies on solid ground.

Mohamad Al Mashnouk

Minister of Environment

Foreword

United Nations Development Programme

Climate change is one of the greatest challenges of our time; it requires immediate attention as it is already having discernible and worsening effects on communities everywhere, including Lebanon. The poorest and most vulnerable populations of the world are most likely to face the harshest impact and suffer disproportionately from the negative effects of climate change.

The right mix of policies, skills, and incentives can influence behaviour and encourage investments in climate development-friendly activities. There are many things we can do now, with existing technologies and approaches, to address it.

To facilitate this, UNDP enhances the capacity of countries to formulate, finance and implement national and sub-national plans that align climate management efforts with development goals and that promote synergies between the two.

In Lebanon, projects on Climate Change were initiated in partnership with the Ministry of Environment from the early 2000s. UNDP has been a key partner in assisting Lebanon to assess its greenhouse gas emissions and duly reporting to the UN Framework Convention on Climate Change. With the generous support of numerous donors, projects have also analysed the impact of climate change on Lebanon's environment and economy in order to prioritise interventions and integrate climate action into the national agenda. UNDP has also implemented interventions on the ground not only to mitigate the effects of climate change but also to protect local communities from its impact.

This series of publications records the progress of several climate-related activities led by the Ministry of Environment which UNDP Lebanon has managed and supported during the past few years. These reports provide Lebanon with a technically sound solid basis for designing climate-related actions, and support the integration of climate change considerations into relevant social, economic and environmental policies.

Ross Mountain

UNDP Resident Representative

Acknowledgements

The authors would like to acknowledge the UNDP/Ministry of Environment climate change team for their input and support, as well as their constructive reviews. We would also like to express our gratitude to the Lebanese Center for Energy Conservation (LCEC, Ministry of Energy and Water) and Dr. Toni Issa (IPTEC) for the data provision.

Finally, the Ministry of Environment would like to thank UNDP/GEF for funding the whole greenhouse gas inventory exercise.

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Acronyms

ASIF	Activity, Structural components, energy Intensity and Fuel use
ASK	Available Seat Kilometers
BAU	Business as Usual
BIA	Beirut International Airport
BRT	Bus Rapid Transit
CAS	Central Administration of Statistics
CDR	Council for Development and Reconstruction
CoM	Council of Ministers
DGCA	Directorate General of Civil Aviation
DGLM	Directorate General of Civil Aviation and Maritime Affairs
DGRB	Directorate General of Roads and Buildings
DO	Diesel Oil
EF	Emission Factor
EMEP/EEA	European Monitoring and Evaluation Programme/European Environmental Agency
EU	European Union
FEV	Fuel-Efficient Vehicles
ForFITS	For Future Inland Transport Systems
GBA	Greater Beirut Area
GDP	Gross Domestic Product
Gg	Gigagram or 1,000 tonnes
GHG	Greenhouse Gas
GWP	Global Warming Potential
HDV	Heavy-Duty Vehicles
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
IEA	International Energy Agency
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
LCC	Lebanese Commuting Company
LDV	Light-Duty Vehicles

M & E	Monitoring and Evaluation
MEA	Middle East Airlines
MMI	Mobility Monitoring Indicators
MoE	Ministry of Environment
MoEW	Ministry of Energy and Water
MoF	Ministry of Finance
MoIM	Ministry of Interior and Municipalities
MoMo	Mobility Model
MoPWT	Ministry of Public Works and Transport
MRV	Measuring, Reporting and Verification
NMVOCs	Non-Methane Volatile Organic Compounds
OCFTC	Office des Chemins de Fer et des Transports en Commun
PC	Passenger Cars
PKM	Passenger Kilometer
PPP	Purchasing Power Parity
PUCE	Parc, Utilization, Consumption and Emissions
QA/QC	Quality Assurance/Quality Control
RPK	Revenue Passenger-Kilometers
RPTA	Railway and Public Transport Authority
SNC	Second National Communication
SRS	Schedule Reference Service
SUV	Sport Utility Vehicle
TEU	Total Equivalent Unit
TMO	Traffic Management Organization
TNA	Technology Needs Assessment
TNC	Third National Communication
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
UNIFIL	United Nations Interim Force in Lebanon

Executive summary

In the framework of Lebanon's Third National Communication (TNC) to the United Nations Framework Convention on Climate Change (UNFCCC), Greenhouse Gas (GHG) emissions' trend resulting from the transport sector in Lebanon was estimated from 1994 to 2011. Calculations were made using the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories and the 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. The GHG emissions from the transport sector, namely carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), along with the indirect GHGs (carbon monoxide (CO), nitrogen oxides (NO_x), sulphur dioxide (SO_2) and non-methane volatile organic compounds (NMVOCs)) have been calculated in order to be reported to the UNFCCC as part of the TNC. The transport sector is divided into road transport, maritime transport, and aviation. Tier 2 was used for the calculation of emissions from road transport and tier 1 for the off-road transport, fisheries and yachts boats, and domestic aviation.

Inventory

Greenhouse gas emissions from transport totaled 3,629 Gg (Gigagram or 1,000 tonnes) CO_2eq. in 2005 and 5,423.98 Gg CO_2eq. in 2010, with carbon dioxide being the main gas emitted. Road transport is the largest contributor, emitting 3,619.23 Gg CO_2eq. in 2005 and 5,268.79 Gg CO_2eq. in 2010 and passenger cars have the highest share of emissions with an average of 60% of the total road transport GHG emissions.

Between 1994 and 2011, GHG emissions from the road transport sector calculated under tier 2 increased by a factor of 3.7 in 2011 compared to 1994, reaching 5,796.75 Gg CO_2eq. This growth is mainly driven by the increase of the fleet volume.

Direct GHG emissions of CO_2, CH_4 and N_2O emitted from the road transport sector significantly increased from 1994 to 2011 by 264%, 159% and 1,000% respectively, with passenger cars as the major contributor.

Direct GHG emissions from 1994 to 2011 in terms of CO_2eq. showed an increase for marine international bunkers, with the highest relative yearly increase of 7% observed in the 2005-2011 period. On the other hand, aviation bunkers, which account for international flights only, showed that direct emissions were steady from 1994 till 2005, and then increased between 2008 and 2011. A significant decrease was highlighted in 2006 due to the war that took place during the summer of that year.

Mitigation

The mitigation options analysis is conducted using the For Future Inland Transport Systems (ForFITS) modeling tool, intended to estimate CO_2 emissions from transport and to evaluate the impact of mitigation options on transport activity, vehicle stock and energy use. The modeled transport system includes local passenger and freight mobility structure, taking into consideration the different vehicle classes of the Lebanese fleet, powertrains and fuels used. The model bases its projections on economic and social parameters such as the change of Gross Domestic Product (GDP) per capita and population growth.

The scenarios examined in the study aim at assessing the potential of the mitigation strategies identified in the Technology Needs Assessment (TNA) report outcomes in reducing CO_2 emissions by 2020 and 2040 compared to the Business as Usual (BAU) trend. The mitigation strategies consist of "renewing the passenger cars fleet with fuel-efficient and hybrid electric vehicles" and "the deployment of a mass transit system in Greater Beirut Area (GBA)". Accordingly, three mitigation scenarios are derived and examined in the model as follow:

Mitigation option 1: assumes the adoption of an incentivizing sale strategy of fuel-efficient vehicles; consequently, a progressive increase in the share of small vehicles from 11.8% in 2010 to 35% by 2040, paralleled with a reduction in the share of large and inefficient vehicles.

Mitigation option 2: same assumptions as mitigation option 1 in addition to introducing hybrid electric vehicles to the market and a progressive increase of their share up to 10% of new registered vehicles by 2040.

Mitigation option 3: assuming the increase of share of passenger-kilometer activity using mass transport from 36% to 53%, through an efficient mass transport system serving the GBA.

Results indicate that the Lebanese transport sector has significant capacity to reduce its future CO_2 emissions with both TNA mitigation strategies. However, the strategy of renewing the fleet with fuel-efficient and hybrid electric vehicles is not sufficient to offset the growth in passenger activity and vehicle stock, both estimated to double by 2040 compared to 2010. Consequently, the adoption of an integrated strategy for a carefully designed portfolio of policies and mitigation incentives is a must, based on the increase of share of mass transport namely in GBA, combined with the replacement of old inefficient vehicles with new fuel-efficient and hybrid vehicles.

الملخص التنفيذي

في إطار البلاغ الوطني الثالث للبنان إلى اتفاقية الأمم المتحدة الإطارية بشأن تغير المناخ، تم تقدير اتجاه انبعاثات غاز الاحتباس الحراري (الغازات الدفيئة) الناجمة عن قطاع النقل في لبنان خلال الفترة ١٩٩٤ – ٢٠١١. وتمت العملية الحسابية باستخدام الخطوط التوجيهية المنقحة للهيئة الحكومية الدولية المعنية بتغير المناخ لعام ١٩٩٦ بشأن عمليات الجرد الوطنية لغازات الإحتباس الحراري ودليل الممارسات السليمة في عمليات الجرد الوطنية لغازات الإحتباس الحراري و درجة عدم اليقين في تقديراتها . كما تم احتساب انبعاثات الغازات الدفيئة الناجمة عن قطاع النقل، وهي ثاني أكسيد الكربون والميثان وأكسيد النيتريك، إضافة إلى انبعاثات الغازات الدفيئة غير المباشرة (أول أكسيد الكربون وأكاسيد النتروجين وثاني أكسيد الكبريت ومركبات عضوية متطايرة غير ميثانية) بهدف رفع التقارير بها إلى اتفاقية الأمم المتحدة الإطارية بشأن تغير المناخ كجزء من البلاغ الوطني الثالث. وتم تقسيم قطاع النقل إلى النقل البري والنقل البحري والملاحة واستُخدِمت منهجية المستوى ٢ لاحتساب الانبعاثات الناجمة عن النقل البري، ومنهجية المستوى ١ للنقل في المناطق الوعرة ومصايد الأسماك واليخوت والملاحة الداخلية.

قوائم الجرد

بلغ مجموع انبعاثات الغازات الدفيئة من قطاع النقل ٣،٢٦٩ جيغاغرام من مكافئ ثاني أكسيد الكربون في عام ٢٠٠٥ و ٥،٤٢٣,٩٨ جيغاغرام في عام ٢٠١٠. النقل البري هو أكبر مساهم، يسبب بانبعاث ٣،٦١٩,٢٣ جيغاغرام من مكافئ ثاني أكسيد الكربون في عام ٢٠٠٥ و ٥،٢٦٨,٧٩ في عام ٢٠١٠، وسيارات الركاب تحتوي على أعلى نسبة من الانبعاثات قدره ٦٠٪ من إجمالي انبعاثات غازات الدفيئة النقل البري.

بين العام ١٩٩٤ والعام ٢٠١١، ارتفعت انبعاثات الغازات الدفيئة الناجمة عن قطاع النقل البري، والتي تم احتسابها باستخدام منهجية المستوى ٢، بعامل ٣,٧ في العام ٢٠١١ مقارنة بالعام ١٩٩٤، لتصل إلى ٥،٧٩٦,٧٥ جيغاغرام من مكافئ ثاني أكسيد الكربون. وتدفع هذا النموّ، بشكل رئيسي، الزيادة في حجم أسطول مركبات النقل.

وأما انبعاثات الغازات الدفيئة المباشرة من ثاني أكسيد الكربون والميثان وأكسيد النيتريك والمنبعثة عن قطاع النقل البري، فقد شهدت زيادة ملحوظة من العام ١٩٩٤ وحتى ٢٠١١ وذلك بنسبة ٢٦٤٪ و ١٥٩٪ و ١،٠٠٠٪ على التوالي، حيث كانت سيارات الركاب المساهِم الأساسي. وأظهرت انبعاثات الغازات الدفيئة المباشرة من العام ١٩٩٤ حتى ٢٠١١، من حيث مكافئ ثاني أكسيد الكربون، زيادة في ما يتعلق بخزانات الوقود الدولية البحرية، وذلك في أعلى زيادة سنوية نسبية بلغت ٧٪ ولوحِظت في الفترة ما بين ٢٠٠٥ و ٢٠١١. ومن ناحية أخرى، أظهرت خزانات وقود الطيران، المعنية بالرحلات الدولية وحسب، ثباتًا في الانبعاثات المباشرة من العام ١٩٩٤ وحتى ٢٠٠٥، ومن ثم زيادة بين ٢٠٠٨ و٢٠١١. وتم تسليط الضوء على انخفاض بارز في العام ٢٠٠٦ نتيجة الحرب التي وقعت خلال صيف ذلك العام.

التخفيف

يجري تحليل خيارات التخفيف باستخدام أداة النمذجة من أجل نظم داخلية للنقل في المستقبل (ForFITS) والتي تهدف إلى تقدير انبعاثات ثاني أكسيد الكربون الناجمة عن النقل كما وتقييم أثر خيارات التخفيف على حركة النقل ومخزون المركبات البرية واستهلاك الطاقة. ويشمل نظام النقل المنمذج الركاب المحليين وبنية نقل الشحن، مع الأخذ بعين الاعتبار الفئات المختلفة للمركبات في الأسطول اللبناني وأنظمة نقل الحركة وأنواع الوقود المستخدمة. ويبني النموذج توقعاته على المعايير الاقتصادية والاجتماعية مثال تغير نصيب الفرد من الناتج المحلي الإجمالي والنمو السكاني.

أما السيناريوهات التي تم استعراضها في الدراسة فتهدف إلى تقييم إمكانات استراتيجيات التخفيف التي تم تحديدها في نتائج تقرير تقييم الاحتياجات التكنولوجية في الحدّ من انبعاثات ثاني أكسيد الكربون بحلول العام ٢٠٢٠ والعام ٢٠٤٠، مقارنة مع نهج العمل المعتاد. وتتألف استراتيجيات التخفيف من «تجديد أسطول سيارات الركاب بسيارات كهربائية هجينة ومقتصدة في استهلاك الوقود» كما و«نشر نظام وسائل نقل جماعية في منطقة بيروت الكبرى». وبناءً على ذلك، يمكن استخراج ثلاثة سيناريوهات للتخفيف ودراستها في النموذج على الشكل التالي:

خيار التخفيف رقم ١: فرضية اعتماد استراتيجية بيع تحفيزية للمركبات المقتصدة في استهلاك الوقود؛ وبالتالي، زيادة تدريجية في حصة السيارات الصغيرة من ١١,٨٪ في العام ٢٠١٠ إلى ٣٥٪ بحلول العام ٢٠٤٠، وذلك بموازاة انخفاض في حصة المركبات الكبيرة وغير المقتصدة.

خيار التخفيف رقم ٢: الفرضيات ذاتها الواردة في خيار التخفيف رقم ١، إضافة إلى إدخال السيارات الكهربائية الهجينة إلى السوق وزيادة تدريجية لحصصها حتى ١٠٪ من المركبات المسجّلة الجديدة بحلول العام ٢٠٤٠.

خيار التخفيف رقم ٣: افتراض زيادة حصص حركة الراكب بالكيلومتر باستخدام وسائل النقل الجماعي من ٣٦٪ إلى ٥٣٪ من خلال نظام نقل جماعي فعّال يخدم منطقة بيروت الكبرى.

وتشير النتائج إلى أن قطاع النقل اللبناني يتمتّع بإمكانية كبيرة على الحد من انبعاثاته المستقبلية من ثاني أكسيد الكربون باستخدام إستراتيجيتي التخفيف التي تم تحديدهما في نتائج تقرير تقييم الاحتياجات التكنولوجية. إلا أن إستراتيجية تجديد أسطول سيارات الركاب بسيارات كهربائية هجينة ومقتصدة في استهلاك الوقود ليست كافية للتعويض عن النمو في حركة الركاب ومخزون المركبات، واللذان يُقدّر أن يبلغا الضعف بحلول العام ٢٠٤٠، مقارنةً بالعام ٢٠١٠. نتيجة لذلك، فإن اعتماد إستراتيجية متكاملة لمحفظة سياسات وحوافز للتخفيف يتمّ تصميمها بإمعان هو أمر ضروري، وذلك بناءً على ازدياد حصة النقل الجماعي بالأخص في منطقة بيروت الكبرى، بالاشتراك مع استبدال المركبات القديمة وغير المقتصدة بمركبات جديدة هجينة ومقتصدة في استهلاك الوقود.

Part 1: Inventory

1. Scope

As a Non-Annex I party to the United Nations Framework Convention on Climate Change (UNFCCC), Lebanon is recommended to report its emissions to the UNFCCC according to decisions 17/CP.8, 2/CP.17 and articles 4 and 12 of the Convention. According to the Second National Communication (SNC) (MoE/UNDP/GEF, 2011), the transport sector is the second consumer of energy in Lebanon, totally dependent on fossil fuels. Its Greenhouse Gas (GHG) emissions account for 28.6% of total emissions from the energy sector and for 21% of the total national GHG emissions for the baseline year of 2000.

This report focuses on the estimates of GHG emissions from the transport sector in Lebanon, for a baseline year of 2005 and for the time series 1994 to 2011. It includes direct and indirect GHGs, i.e. carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) for direct GHGs; nitrogen oxide (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs) and sulphur dioxide (SO_2) for indirect GHGs. The preparation and reporting of this inventory are based on the 1996 Revised Intergovernmental Panel on Climate Change (IPCC) Guidelines (IPCC, 1997), and the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000).

National circumstances of the current transport sector are outlined in section 2. Section 3 covers the gaps and constraints identified in the first and second national communications. In section 4, the preparation process and calculation methodology of the GHG emission inventory are presented, including activity data for 2005 to 2011, and emission factors. Section 5 presents the GHG inventory results for the year of 2005 and the time series 1994 to 2011, illustrated by gas and by transport modes.

2. National circumstances

The Lebanese transport sector encompasses land, marine and air mobility subsectors.

Land transport

The land transport sector only consists of road-motorized vehicles, since no appropriate infrastructure for non-motorized vehicles exists (i.e. bicycle lanes, safe storage, and convenient and affordable bike rentals) and the entire rail network is currently derelict (Lebanon used to operate four rail lines: (1) Beirut-Damascus, (2) Naqoura-Tripoli, (3) Tripoli-Homs and (4) Rayak-Aleppo).

Road-motorized vehicles mainly rely on personal-owned passenger cars. The 2012 vehicle fleet database shows a total of 1.58 million registered vehicles, with a distribution presented in Figure 1. The age distribution of passenger cars (public and private) illustrated in Figure 2 reflects the old nature of the fleet, with 71% older than 10 years. Moreover, the engine distribution of the passenger car fleet in 2007 shows that the fleet is mostly inefficient, since 60% of the cars have engine displacements exceeding 2.0 liters, while only 8% have engines less than 1.4 liters (MoE/URC/GEF, 2012).

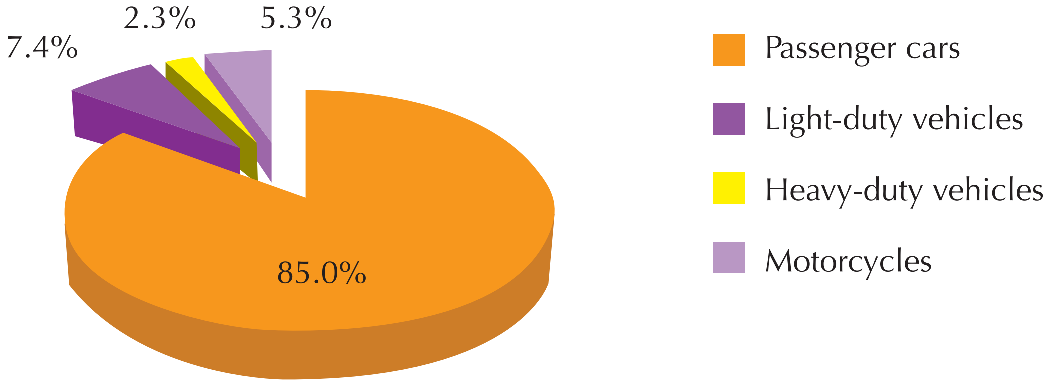

Figure 1: The 2012 vehicle fleet distribution
Source| MoIM, 2013

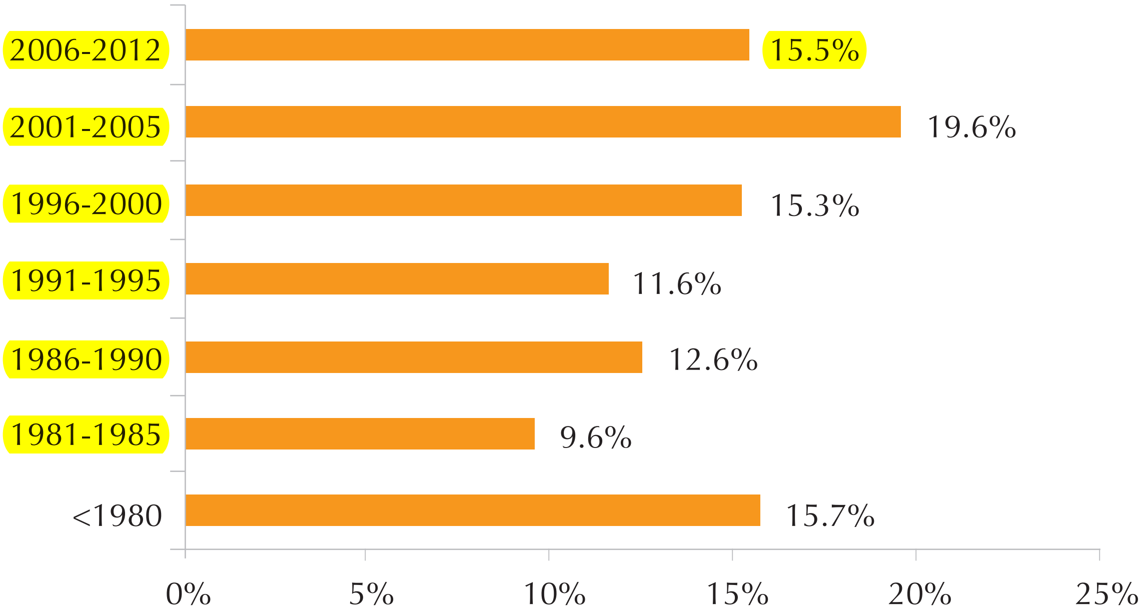

Figure 2: Vehicle percentage distribution per model year of production

Mass transport consists of public and private buses, minivans and exclusive and shared-ride taxis, all operating on an ad-hoc basis without any coordination, resulting in very poor occupancy rates of about 1.2 passengers per vehicle for taxis, 6 for vans and 12 for buses (MoE/URC/GEF, 2012). In 2002, the mass transport market share in the Greater Beirut Area (GBA) was 31%, split between modes as illustrated in Figure 3 (Baaj, 2002), clearly illustrating the level of underdevelopment of mass transportation in Lebanon. This limited share of the market continues today due to the impracticality, lack of safety and restricted reach of public transportation compared to the attractiveness of owning a private automobile, an alternative that is still promoted over mass transportation in Lebanon through bank loan facilities and affordable new and used car imports.

This reality is due in large part to the chaotic, inefficient and unreliable management of the transportation sector, preventing the modernization and growth of the system and allowing the market to be controlled by private operators. For example, the system is oversupplied with 50,000 taxi licenses (known as “red plates”), where an estimated 17,000 of these are illegally procured and operated, with a similar situation of poor forecasting and control of the number of shared taxis and minibuses relative to actual market demand.

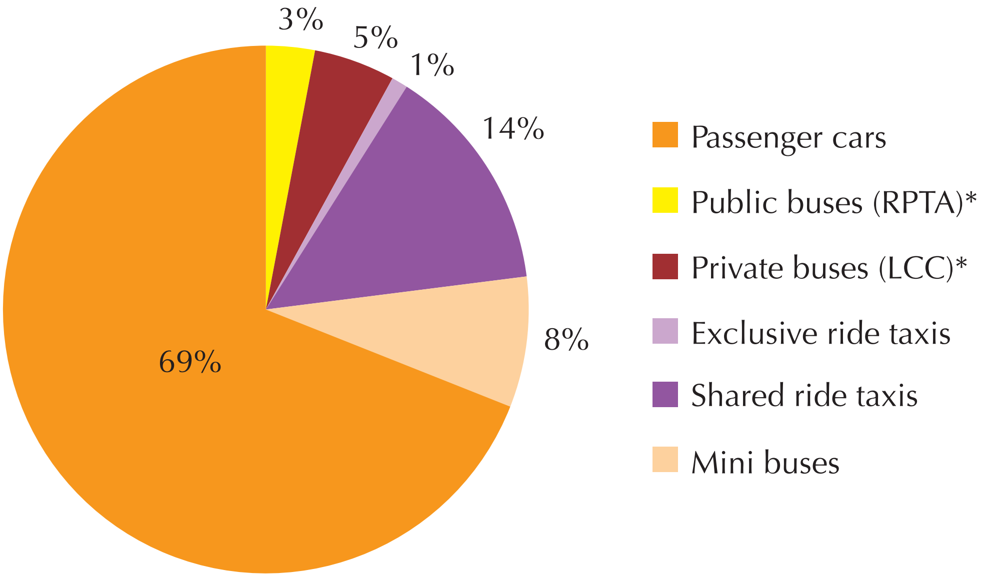

Figure 3: Market share of transport systems in GBA in 2002

*RPTA: Railway and Public Transport Authority, LCC: Lebanese Commuting Company

Based on collected data from on-road measurements in the GBA with a GPS-guided survey of typical driver habits, the driving patterns in 2011 can be characterized by a relatively low driving range with a high rate of congestion and frequent stops at short time intervals. In fact, it was found that 50% of the trips have a distance lower than 5 km, 25% of stops are below 2 seconds and the total stop time per trip corresponds to more than 15% of travel time (Mansour, 2011). Moreover, observed results reflect the continuous stop-and-go driving patterns, therefore resulting in the inefficient operation of internal combustion engines, and a high rate of fuel consumption and pollutant emissions as a result.

The main road transport legislation are law 341 (6-08-2001) and decree no. 7858/2002, banning the use of private and public cars with diesel engines starting from 15-6-2002, and the use of public buses of 16 to 24 passengers with diesel engines starting from 31-10-2002.

Aviation

Middle East Airlines (MEA) is the national air carrier of Lebanon and Beirut International Airport (BIA) is the only operational commercial airport in the country. In 2012, the number of flights at the BIA reached over 60,000 commercial flights with around 5.9 million incoming and outgoing passengers (BIA statistics, 2014). The BIA is designed to host a maximum of 16 million passengers per year.

MEA flies to 21 countries serving a total of 30 different airports with 62 departures daily. Data is based on the Schedule Reference Service (SRS) Analyser database. It has a fleet mainly consisting of A320 and A330 that stands at 18 aircrafts operating at 68% capacity according to the Figure 4 on Available Seat Kilometers (ASK) and total Revenue Passenger-Kilometers (RPK) (Zouein, 2014).

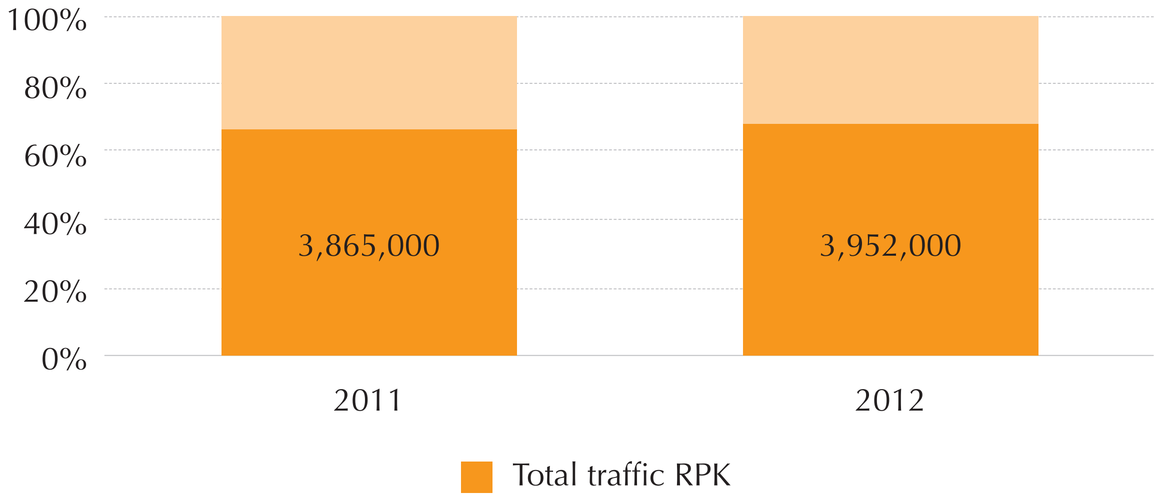

Figure 4: MEA operating capacity percentage (ratio of total revenue passenger-kilometers to total available seat-kilometers)

The other remaining airports in Lebanon such as the Riyak and the Kleyaat airports are reserved for military services. Regarding domestic flights in Lebanon, they show very limited activity since aircrafts are of small propeller engine types, used only for training.

Marine transport

Legal harbors in Lebanon are limited to five: Beirut, Tripoli, Saida, Tyr and Jounieh. Beirut and Tripoli are the two largest commercial ports. In fact, the port of Beirut hosts around 78% of the incoming ships to Lebanon and the port of Tripoli hosts around 16% (CAS, 2014). The number of yearly incoming ships and oil tankers to Beirut port ranges between 2,000 and 2,400 ships, with a total capacity around 700,000 containers Total Equivalent Unit (TEU) per year (Beirut port statistics, 2014). Moreover, Beirut port also observes transit traffic with an average value of 1.8 million tonnes of goods per year. As for Tripoli, its port hosts around 350 to 450 yearly incoming container and cargo ships, and 50 to 90 oil tankers (Tripoli port statistics, 2014).

The fisheries host a fleet of around 2,860 boats with a yearly catch of 9,000 tonnes, insufficient to cover the local fish consumption of 35,000 tonnes; consequently, 74% of the fish is imported. About 98% of the fleet is constituted of open woody boats with length less than 12 meters (EastMED, 2012). The fleet is old (e.g. average age of 17 years at the port of Tyr) and spread over 44 harbors, most of which requires major infrastructure maintenance intervention.

3. Gaps and constraints identified by INC and SNC

The gaps and needs for the calculation of GHG emissions from the transport sector that were identified in the Initial National Communication (INC) and Second National Communication (SNC) are summarized in Table 1. They consist of (1) the underdeveloped institutional arrangement for transport data monitoring and collection, (2) the unavailability of specific data and/or the inaccessibility of existing data for adopting tiers 2 and 3 methodologies, and (3) the use of default Emission Factors (EF) from IPCC guidelines instead of Lebanon fuel-specific EF. Note that these gaps still exist during the elaboration of the TNC.

Table 1: Gaps and needs for the calculation of GHG emissions identified in the INC and SNC

		INC	SNC
Gaps	Underdeveloped data collection for the inventory	1. Lack of institutional arrangement for data monitoring and reporting. 2. Need to improve the uncertainty calculation methodologies in the Quality Assurance/Quality Control (QA/QC) procedure.	
	Unavailable and/ or unshared specific data for tiers 2 and 3 calculations	1. Missing road transport activity data on annual fuel consumption per type of fuel and yearly average vehicle mileage per category. 2. Activity data of off-road vehicles not considered. 3. Unshared activity data between public/private institutions due to lack of coordination and/or confidentiality.	
		4. Emissions of national navigation and aviation are calculated using unclear assumptions on shares of fuel imports.	4. National aviation and navigation emissions not included.
Needs	Use of IPCC default emission factors	No fuel-specific emission factors elaborated for Lebanon.	
	Enforce specific activity data collection for the preparation of the inventory	1. Create a national institutional arrangement for the preparation of the GHG inventory, empowering the Central Administration of Statistics (CAS), the relevant ministries and concerned public authorities to develop a Mobility Monitoring Indicators (MMI) platform, in charge of collection (Measuring, Reporting and Verification (MRV)) of transport activity data. 2. MMI platform should include all activity data needed to estimate Lebanon's transport sector GHG emissions using tiers 2 and 3 of the IPCC guidelines. Activity data should be reported with uncertainty assessments in order to have statistically acceptable data.	
	Share of data	Standardize/centralize data reporting and develop protocols for data accessibility.	
	Develop Lebanon's fuel-specific emission factors and methodologies	1. Conduct measurements campaigns in order to elaborate specific emission factors representative of the Lebanese transportation fleet. 2. Develop GHG emissions estimation models with local research institutes to create Lebanon-specific methodologies using advanced bottom-up approaches for inventory preparation.	

4. General description of methodologies and data sources

4.1. Adopting the IPCC guidelines

The Lebanese transport GHG inventory is carried out based on calculation methodologies of the 1996 Revised IPCC Guidelines (IPCC, 1997), and the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000). Lebanon's transport emissions include all domestic transport modes, divided into the reporting categories summarized in Table 2: aviation, maritime transport and road transport vehicles. Emissions mainly originate from road transport vehicles, since aviation and maritime transport are mostly used for international mobility. The results of direct (CO_2, CH_4 and N_2O) and indirect GHG emissions (NO_x, CO, NMVOCs and SO_2) for the year of 2005 and the trend for the period 1994 to 2011 per transport mode are given in section 5. Note that emissions from international transport modes: aviation and maritime transport are only reported under the international bunkers section, as per the IPCC guidelines, and are not added to the national total GHG emissions from the transport sector.

Table 2: Reporting categories investigated in the inventory of the Lebanese transport sector

Reporting categories	Description	Remarks	Methodology
Aviation	Military helicopters, civil, commercial aircrafts, and private jet- and propeller-type aircrafts.	Emissions from military aircrafts are not calculated due to the confidentiality of activity data for military cases.	Civil, private and commercial aircrafts emissions are calculated based on the tier 1 methodology.
Maritime transport	Domestic navigation between local ports, fisheries and international navigation.	Emissions from military navigation are not calculated due to the unavailability of activity data for military cases. Emissions from fisheries are reported under this category. They are reported under the agriculture/forestry/fisheries category of the energy sector.	International navigation from marine bunkers and national navigation from fishing boats and yachts were calculated based on the tier 1 methodology.
Road transport vehicles	On-road vehicle technologies rely on gasoline and gas/diesel internal combustion engines. The fleet encompasses motorcycles, passenger cars, vans, buses and trucks.	Road transport is the only mobility mean considered under land transport as the entire rail network is derelict.	Emissions are estimated using the tier 2 methodology.

No national system is established in Lebanon assuming the responsibility for collecting data for the GHG inventory, particularly for the transport sector. Consequently, data are collected from different public and private authorities, local and international organizations, survey and reports, as summarized in Table 3.

Table 3: Data sources collected for the reporting categories

Reporting categories	Activity data	Sources
Aviation	Fuel imports	Ministry of Energy and Water (MoEW, 2014), the International Energy Agency (IEA, 2014) and IPT Energy Center (IPT, 2014)
Road transport	Fuel imports	Ministry of Energy and Water (MoEW, 2014), the International Energy Agency (IEA, 2014) and IPT Energy Center (IPT, 2014)
	Number of registered vehicles	Ministry of Environment (MoE, 2014)
	Number of vehicles equipped with a catalyst for emission control	Waked and Afif (2012)
	Classification of vehicles by country of origin	Ministry of Finance (MoF, 2011)
Off-road transport	Fuel imports	IPT Energy Center (IPT, 2014)
Navigation	Fuel imports	International Energy Agency (IEA, 2014) and IPT Energy Center (IPT, 2014)

4.2. Road transport

Methodology

Road transport covers all internal combustion vehicles used for passengers and goods mobility in Lebanon, except farm tractors and public works vehicles. Types of vehicles investigated in this inventory are motorcycles, passenger cars, vans, buses and trucks, classified into categories in accordance with the guidelines: Passenger Cars (PC), Light-Duty Vehicles (LDV), Heavy-Duty Vehicles (HDV) and motorcycles (Table 4). After banning the use of diesel for vehicles with gross weight lower than 3,500 kg (law 341 (6-08-2001) and decree no. 341/2002), passenger cars, light-duty vehicles and motorcycles run only on gasoline, where heavy-duty vehicles run on diesel.

Table 4: Description of the vehicles categories used in the calculation of road transport emissions

Vehicle category	Description
Passenger cars	Private personal gasoline cars used for mobility including Sport Utility Vehicles (SUV).
Light-duty vehicles	Gasoline vehicles with rated gross weight less than 3,500 kg including light trucks and coaches, designed for transportation of cargo or passengers.
Heavy-duty vehicles	Diesel vehicles with rated gross weight exceeding 3,500 kg including heavy trucks and coaches, designed for transportation of cargo or passengers.
Motorcycles	Includes a mixture of 2-stroke and 4-stroke engines as well as mopeds having an engine less than 50cc.

GHG emissions are estimated using the tier 2 methodology, presented in equation (1), and based on the number of vehicles per category (PC, LDV, HDV and motorcycles) and their activity in terms of distance and/or fuel consumption.

$$E = \sum_a [EF_{abc}.Activity_{abc}]$$

where

E is CO_2, CH_4, N_2O, CO, NO_x and NMVOCs emissions (kg)
EF: emission factor in g/km, g/kg or g/MJ
Activity: travelled distance in km or fuel consumption in kg or MJ for a given mobile source activity
a: fuel type (diesel, gasoline)
b: vehicle type (PC, LDV, HDV and motorcycles)
c: emission control technology depending on the age of vehicles

For quality check, the road transport GHG emissions are also calculated using the top-down tier 1 methodology, based on the amount of gasoline and gas/diesel fuel imports for the road transport sector. Emissions are calculated from 1994 to 2011 for completeness, using equations (2), (3) and (4) (IPCC, 1997).

$$E = \sum_a [Fuel_a . EF_a]$$

where E is CO_2 emissions (kg)

$Fuel_a$: fuel sold (TJ)

Lebanon's fuel imports are reported in kilotonnes (ktonnes)and converted to TJ using the net calorific value for each type as reported in the guideline, i.e. a net calorific value of 44.80 kg/TJ for gasoline and 43.33 kg/TJ for diesel.

EF_a: emission factor (kg/TJ)

For CO_2, it corresponds to the carbon content (carbon EF tC/TJ multiplied by the consumption in TJ) of the fuel multiplied by the fraction of carbon oxidized of 0.99 multiplied by 44/12.

a: type of fuel (gasoline/diesel)

$$E = \sum_a [Fuel_a . EF_a]$$

where E is CH_4, N_2O, CO, NO_X and NMVOCs emissions (kg)

$Fuel_a$: fuel sold (TJ)

EF_a: emission factors of CH_4, N_2O, CO, NO_X and NMVOCs (kg/TJ)

a: type of fuel (gasoline/diesel)

$$E = \sum_a \left[\begin{array}{c} \text{(Fuel a.(2.sulphur content of fuel a|100).} \\ \text{(1|net calorific value of fuel a).1,000,000.} \\ \text{((100 - sulphur retention in ash of fuel a|100)).} \\ \text{(100 - abatement efficiency of fuel a|100))|1,000} \end{array} \right]$$

where E is SO_2 emissions (kg)

$Fuel_a$: fuel sold (TJ)

Sulfur content of $fuel_a$: 0.1% for gasoline and 0.3% for diesel

Net calorific value of 44.80 kg/TJ for gasoline and 43.33 kg/TJ for diesel

Sulfur retention in ash: 1%

The amount of sulfur retained in ash during fuel combustion

Abatement efficiency of fuel: 1%

Abatement technologies for SO_2 emissions reductions

a: type of fuel (gasoline/diesel)

Activity data

For the tier 1 approach, the needed activity data is Lebanon's annual gasoline and diesel oil consumption for road transport. Gasoline imports data for road transport are collected from the Ministry of Energy and Water (MoEW) and Ministry of Finance (MoF) (MoEW, 2014, MoF, 2014), whereas gas/diesel oil consumption for road transport are estimated as 14%[1] of the total imports (MoEW, 2014; IPT, 2014). They are presented in Figure 5 and in Table 5. It should be noted that gasoline imports data for road transport showed a consistency among MoEW and International Energy Agency (IEA) data, with calculated differences less than 1%.

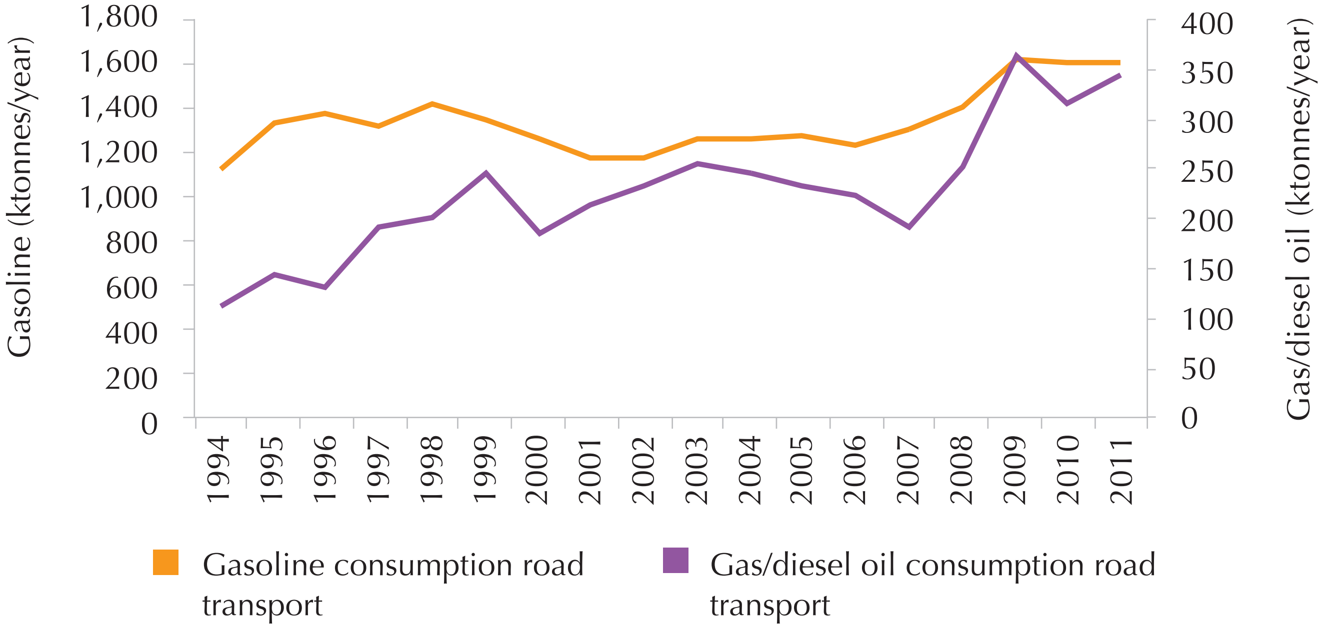

Figure 5: Gasoline and gas/diesel oil imports for the road transport sector from 1994 to 2011

Table 5: Road transport gasoline and gas/diesel oil consumption

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002
Gasoline (ktonnes)	1,121	1,325	1,377	1,318	1,410	1,342*	1,261*	1,176*	1,177*
Gas/diesel oil (ktonnes)	111	143	130	193	200	245	184	215	233
Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Gasoline (ktonnes)	1,257*	1,260*	1,270*	1,222*	1,304*	1,398*	1,614*	1,592*	1,595*
Gas/diesel oil (ktonnes)	256	245	233	223	191	252	363	315	343

Source | IEA, 2014

*MoEW, 2014, IPT, 2014

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[1] 14% is the average percent of Diesel Oil (DO) consumption of the fleet in Lebanon (total DO-fuel vehicles/DO consumption per vehicle) for the period 2005-2012.

For the tier 2 approach, the following activity data are considered:

- The number of registered vehicles from 1994 to 2011 is provided by the Ministry of Interior and Municipalities (MoIM), traffic, truck and vehicle management authority (MoIM, 2013). The database includes the number of registered vehicles by category, type of use (private or public), production date, circulation date, horse power, and type of fuel used. Vehicles are classified under PC, LDV, HDV, and motorcycles; as well as per emission control technologies, following the European Union (EU) classification described in the IPCC guidelines (IPCC, 1997).

- Table 6 summarizes the classification of the 2011 vehicle fleet per vehicle category and EU emission control technology. Note that the classification per emission control technologies takes into consideration the common practice in Lebanon of removing the emission control catalyst without any replacement. The fraction of vehicles for which the catalyst was removed is obtained from a survey conducted in Beirut on 3,000 vehicles (Waked, 2012, unpublished data; Waked and Afif, 2012). The results from this survey were extrapolated to the rest of the vehicle fleet.

Table 6: Classification of the 2011 vehicle fleet per category and EU emission control technologies

EU emission control technology	Passenger cars	Light-duty vehicles	Heavy-duty vehicles	Motorcycles
Uncontrolled	7,718	658	320	-
Early non-catalyst control	178,525	8,589	3,192	-
Non-catalyst control	577,589	22,913	3,099	-
Oxidation catalyst	9,973	14,182	401	-
Three-way catalyst	537,916	66,748	28,593	-
<50 cc[1]	-	-	-	70,442
2-strokes[2]	-	-	-	3,988
4-strokes[3]	-	-	-	2,073
Total	**1,311,721**	**113,090**	**35,605**	**76,503**

[1] Motorcycles having 1 cylinder

[2] Motorcycles having 2 to 3 cylinders

[3] Motorcycles having 4 cylinders and above

- The annual travelled distance per vehicle category is considered. Due to field data unavailability, an assumption was made using the ForFITS (For Future Inland Transport Systems) database. ForFITS is a modeling tool intended to evaluate the transport activity, energy use and CO_2 emissions, using transport data collected from different national and international transport related agencies (UNECE, 2014). For countries with mobility characteristics similar to Lebanon, a value of 12,000 km/year is estimated for passenger cars, 25,000 km/year for light-duty vehicles, 50,000 km/year for heavy-duty vehicles and 5,000 km/year for motorcycles.

Emission factors

Used emission factors for the tier 1 approach are the default values of the IPCC guideline for gasoline and diesel fuels, since no fuel-specific emission factors are established for Lebanon. Values are summarized in Table 7.

Table 7: Default EF for road transport under the tier 1 methodology

Activity data	Fuel used	CO_2	CH_4	N_2O	SO_2	NO_X	CO	NMVOCs
Road transport	Gasoline	18.9	20	0.6	43.75	600	8,000	1,500
	Gas/diesel oil	20.0	5	0.6	135.72	800	1,000	200

*CO_2 EF are in tC/TJ while for CH_4, N_2O, SO_2, NO_x, CO and NMVOCs, EF are in kg/TJ.

For the tier 2 methodology, emission factors depend on the production date of vehicles, the vehicle category and the type of fuel used. Therefore, besides the classification per category, the vehicles are also categorized by model year of production, as illustrated in Figure 2. Default EU emission factors are used since no emission factors have been established yet for Lebanon, and on the other hand, the Lebanese vehicle fleet is mostly constituted of European vehicles, as shown in Figure 6 (MoF, 2011). Emission factors values are summarized in Table 8 to 12.

Table 8: Default EU emission factors for gasoline passenger cars under the tier 2 methodology

Estimated emission factors for EU gasoline passenger cars					
Emissions (g/km)					
NO_X	CH_4	NMVOCs	CO	N_2O	CO_2
Three-way catalyst: assumed fuel economy 11.8 km/l (8.5 l/100 km)					
0.5	0.02	0.5	2.9	0.05	205
Oxidation catalyst: assumed fuel economy 12.3 km/l (8.1 l/100 km)					
1.4	0.07	1.4	7.5	0.005	190
Non-catalyst controls: assumed fuel economy 12.0 km/l (8.3 l/100 km)					
2.3	0.07	4.5	19	0.005	200
Early non-catalyst controls: assumed fuel economy 10.6 km/l (9.4 l/100 km)					
2.0	0.08	5.2	29	0.005	225
Uncontrolled: assumed fuel economy 8.9 km/l (11.2 l/100 km)					
2.2	0.07	5.3	46	0.005	270

Table 9: Default EU emission factors for gasoline light-duty vehicles under the tier 2 methodology

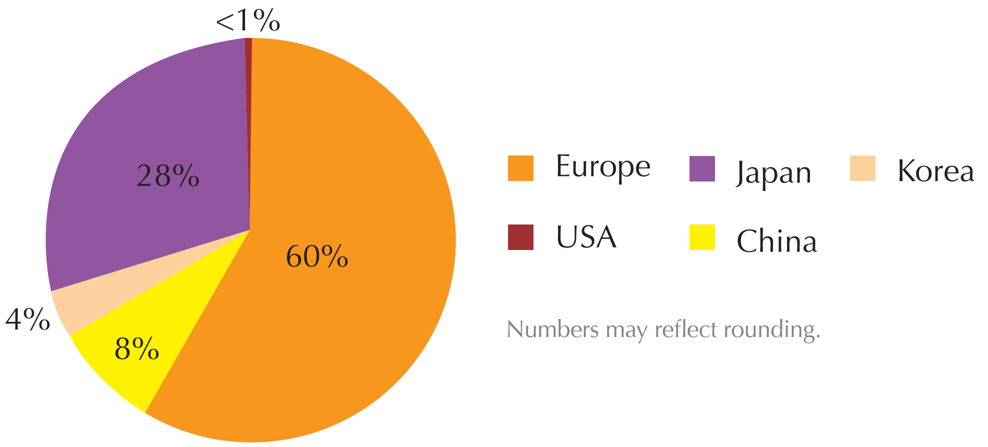
Estimated emission factors for EU LDV gasoline cars					
Emissions (g/km)					
NO_X	CH_4	NMVOCs	CO	N_2O	CO_2
Moderate control: assumed fuel economy 7.4 km/l (13.6 l/100 km)					
2.9	0.08	6.1	37	0.006	325

Table 10: Default EU emission factors for diesel heavy-duty vehicles under the tier 2 methodology

Estimated emission factors for EU HDV diesel cars					
Emissions (g/km)					
NO_X	CH_4	NMVOCs	CO	N_2O	CO_2
Moderate control: assumed fuel economy 3.3 km/l (29.9 l/100 km)					
10	0.06	1.9	9	0.03	770

Table 11: Default EU emission factors for motorcycles under the tier 2 methodology

Estimated emission factors for motorcycles					
Emissions (g/km)					
NO_X	CH_4	NMVOCs	CO	N_2O	CO_2
Motorcycles < 50 cc **Uncontrolled: assumed fuel economy 41.7 km/l (2.4 l/100 km)**					
0.05	0.1	6.5	10	0.001	57
Motorcycles > 50 cc 2-strokes **Uncontrolled: assumed fuel economy 25.0 km/l (4.0 l/100 km)**					
0.08	0.15	16	22	0.002	95
Motorcycles > 50 cc 4-strokes **Uncontrolled: assumed fuel economy 19.6 km/l (5.1 l/100 km)**					
0.3	0.2	3.9	20	0.002	120



Numbers may reflect rounding.

Figure 6: Classification per country of origin of the 2010 Lebanese vehicle fleet *(Customs register cars at import as per the manufacturing country although the car may have been imported from another country)*

4.3. Aviation

Methodology

Aviation comprises international, national and military flights. According to the Directorate General of Civil Aviation (DGCA), 5,055 international private flights and 35,479 international commercial flights were recorded in 2008 of which around 30% were operated by MEA (CAS, 2014).

Domestic flights consist of the limited usage of small propeller-type aircrafts, used only for training. The fleet includes around 5 Cessna aircrafts operating on gasoline (AVGAS LBP 100) with an annual consumption ranging between 2 and 3 ktonnes. It remains non-significant when compared to the gasoline consumption for road transport (1,000 to 1,600 ktonnes).

Consequently, only emissions related to international aviation are accounted under international bunkers. Emissions related to national domestic aviation are reported in the national inventory.

The tier 1 methodology of the 1996 Revised IPCC Guidelines is used, where fuel consumption of jet kerosene for international aviation bunkers, gasoline for domestic aviation and gas/diesel oil for domestic navigation have been used with their associated emission factor.

Used emission factors correspond to the default values of the tier 1 methodology of the 1996 Revised IPCC Guidelines. Consequently, CO_2 emissions are estimated using equation (2), emissions estimation for CH_4, N_2O, NO_x, CO and NMVOCs using equation (3) and emissions estimation for SO_2 are based on equation (4). Note that the tier 2 methodology is not considered for international civil aviation due to the lack of data on the types of aircrafts and their associated fuel consumption during landing/taking-off cycles and cruising.

Activity data

The activity data for international civil aviation includes the kerosene consumption for international bunkers and gasoline for domestic aviation. It is collected from the Ministry of Energy and Water (MoEW, 2014) and the International Energy Agency (IEA, 2014). The activity data in ktonnes/year are presented in Table 12 and Figure 7.

Domestic aviation gasoline consumption is estimated on a capita basis (personal communication with Captain Said El-Hage; El-Hage, 2014), then weighted by the population and extrapolated to cover the 1994-2011 yearly consumption (Table 12).

Table 12: Airplanes jet-kerosene for aviation bunkers and gasoline for domestic flights

Year	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Jet-kerosene in ktonnes[1]	146	103	107	109	107	126	125	128	127
Estimated jet-gasoline [2]	2.3	2.3	2.4	2.4	2.4	2.4	2.5	2.6	2.7
Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Jet-kerosene in ktonnes	125	127	147	104	140	167	175	221	224
Estimated jet-gasoline	2.8	3.0	3.1	3.1	3.2	3.2	3.3	3.3	3.4

Source | [1] 1994 to 1998 kerosene data are provided from IEA (IEA, 2014). 1999 to 2011 data are provided from MoEW (MoEW, 2014).

[2] 1994 to 2011 data are estimated based on population and gasoline consumption (El Hage, 2014)

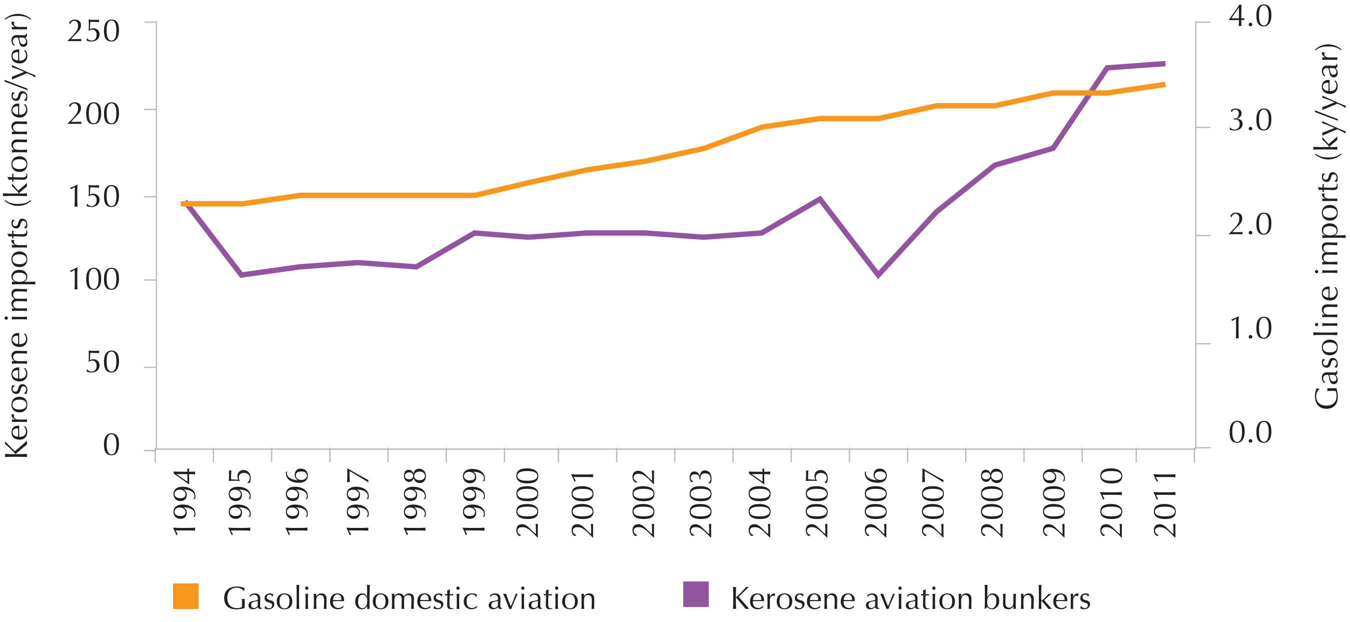


Figure 7: Fuel imports for the aviation sector from 1994 to 2011

Emission factors

In the absence of specific Lebanese emission factors, default values of the IPCC tier 1 methodology are used (IPCC, 1997), and summarized in Table 13.

Table 13: Default emission factors for aviation

EF	CO_2 (tC/TJ)	CH_4 (kg/TJ)	N_2O (kg/TJ)	NO_x (kg/TJ)	CO (kg/TJ)	NMVOCs (kg/TJ)	SO_2 (kg/TJ)
Jet-kerosene	19.5	0.5	2	300	100	50	21.98
Jet-gasoline	18.9	0.5	0.6	300	100	50	43.75

4.4. Maritime transport

Methodology

Maritime transport encompasses international, national and military navigation. Activities related to fisheries are reported in the energy sector, under the category agriculture/forestry/fisheries (MoE/UNDP/GEF, 2015), and consequently, their emissions are not reported in this report. Emissions related to military maritime transport were not considered due to the unavailability of the activity data.

The IPCC tier 1 methodology is used, where fuel consumption for international marine bunkers and its associated emission factors are considered.

Activity data

The activity data for navigation is limited to the heavy fuel oil consumption for international bunkers and it is collected from the fuel imports data by the International Energy Agency (IEA, 2014). Fuel consumption in ktonnes/year is presented in Table 14.

Table 14: Fuel consumption for marine bunkers (ktonnes/year)

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002
Marine bunkers	12.00	13.00	14.00	14.00	15.00	15.00	15.00	16.00	17.00
Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Marine bunkers	18.00	19.00	19.00	19.00	20.00	22.00	24.00	26.00	27.00

Emission factors

Used emission factors correspond to the default values of the tier 1 methodology of the 1996 Revised IPCC Guidelines, summarized in Table 15. Consequently, direct and indirect GHG emissions are estimated using equations (2), (3) and (4). Note that the tier 2 methodology is not considered for maritime transport due to the lack of data on the types of ships (fisheries, cargo, container, tankers, etc.) and the fuel consumption for each type of ship during hostelling, maneuvering and cruising.

Default values of the IPCC tier 1 methodology are used (IPCC, 1997), and summarized in Table 15.

Table 15: Default emission factors for maritime transport

EF	CO_2 (tC/TJ)	CH_4 (kg/TJ)	N_2O (kg/TJ)	NO_x (kg/TJ)	CO (kg/TJ)	NMVOCs (kg/TJ)	SO_2 (kg/TJ)
Marine bunkers	21.1	5	0.6	1,500	1,000	200	1,463.20

4.5. Uncertainty assessment

QA/QC of data

The QA/QC procedure for the validation of activity data as well as the emission factors used in tier 1 and tier 2 methodologies are presented in Table 16.

Table 16: QA/QC data procedure

Actions	Parameters assessed	Uncertainty estimation
Judgment of the activity data used for the tier 1 methodology for international aviation bunkers.	Fuel imports data for kerosene are collected from different sources (MoEW and IEA).	15%
Judgment of the activity data used for the tier 1 methodology for international marine bunkers.	Fuel imports data for fuel oil are collected from the IEA.	50%
Judgment of the activity data used for the tier 1 methodology for national navigation, national aviation and off-road transport.	Fuel consumption data estimated from the IPT (IPT, 2014) and from DGCA (El-Hage, 2014).	50%

Actions	Parameters assessed	Uncertainty estimation
Judgment of the emission factors used for the tier 1 methodology for international and national aviation, marine bunkers as well as off-road transport.	Default emission factors of the Revised 1996 IPCC Guidelines are used, since no fuel-specific emission factors are established for Lebanon.	CO_2 5% CH_4 factor of 2 N_2O factor of 10
Judgment of the activity data used for the tier 1 methodology for road transport.	Fuel imports data for gasoline, and gas/diesel oil are collected from different sources (MoF, MoEW, IEA and World Bank).	10%
Judgment of the emission factors used for the tier 1 methodology for road transport.		CO_2 5% CH_4 40% N_2O 50%
Judgment of the activity data used for the tier 2 methodology.	Due to the lack of activity data from different sources, a qualitative uncertainty assessment is performed. Activity data assessed are: the number of registered vehicles, the annual travelled distance by vehicle category and the number of vehicles not equipped with a catalyst for emissions control.	1. Data on the number of vehicles provided by public institutions have a low uncertainty in the range of 2 to 5%. 2. Data on annual travelled distance have moderate uncertainty since they are based on estimated values. 3. Data on the survey conducted in Beirut have also moderate uncertainties since they are specific for Beirut and are applied to Lebanon in this inventory.
Judgment of the emission factors used for the tier 2 methodology.	EU emission factors used for the tier 2 methodology.	EU emission factors have moderate uncertainty since they are not specific to the Lebanese fleet. However, they are specific to Mediterranean countries. Their reported uncertainties according to the European Monitoring and Evaluation Programme/ European Environmental Agency (EMEP/EEA) guide book are in the range of 50-200% for the road transport section (EMEP/EEA, 2013).

QA/QC of calculation process

The QA/QC procedure for the emissions calculation process for tier 1 and tier 2 methodologies are presented in Table 17.

Table 17: QA/QC of the calculation process procedure

Calculation method	Actions assessed	Uncertainty estimation
Tier 1 methodology	Verification of quantities of fuel imports from different sources (IEA, MoEW and MoF).	The obtained results show differences of less than 1%.
	Verification of the calculation through multiple checks of the calculation files.	
	Comparison of the obtained emissions results to the results generated in the SNC from 2000 to 2006.	Obtained results are comparable (Annex III).
Tier 2 methodology	Verification of the number of registered vehicles from 1994 to 2006 from two sources (MoIM and MoE).	The results show a difference of less than 2%.
	Verification of the annual travelled distance as well as the annual fuel consumption for each vehicle category.	The annual travelled distance per vehicle are estimated from ForFITS on the basis of the following considerations: - Information from household/travel surveys in developed countries as a reference; - By means of assuming the average speed (km/h) and vehicle usage (hours/day and days/week). The obtained annual travelled distances were verified by checking the consistency of the assumptions and the statistics on the number of vehicles in the stock, their average travel and their average fuel consumption with the total energy use.
	Verification of the use of the appropriate EF for final calculation.	Since local EF do not exist, and to make IPCC EF more appropriate to Lebanese conditions, the absence of a catalyst, the car manufacturer, and the climatic conditions were taken into account in the choice of the EF.
	Verification of the calculation through multiple checks of the calculation files.	
	Comparison between the results of tier 1 methodology and tier 2 methodology (Annex II).	The obtained results show consistency between the two methodologies for CO_2, NO_x, CH_4 and SO_2. For N_2O, emissions under the tier 2 methodology were overestimated while CO and NMVOCs were underestimated.

5. Results and discussion

The results of the GHG emissions from the transport sector include the road transport sub-category; as well as domestic aviation since as per the 1996 Revised Guidelines, international aviation and maritime transport are not considered as national emissions and are categorized under bunkers. Therefore, emissions from international aviation and marine activities are not included in the total emissions of the transport sector.

The results of this GHG emissions inventory encompass both years 2005 and 2010 since the last inventory reported emissions up to 2004 (MoE/UNDP/GEF, 2011).

5.1. Transport sector GHG inventory for 2005

In 2005, GHG emissions from transport totaled 3,629 Gg (Gigagram or 1,000 tonnes) CO_2eq. Carbon dioxide, methane, and nitrous oxide constitute 3,550, 0.85, and 0.20 Gg, respectively. Consequently, they contribute to 97.8%, 0.5%, and 1.7% of total CO_2eq. respectively for 2005 (Table 18).

Table 18: Transport sector GHG emissions for the base year 2005

	CO_2eq.	CO_2	CH_4	N_2O
Emissions (Gg)	3,629	3,550	0.85	0.20
Contribution		97.8%	0.5%	1.7%

A Global Warning Potential (GWP) of 1 was used for CO_2, 21 for CH_4 and 310 for N_2O, as per the IPCC Second Assessment Report (SAR), 1995.

As for the contribution of the different categories to total emissions, road transport is by far the largest contributor, emitting 3,619.23 Gg CO_2eq. in 2005. These emissions are distributed over the three direct GHGs as shown in Figure 8. The values are calculated using the tier 2 methodology with EU emission factors as the Lebanese fleet is mostly constituted of European vehicles (Figure 6). The contribution did not vary significantly on a relative basis compared to 1994 where CO_2 contributed to 98.62%.

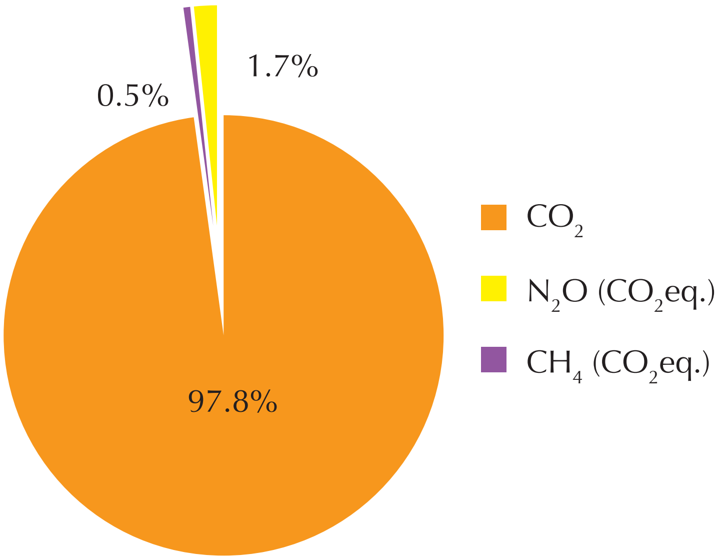


Figure 8: Distribution of the different direct GHGs for the road transport category for 2005

As for the contribution of the different vehicle categories, passenger cars have the highest share of the 2005 emissions with 61.25% of the total road transport GHG emissions (CO_2eq.), while LDV, HDV, and motorcycles account for 15.98%, 22.63%, and 0.14% respectively. The contribution of the different vehicle categories to emissions of direct GHGs shows that passenger cars contribute the most. LDV is an important contributor to methane and HDV to CO_2 and nitrous oxide, as illustrated in Figure 9.

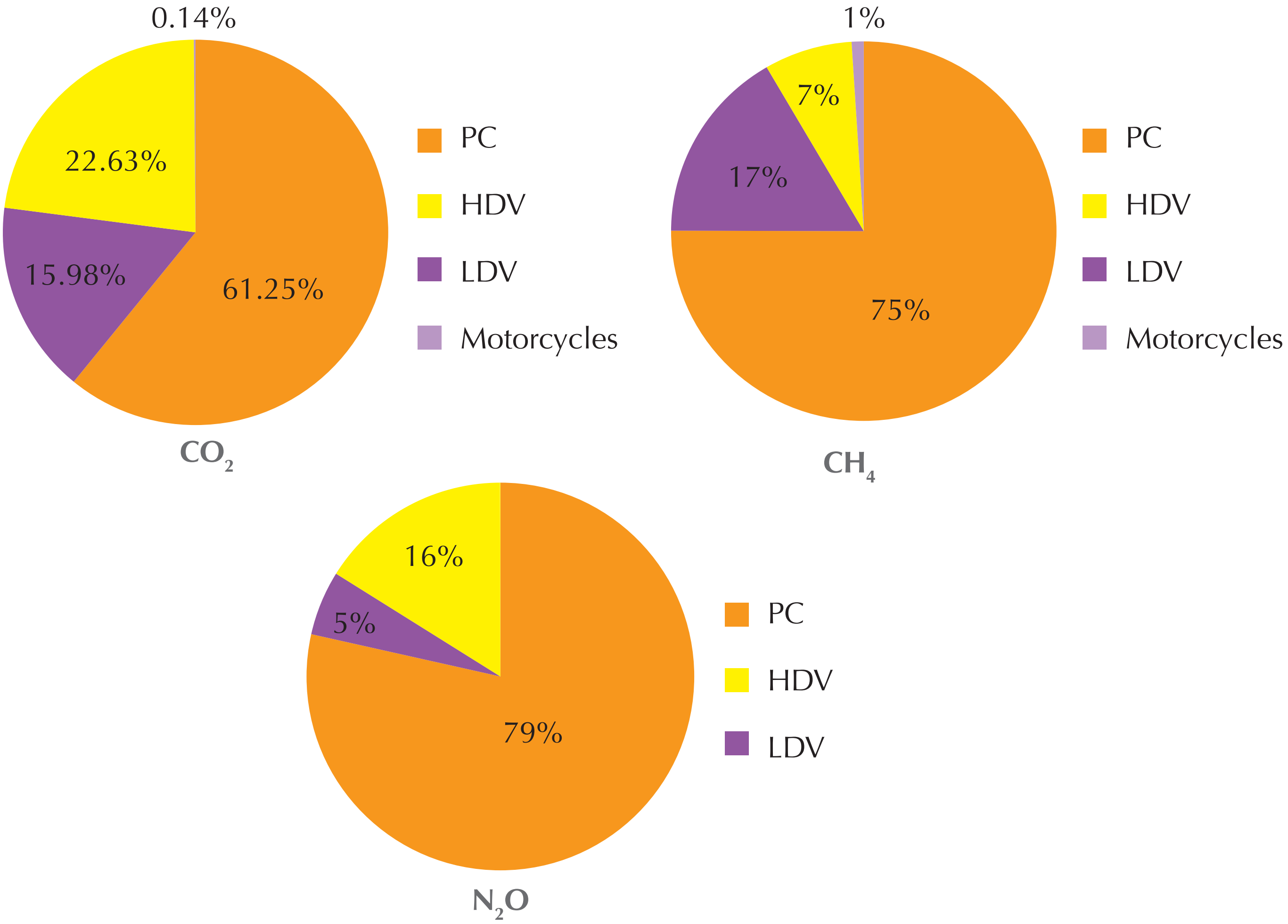


Figure 9: Contribution of the different vehicle categories to the direct GHG emissions for 2005

Indirect GHG emissions from the road transport sector in 2005 account for around 35 Gg for NO_x, 260 Gg for CO, 52 Gg for NMVOCs and 3 Gg for SO_2 (Table 19). Emissions per vehicle category are dominated by passenger cars. HDV contribution to SO_2 emissions is considerable as HDV uses diesel fuel with higher sulphur content than gasoline used for PC.

Table 19: Indirect GHG emissions for the transport sector in Gg in 2005

Category	CO_2eq.	NO_x	CO	NMVOCs	SO_2
PC	2,216.957	19.162	184.268	39.096	1.300
LDV	578.435	5.106	65.143	10.740	0.347
HDV	818.651	10.488	9.439	1.993	1.534
Motorcycles	5.186	0.005	0.897	0.563	0.003
Total	**3,619.2**	**34.8**	**259.8**	**52.4**	**3.2**

International bunkers

For international bunkers, the total direct GHG emissions from aviation and marine amounted to 519 Gg of CO_2eq. in 2005. Around 89% of these direct GHG emissions originated from aviation. The GHG emissions results from international bunkers are given in Table 20.

Table 20: Direct GHG emissions from international bunkers in Gg/year in 2005

Category	CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)	Total emissions CO_2eq. (Gg)
Aviation bunkers	459	0.003	0.004	460.61
Marine bunkers	58	0.004	0.0005	58.73

5.2. Transport sector GHG inventory for 2010

In 2010, GHG emissions from transport totaled 5,423.98 Gg CO_2eq. Carbon dioxide, methane and nitrous oxide constitute 5,279.03, 1.14, and 0.39 Gg respectively. Consequently, they contribute to 97.33%, 0.44%, and 2.23% of total CO_2eq. respectively for 2010 (Table 21).

Table 21: Transport sector GHG emissions in 2010

	CO_2eq.	CO_2	CH_4	N_2O
Emissions (Gg)	5,423.98	5,279.03	1.14	0.398
Contribution		**97.33%**	**0.44%**	**2.23%**

A GWP of 1 was used for CO_2, 21 for CH_4 and 310 for N_2O.

As for the contribution of the different categories to total emissions, road transport is by far the largest contributor with 5,268.79 Gg CO_2eq. in 2010. These emissions are distributed over the three direct GHGs as shown in Figure 10. The values are calculated using tier 2 methodology with EU emission factors as the Lebanese fleet is mostly constituted of European vehicles (Figure 6). The contribution did not vary significantly on a relative basis compared to 1994 during which CO_2 contributed to 98.62%.

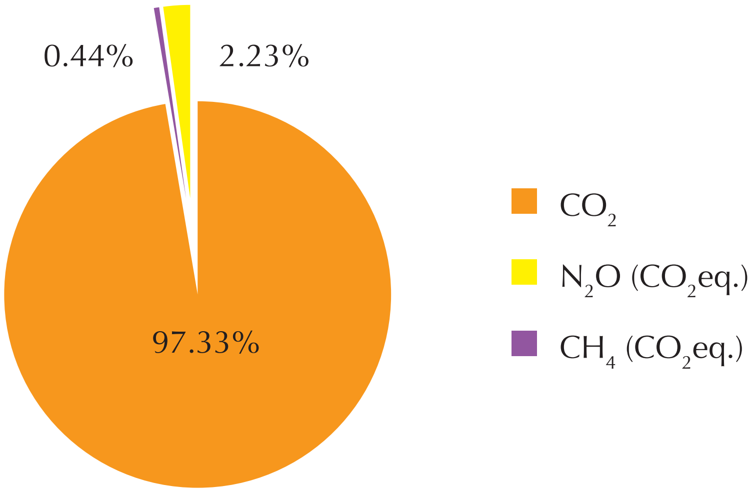


Figure 10: Distribution of the different direct GHGs for the road transport category for 2010

As for the contribution of the different vehicle categories, passenger cars have the highest share of the 2010 emissions, with 58.38% of the total road transport GHG emissions (CO_2eq.); while LDV, HDV, and motorcycles account for 17.46%, 23.81%, and 0.35% respectively. The contribution of the different vehicle categories to emissions of direct GHGs shows that passenger cars contribute the most. LDV is an important contributor to methane and HDV to CO_2 and nitrous oxide, as illustrated in Figure 11.

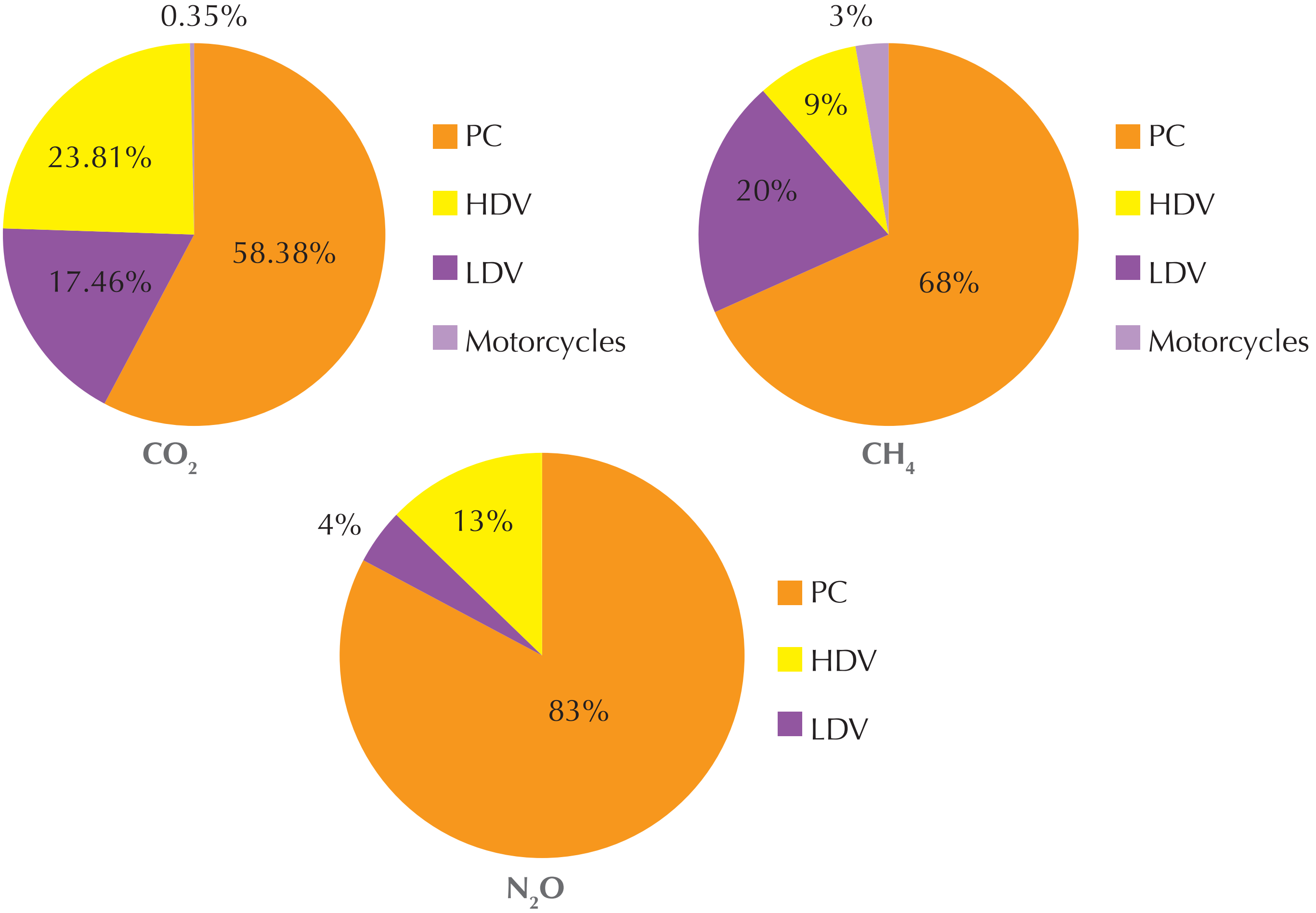


Figure 11: Contribution of the different vehicle categories to the direct GHG emissions for 2010

Indirect GHG emissions from the road transport sector in 2010 account for around 48 Gg for NO_x, 339 Gg for CO, 68 Gg for NMVOCs and 5 Gg for SO_2 (Table 22). Emissions per vehicle category are dominated by passenger cars. HDV contribution to SO_2 emissions is considerable as HDV uses diesel fuel with higher sulphur content than gasoline used for PC.

Table 22: GHG emissions for the transport sector in Gg for the base year of 2010

Category	CO_2eq.	NO_x	CO	NMVOCs	SO_2
PC	3,160.253	23.294	214.420	45.617	1.834
LDV	945.067	8.342	106.433	17.547	0.567
HDV	1,289.173	16.516	14.864	3.138	2.416
Motorcycles	19.156	0.018	3.302	2.099	0.011
Total	**5,413.6**	**48.2**	**339.0**	**68.4**	**4.8**

For international bunkers, the total direct GHG emissions from aviation and marine amounted to 779.68 Gg of CO_2eq. in 2010. Around 90% of these direct GHG emissions originated from aviation. The results from GHG emissions from international bunkers are given in Table 23.

Table 23: Direct GHG emissions from international bunkers in Gg/year for a base year of 2010

Category	**CO_2 (Gg)**	**CH_4 (Gg)**	**N_2O (Gg)**	**Total emissions CO_2eq. (Gg)**
Aviation bunkers	697.39	0.005	0.006	699.35
Marine bunkers	80.04	0.005	0.0006	80.33

5.3. Trends in Lebanon's GHG emissions for the transport sector: 1994-2011

The transport sector evolved drastically between 1994 and 2011 in terms of GHG emissions. Considering the base year of the initial national communication in 1994, GHG emissions from the road transport sector increased since by a factor of 3.7 reaching 5.8 million tonnes CO_2eq. in 2011 (Figure 12). A key driver to this significant increase is the fleet volume, which doubled in around two decades.

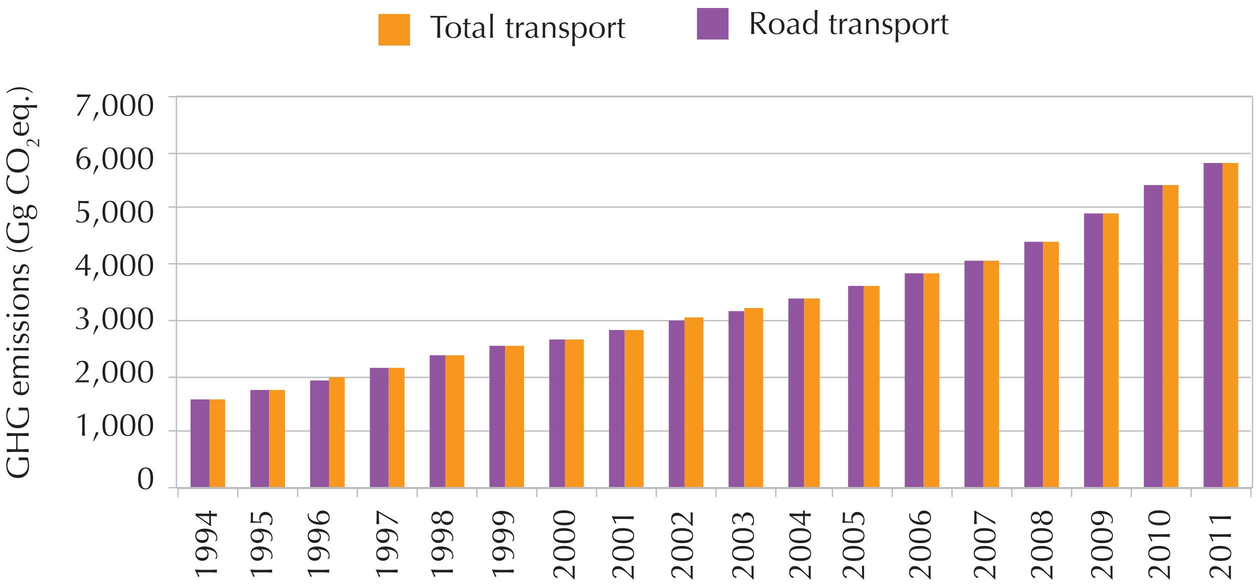


Figure 12: GHG emissions from 1994 to 2011 for road transport in Gg of CO_2eq.

The emissions variation of the three main greenhouse gases normalized to the 1994 level are presented in Figure 13. These emissions were calculated under the tier 2 methodology for the road transport sector and from 1994 to 2011, and under tier 1 methodology for national civil aviation.

The results obtained showed that carbon dioxide has the highest greenhouse impact in Lebanon's transport sector as its share is 97.8% of the total GHG emissions in 2005. Compared to 1994, it has increased by 2,051 Gg in 2005 and by 4,229 Gg in 2011.

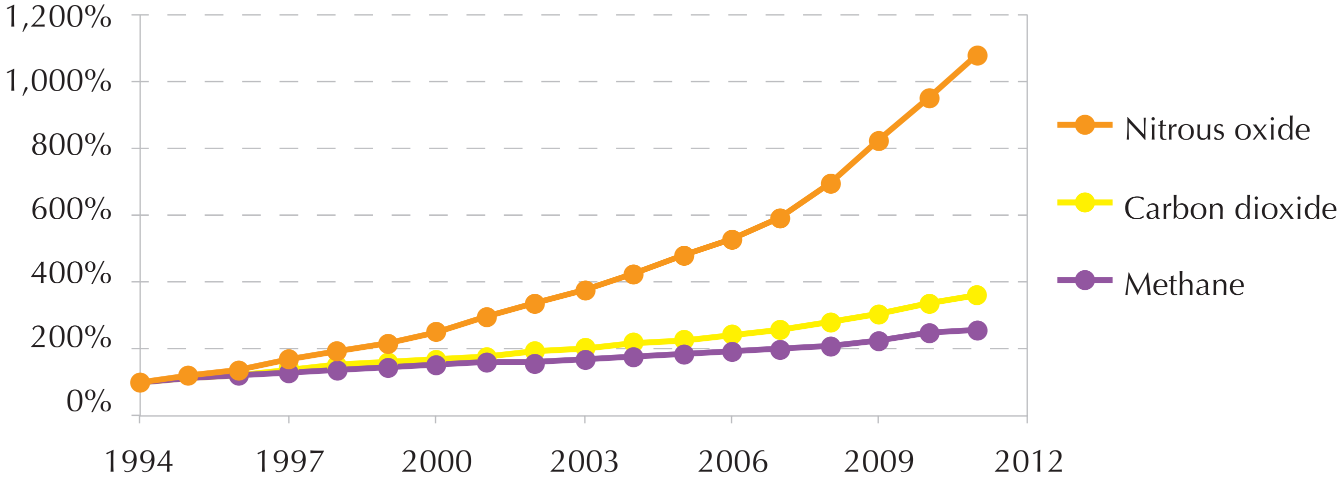


Figure 13: Variation of the emissions of CO_2, CH_4, and N_2O relative to the 1994 level

CO_2 emissions from the transport sector increased by a factor of 3.63 compared to the 1994 level i.e. from 1,555.19 to 5,645.14 Gg while methane emissions have increased by a factor of 2.57 i.e. from 0.46 Gg to 1.2 Gg. This is mainly due to the remarkable growth in the vehicle fleet number. Similarly, nitrous oxide has also increased in 2011 by a significant factor of 10.79 compared to the 1994 level, i.e. from 0.04 Gg to 0.4 Gg due to the fact that vehicles equipped with technologies for emission control are suspected to emit higher amounts of nitrous oxide (IPCC, 1997).

For indirect GHGs, an increase by at least a factor of 2 was observed in 2011 in comparison to 1994. Figure 14 presents the evolution of NO_x, CO, NMVOCs and SO_2 from 1994 to 2011.

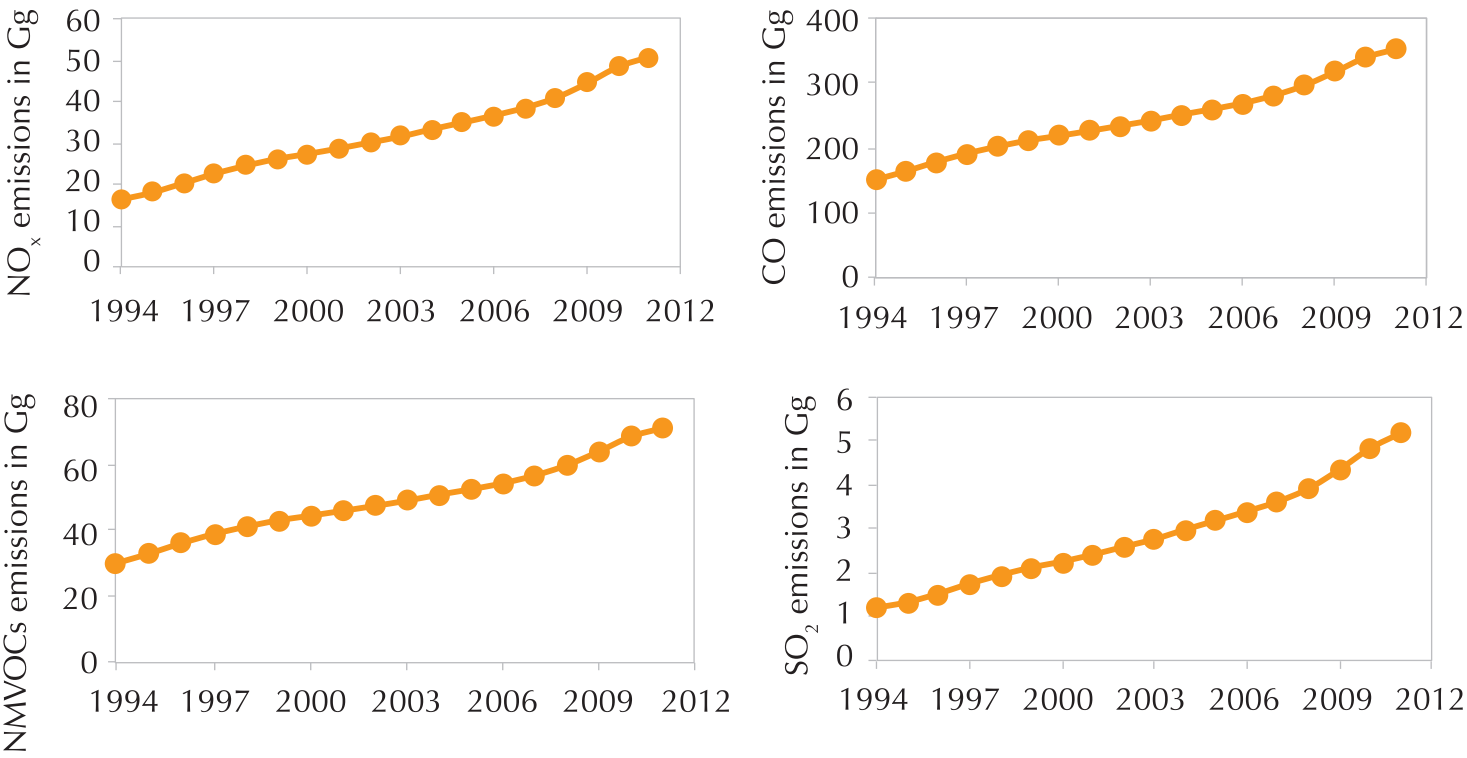


Figure 14: Evolution of NO_x, CO, NMVOCs and SO_2 from 1994 to 2011

Road transport

Road transport constitutes the biggest contributor to emissions originating from the transport sector. Direct GHG emissions of CO_2, CH_4 and N_2O emitted from the road transport sector significantly increased from 1994 to 2011 by 263%[1] for CO_2, 158% for CH_4 and 979% for N_2O (Figure 15). Consequently, a yearly increase of 8% for CO_2, 6% for CH_4 and 15% for N_2O are observed. Emissions results are summarized in Annex I.

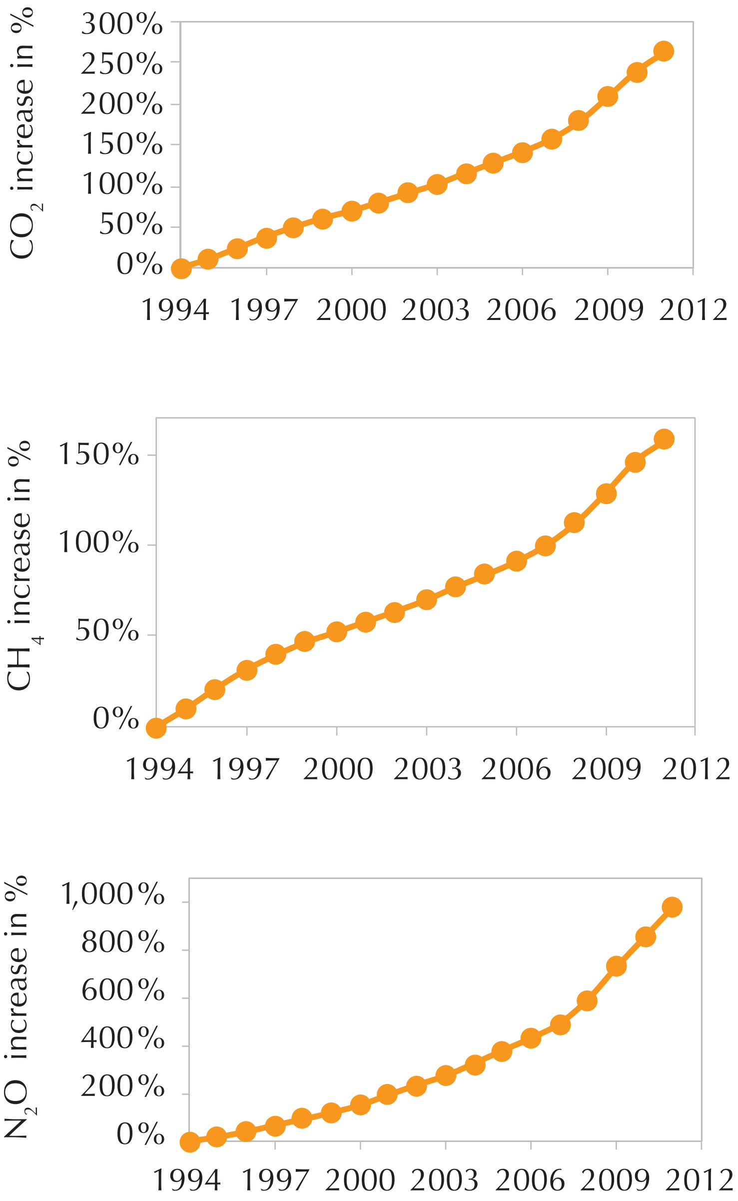


Figure 15: Increase of direct GHG emissions in % for the road transport sector in comparison to the 1994 level

This increase is mostly related to the upturn of the number of registered vehicles in Lebanon from 500,000 in 1994 to 1,500,000 in 2012; whereas the population growth did not follow (Figure 16) the same rate. In fact, 175 vehicles per 1,000 persons were observed in 1995 and 330 in 2010 (ESCWA, 2014; MoE, 2014).

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[1] Note that the increase from 1994 to 2011 is calculated considering the year 1994 as a reference year, therefore, the increase in % during the year of 1994 is equal to 0.

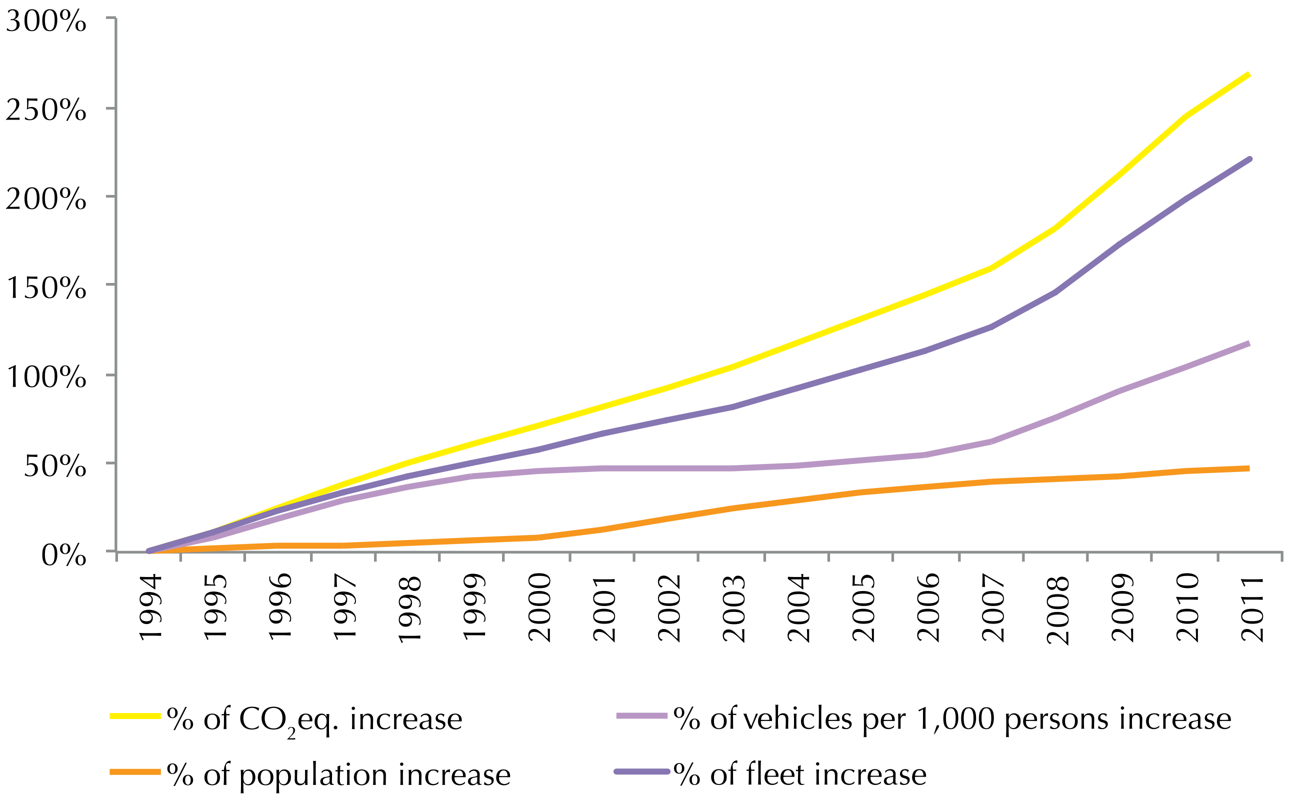

Figure 16: Increase of direct GHGs in terms of CO_2eq., population, fleet and vehicles per 1,000 persons for the road transport sector

Among the main reasons for this significant increase is the inefficient and unreliable management of the mass transport sector, preventing the modernization and growth of the system and allowing the market to be controlled by private operators with an ad-hoc evolution strategy; consequently this encourages passengers to rely on their private cars for their daily trips, along with the lack of policy enforcement for encouraging deployment of new fuel-efficient vehicle technologies.

Looking into the different periods between the years of 1994, 2000 and 2005, Table 24 presents the relative emissions variation per period for the different pollutants. Results show for all the GHG types that the yearly increase from 2000 to 2005 is the lowest between the three periods. This is explained by the yearly increase in the number of registered vehicles for 1994-2000, 2000-2005, and 2005-2011, observed to be 9.66%, 5.65%, and 9.72% respectively.

The highest yearly increase in GHG emissions was for N_2O (18-25%) from 1994 to 2011 due to the fact that the vehicles equipped with a catalyst for emissions control emit 10 times more N_2O than the older vehicles especially for PC (IPCC, 1997).

It is worth mentioning that the decrease in the yearly emission rates of the different greenhouse gases between 1994-2000 and 2000-2005 is a natural consequence to the advancements in reduction of consumption and emissions of new vehicles with emission control technologies. In fact, the observed average yearly increase of CO_2 emissions per car is 1.25% over 1994-2000, 0.99% for 2000-2005 and 0.08% for 2005-2011. However, this technology advancement in emissions savings did not reduce the fleet average emissions over the period 2005-2011 as shown in Table 24, and the upturn that took place is explained by the 9.72% yearly increase in the number of registered vehicles over the same period, and more likely in the increase in the yearly average distance traveled.

Table 24: Trends of road transport emissions in Gg/year and in % during the period 1994-2011

	Number of vehicles	CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)	NO_x (Gg)	CO (Gg)	NMVOCs (Gg)	SO_2 (Gg)
1994	479,120	1,548.18	0.46	0.04	16.14	150.99	29.97	1.20
2000	756,885	2,629.29	0.71	0.10	27.19	218.86	44.38	2.25
2005	970,803	3,540.62	0.85	0.20	34.76	259.75	52.39	3.18
2011	1,536,919	5,634.81	1.19	0.44	50.59	351.91	71.05	5.18
Yearly increase (%) 1994-2000	9.66	11.64	8.67	25.29	11.41	7.49	8.01	14.63
Yearly increase (%) 2000-2005	5.65	6.93	4.14	18.20	5.57	3.74	3.61	8.30
Yearly increase (%) 2005-2011	9.72	9.86	6.72	20.89	7.59	5.91	5.93	10.43

The trend in direct and indirect emissions from 1994 to 2011 shows that PC are the major contributor (Figure 17), with CO_2 emissions in 2011 accounting for more than threefold when compared to 1994. LDV and HDV present comparable emissions trends for CO_2, N_2O and NO_x, however HDV show a double SO_2 trend despite the lower number of HDV compared to LDV (2% HDV and 7% LDV in 2012) (Figure 18). This is due to the high sulphur content contained in diesel. Note that the contribution of motorcycles shows an upturn of NMVOCs since 2006, as the number has increased by 5% compared to 1994 to reach 84,000 motorcycles in 2012.

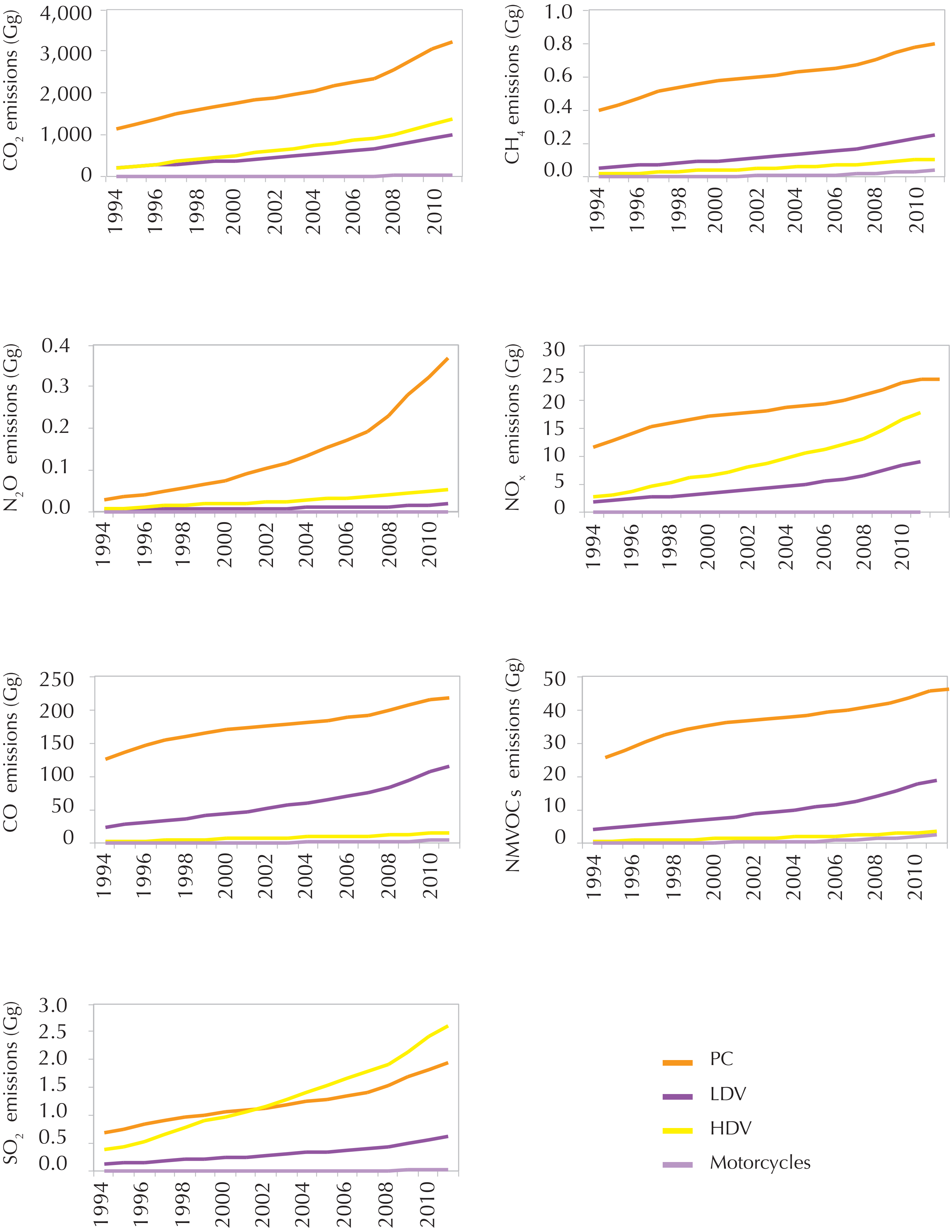

Figure 17: Evolution of the road transport emissions between 1994 and 2011

Figure 18: Percentage distribution of road motorized vehicles from 1994 to 2011

Comparison of road transport calculations methodologies

Comparison between tier 1 and tier 2 methodologies for the road transport sector showed comparable values for CO_2 and CH_4 from 2004 to 2011 (Figure 19) whereas N_2O emissions among both methodologies were different.

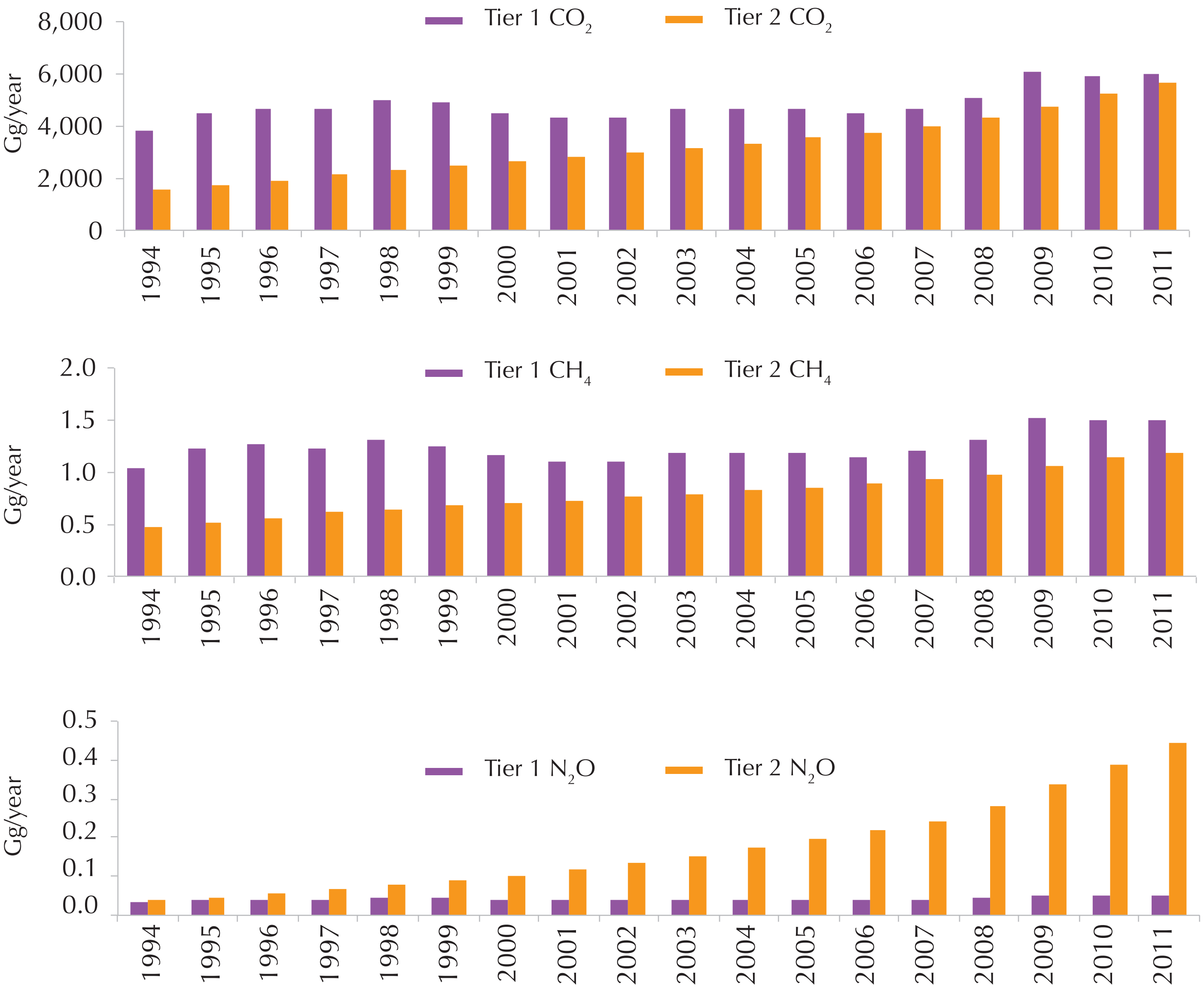

Figure 19: Comparisons of GHG emissions of CO_2 and CH_4 with the use of the tier 1 and tier 2 for the road transport sector

Observed significant differences between tier 1 and tier 2 methodologies for nitrous oxide are mostly related to the fact that under the tier 2 methodology, newer vehicles emit 10 times more N_2O when compared to old vehicles because of the introduction of emission control technologies. For this purpose, N_2O calculated emissions for both methodologies are comparable from 1994 to 1998 and are different from 2000 to 2011. In term of CO_2eq. emissions, the recorded direct GHG emissions for a base year of 2000 is 2,675.90 Gg under the tier 2 methodology and 4,503.43 Gg if tier 1 was used. The tier 1 reported value in this study for a base year of 2000 is therefore higher by a factor of 1.14 to that of the SNC (3,963 Gg; MoE/UNDP/GEF, 2011). The differences observed between SNC and TNC values are mainly related to the use of different estimation methodologies for gas/diesel consumption for the road transport sector.

International marine bunkers

The trend of direct GHG emissions from 1994 to 2011 in terms of CO_2eq., presented in Figure 20, shows an increase for marine international bunkers from 1994 to 2011. The period from 2005 to 2011 has the highest relative yearly increase with 7%, whereas periods from 1994-2000 and 2000-2005 showed an increase by 4% and 5%, respectively.

Figure 20: Evolution of direct GHG emissions from 1994 to 2011 for international marine bunkers

The 7% yearly increase in GHG emissions from 2005 to 2011 is partly related to the increase in the number of imports/exports of cargo at the Beirut port (Figure 21) with an average value from 2005 to 2011 of 5,605,000 tonnes in comparison to a value of 4,983,000 tonnes from 2000 to 2005. In addition, United Nations Interim Force in Lebanon (UNIFIL) ships' consumption could have also contributed to the increase in GHG emissions over this same period.

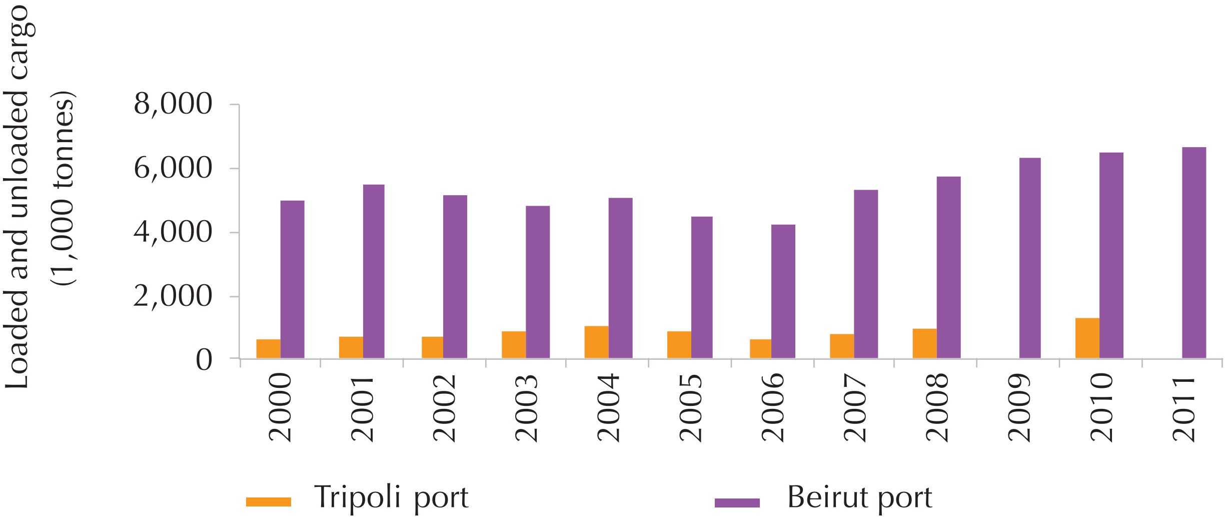

Figure 21: Loaded and unloaded cargo in Beirut and Tripoli ports from 2000 to 2011

International aviation bunkers

Aviation bunkers only take into account international flights. The study of the trend from 1994 to 2011 shows that direct emissions were steady from 1994 till 2005, they increased between 2008 and 2011 and decreased significantly during the year of 2006 (Figure 22). The decrease in emissions during the year of 2006 is mainly related to the war that occurred in the typical tourism period of the summer. Consequently, only 32,980 flights (landing and taking off) were recorded in 2006 in comparison to a value of 38,196 for 2005 and a value of 39,060 for 2007 (CAS, 2014). The increase in emissions from 2008 to 2011 is mostly related to the increase in the yearly number of departures and arrivals at the BIA (Figure 23).

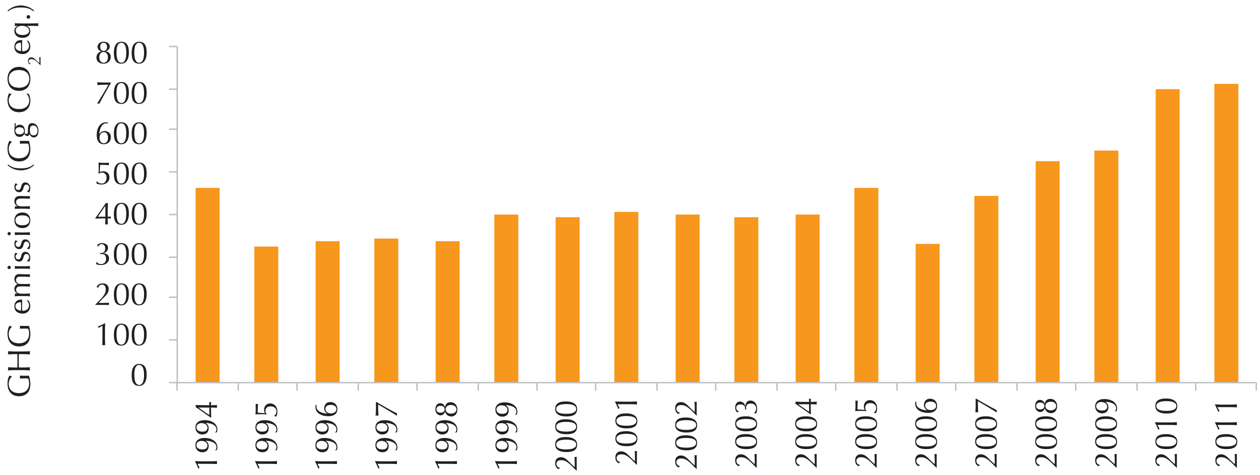

Figure 22: Evolution of direct GHG emissions from 1994 to 2012 for international aviation bunkers

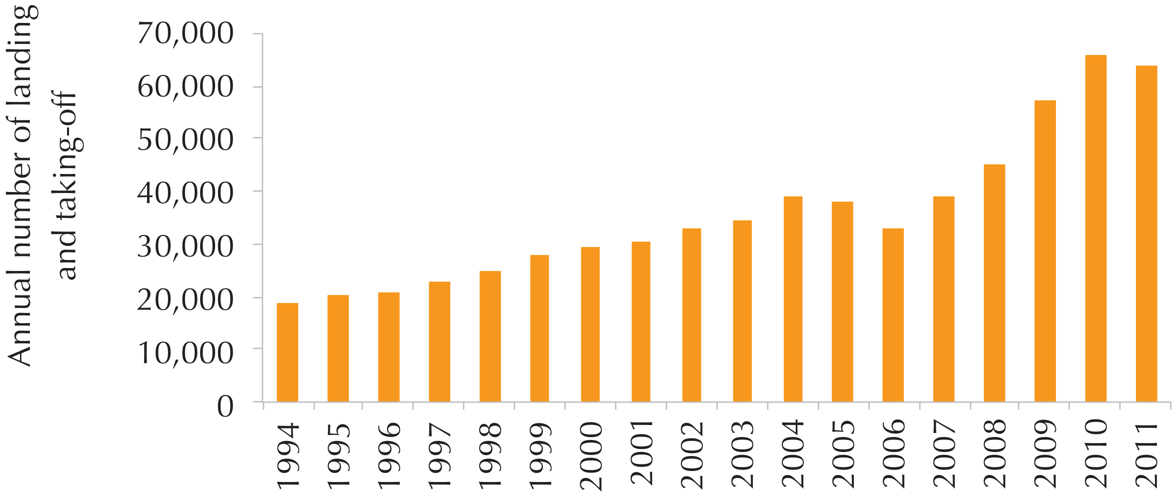

Figure 23: Number of arrivals and departures of aircrafts at the BIA between 1994 and 2011

5.4. Indicators and comparison with other countries

The results obtained for direct and indirect GHG emissions from the road transport sector increased significantly from 1994 to 2011. This observed increase in emissions is related to the increase in the number of registered vehicles, population growth and the GDP per capita. Indeed, correlation coefficients R between the GDP per capita (World Bank, 2014), vehicle per capita, population and GHG show values above 0.9 (Table 25) which indicates that a linear correlation exists between the two variables considered for this analysis. This explains how the growth of GDP per capita is causing the observed evolution in the number of vehicles per 1,000 persons, as passengers purchase more private cars to cover their mobility needs in the absence of alternative mass transport systems (Waked and Afif, 2012). Consequently, more GHG emissions are generated.

Table 25: Correlation between GDP/capita, veh/capita and GHG emissions

	CO_2	CH_4	N_2O	NO_x	CO	NMVOCs	SO_2
R* (veh/capita vs. GHG) 1994 to 2011	0.96	0.96	0.94	0.96	0.96	0.96	0.96
R (GDP/capita vs. GHG) 1994 to 2011	0.95	0.95	0.94	0.94	0.95	0.95	0.94
R (population vs. GHG) 1994 to 2011	0.96	0.96	0.94	0.96	0.96	0.96	0.96

*R is the correlation coefficient that measures the interdependence of two random variables. It ranges from -1 to +1 indicating perfect negative correlation at -1, absence of correlation at 0 and perfect positive correlation at +1.

Comparison to other countries for a base year of 2005 (ENERDATA, 2012, World Bank, 2014) (Figure 24) shows that Lebanon's total CO_2 emissions per capita from the transport sector are exceeding the emissions level of Jordan, Syria, Tunisia and Turkey. Lebanon's CO_2 emissions per car are comparable to that of Mediterranean European countries such as Cyprus and Greece highlighting a high car ownership for Lebanon comparable to that of developed countries. Lebanon's CO_2 emissions per GDP remain lower than emissions observed in Jordan and Syria, comparable to that of Tunisia, and higher than the reported values of European countries such as Cyprus and Greece. All these indicators show that Lebanon is an important contributor to CO_2 emissions on a capita basis and therefore, its GHG emissions need to be reduced.

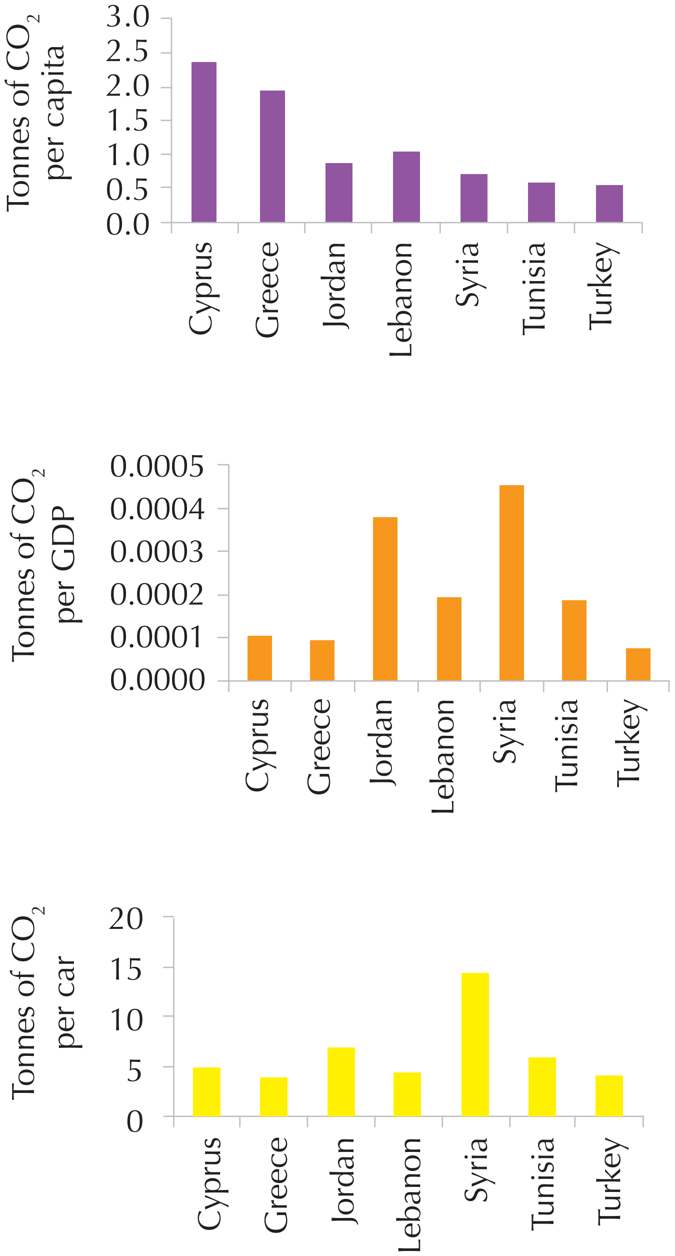

Figure 24: CO_2 emissions per capita, per GDP and per car for some Mediterranean and European countries for a base year of 2005

Part 2: Mitigation analysis

6. Scope

This section has been developed in the framework of Lebanon's Third National Communication (TNC) to the United Nations Framework Convention on Climate Change (UNFCCC). It covers the preparation of the mitigation options analysis for the transport sector, which consist in (1) the elaboration of a baseline scenario to project Greenhouse Gas (GHG) emissions from the transport sector for the short-term (2020) and medium-term (2040) under Business as Usual (BAU) conditions, and (2) the proposition of mitigation options and calculation of their emission reduction potential for 2020 and 2040.

This section builds on the results of model runs applied to the transport sector in Lebanon using the For Future Inland Transport Systems model (ForFITS), a modeling tool developed in the context of a project of the United Nations Economic Commission for Europe (UNECE) and intended to assess transport CO_2 emissions and to evaluate potential policies to mitigate them (UNECE, 2013). Key parameters discussed in this report include in particular vehicle stock, transport activity, energy use and CO_2 emissions.

This section concludes with the formulation of a set of actions for the definition of transport policies having implications for climate change mitigation, leveraging on the results of the ForFITS runs and the assessed mitigation scenarios.

7. Introduction

Eradicating the problems of the Lebanese transport sector is neither affordable, nor economically feasible. However, much can be done to reduce and lessen the burden of their negative impacts on travelers and the government. Hence, effectively managing this sector requires both a holistic and integrated strategy that goes beyond the visible incidence of these problems and the scope of this study, and extends to setting a national transport strategy managing all transport services as a whole.

The Technology Needs Assessment (TNA) report for the transport sector prepared by the MoE/ United Nations Development Programme (UNDP) in 2012 tackled the needs to deploy an efficient "mass transit system" in the Greater Beirut Area (GBA) and to "renew the passenger cars fleet with fuel-efficient and hybrid electric vehicles": two mitigation options that were highly prioritized by transport experts and stakeholders gathered for the purpose of identifying the technology needs for the transport sector. Consequently, the TNA highlighted the barriers as well as the measures and enabling framework to deploy these options (MoE/URC/GEF, 2012).

As a complement to the TNA, this study synthesizes the projection assessments of these two options, underlined in the report as mitigation options "shift to mass transport" and "shift to fuel-efficient and hybrid electric vehicles". It emphasizes their impact on the transport activity, energy use and CO_2 emissions by the years 2020 and 2040, and concludes with action plans for their deployment.

8. Existing and planned mitigation actions

Few are the mitigation actions that addressed the problems pertaining to the transport sector over the last decade. The enacted decrees and laws mostly concerned improving the air quality and reorganizing the land public transport sector.

Some of the measures tackled indirectly reducing GHG emissions of the transport sector, such as decree no. 8243/2003 requiring mandatory annual vehicle inspection, which consequently force drivers to annually control the engine operation; and the Lebanese customs restriction on used cars, banning the import of vehicles older than 8 years.

In 2014, the Ministry of Public Works and Transport (MoPWT) presented to the Council of Ministers (CoM) the master plan to revitalize the land public transport for passengers. It encloses a set of actions to be implemented on the short and medium terms, shifting the passenger transport demand to mass transit systems. The main actions with direct impact on reducing GHG emissions are:

On the short-term:

- Implementation of phase 1 of the rail transportation plan, namely the lane connecting the port of Tripoli to the Syrian border;
- Revitalization and restructuring of the operation of public buses inside the cities;
- Continuation of the development project of traffic management in GBA;
- Improvement of the pedestrian infrastructure.

On the long-term:

- Deployment of a Bus Rapid Transit (BRT) on Beirut's north and south gates, commuting Jounieh to Jiyeh;
- Development of a mass transit system covering territories all over Lebanon and commuting cities;
- Restructuring the freight transport.

9. Proposed mitigation analysis

9.1. Methodology

Modeling framework: transport system characteristics

The mitigation options analysis has been performed using ForFITS, a modeling tool that converts information on transport activity into fuel consumption and CO_2 emission estimates considering the influence of the demographic and socio-economic context, including policy inputs (UNECE, 2013). The study covers passenger and freight mobility services on inland transport modes, taking into consideration the different vehicle classes, powertrains and fuel blends consistent with the technology requirements. Table 26 characterizes the modal and sub-modal levels considered in the modeling framework. Note that non-motorized transport (walking and cycling), aviation and maritime transport were excluded from the study. Freight transport was only considered in the baseline scenario in order to weigh its energy use and CO_2 emissions evolution with respect to passenger transport. It was excluded from the mitigation scenario projections as the scope of this study considers only mitigation measures for passenger transport.

Table 26: Transport modal characteristics considered in the ForFITs model

Urban and non-urban	Passenger	Motorcycles	Small motorcycles and scooters (engine not exceeding 50 cm^3)	Internal Combustion Engine (ICE)	Gasoline
			Motorcycles (engine exceeding 50 cm^3)		
			Three-wheelers		
		Light-duty vehicles	Small light vehicles (unladen kerb mass < 1 t)	ICE and hybrid electric	Gasoline
			Midsize light vehicles (unladen kerb mass ≥ 1 t and < 1.5 t)		
			Large light vehicles (unladen kerb mass ≥ 1.5 t)		
			Taxi		
		Large roads	Buses (carry more than 8 seated passengers)	ICE	Gasoline/diesel
	Freight	Light-duty vehicles	Light commercial vehicles	ICE	Gasoline
		Large roads	Medium and heavy-duty vehicles	ICE	Diesel

🟧 Transport zones	🟧 Vehicle classes
🟪 Transport services	🟪 Powertrain technologies
🟨 Transport modes	🟨 Fuel blends

Calculation methodology

The study provides yearly projection figures on vehicle stock, transport activity, energy use and CO_2 emissions as presented in Table 27, to help understand and assess trends in the evolution of the transport sector in 2020 and 2040.

Table 27: Output parameters of the ForFITS model

Output parameter	Unit	Description
Vehicle stock	Vehicles	The annual number of vehicles in the fleet stock, provided by transport mode (motorcycles, passenger LDV and buses), and by vehicle class for passenger LDV (small, midsize and large vehicles).
Passenger transport activity	Vehicle-km	The annual vehicles overall distance travel activity.
Energy use	toe (tonne-oil-equivalent)	The annual overall fuel consumed by vehicles. For consistency, gasoline and diesel consumption units are converted to tonne-oil-equivalent.
CO_2 emissions	Gg	The annual overall tank-to-wheel CO_2 emissions from vehicles.

The evaluation of energy use and CO_2 emissions is performed using the Activity, Structural components, energy Intensity and Fuel use (ASIF) framework of equations (5) and (6), based on the decomposition of fuel use into transport activity, energy intensity and structural components, such as the type of transport service (passenger vs. freight), mode, vehicle class and powertrain group. This methodology is used by the International Energy Agency (IEA) in its Mobility Model (MoMo), and is known as Parc, Utilization, Consumption and Emissions (PUCE), which works to ensure consistency between the vehicle parc (stocks), utilization (travel per vehicle), consumption (energy use per vehicle, i.e. fuel economy) and emissions (fuel CO_2 emission factors) (OECD/IEA, 2012).

$$F = \sum_i F_i = A\sum_i (A_i/A)(F_i/A_i) = A\sum_i S_i I_i$$

F	total fuel use
A	overall vehicle activity (in vehicle-kilometer (vkm))
F_i	fuel used by vehicle (i) with a given set of characteristics (by service, mode, vehicle class and powertrain)
S_i	sectoral structure (expressed as shares of vkm by service, mode, vehicle class and powertrain)
I_i	energy intensity (the average fuel consumption per vkm by service, mode, vehicle class and powertrain)

$$E = \sum_i E_i = A\sum_i (A_i/A)(F_i/A_i)(F_{ij}/F_i)(E_{ij}/F_{ij}) = A\sum_i S_i I_i EF_{ij}$$

E	total emissions use
E_i	emissions generated per vehicle (i) (by service, mode, vehicle class and powertrain)
F_{ij}	fuel (j) used in the vehicle (i)
EF_{ij}	emission factor for the fuel (j) used in the vehicle (i)

These equations constitute the basis of the ForFITS model structure for the calculations per year. They depend on the transport activity expressed as shares of vehicle-kilometer per service, mode, vehicle class and powertrain, which is evaluated on a yearly basis as function of the GDP per capita evolution. Hence, information characterizing the transport system in the base year (2010) are combined with the evolution of population and GDP up to 2040 (Figure 25 and Figure 26), in order to generate transport activity, vehicle stock, fuel consumption and CO_2 emission estimates. Figure 27 provides a synthetic description of the calculation flow outlined, also highlighting the links associated with the ASIF calculations. Further information on the calculation methodology is extensively discussed in the ForFITS user manual (UNECE, 2013).

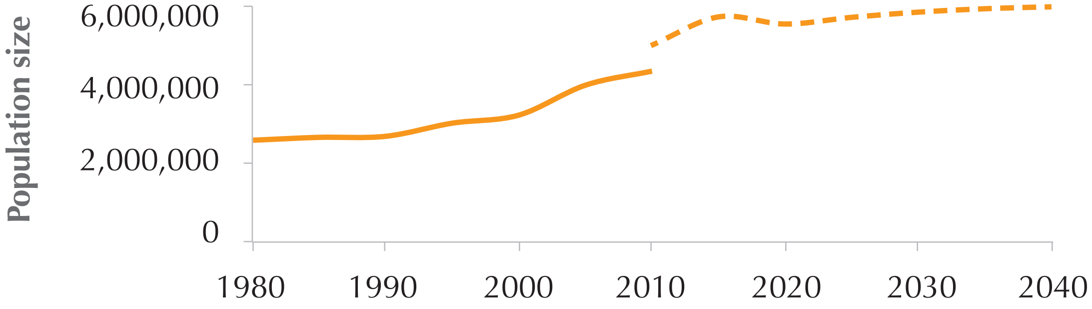

Figure 25: Population size of Lebanon, 1980-2050

Source | ESCWA, 2014

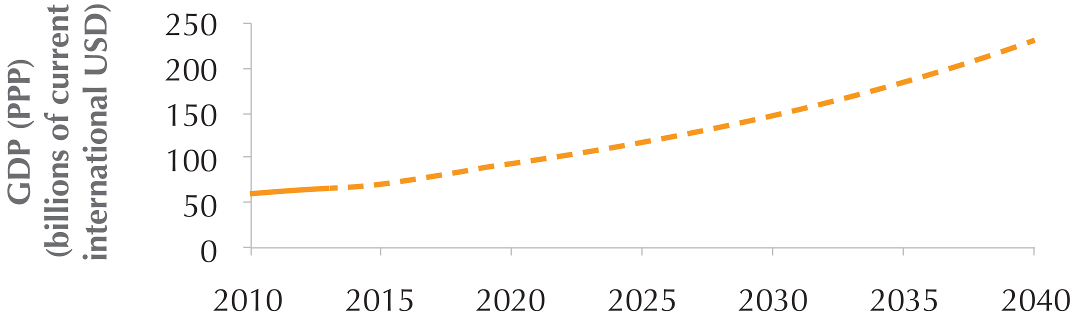

Figure 26: GDP of Lebanon based on Purchasing Power Parity (PPP), 2010-2040

Source | International Monetary Fund, World Economic Outlook database, April 2014, for 2010-2019 values. 2020-2040 values are estimated considering the average growth of 4.61% between 2012 and 2019.

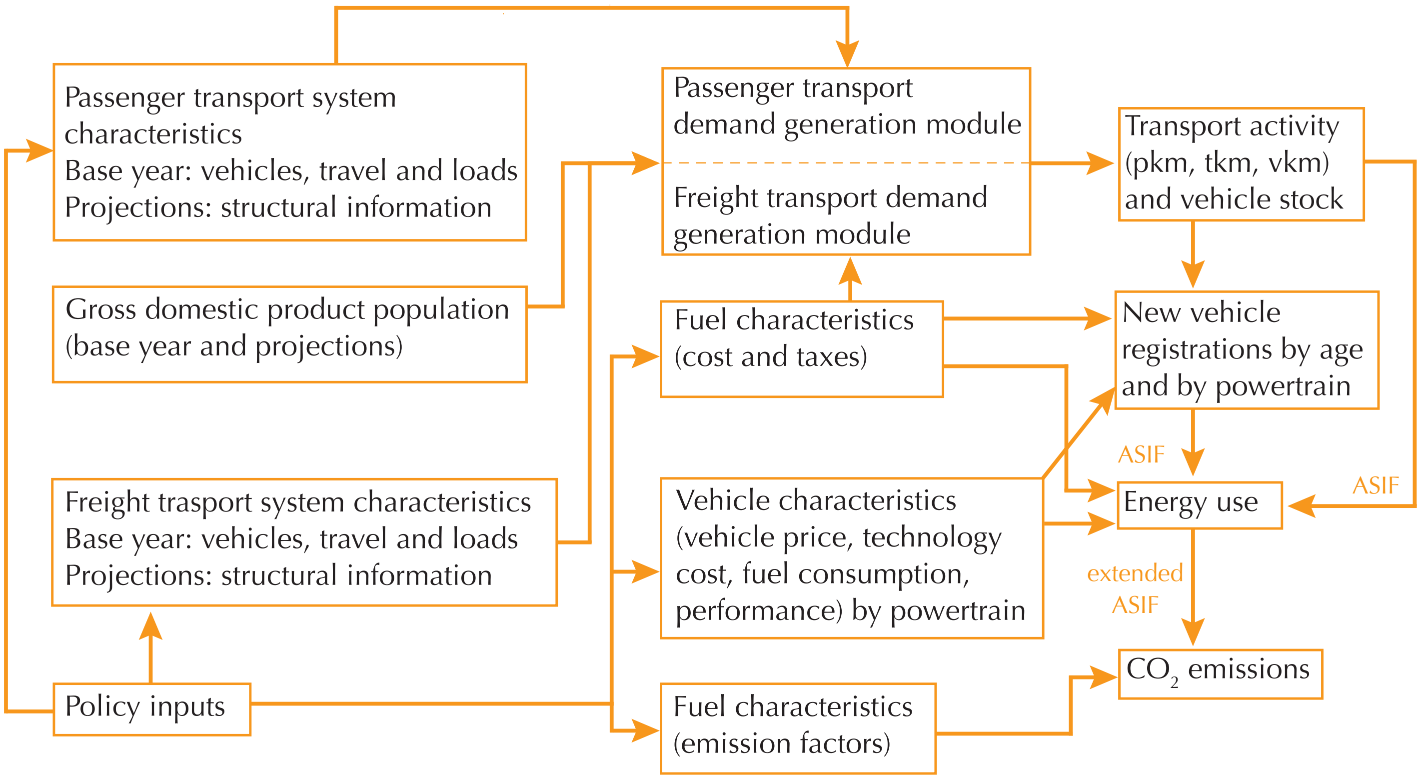

Figure 27: ForFITS simplified model structure

Source| ForFITS manual

Projection scenarios

A baseline scenario has been carried out first in order to estimate CO_2 emissions projection under BAU conditions, basing the projections calculations on available transport system data in the base year (2010) and on data 5 and 10 years prior to the base year (2005 and 2000 respectively). Then mitigation scenarios to increase the share of fuel-efficient vehicles, hybrid electric vehicles and mass transport have been developed and compared to the baseline. They are run on the basis of a set of hypotheses, intended to evaluate policy impacts of shifting the mobility demand from high consuming vehicles to efficient passenger vehicles and mass transit systems. Table 28 provides details on the set of hypotheses that defines each of the scenarios and summarizes the parameters that are subject to a variation across the different scenarios.

Table 28: Set of hypotheses adopted in the baseline and mitigation scenarios
(Shaded cells highlight the key changes from a scenario to another)

	Gasoline and diesel price	Passenger transport system index[1]	Passenger LDV powertrain shares	
			Conventional	Hybrid
Baseline scenario: *BAU scenario*			Constant over time[2]	
Mitigation option 1: *Increase share of Fuel-Efficient Vehicles (FEV)*	50% up by 2040	Constant over time	Share increase of small and midsize vehicles[3]	0%
Mitigation option 2: *Increase share of FEVs and hybrid vehicles*			Share increase of small and midsize vehicles[3]	10% of new registered vehicles[4]
Mitigation option 3: *Increase share of mass transport*		Passenger Kilometer (PKM) share growth on collective passenger vehicles[5]	Constant over time[2]	0%

[1] The "passenger transport system index" aims to allow the understanding of the modal shift in passenger transport (changes associated with shifts to/from private vehicles from/to mass transport). It is related to the shares of PKM on personal and mass passenger transport. An index of 1 reflects a full reliant transport system on collective passenger vehicles, and an index of 0 reflects a totally dependent system on personal vehicles. According to the transport activity data, the passenger transport index is barely 0.1 for Lebanon in 2010.

[2] Same powertrain shares as 2010 (base year): 11.8% for small vehicles, 54.9% for midsize vehicles and 33.3% for large vehicles.

[3] Target powertrain shares by 2040: 35% for small vehicles, 55% for midsize vehicles and 10% for large vehicles.

[4] 10% of new registered vehicles are assumed to be hybrids.

[5] Increase the passenger transport system index to 0.15 in order to reduce the gap by 15% with high populated European city (where passenger transport index is 0.45).

9.2. Description of baseline scenario

Assumptions

The baseline scenario emulates the evolution of the transport activity based on the current BAU conditions; therefore, the scenario maintains all identified transport characteristics for the base year 2010 constant across time:

- Constant passenger transport system index reflecting the preferential use of personal motorized passenger vehicles despite of collective transportation systems. The passenger transport system index is related with the shares of passenger-kilometer on personal and mass passenger transport. An index of 1 reflects a full reliant transport system on mass transport, and an index of 0 reflects a totally dependent system on personal vehicles. A value of 0.1 has been reported from the passenger activity data of 2010.

- Constant low environmental culture index reflecting the poor behavioral changes associated with environmental consciousness. A value of 0.2 is estimated, knowing that a value of 1 represents a culture strongly focused on protecting the environment, while a value of 0 represents the absence of environmental consciousness in decision making.
- Constant powertrain technology share for all vehicles and all modes equal to the shares observed in 2010: 11.8% for small vehicles, 54.9% for midsize vehicles and 33.3% for large vehicles; however taking into account the improvement of the fuel consumption characteristics of each powertrain technology.
- Constant CO$_2$ emission factors, reflecting no changes in fuel blends with respect to tank-to-wheel emission characteristics, and therefore excluding switches towards higher or lower energy-and carbon-intensive fuel options.

In addition, the baseline scenario considers the following parameters:

- A growth in gasoline and diesel fuel price by 50% in 2040; a common hypothesis adopted for all scenarios under consideration.
- The total population is expected to increase by 22% by 2040.
- The GDP is projected to be almost multiplied by 4.

Transport characteristics at the base year 2010

In addition to the socio-economic data that define the context in which the transport system should evolve, information on the characteristics of the transport system in the base year (2010) is provided, summarized in Table 29. This information is compiled and used in the ASIF equations 1 and 2 to determine the total energy and emissions use.

Table 29: Characteristics of the road transport sector in 2010

	Vehicle stock	New registered vehicles	Annual travelled distance (km)	Vehicle load (pass/veh)	Vehicle fuel consumption (lge/100 km)
Passenger					
2-3 wheelers	60,588	13,416	5,000	1	3-6.5
Passenger LDV					
Small vehicles	139,503	11,258	10,000	1.18	8
Midsize vehicles	649,044	52,423	10,000	1.18	12
Large vehicles	393,682	31,798	10,000	1.18	16
Taxi	50,000	1,785	25,000	1.18	15
Buses	12,388	1,188	50,000	11.2	25
Freight				(t/veh)	
Freight LDV	96,236	10,303	25,000	0.5	15
Trucks	29,970		50,000	3-6	17-45

Baseline energy use, CO_2 emissions and transport activity projections

Table 30 and Table 31 show the values of the main outputs for passenger and freight transport in the reference scenario at the base year 2010, 2020 and 2040.

Table 30: Baseline scenario projections for passenger transport

	Unit	Base year (2010)	2020	2040	Ratio 2020/2010	Ratio 2040/2010
Total passenger vehicle stock	Vehicles	1,292,433	1,693,136	2,663,349	1.31	2.06
2-3 wheelers	Vehicles	60,587	79,632	124,268	1.31	2.05
Passenger LDV	Vehicles	1,219,460	1,599,130	2,523,080	1.31	2.07
Buses	Vehicles	12,387	14,375	16,001	1.16	1.29
Total vehicle-km	Billion vkm/year	13.68	17.98	27.74	1.31	2.03
Total energy use	toe/year	1,497,765	1,633,910	1,898,235	1.09	1.27
Total CO_2 emissions	Gg CO_2/year	4,350	4,747	5,514	1.09	1.27

Table 31: Baseline scenario projections for freight transport

	Unit	Base year (2010)	2020	2040	Ratio 2020/2010	Ratio 2040/2010
Total freight vehicle stock	Vehicles	126,202	188,162	495,484	1.49	3.93
Freight LDV	Vehicles	96,235	150,093	433,496	1.56	4.50
Trucks	Vehicles	29,968	38,069	61,988	1.27	2.07
Total vehicle-km	Billion vkm/year	3.90	5.66	14.08	1.45	3.61
Total energy use	toe/year	660,446	803,046	1,578,551	1.22	2.39
Total CO_2 emissions	Gg CO_2/year	1,990	2,410	4,700	1.21	2.36

In terms of projections, both the passenger and freight activity increase substantially compared to the base year, which is a direct consequence of the economic growth and leads to an increase in transport activity and fuel consumption use during this period. The economic growth triggers an increase in the number of personal passenger cars (Figure 28) and their annual distance travel (Figure 29), especially for Light-Duty Vehicles (LDV) where vehicle-kilometer (vkm) activity increases by 31% in 2020 and 103% in 2040 compared to the base year. Thus, any fuel saving measure adopted to improve the vehicle performance and efficiency will only partly offset the increasing trend of emissions.

The increase in CO_2 emissions (Figure 31) follows closely the trend of the energy demand since emissions are mostly related to fuel consumption (Figure 30). As for the distribution of emissions per vehicle class, passenger CO_2 emissions are largely dominated by midsize and large vehicles as illustrated in Figure 32. This is due to the absence of environmental considerations during vehicle purchase, resulting in 88% share of midsize and large vehicles of the total passenger vehicle fleet.

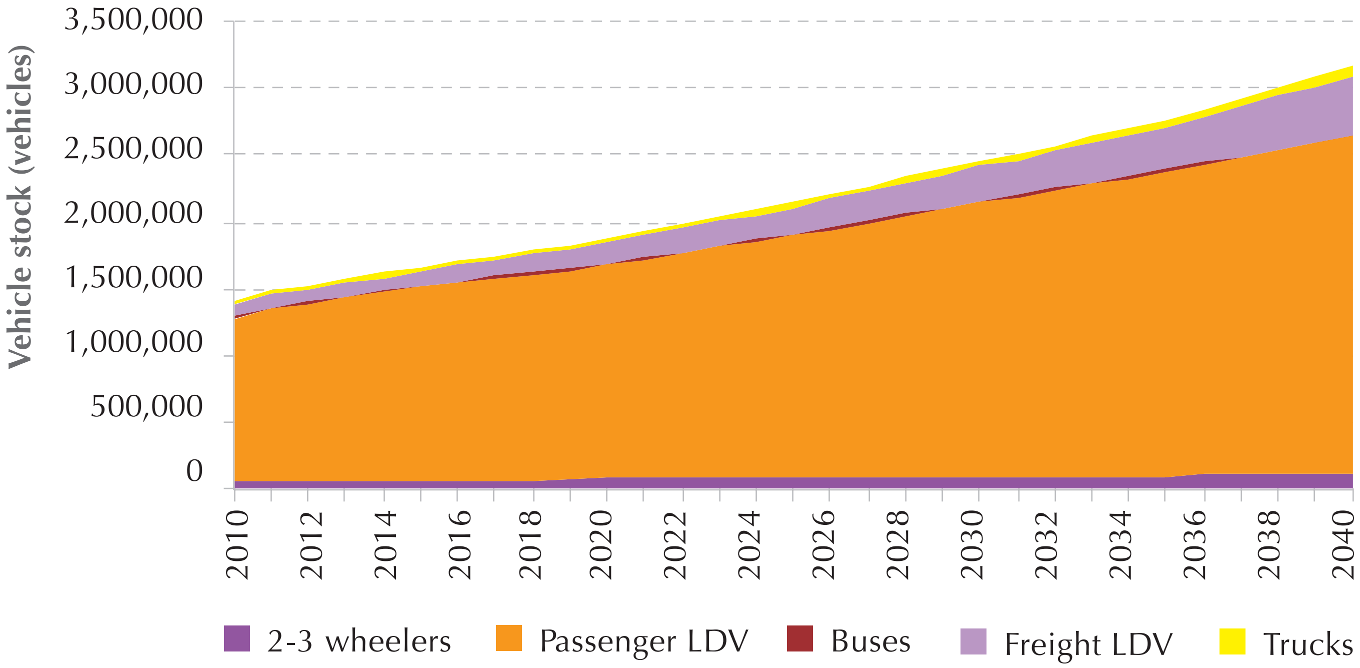

Figure 28: Baseline projection of passenger and freight vehicle stock

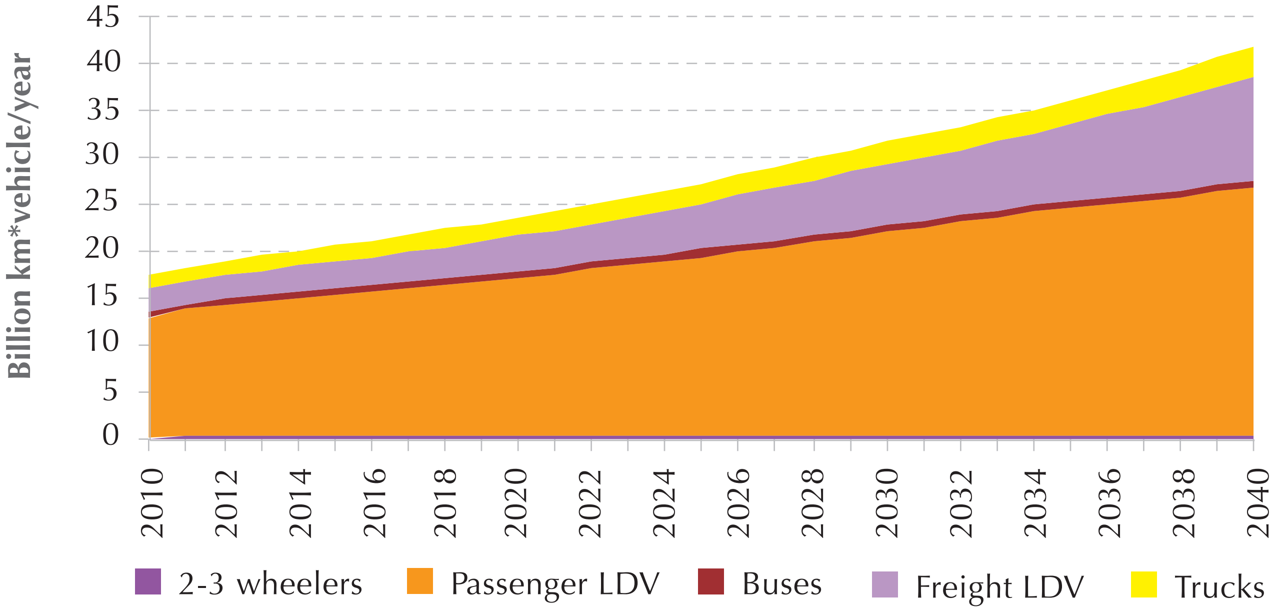

Figure 29: Baseline annual estimated passenger and freight activity

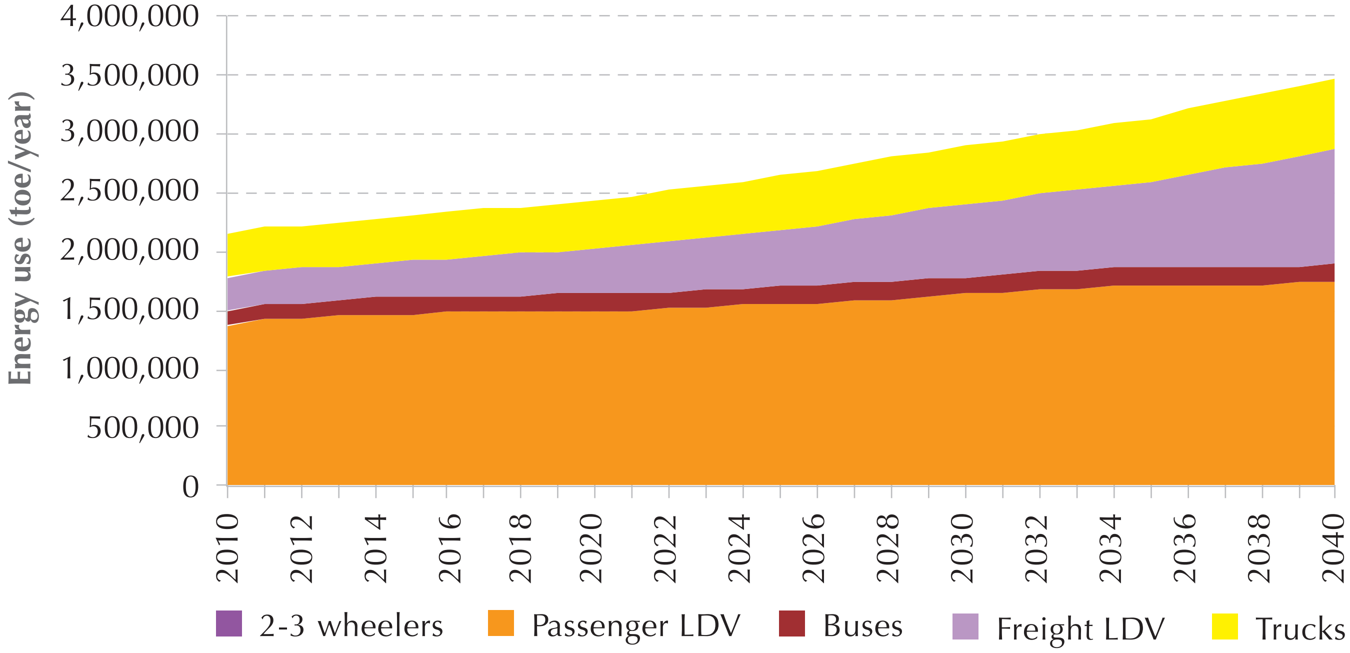

Figure 30: Baseline projection of passenger and freight energy use

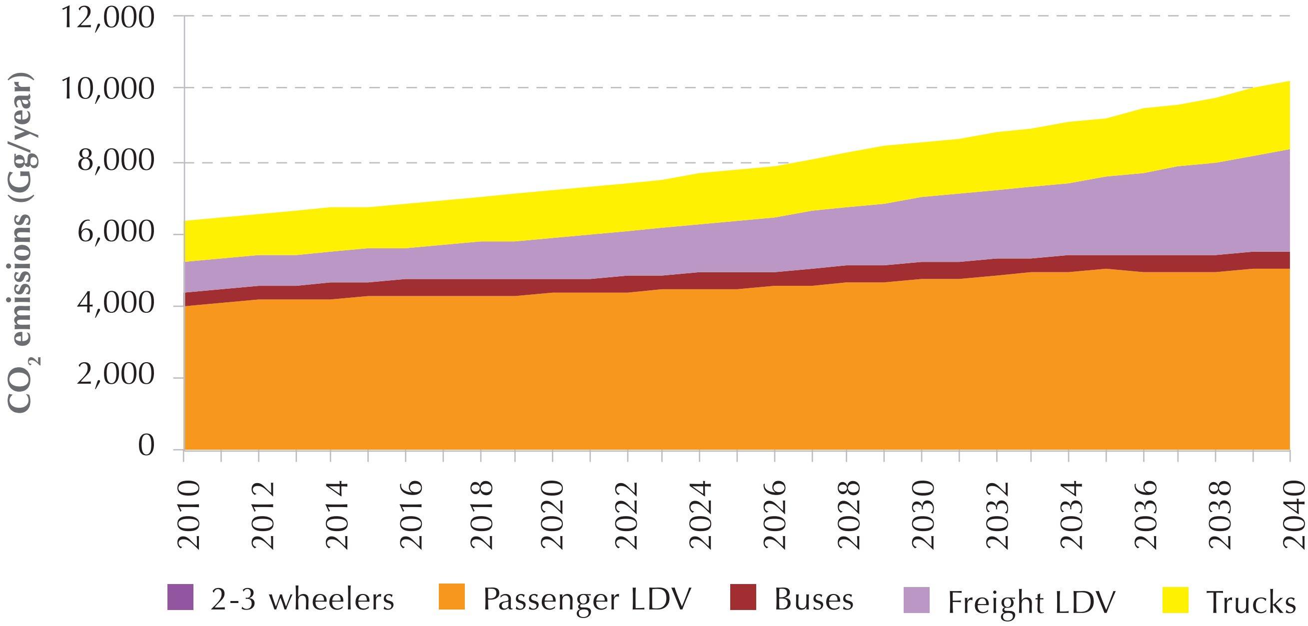

Figure 31: Baseline projection of passenger and freight CO$_2$ emissions

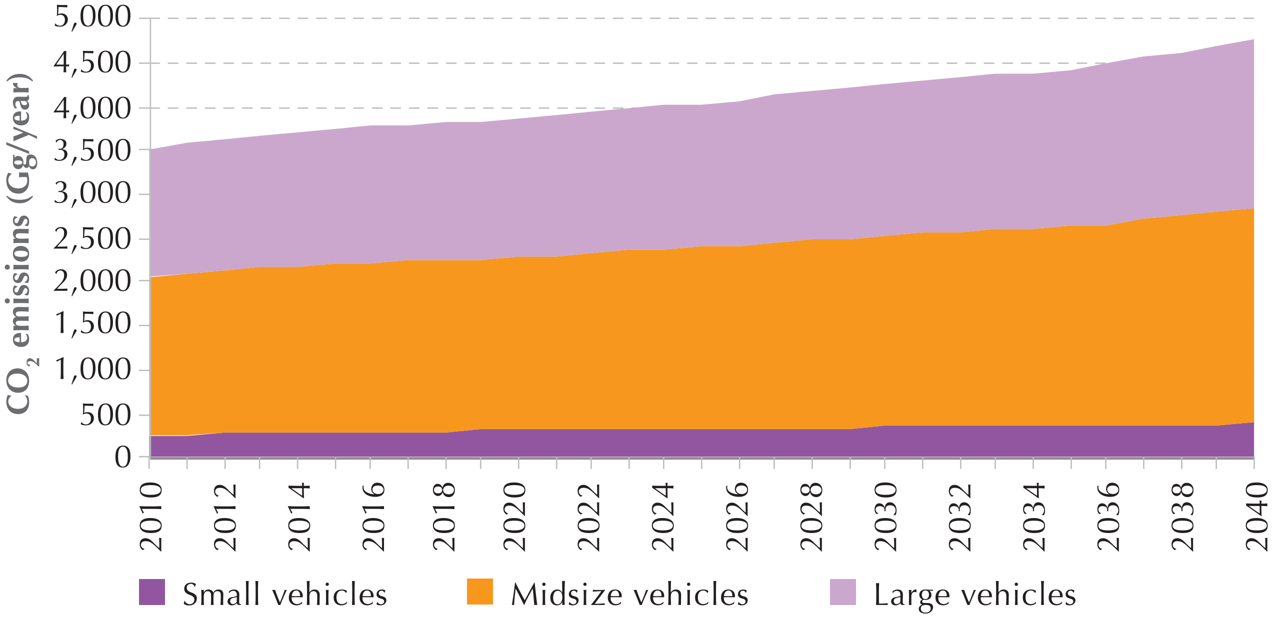

Figure 32: Baseline projection of passenger vehicles CO$_2$ emissions per vehicle class

Freight transport represents 30.6% of the total energy use at the base year, and it is estimated to contribute to 45.4% in 2040 (Figure 30). This increase is the result of the combination of two aspects: (1) the economic growth which is correlated to the increase in freight activity, and (2) the reliance of the increase in freight activity on light freight vehicles (76% of the total freight vehicles at the base year, estimated to reach 87.5% in 2040) (Table 31) which are less energy efficient (per tonne-kilometer) than large freight modes.

For the purpose of this study, freight activities will remain unchanged in the 3 mitigation scenarios, as the study focuses only on mitigating CO_2 emissions of passenger transport. However, measures for mitigating freight emissions should be considered in future studies, since freight is expected to be one of the major sources of GHG emissions in 2040 (Figure 31).

9.3. Mitigation options

Description of scenarios

Mitigation option 1: increase share of fuel-efficient vehicles

Fuel-efficient vehicles are commonly known in Lebanon by conventional gasoline powered vehicles with reduced fuel consumption compared to similar gasoline vehicles within the same vehicle segment. These vehicles are equipped with advanced technologies like downsized turbocharged engines. In general, fuel-efficient vehicles fall mainly under the small vehicles category; however, continuous developments are held to reduce consumption of conventional midsize and large vehicles, and therefore might be more efficient than small vehicles if these cars are used regularly by more than one occupant. Consequently, for future work, fuel-efficient vehicles should be defined as vehicles presenting reduced consumption per vehicle occupant.

This scenario considers a higher market penetration of fuel-efficient vehicles technologies and a reduction of the share of large vehicles. This scenario aims at increasing the share of small passenger vehicles to 35%, maintaining the share of midsize vehicles at 55% and decreasing the share of large vehicles to 10%. The market for these fuel-efficient vehicles will develop gradually with new vehicles registrations and will rely on the implementation of policies and awareness campaigns to improve the environmental awareness of drivers and direct their purchases to environmentally-friendly vehicles (MoE/URC/GEF, 2012).

Mitigation option 2: increase share of fuel-efficient vehicles and hybrid electric vehicles

Hybrid Electric Vehicles (HEV) combine an electric motor and battery pack to the internal combustion engine found in conventional vehicles. They are classified as micro-hybrid, mild-hybrid, full-hybrid, plug-in hybrid and range-extender electric vehicles; and differentiate by the fraction of electric power added onboard and consequently, the ability to achieve more hybrid functions. Note that the more electric energy is available onboard, the more fuel reduction will result, at the expense of additional purchase cost.

This scenario adopts the same assumptions as mitigation option 1, i.e. an increase of the share of small vehicles with fuel-efficient powertrains and decrease in large vehicles. In addition, this scenario considers the introduction of hybrid electric vehicles to the market, assuming that the share of hybrid electric vehicles sales of new registered vehicles will increase over time and reach 10% by 2040.

Mitigation option 3: increase the share of mass transport

The shift to mass transport scenario is illustrated by the increase in the passenger transport system index, for which the share of passenger-kilometer activity is assumed to increase from 36% in 2010 to 53% by 2040. The rationale is to reduce the gap between the passenger transport system indexes of Lebanon (0.1) and mass-transport-oriented sustainable European cities (0.45) by 15% in 2040.

In practice, this assumption is represented by the deployment of a well-designed mass transit system covering GBA, part of which is the public transport plan prepared by the Ministry of Public Works and Transport (MoPWT), in addition to a wide number of policies favoring mass transport over personal vehicles, such as parking and access restrictions for personal vehicles, land use policies that encourage lane dedication for buses, and support for the provision of appealing, widely available and high-quality public transport services (MoE/URC/GEF, 2012).

Emission reduction potential

Figure 33 to Figure 35 illustrate the evolution of the passenger activity (vkm), energy use (toe) and CO_2 emissions (Gg) of the 3 considered scenarios. This allows a comparative assessment of the impacts caused by the changes in each scenario compared to the baseline (as highlighted in Table 34).

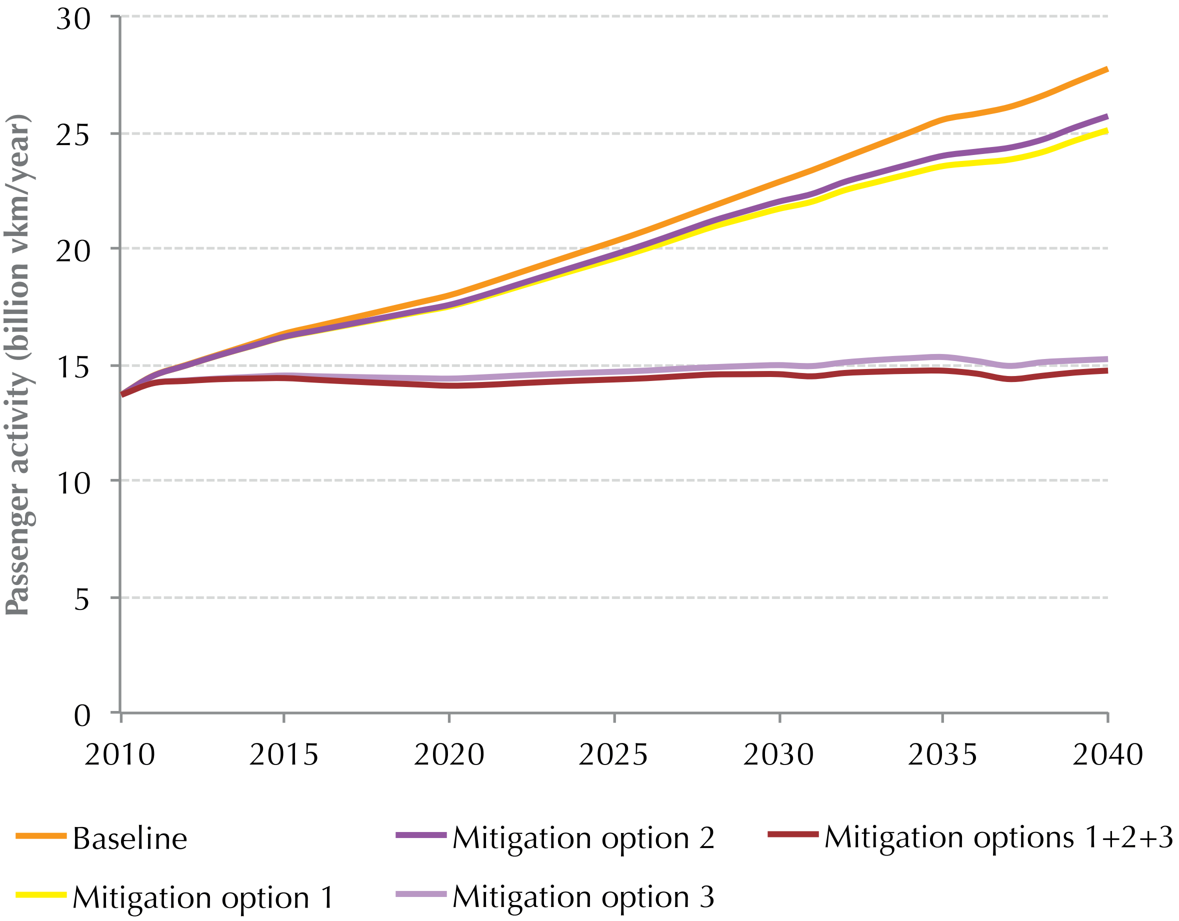

Figure 33: Change in transport activity

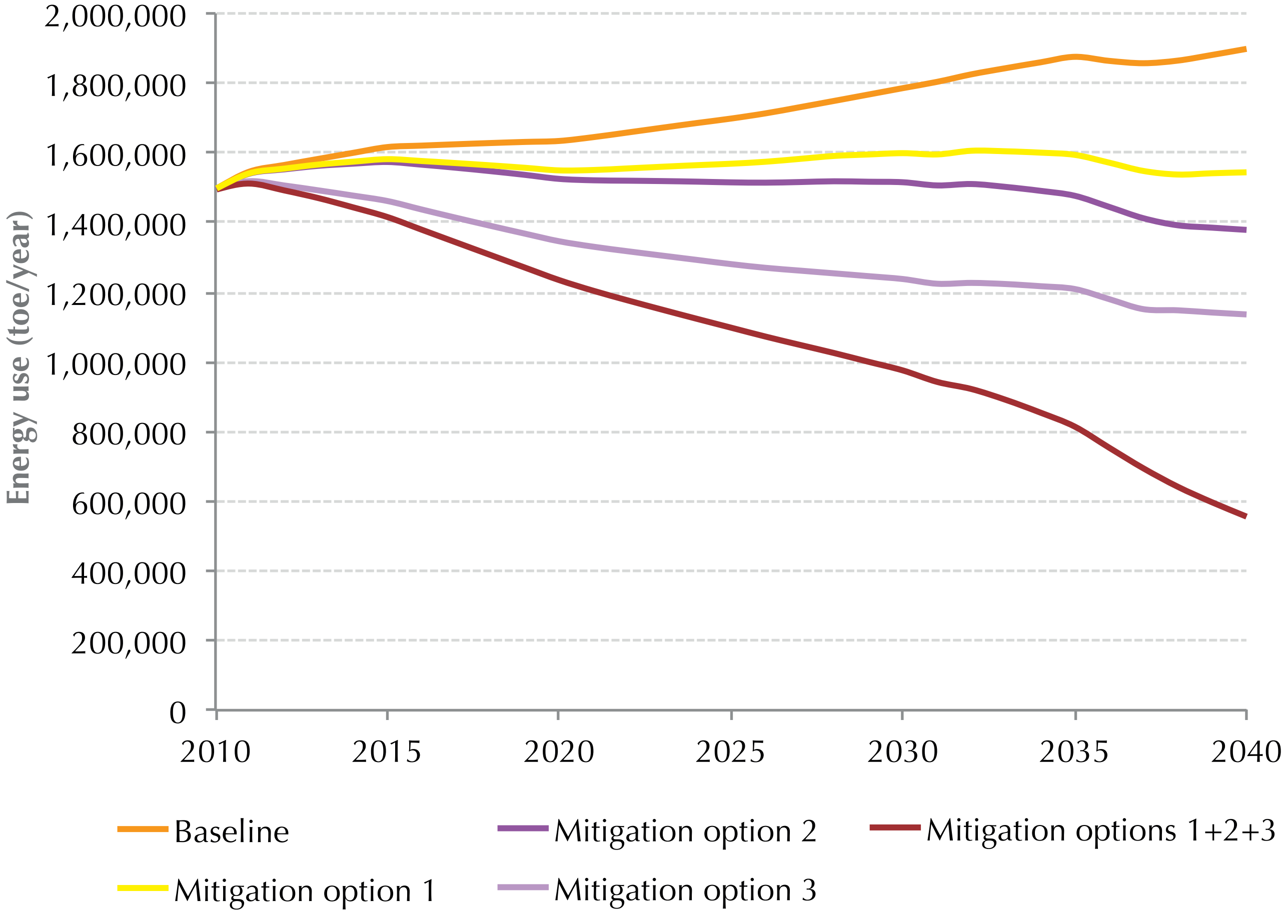

Figure 34: Change in energy use

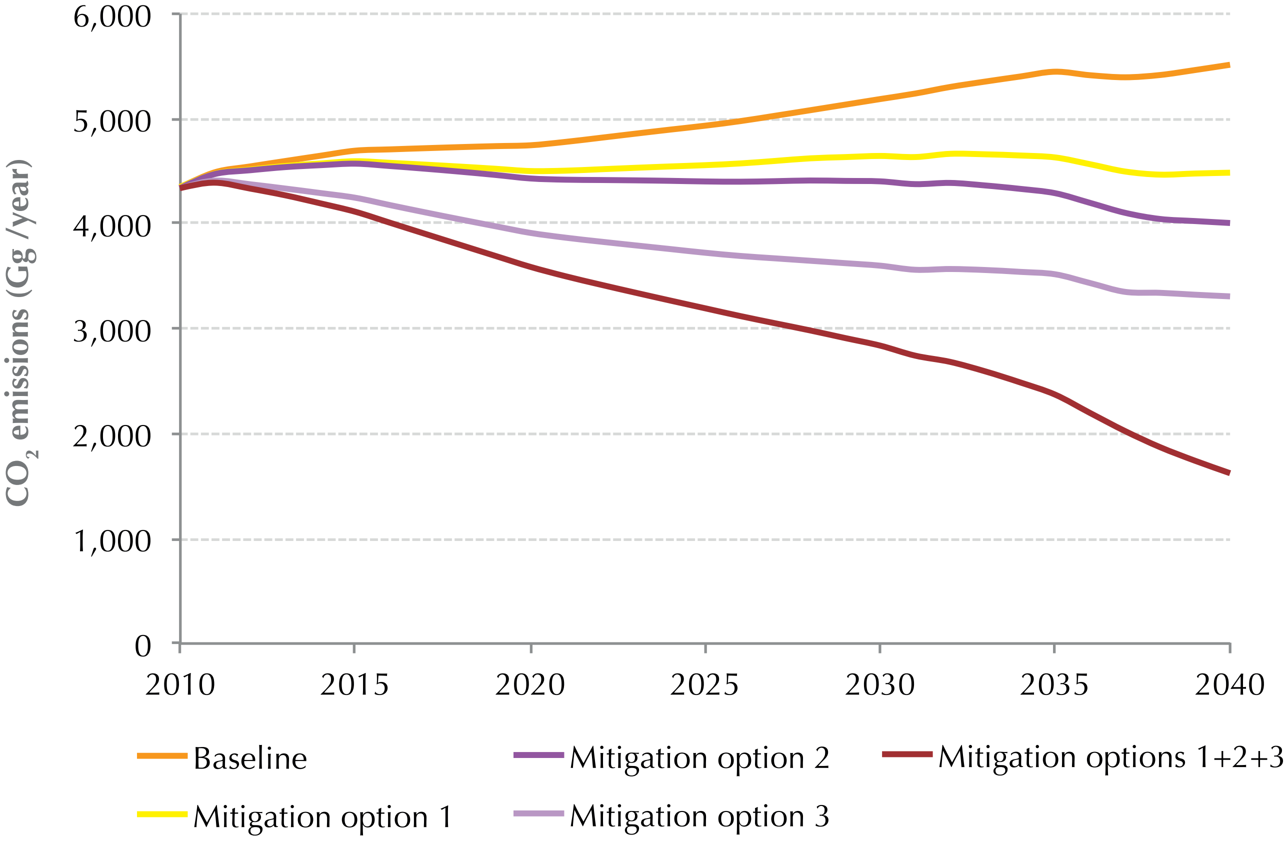

Figure 35: Change in CO_2 emissions

Emission reduction from mitigation option 1: increase share of fuel-efficient vehicles

Despite the fact that this scenario reduces the passenger transport energy use and CO_2 emissions in 2040 by 19% compared to baseline scenario (Figure 34 and Figure 35), the transport system remains characterized by being highly personal-vehicle oriented, as use of mass transport still represents less than 10% of the total passenger-kilometer transport activity.

Reduction in energy use and CO_2 emissions are the consequence of two mitigation actions: (1) the share increase of fuel-efficient vehicles from 11.8% to 35%, and consequently the decrease of large low-efficiency vehicles from 33.3% to 10%; (2) the fuel price increase by 50% in 2040 compared to 2010. The combination of both mitigation actions leads to a reduced transport activity compared to the baseline as shown in Figure 33. Note that a no-growth fuel price scenario in 2040 would result in an increase in the transport vehicle-kilometer activity; consequently, CO_2 emission savings will be counterweighed. Therefore, the fuel price (or from a wider perspective: the mobility cost per mode) is a key parameter to ensure the successful implementation of this scenario, by controlling the transport activity.

Table 32 presents the values of the main outputs of this scenario by 2020 and 2040. Note that the energy use over time is stabilized: a slight increase by 3% between 2010 and 2020, and between 2010 and 2040. CO_2 emissions follow the same trend. This steadiness of energy use and emissions is due to the balance effect of increased passenger-kilometer activity and reduced fuel consumption of the fleet, since new fuel-efficient vehicles are replacing large and non-efficient vehicles.

Table 32: Passenger transport projections of the mitigation option 1 scenario

	Unit	**Base year (2010)**	**2020**	**2040**	**Ratio 2020/2010**	**Ratio 2040/2010**
Total passenger vehicle stock	Vehicles	1,292,433	1,652,426	2,425,655	1.28	1.88
2-3 wheelers	Vehicles	60,587	77,797	113,503	1.28	1.87
Passenger LDV	Vehicles	1,219,460	1,560,650	2,297,710	1.28	1.88
Buses	Vehicles	12,387	13,978	14,442	1.13	1.17
Total vehicle-km	Billion vkm/year	13.68	17.50	25.10	1.28	1.83
Total energy use	toe/year	1,497,765	1,549,395	1,543,931	1.03	1.03
Total CO_2 emissions	Gg CO_2/ year	4,350	4,502	4,486	1.03	1.03

Emission reduction from mitigation option 2: increase share of fuel-efficient vehicles and hybrid electric vehicles

Same trend in transport vehicle-kilometer activity is observed compared to the mitigation option 1 scenario (Figure 33); therefore, the transport system still evolves in a highly personal vehicle oriented scheme. Nevertheless, the deployment of Hybrid Electric Vehicles (HEV) leads to further energy and CO_2 emissions:

- Compared to energy use and CO_2 emissions of passenger transport in 2010, 8% of reductions are observed by 2040 (Table 33, Figure 34 and Figure 35).

- Compared to the mitigation option 1, the impact of a 10% HEV share of new registered vehicles in 2040 engenders 11% of additional savings in energy use and CO_2 emissions. They result from technological advancements of hybrid vehicles in terms of fuel consumption.

- Compared to the baseline, the energy and CO_2 emissions savings of mitigation option 2 are 27% by 2040 (Figure 34 and Figure 35). This is due to the combination of (1) powertrain technology shift of high-consuming vehicles into high-efficient vehicles (Figure 36), and (2) the deployment of HEV technologies.

Table 33: Passenger transport projections of the scenario shift powertrain technology to FEV and HEV

	Unit	**Base year (2010)**	**2020**	**2040**	**Ratio 2020/2010**	**Ratio 2040/2010**
Total passenger vehicle stock	Vehicles	1,292,433	1,653,549	2,437,284	1.28	1.89
2-3 wheelers	Vehicles	60,587	77,838	113,950	1.28	1.88
Passenger LDV	Vehicles	1,219,460	1,561,750	2,308,995	1.28	1.89
Buses	Vehicles	12,387	13,961	14,339	1.13	1.16
Total vehicle-km	Billion vkm/year	13.68	17.57	25.70	1.28	1.88
Total energy use	toe/year	1,497,765	1,525,047	1,378,665	1.02	0.92
Total CO_2 emissions	Gg CO_2/ year	4,350	4,431	4,007	1.02	0.92

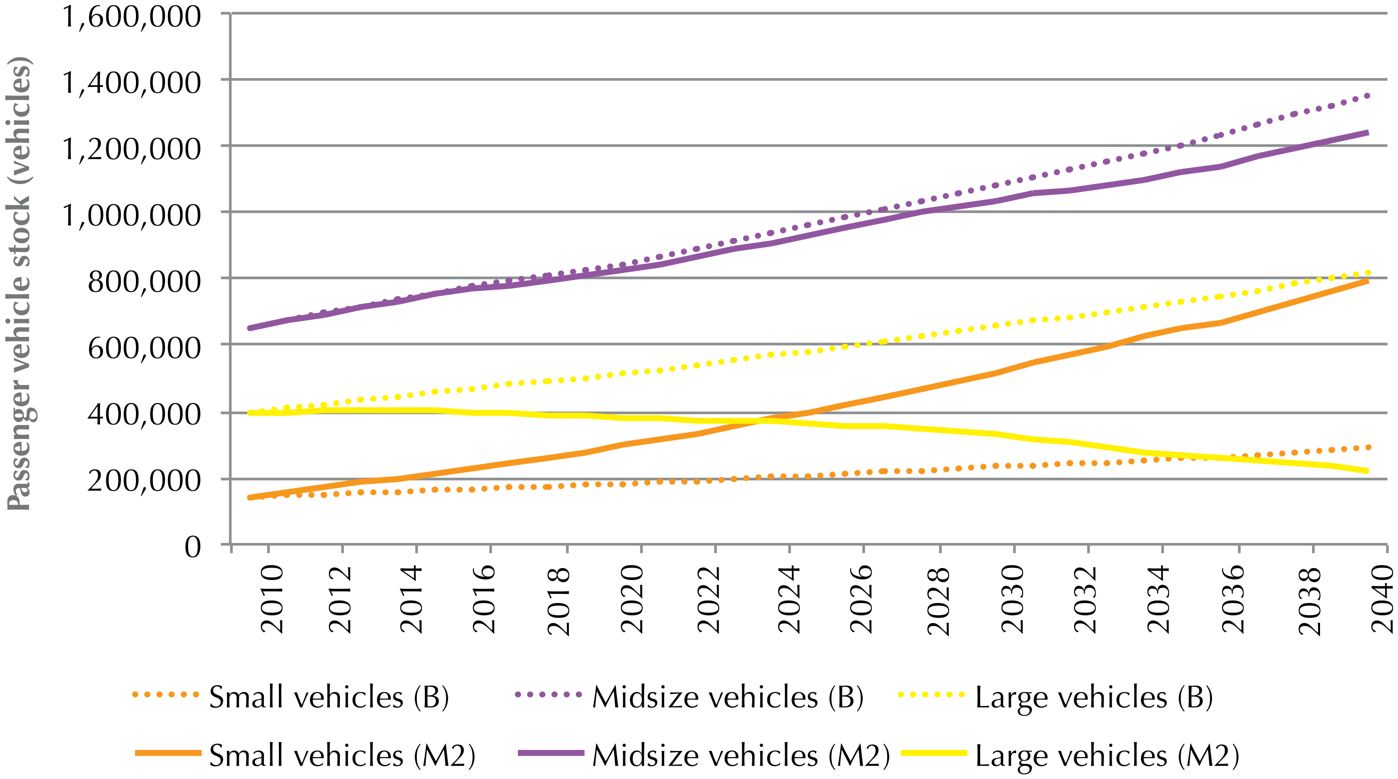

Figure 36: Passenger LDV activity per vehicle class under baseline (B) and mitigation option 2 scenario (M2)

Emission reduction from mitigation option 3: increase share of mass transport

The shift to mass transport in this scenario takes into account a change of the passenger transport characteristic index from 0.1 to 0.15, representing a mass transport passenger-kilometers share increase from 36% in 2010 to 53% by 2040.

Shifting to mass transport results in 45% reduction of vehicle-kilometer activity in 2040 compared to the baseline scenario, which obviously reflects a net improvement in traffic congestion. As a result, the energy use and CO_2 emissions are reduced by 10% in 2020 and 24% in 2040 compared to 2010. Compared to the baseline, the energy and CO_2 emissions savings by 2040 are 40% (Table 34, Figure 34 and Figure 35).

Table 34: Passenger transport projections of the scenario shift to mass transport

	Unit	**Base year (2010)**	**2020**	**2040**	**Ratio 2020/2010**	**Ratio 2040/2010**
Total passenger vehicle stock	Vehicles	1,292,433	1,515,801	2,163,453	1.17	1.67
2-3 wheelers	Vehicles	60,587	71,099	99,530	1.17	1.64
Passenger LDV	Vehicles	1,219,460	1,429,350	2,040,880	1.17	1.67
Buses	Vehicles	12,387	15,352	23,043	1.24	1.86
Total vehicle-km	Billion vkm/year	13.68	14.40	15.24	1.05	1.11
Total energy use	toe/year	1,497,765	1,345,957	1,135,994	0.90	0.76
Total CO_2 emissions	Gg CO_2/ year	4,350	3,912	3,308	0.90	0.76

Mitigation action plan

The TNA report for the transport sector tackled the needs to deploy the mitigation options of this study: an efficient "mass transit system" and a swap program to "renew the passenger cars fleet with fuel-efficient and hybrid electric vehicles". The root cause to barriers of both options is the inadequate current transport policy and the absence of national policy providing a coherent transport demand management strategy. This lack of national policy is mainly due to the government clash of interests and therefore its limited willingness to invest.

Measures for overcoming the barriers are specific to each mitigation option; however, a common enabling framework serving both mitigation options mainly consists of creating a financial mechanism incentivizing the use of mass transit systems and environmentally-friendly vehicles and discouraging the use and purchase of inefficient vehicles. Specific measures and action plan for each option are discussed in Table 35 and Table 36 (MoE/URC/GEF, 2012).

Table 35: Action plan for implementation of scenario shift to fuel-efficient and hybrid electric vehicles

Measures	Why	How to do it	Priority	Responsible party	Time scale	Monitoring and Evaluation (M & E) indicators
Create appropriate financial incentives for hybrid and fuel-efficient cars purchase.	Reduce car purchase and ownership costs.	Exemption from customs and excise fees, exemption from registration fees, exemption from road-usage fee at registration.	1	MoF	Short-term	Law on tax exemption by government
		Payments of minimum salvage value (ex. USD 2,500) as down payment for car loan, extension of loan period to 8 years, reduce loan interest.	1	MoF BDL Commercial banks	Short-term	Car loan package and facilities for hybrid and fuel-efficient cars
Create disincentives for import of non-efficient pre-owned cars.	Limit the import of pre-owned non fuel-efficient vehicles.	Gradually reduce maximum age of imported pre-owned vehicles to 3 years with a mileage lower than 100,000 km, rather than 8 years as the current figure.	1	Ministry of Interior and Municipalities (MoIM)	Short/medium-term	Law on import of pre-owned cars
Set up new coherent tax policies.	Cope with the high demand for high fuel consuming pre-owned vehicles.	Adopt a Bonus-Malus tax policy where polluters pay more annual road-usage fees, and where taxes like the road usage fees are reconsidered according to fuel efficiency and/or emissions rather than engine displacement as the current figure.	2	MoF	Short-term	Bonus-Malus tax scheme

Measures	Why	How to do it	Priority	Responsible party	Time scale	Monitoring and Evaluation (M & E) indicators
Renew the passenger car fleet.	Enhance the efficiency of the passenger car fleet.	Create a car scrappage program based on swapping current passenger cars with hybrid and fuel-efficient cars.	2	MoF New cars dealers	Short-term	Car scrappage program
Implement a vehicle retirement program.	Remove old cars from the fleet.	Create a car termination plant that deals with the car termination process after the swap in the scrappage program.	3	MoPWT MoIM MoE	Short/medium-term	Car termination plant
Implement legislation governing vehicle emissions.	Improve air quality as transport sector is the main air polluter.	Update decree no. 6603/1995 relating to standards on permissible levels of exhaust fumes and exhaust quality to cover all types of vehicles.	4	MoE	Short/medium-term	Updated decree 6603/1995
		Update the vehicle inspection program requirements taking into consideration special requirements for hybrid cars' inspection, in addition to mandating the presence of catalytic converters on conventional gasoline vehicles.	4	MoE MoIM	Short/medium-term	Updated vehicle inspection program

Measures	Why	How to do it	Priority	Responsible party	Time scale	Monitoring and Evaluation (M & E) indicators
Create institutions to support technical standards for transportation.	Limit the import of deficient and crashed pre-owned cars.	Set up a mechanical inspection unit at the port of Beirut in charge of checking the emissions and safety standards of imported pre-owned cars before entering the country.	5	MoPWT MoE	Short/medium-term	Mechanical inspection unit at the port of Beirut
Establish awareness campaign.	Promote hybrid and fuel-efficient cars.	Enforce all marketing campaigns (billboards, TV, etc.) and new car dealers to post up factsheets on all vehicles, clearly displaying information on vehicle average fuel consumption and annual fuel costs, in addition to average CO_2 emissions.	6	MoPWT MoE	Short/medium-term	Awareness campaign
Create Mobility Monitoring Indicators (MMI) framework.	Develop sustainable transportation strategies.	Delegate the CAS with additional experimented personnel and authority to provide the complete MMI set on a yearly basis.	7	MoPWT MoE	Short/medium-term	Mobility monitoring indicator framework delegated to CAS

Table 36: Action plan for implementation of scenario shift to mass transport

Measures	Why	How to do it	Priority	Responsible party	Time scale	M & E indicators
Deploy effective infrastructure measures.	Shift travel demand to efficient transport means: bus transit system.	Design a complete bus network covering all boroughs within the Greater Beirut Area (GBA) and reserve lanes for bus operation.	1	Municipalities Office des Chemins de Fer et des Transports en Commun (OCFTC) Directorate General of Roads and Buildings (DGRB) Council for Development and Reconstruction (CDR)	Short-term	Bus network on reserved lanes in GBA
Develop the supply channels of the bus mass transit system.	Cover the designed network with sufficient number of buses and avoid irregularities in operation.	Ensure sufficient number of transit buses with the proper powertrain technology.	1	MoPWT	Short-term	Purchase of the required buses
Give appropriate financial incentives for mass transit buses.	Decrease the cost incurred for the government on the import of the mass transit buses.	Exempt mass transit buses (and their spare parts) from custom and excise fees, and from registration fees.	1	MoF	Short-term	Law on fee exemption enacted by the government

Measures	Why	How to do it	Priority	Responsible party	Time scale	M & E indicators
Encourage taxi and shared taxi owners to work in the bus mass transit system.	Limit the number of illegal taxis (17,000 taxis) and reduce the extensive number of taxis (33,000 taxis).	Create an employee package for taxi drivers including social benefits, insurance, retirement plans, etc.	1	MoPWT OCFTC MoF	Short/medium-term	Package for bus drivers
Stimulate passengers' demand to use mass transit buses.	Shift travel demand to efficient transport means: bus transit system.	Establish smart card ticketing schemes with appropriate reduced tariffs.	2	OCFTC	Medium-term	Smart card ticketing schemes
Deploy effective operation measures.	Provide a quality of service that approximates that which car drivers have been used to with passenger cars.	Optimize the operation management of the bus mass transit system: conserve a clear and regular bus operation, implement a real-time information system, deploy personalized travel planning tools, implement transit signal priority, set up stringent maintenance and cleanliness program , construct relevant maintenance and repair workshops.	2	MoPWT Directorate General of Civil Aviation and Maritime Affairs (DGLM) OCFTC	Short/medium-term	Operation management strategy

Measures	Why	How to do it	Priority	Responsible party	Time scale	M & E indicators
Set up a regulatory framework for the mass transit sector.	Manage the transport demand rather than being controlled by incumbents (private and public operators and the taxi owners).	Set clear regulations specifying the operation maneuvers of private bus operations and taxi owners.	3	MoPWT	Short-term	Legislation on specifying the operation maneuvers between the various mass transit operators
Induce/initiate legislative reforms in urban planning laws, expropriation laws, and traffic laws.		Draft new amended laws for increasing parking space and reserving lanes for buses.	4	MoPWT	Short/Medium-term	Parking spots and reserved lanes for mass transit buses in congested urban areas
Enhance the role of the Traffic Management Organization (TMO).	Carry out the traffic management mandates it was conceived for.	Develop technical expertise among TMO staff and high level management.	5	MoPWT	Medium-term	Well-trained TMO staff
Increase awareness of travelers on ecological and economic benefits of transit bus systems.	Shift travel demand to efficient transport means: bus transit system.	Provide information on CO_2, fuel and cost savings comparing to passenger cars.	6	MoPWT	Short/medium-term	Information display tools on CO_2 and fuel savings: mobile applications, dedicated website, media campaigns, etc.

10. Conclusion

In the current patterns of transport activity, mainly based on passenger vehicles, the Lebanese transport sector generates many environmental and economic burdens on the government and the population. It was represented for example in 2010 by the 4,350 Gg CO_2 emissions, the 1.5 million tonne-oil-equivalent of fuel consumed for passenger mobility, and the chronic traffic congestion at every intersection inside the GBA and on the entry gates of the city.

This report highlighted the impact of adopting mitigation measures to lessen the burdens namely reduce the CO_2 emissions while responding to the transport sector technology needs identified in the TNA report. The mitigation measures consisted of (1) the replacement of old and inefficient vehicles gradually with fuel-efficient and hybrid electric vehicles to renew the fleet, and (2) the restructuring and modernization of the bus transport system in the GBA to increase the passenger-kilometer activity share of the mass transport from 36% in 2010 to 53% by 2040.

The analysis of the potential CO_2 emissions and energy use reductions using the ForFITS model showed that renewing the fleet with efficient and hybrid vehicles leads to significant reductions of 27% by 2040 compared to the BAU mobility patterns. However, the vehicle stock and vehicle-kilometer activity will both increase by 88% by 2040 compared to 2010. Therefore, problems pertaining to the chronic congestion and all related complications of time and productivity losses will persist.

The analysis of increasing the share of mass transport activities indicated also significant CO_2 and fuel savings of 40% by 2040 compared to the BAU patterns, and reduced the vehicle-kilometers activities compared to the fleet renewal strategy. Consequently, the lessons learned from the modeling exercise lead us to the conclusion that the future transport national strategy for Lebanon should necessarily be based on the integration of a carefully designed portfolio of policies and incentives, promoting the mitigations strategies assessed in this report.

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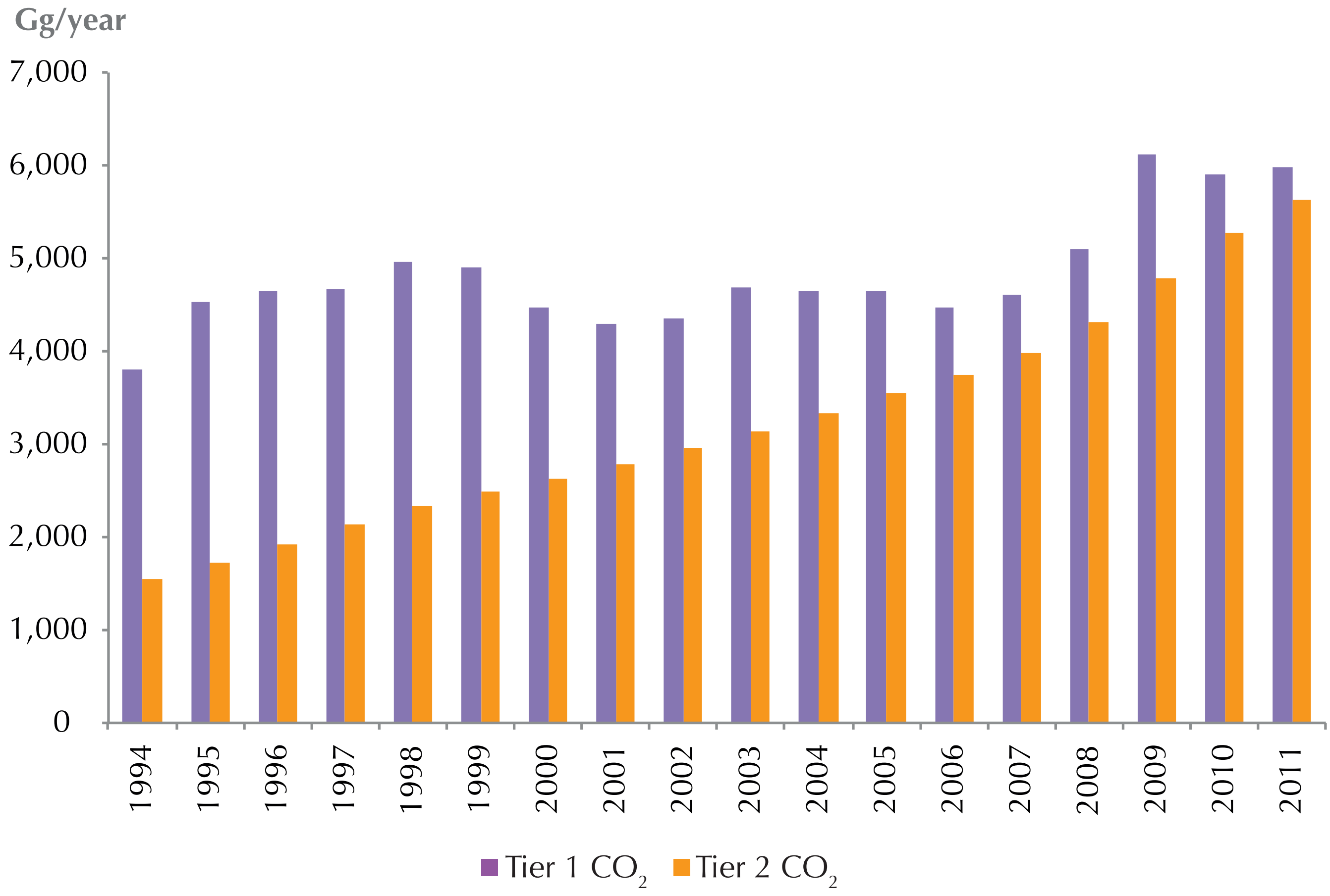
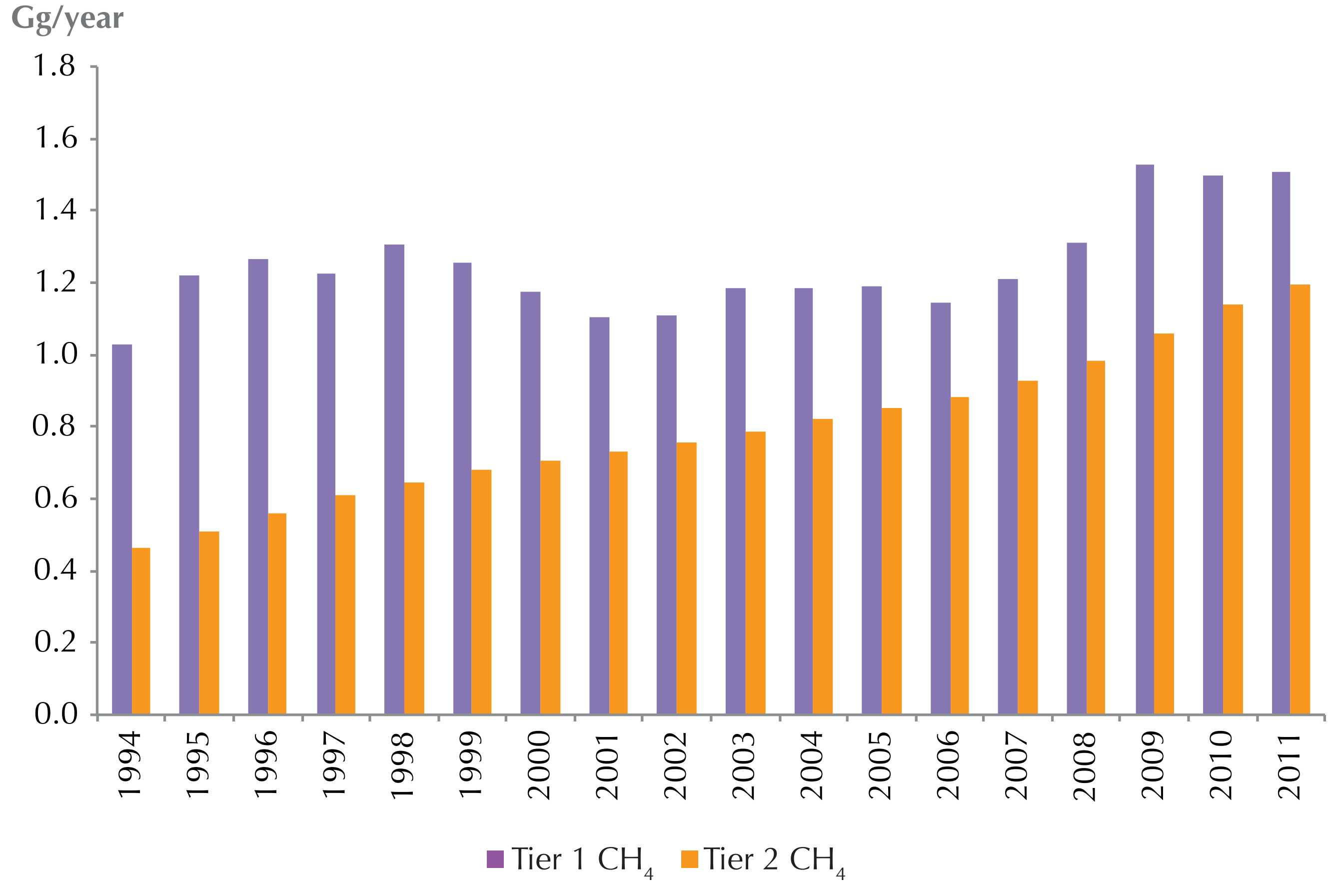
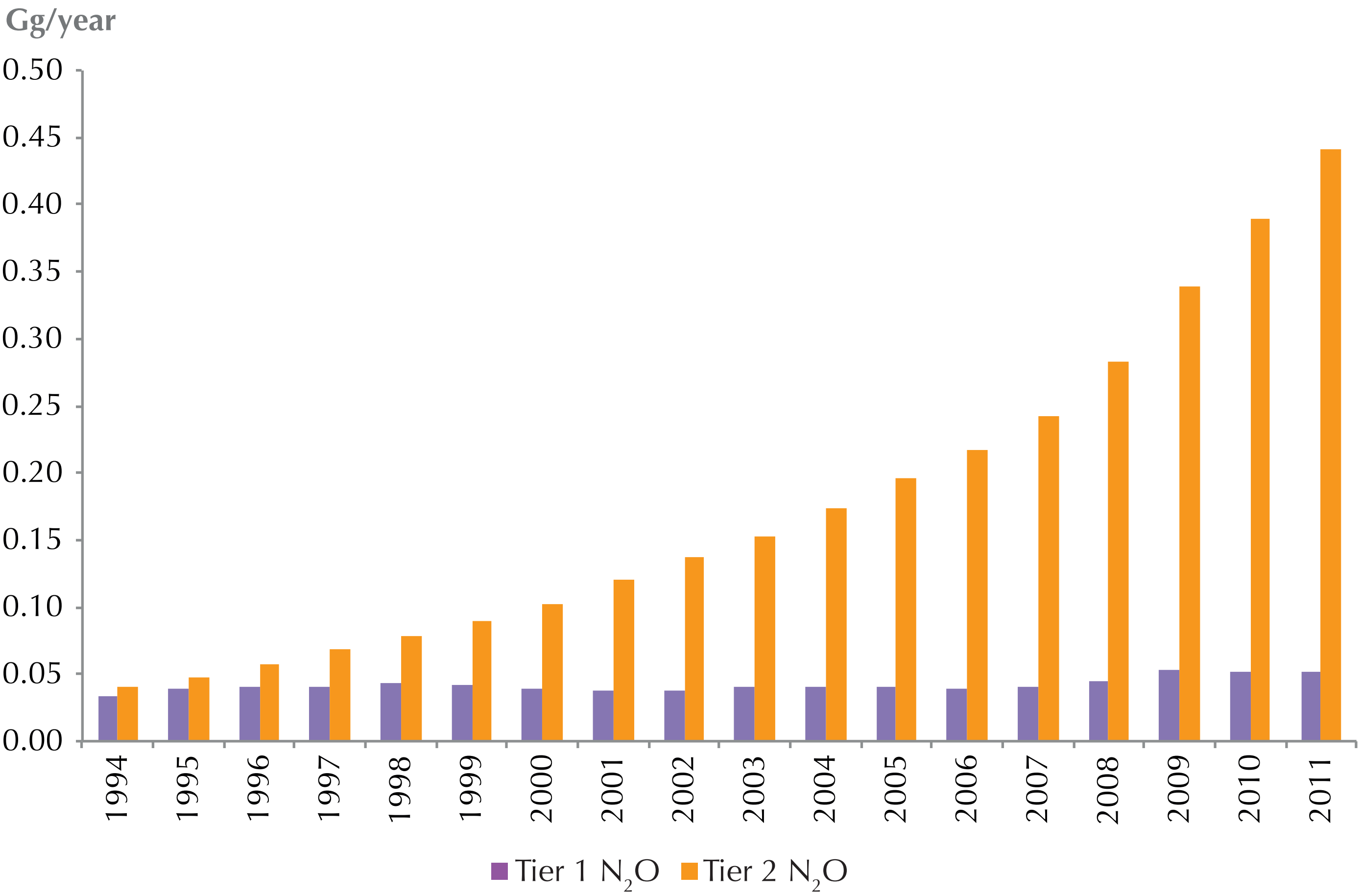
Annex I: Time series of the road transport emissions using tier 1 (Gg)

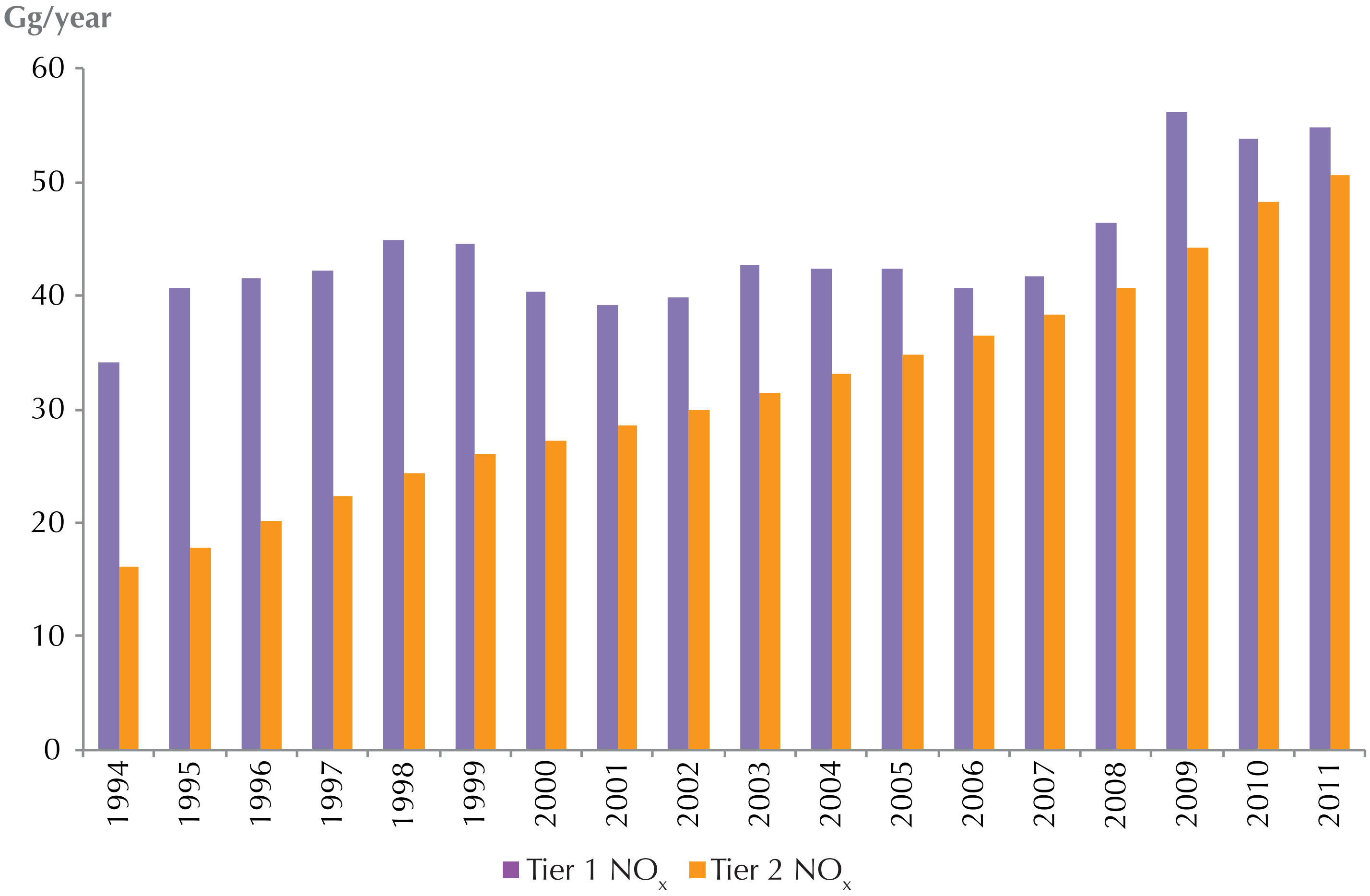
Year	CO_2	CH_4	N_2O	NO_x	CO	NMVOCs	SO_2
1994	3,801.77	1.03	0.03	34.04	407.31	76.43	2.86
1995	4,528.75	1.22	0.04	40.63	481.80	90.41	3.44
1996	4,648.06	1.26	0.04	41.58	499.88	93.80	3.47
1997	4,663.14	1.22	0.04	42.16	481.44	90.37	3.72
1998	4,967.49	1.31	0.04	44.87	514.71	96.62	3.94
1999	4,901.07	1.26	0.04	44.61	492.33	92.44	4.07
2000	4,466.77	1.17	0.04	40.38	461.27	86.59	3.56
2001	4,298.42	1.10	0.04	39.13	431.78	81.08	3.57
2002	4,361.18	1.11	0.04	39.81	433.15	81.34	3.68
2003	4,679.56	1.18	0.04	42.76	462.83	86.92	3.98
2004	4,652.02	1.18	0.04	42.43	463.34	87.01	3.91
2005	4,646.20	1.19	0.04	42.30	466.38	87.57	3.87
2006	4,466.95	1.15	0.04	40.66	448.58	84.23	3.71
2007	4,616.98	1.21	0.04	41.74	476.63	89.47	3.68
2008	5,100.57	1.31	0.04	46.41	513.12	96.35	4.23
2009	6,115.07	1.53	0.05	56.08	595.52	111.86	5.31
2010	5,893.99	1.50	0.05	53.80	585.29	109.91	4.98
2011	5,991.02	1.51	0.05	54.85	587.72	110.38	5.15

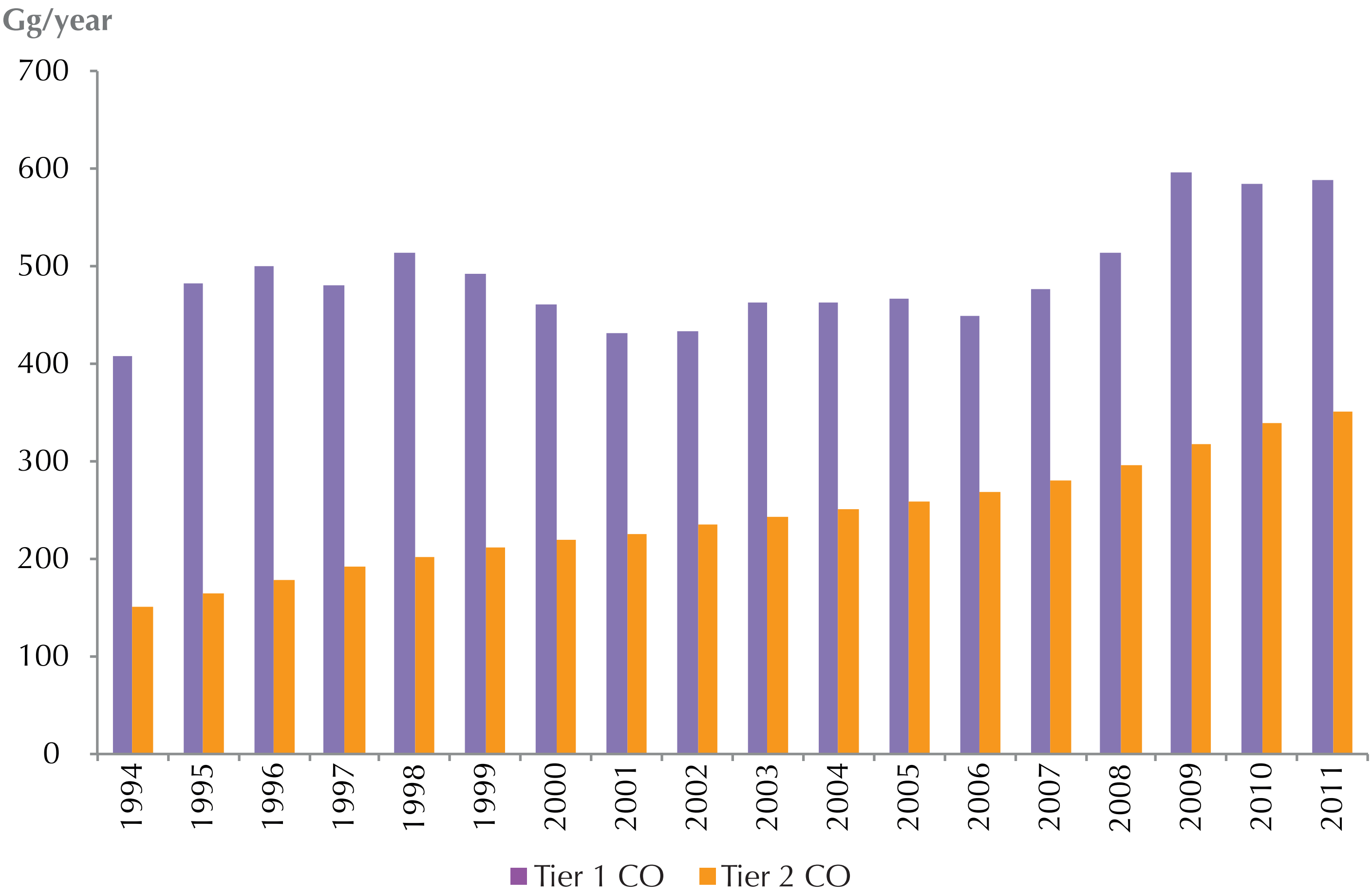
Annex II: Tier 1 and tier 2 GHG emissions comparison for the road transport sector

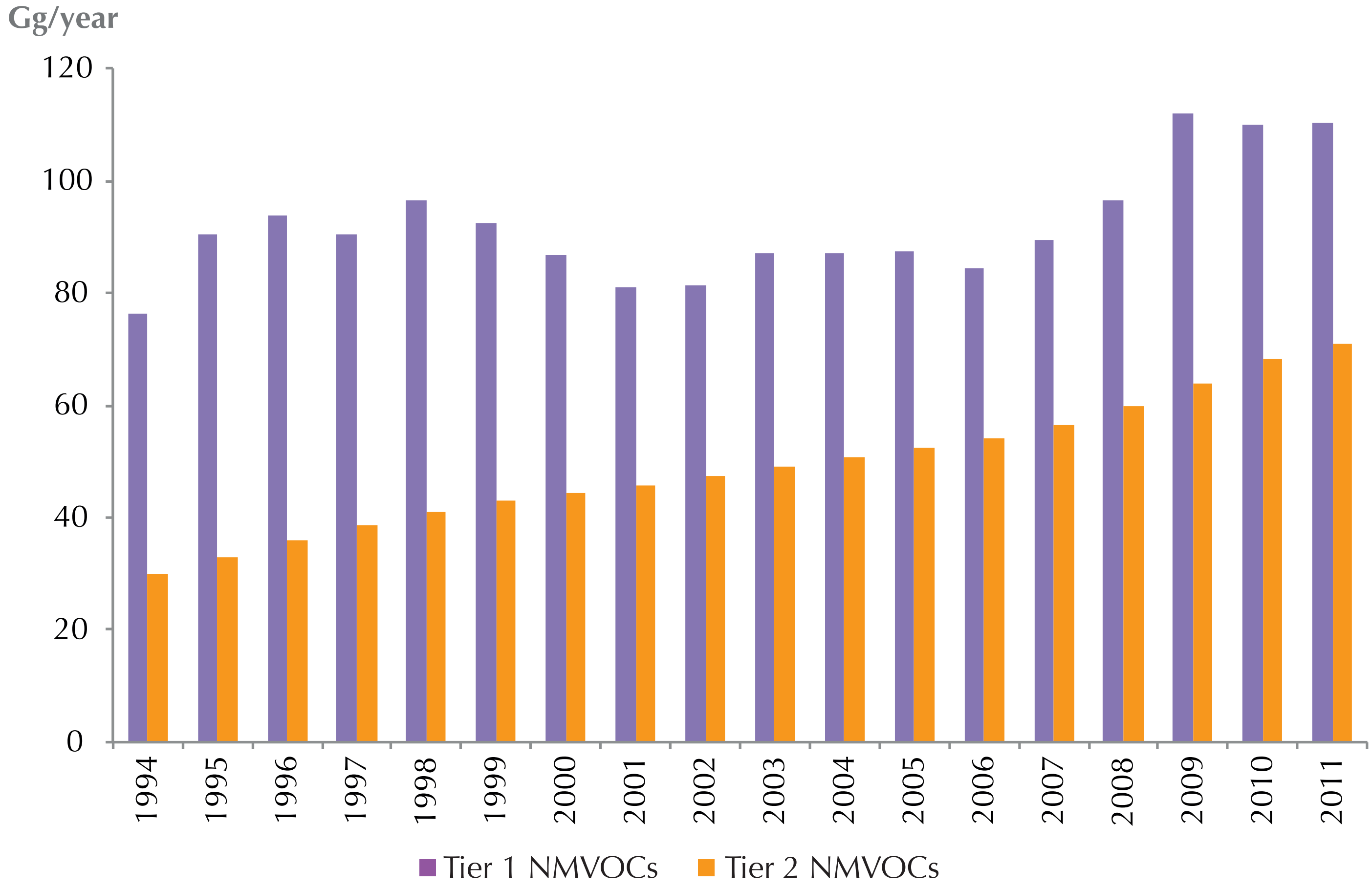


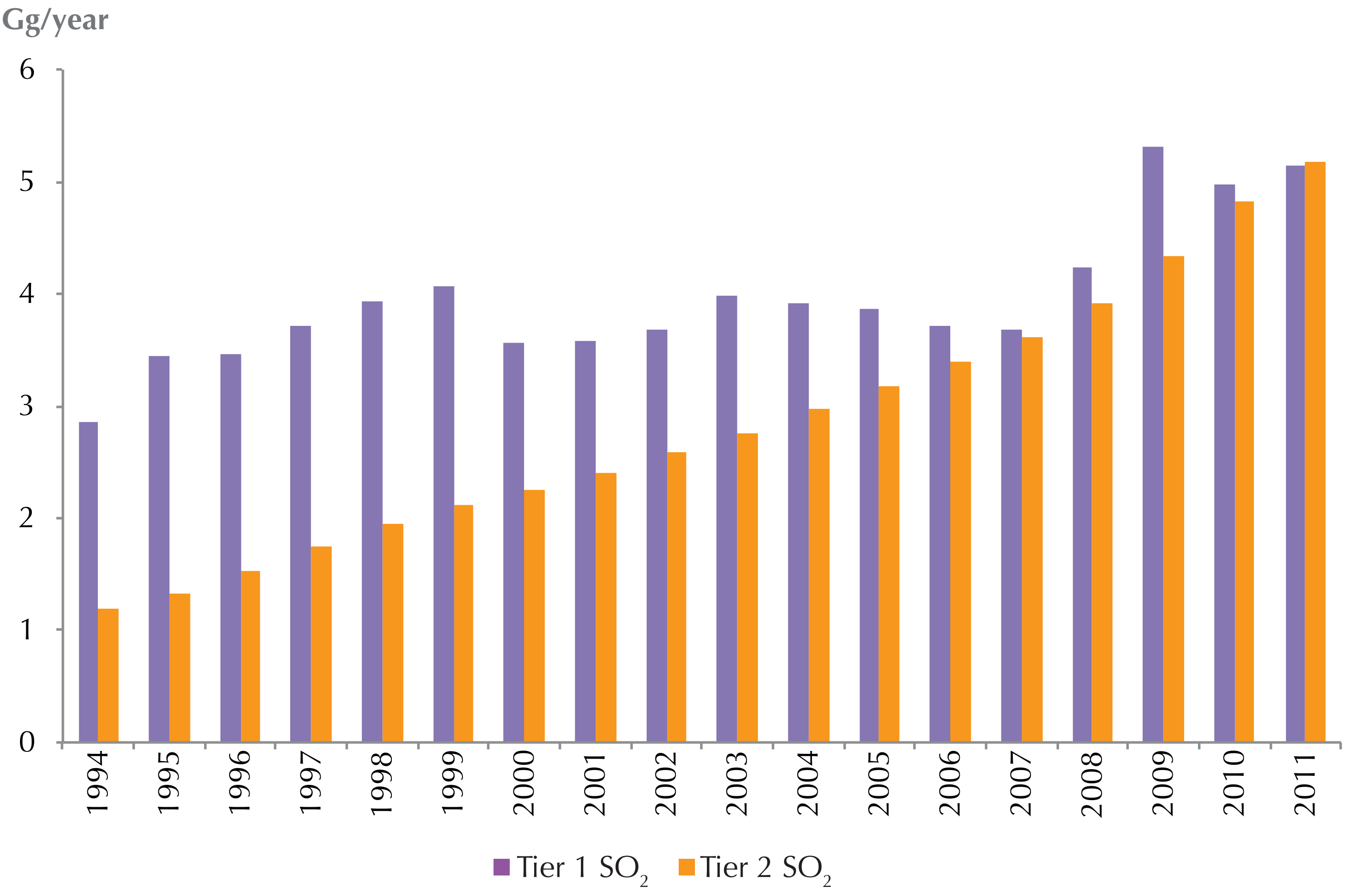



Gg/year
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Tier 1 N_2O
Tier 2 N_2O

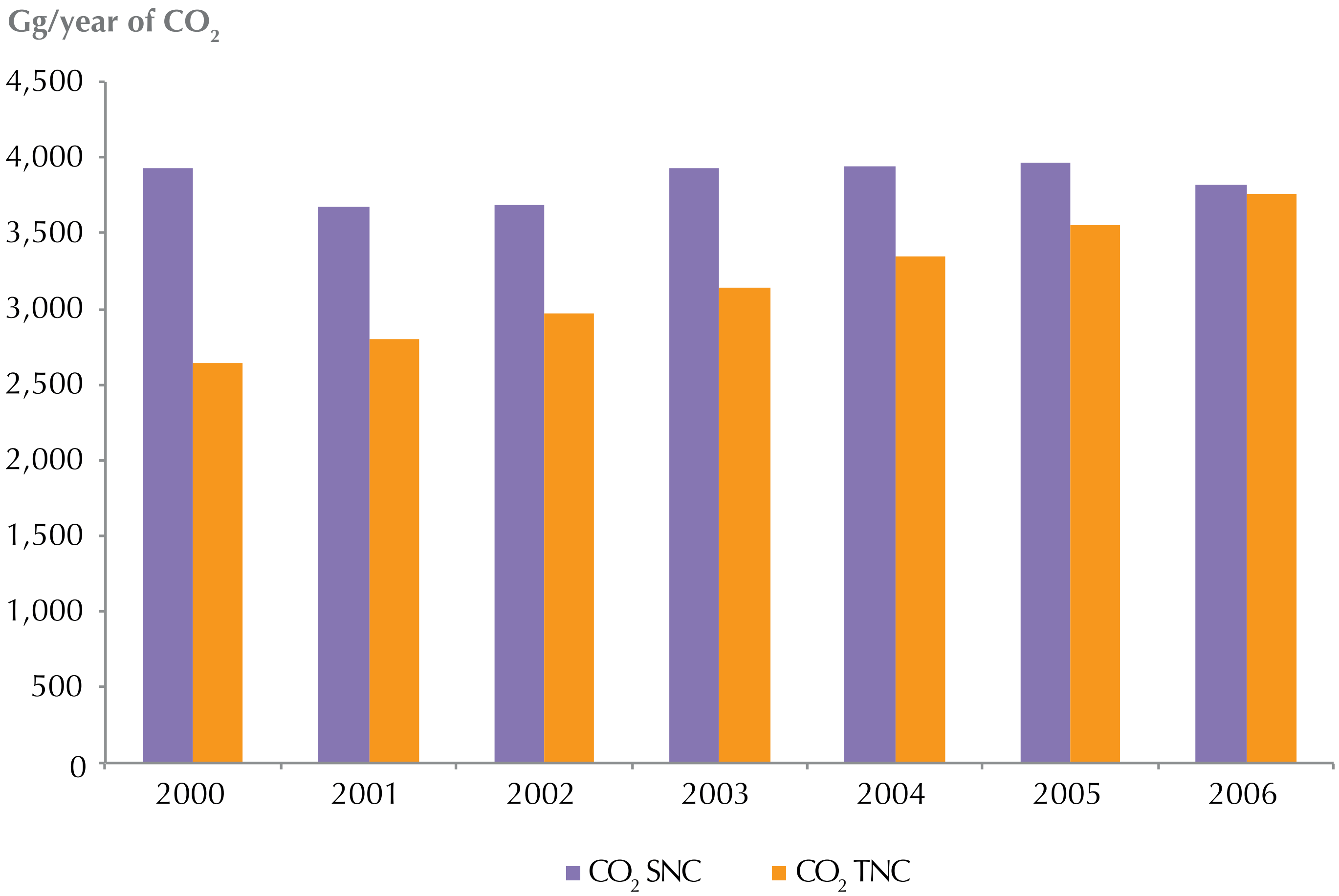

Gg/year
60
50
40
30
20
10
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Tier 1 NO_x
Tier 2 NO_x

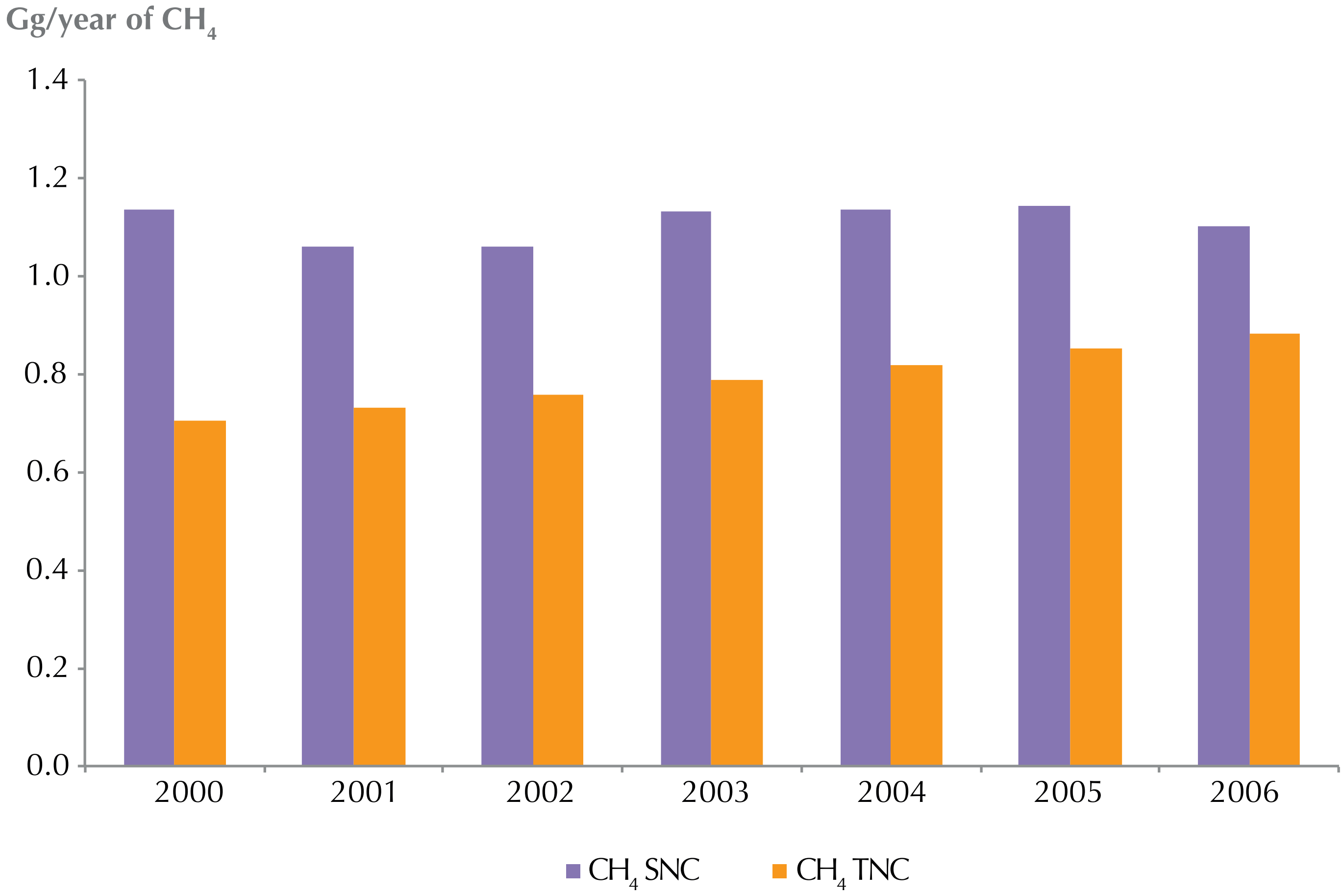

Gg/year
700
600
500
400
300
200
100
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Tier 1 CO
Tier 2 CO

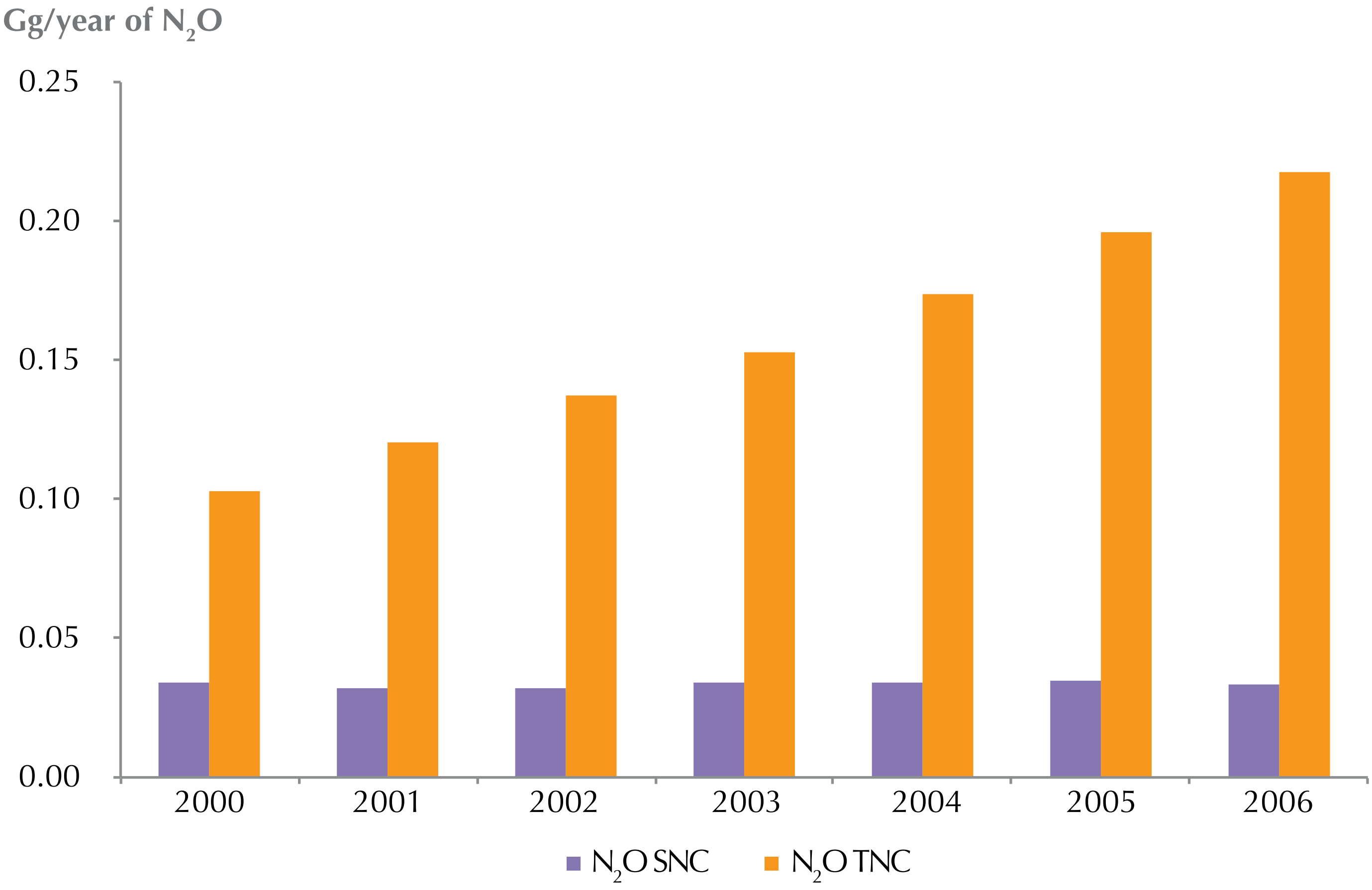

Gg/year
120
100
80
60
40
20
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Tier 1 NMVOCs
Tier 2 NMVOCs


Gg/year
6
5
4
3
2
1
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Tier 1 SO_2
Tier 2 SO_2

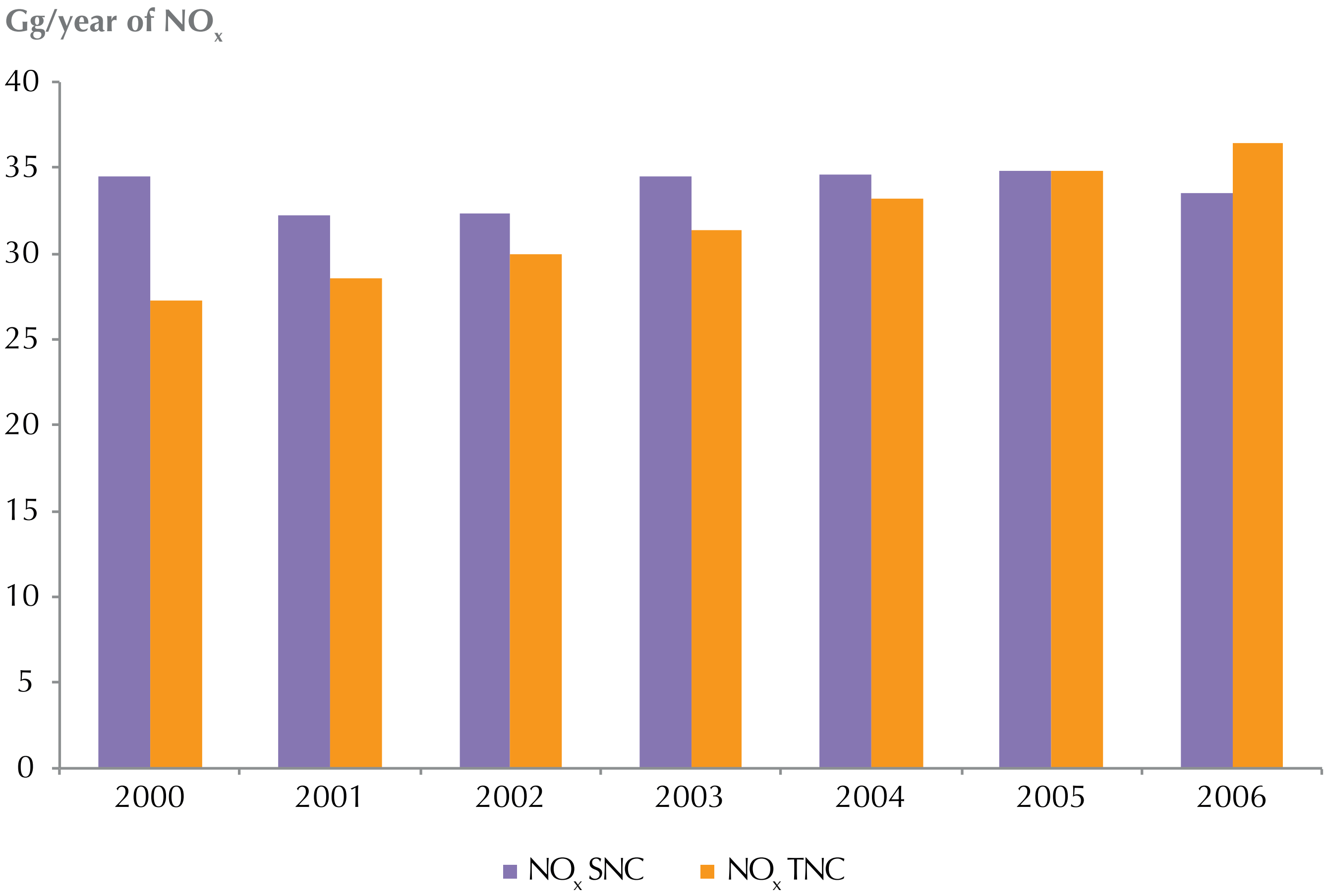
Annex III: Tier 1 GHG emissions comparison between SNC and TNC



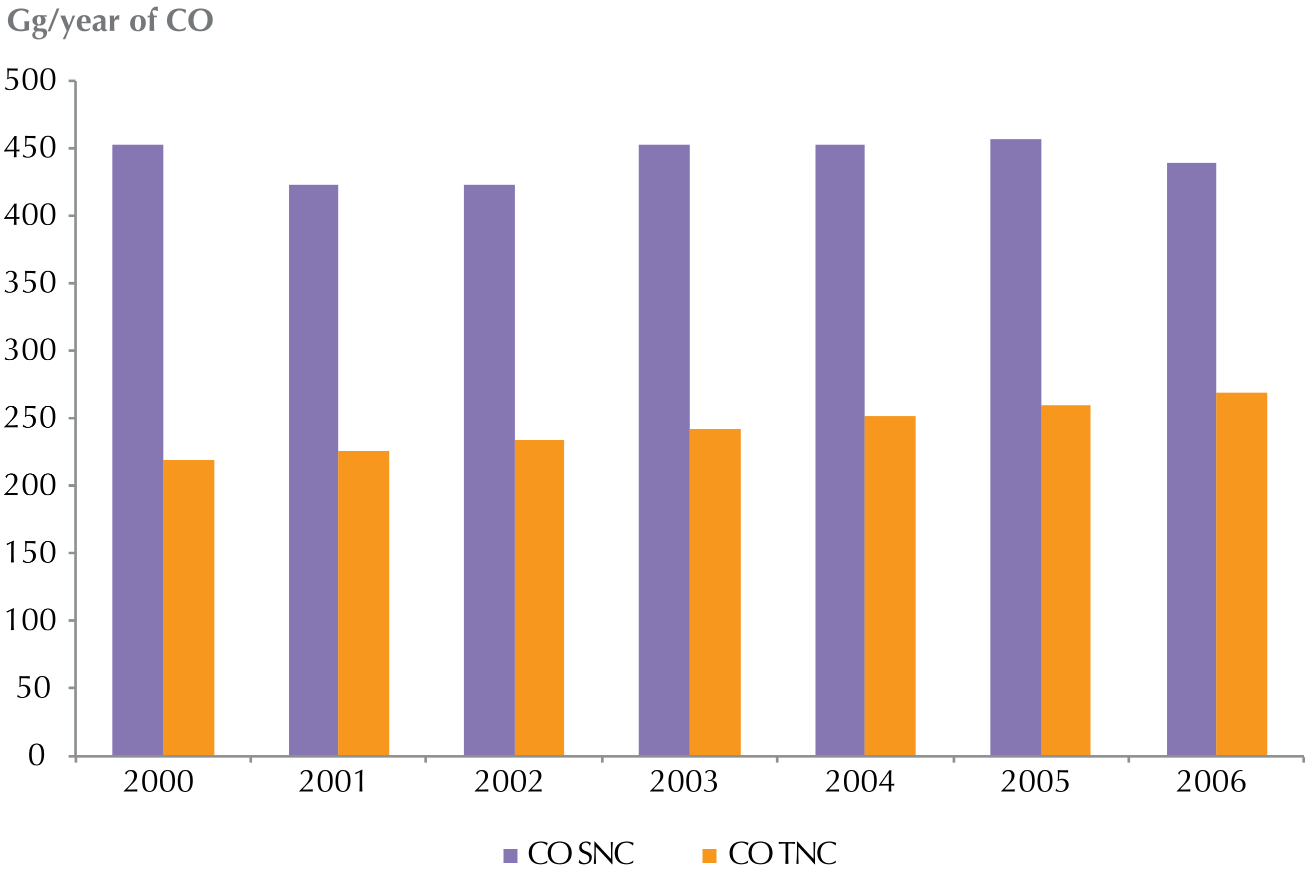


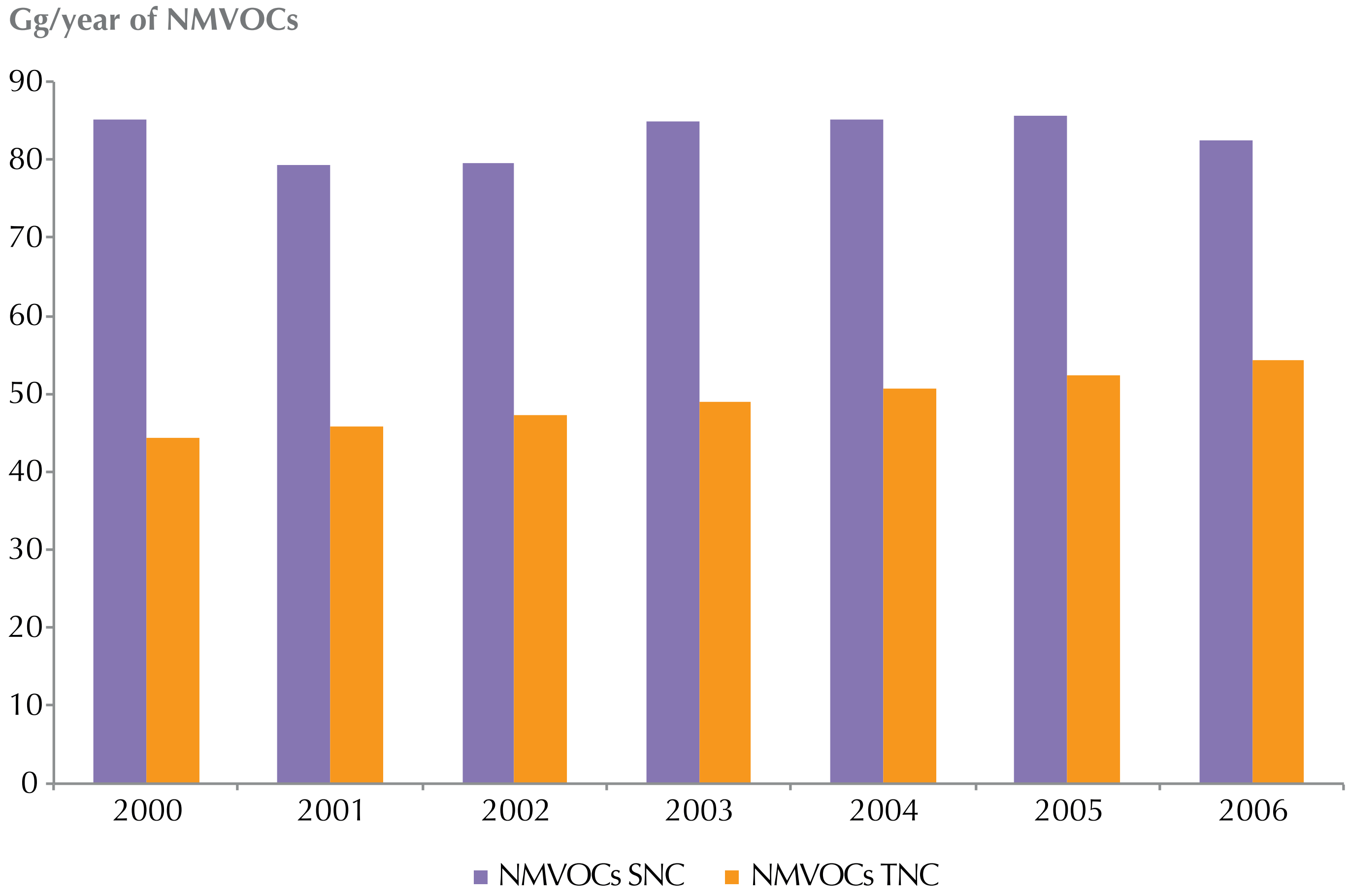


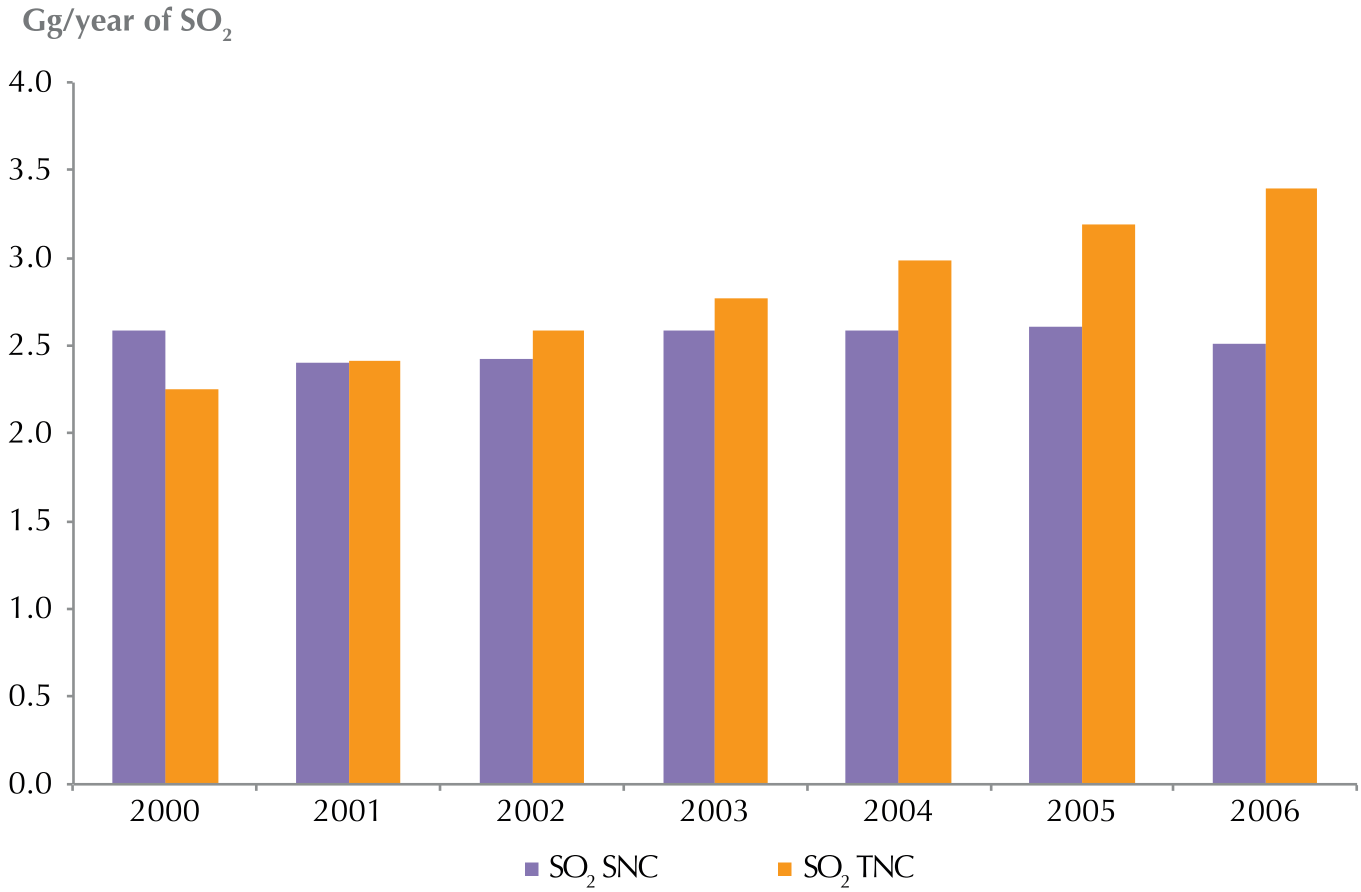
Gg/year of N_2O
0.25
0.20
0.15
0.10
0.05
0.00
2000
2001
2002
2003
2004
2005
2006
N_2O SNC
N_2O TNC



Gg/year of NO_x
40
35
30
25
20
15
10
5
0
2000
2001
2002
2003
2004
2005
2006
NO_x SNC
NO_x TNC


Gg/year of CO
500
450
400
350
300
250
200
150
100
50
0
2000
2001
2002
2003
2004
2005
2006
CO SNC
CO TNC


Gg/year of NMVOCs
90
80
70
60
50
40
30
20
10
0
2000
2001
2002
2003
2004
2005
2006
NMVOCs SNC
NMVOCs TNC


Gg/year of SO2
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2000
2001
2002
2003
2004
2005
2006
SO2 SNC
SO2 TNC