Sustainable Transport; Grouped Publication

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1 Steering Towards a Sustainable Road Transport Sector in Greater Beirut Area

Guest Authors: C. Mansour and M. Haddad

Growing economies are leading to growth in energy demand in all sectors, the transport being one of the leading. According to the International Energy Outlook (2013) the transport is the highest fuel consuming sector with a 19% consumption in 2010, mostly of fossil fuels. The first of the two exchanges set focuses on the road transport sector in the Greater Beirut Area ranging from Nahr - el - Damour to Nahr - el - Kalb. A detailed analysis of the current transport sector showcasing the mitigation actions adopted by the government and their repercussions on its development. Through mere review of success stories in the transportation planning, the national strategy for sustainable transportation in Lebanon ought to be developed through the integration of targeted policies, mitigations actions, incentives and other appropriate instruments.

2 Sustainable Aviation: MEA Case

Guest Authors: P. Zouein, M. Haddad and C. Mansour

With growing economies comes globalization and air transport which provides the much needed connection and caters for the needs of the continued growth. Studies have showed that unlike other sectors, the transport sector including aviation was the only one featuring growth in GHG emissions for the years ranging from 1997 to 2007. The second of the two exchanges set focuses on the aviation sector and the Middles East Airline case in particular. Even though great efforts are evident whether on the regional level with the ACAC or on the national level with MEA, a legislative body is needed to regulate the environmental impacts, furthermore strategies and policies are still not popular mainly due to the fact that most initiatives are on voluntary basis. A mixture of approaches needs to be evaluated on a country basis, especially that air transport is an international industry that extends to national jurisdictions.
1 Introduction

Every year, countless reports, research papers and governmental assessments are being published about Global Warming and the need for shifting the world's energy consumption trend into one with “sustainable dynamics”. The long-term environmental impacts and the human health implications of Global Warming can never be overstated, and focus is currently on mitigating the causes of this phenomenon by reducing fossil fuel consumption, especially in the transport sector, a sector that is among the most responsible for harmful emissions in both industrialized and developing countries alike.

This is because economic growth is inevitably accompanied by an increase in energy demand in most sectors of the economy, primary of which is the transportation sector. According to the World Energy Council, the demand for fuel will increase by up to 200% by the year 2050 (World Energy Council, 2011). The transportation sector holds the highest share of fuel consumption (International Energy Outlook, 2013), and has consumed in 2010 the equivalent of 19% of global energy supplies, the majority of which is classified as fossil fuels (gasoline, diesel and gas) (World Energy Council, 2011). The natural consequence of this trend is an increasing pressure on the supply of fossil fuel worldwide, which is expected to continue over the years to come as the needs of passenger mobility continue to grow.

This same picture is observed in the Lebanese road transport sector. According to Lebanon’s Second National Communication to the UNFCCC (SNC), road transportation is the second largest consumer of energy, dependent totally on fossil fuels (gasoline and diesel) (Second National Communication, 2011). The Lebanese vehicle fleet relies mostly on older and less efficient passenger cars as the main vehicle type for mobility, in the absence of a decently operated public transportation system (Technology Needs Assessment, 2012). And in the absence of any other local modes of passenger transportation such as marine ferry or rail service, it becomes
clear that the land transportation sector in Lebanon should be the focus of a major transformation effort to turn it into a sustainable engine of the economy, while still responding to people’s needs for mobility.

The focus of this paper is to provide mitigation options to improve the inefficiencies of the Lebanese road transport sector, and therefore to, (1) reduce reliance on fossil fuels, (2) decrease pollutants and Greenhouse Gas (GHG) emissions, and (3) reduce mobility costs; the three main pillars of a sustainable transport sector.

The scope of this exchange is the road transport sector for passengers in the Greater Beirut Area (GBA), extending from Nahr-el-Damour south, to Nahr-el-Kalb north. The current state of road passenger mobility is presented first, along with the main problems resulting from the unsustainable conditions of this sector. Second, a roadmap for improvement is presented, starting with the current trends of sustainable mobility, the so-called Avoid-Shift-Improve (ASI) approach. The ASI strategy allows moving away from unnecessary unsustainable practices, and outlines steps to decrease the use of fossil fuels and emissions of polluting substances. Finally, some measures of the ASI approach are tailored for the case of the GBA in order to modify the current unsustainable situation of road transportation and present concrete, viable solutions to the problem.

Overview of current problems in road passenger transport

Local passengers commuting through the GBA suffer from daily frustration, which stems from heavy congestion, pollution and the unwillingness of drivers to adhere to the driver’s code of conduct and road rules. The heavy congestion is due to demographic growth, the increase in the number of vehicles on the road, the unregulated and chaotic driving behaviors on major highways as well as side-roads, and the under-developed and mismanaged mass transportation system. High pollution levels originate from the dominance of old, inefficient cars in the Lebanese vehicle fleet, as well as from long idling times and very slow driving speeds in gridlocked traffic. Chaotic driver behavior and breach of driving rules paired with the absence of modern regulations and corrective actions reduce safety level on the roads, leading to further congestion in a seemingly endless vicious circle. This illustrates the current state of the Lebanese road passenger transport and it is illustrated through a multitude of observations and data presented in the following sections.

2.1. Volume growth and driving patterns in GBA

The GBA includes more than 40% of the Lebanese population and is a major “hub” expected to host 5 million daily passenger trips by 2015 (Second National communication, 2011).

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 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. Moreover, the speed acceleration frequency distribution presented in Figure 1 shows that the acceleration rates are significant at very low speed, which reflects 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.

Consequently, the road passenger transport sector suffers from high energy demands, with deployed technologies fully dependent on fossil fuels, making it economically unsustainable especially at a time when oil supply and oil prices continue to be highly sensitive to uncontrollable external factors such as political instability in the OPEC region.
2.2 Vehicle fleet overview

GBA mobility relies mainly on personal-owned passenger cars. The 2012 vehicle fleet database shows a total of 1.58 million registered vehicles: 85% passenger cars, 0.9% buses, 8.9% trucks and 5.2% motorcycles. 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, indicated in Figure 3 (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.

![Speed-acceleration frequency distribution in GBA](image)

**Figure 1. Speed-acceleration frequency distribution in GBA**

![Model year distribution (Passenger cars fleet 2012)](image)

**Figure 2. Model year distribution of the fleet of private and public passenger cars in Lebanon**
2.3. Congestion

With the high demographic growth in GBA and uncontrolled increase in car ownership, traffic congestion is likely to occur at every intersection. Several road expansion projects were undertaken; however, poor planning has led to inevitable congestion, and a quasi-impossibility of expanding current roads. Hence, new road infrastructures need to be created to accommodate for the increase in the number of cars, which is deemed as an insufficient solution given the very limited space available for new construction and the rapid growth of demand. On another note, car occupancy rates in GBA were found to be very low, slightly above one passenger per car (Technology Needs Assessment, 2012) providing another explanation for the ever increasing number of cars on the road.

Another major cause for congestion is driver behavior on the road. In narrow streets which are predominant in the GBA, a “common practice” is double parking for a quick pick-up or delivery, which further reduces the space dedicated to cars and causes heavy traffic. On highways, the non-adherence to driving between the lanes causes the crowding of two cars per lane instead of one, which severely restricts flow speeds and compromises road safety, thereby leading to a higher risk of accidents and even more congestion. Furthermore, the lack of respect for traffic signals triggers the blocking of intersections and further traffic jams at all hours of the day, extending the periods of peak traffic and affecting more areas outside the normally busy business districts. Finally, as speed limits are also not respected on GBA highways, this also leads to unnecessary traffic congestion, whether from accidents due to high speeds or from driving at low speeds on the fast lane.

Current mass transport driving patterns also play a role in increasing traffic congestion through the lack of dedicated lanes and the irregular pickup/drop-off patterns of passenger buses. For instance, the unrestrained competition between public and private mass transport operators (buses, taxis and shared taxis) pushes drivers to abruptly switch lanes and stop virtually anywhere for passenger pickup. Consequently, additional congestion and stop-and-go patterns are generated for the other cars on the road, not to mention the increasing risks of collisions and accidents.

2.4. Mass Transport System

Mass transport in GBA consists only of public and private buses, minivans and exclusive- and shared-ride taxis, all operating ad-hoc 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 (Technology Needs Assessment, 2012). In 2002, the mass transport market share in GBA was 31%, split between modes as illustrated in Figure 4 (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.

Some of the main roots of this sector’s mismanagement are the limited capacities of the overseeing institutions and organizations and the fragmentation of responsibilities between them. Several governmental and institutional actors have authority over the organization and operation of various aspects of the mass transportation system, and their decisions often influence other parts of the system outside their jurisdiction or even the whole system. These actors are:

- Directorate General of Land and Maritime Transport (DGLMT)
- Directorate General of Roads and Buildings, operating under the umbrella of the MoPWT, and responsible for the construction, rehabilitation and maintenance of public roads and government buildings.
- Ministry of Interior and Municipalities (MoIM), in charge of vehicle registration and inspection, driver’s licensing and traffic code implementation.
- Traffic Management Organization (TMO), in charge of the traffic management.
- Railway and Public Transport Authority (RPTA), (Office des Chemins de Fer et des Transports en Commun - OCFTC) in charge of public transport operations.
- Municipalities, in charge of roads within municipal jurisdiction, and associated regulation of transport and traffic.

This fragmentation of responsibilities and overlapping jurisdictions along with the lack of coordination between entities has naturally led to the above-mentioned gap in the management of the mass transport system as a whole.

An additional aspect of mismanagement is related to the fiscal burden of the system on the public treasury, which can be considered to be economically unsustainable as is. As an example, the RPTA, which maintains minimal services since the decommissioning of much of the network in the 1970’s, still requires every year heavy subsidies to cover its operating costs. These costs continue to increase and have gone from requiring subsidies of USD 9 million in 1998 and 1999, to USD 13.3 million in 2000, more than the fare revenues earned in these years. Moreover, USD 2.2 million of the subsidies was channeled to cover railway employee salaries, when rail service has actually been suspended in Lebanon since the 1970’s (Baaj, 2002). Along similar lines, the Lebanese government continues to subsidize the social security obligations of the 33,000 red-plate holders which are estimated at about USD 32.4 million per year (Technology Needs Assessment, 2012).
2.5. Energy consumption and Environmental Impact

Greenhouse Gas (GHG) emissions, mainly CO₂, which are responsible for Global Warming and the degradation of the environment (Black, 2010), have been scientifically proven to be proportional to fuel consumption. Therefore, the more fuel is consumed in the transport sector, the more emissions are discharged into the atmosphere.

According to a report of the International Energy Agency, the oil consumption in 2008 of the road transport sector constituted more than 62% of the total oil consumption in Lebanon, 99.2% depending on gasoline (International Energy Agency, 2008). Consequently, the road transport sector is the second biggest emitter of GHG. It accounts for nearly 21.4% of Lebanon’s GHG emissions for the year 2000, and it is the main source of CO, NOx and NMVOC emissions, with 94%, 59% and 66% respectively (Second National Communication, 2011; Technology Needs assessment, 2012).

All of these existing conditions have led the road transport sector in Lebanon to have high passenger transport energy intensity in 2007, estimated at 3.08 MJ/passenger-kilometer (Figure 5), in addition to having a high energy demand per capita of 15.06 GJ/capita, exceeding the world average (Figure 6) (Technology Needs assessment, 2012).

![Figure 5. Transport energy intensity. (2007 for Lebanon and 2005 for the other regions)](image)

![Figure 6. Passenger transport energy demand per capita. (2007 for Lebanon and 2005 for the other regions)](image)

It can therefore be concluded that all of the elements of an unsustainable transport system are major constituents of the current mobility model in the GBA: passengers suffer from high mobility costs, high dependence on fossil fuels, in addition to alarming pollution rates particularly in dense urban areas. Therefore, the road passenger transport sector needs to be restructured from a sustainability perspective.

**Tackling the problem: current trends towards sustainable road transportation**

Based on the current situation of increased mobility demand, the Lebanese passenger transport sector is far from sustainable. Until now, a traditional approach has been applied, to tackle the increase in mobility demand: it consists mainly of providing additional road space through widening existing and/or building new road infrastructure. This approach can be reviewed in detail in the Urban Transport Development Plan implemented by the Council for Development and Reconstruction (CDR).

This supply-side approach has not delivered the expected benefits, and the reasons for that are explained in a causal-loop diagram shown in Figure 7 (Causal-loops are a common practice in the analysis of systems, and are used to reveal connections and feedback interactions between different components of a system). The diagram shows two feedback loops, a large positive loop...
(shown in green) and a small negative loop (in red). In the negative loop we see the typical situation where traffic congestion increases the pressure to expand the road network (the top green positive arrow between “Traffic Congestion” and “Expand Road Network”), which once implemented goes back to reduce traffic congestion (the reverse arrow in red). However, what policymakers don’t usually see is the long-term effect of this action (shown in the green loop) where road expansion encourages more people to get on the road as they get the impression that roads have improved and traffic congestion has been decreasing. This ends up canceling out the benefit of the original road expansion as congestion is increased again through the newly induced traffic.

The diagram also shows that harmful emissions and fuel consumption continue to increase despite the expansion of the road network. Therefore, the traditional supply-side approach has come to be regarded as only a short-term solution which can be counter-productive in the long-term, especially if implemented alone without other mitigating measures.

The principles of sustainability require tackling not only the supply side, but the demand side as well. On the demand side, the logic is to maximize efficiencies by the individual users of the system, namely at three levels of decision-making for a typical trip, as illustrated in Figure 8. The target is maximizing (1) the system efficiency, (2) the trip efficiency and (3) the vehicle efficiency. Hence three factors have to be considered: how far the distance to go, the mode of transport to use, and the type of vehicle to use.

Based on this approach, several organizations such as the United Nations Environment Programme (UNEP) and the German Society for International Cooperation (GIZ) have committed themselves to promoting the Avoid-Shift-Improve (ASI) approach, as introduced in Dalkmann and Brannigan in 2007 (Dalkmann et al., 2007). This approach entails a three-fold strategy to address maximizing the efficiency of road transport, and calls for:

- Avoiding or reducing travel by motorized modes through, for instance, the integration of land use and transportation planning
- Shifting to more environmentally friendly modes such as public transport and non-motorized transport
- Improving vehicle and fuel technology of all modes of transport to improve the environmental efficiency from each kilometer travelled

Figure 7. Why building more roads doesn’t solve the congestion-consumption-pollution problems. (Adapted from: Sterman, 2000)

Figure 8. The Avoid-Shift-Improve Strategy as a response to reduce GHG emissions at all decision-making levels of a trip (Reference: sutp.org).
3.1. Avoid Strategy

The Avoid strategy refers to the need to improve the efficiency of the transport system. It consists of reducing or totally cancelling the need and/or desire to travel. Several techniques and solutions were adopted in sustainable cities, among them is telecommuting to work. For the case of Lebanon, the concept of telecommuting needs to be introduced to the local work culture as it is currently an uncommon practice. Not only would this contribute to reducing congestion and fuel consumption, but it would also lead to economic benefits at the multiple levels from reduced costs, higher employee satisfaction and retention, and increased productivity from the saved travel time.

Since walking is the “built-in” motion in human nature, walking and bicycle riding zones should be the center of transportation planning (Schiller et al., 2010). It might be too late for countries with fully-developed or saturated infrastructure, but it is a chance for developing countries to take the initiative, particularly for some of the densely populated areas in the GBA. Since 35% of passenger cars trips have a distance lower than 4 km, 11% lower than 2 km (Mansour et al., 2012), reserved walking and biking zones could become effective measures if the concept of environmental responsibility is promoted and enforced in Lebanese culture, at both the government and population levels.

Another globally applied policy is to disincentive the use of motorized vehicles, such as congestion pricing in London and Singapore, air pollution pricing in Milan, and vehicle caps in Singapore (Hidalgo and Huizenga, 2013). Also, tolls are introduced in some areas of congested cities to relieve its traffic and motorized vehicle density. The reverse is also valid, such as giving incentives to individuals who drive “clean” cars: for example, the Swedish government implemented subsidies for eco-friendly cars in 2007, and provided free parking in cities for “clean” car owners.

Such policies and measures are worth serious consideration in some areas of the GBA in order to change the culture of dependence on the use of motorized vehicles. However, it is clear that in order to apply this “Avoid” strategy in the GBA, serious cultural changes are necessary at all levels: from decision-makers and stakeholders to passengers, in conjunction with deep and carefully considered changes to the existing infrastructure. Along those lines, capacity building and expertise are required at the level of the relevant authorities, to carry out these changes, and awareness campaigns will be needed in order to fight resistance to change at the user level. This will necessitate substantial and sustained funds to ensure success of this massive transformation. For the time being, the Avoid strategy can be considered a long-term target for Lebanon, until such time as serious governmental planning or a National Transport Strategy are enacted to organize the ad-hoc evolution of the system and prepare the ground for modern measures.

3.2. Shift Strategy

The shift strategy seeks to improve the trip efficiency. It consists of a modal shifting from means with high energy/oil consumption to more environmentally friendly modes.

The most efficient non-motorized mean is cycling. While no data is available on the percentage of the population using bicycles as a mode of transport in the GBA, it is clearly the least popular, with no bicycle lanes or laws to protect bicyclists. Therefore, as a first step to encourage the use of bicycles, the appropriate infrastructure needs to be created in the form of bicycle lanes, safe storage, and convenient and affordable bike rentals, among others.

A second way to push the Shift strategy is the introduction of the “Park and Ride” concept, a very popular and heavily-used facility in major cities such as Melbourne, Australia (Hamer, 2013). It consists of breaking the total travel distance in two parts: first using personal transport, then using either public transport or bicycles to complete the trip. People would park their cars in a public car park, which is next to a bus and/or train station, and complete the trip via buses or train. The car park is also fitted with bicycle racks if the person chooses to ride to work. “Ride2Work” is also a program for shifting mobility out of motorized means, applied for example in Victoria, Australia, and supported by the local city council (Warrnambool City Council, 2010), where the third Wednesday of every October is designated as the Ride2Work national day to encourage riding bicycles to work and to raise environmental (and physical health) awareness.

Furthermore, carpooling offers a sustainable transport alternative to single-ride passenger cars. In Lebanon, several websites and mobile applications are dedicated to match individuals, mainly students, for carpooling. The websites caused hype for a brief
period of time before being forgotten. But the implications of these tools could be significant in the Lebanese context since carpooling with two or three passengers onboard would equal the trip-efficiencies of local buses; and hence, lower CO₂ emissions per passenger-kilometer, as illustrated in Figure 9 and Figure 10.

Figure 9. Efficiency of bus technologies as function of bus occupancy, relative to the Lebanese average passenger cars efficiency, with 1 and 3 pass/veh occupancy. (Reference: Technology Needs Assessment, 2012)

A last example of shifting to environmentally-friendly mass transport options is the rail transport. The particularity of rail is its high transport capacity per trip compared to other modes of transportation (Golinska et al., 2012). In this case, the energy requirements per passenger-trip dramatically decrease and savings are not only in terms of energy and emissions, but in space as well since one train transporting two hundred passengers would take less space than two hundred cars, for example.

Lebanon used to have four rail lines: (1) Beirut-Damascus, (2) Naqoura-Tripoli, (3) Tripoli-Homs and (4) Rayak-Aleppo. Though the entire rail network is currently derelict, study into the feasibility of rebuilding, rehabilitating and reopening the approximately 80 km of disused railway from Beirut north along the coast to Tripoli, is under consideration by the European Investment Bank.

Figure 10. CO₂ emissions of bus technologies as function of bus occupancy, relative to the Lebanese average passenger cars efficiency, with 1 and 3 pass/veh occupancy. (Reference: Technology Needs Assessment, 2012)
3.3. Improve Strategy

The Improve strategy focuses on vehicle and fuel efficiency. It consists of improving the energy efficiency of vehicle powertrain technologies, and the use of alternative energies.

In order to comply with EURO emission regulations, car manufacturers adopted engine downsizing as a common design technique; these vehicles are also referred to as fuel-efficient gasoline cars. By decreasing the displacement of the engine and turbocharging it, fuel consumption is decreased and vehicle power is increased. Moreover, additional passive and active technology systems are incorporated in order to further reduce fuel consumption (Figure 11). As a result, considerable consumption and CO2 emissions savings of fuel-efficient gasoline cars are observed relative to the average consumption (11.2 l/100 km) of the Lebanese passenger cars fleet under GBA driving conditions, as indicated in Figure 12. Savings range from 10 to 36%, depending on the car segment.

Figure 11. Passive and active system technologies of fuel efficient gasoline powered vehicles. (Reference: Technology Needs Assessment, 2012)

Figure 12. Consumption of different fuel efficient gasoline car segments, and fuel and CO2 emissions savings relative to the Lebanese fleet of 2007 under GBA driving conditions. (Reference: Mansour, 2013)
Further advancement on powertrain efficiencies is characterized by their low consumption, as the electrification of powertrains, combining a high efficiency electric motor to an internal combustion engine. Hybrid electric vehicles (HEV) are summarized in Figure 13. Savings range from 37 to 67%.

**Figure 13.** Consumption of different HEV segments, and fuel and CO2 emissions savings relative to the Lebanese fleet of 2007 under GBA driving conditions. (Reference: Mansour, 2013)

Additional fuel savings for less than 2.5 l/100 km are currently conceivable with plug-in hybrid vehicles (PHEV) or range-extender electric vehicles (REEV), where extended battery capacities are used to offer additional 20 to 60 km of electric drive range. Once depleted, the batteries are restored to full charge by connecting a plug to an external electric power source. However, serious concerns need to be addressed like the infrastructure investment for charging stations.

Battery electric vehicles (BEV) could be an effective means for a long-term solution to today’s environmental and noise pollution issues in the GBA. Technological innovations now make it possible to mass market an electric vehicle at reasonable cost if incentives are considered. In addition, changes in vehicle use make electric cars ideal for the majority of trips in the GBA, since 94% of the trips are lower than 20 km (Mansour et al., 2011).

The energy efficiency of BEV is very high compared to their fossil fuel counterparts, which leads theoretically to zero GHG emissions. Nevertheless, the actual GHG emissions and total energy use associated with the use of BEVs depend largely on the way the required electricity has been produced. Therefore, the well-to-wheel (WTW) analysis must be considered in this assessment. Figure 14 outlines the WTW energy use improvements of BEVs comparing to WTW average consumption of the Lebanese cars fleet of 2007.

7.2% of energy savings are achievable under the Lebanese electricity mix of 2010, relying 92% on residual oil; however, 33 to 42% of savings will be possible in 2030 if mitigation scenarios of electricity generation mix are adopted, based on increasing the part of renewable energy up to 17%, natural gas to 83% and eliminating completely the use of residual oil (Technology Needs Assessment, 2012). Nevertheless, BEV cannot be conceivable on the short- or medium-terms due to the electricity generation shortage as well as the need for charging stations infrastructure.

In terms of alternative fuels, bio- and synthetic fuels are being considered around the world, mainly blended with gasoline and diesel. By the National Bioenergy Strategy, published the UNDP-CEDRO project, indicated, under the more optimistic scenario, that 18% of the total fuel requirement for the Lebanese transport sector can be secured through sustainable bioenergy streams. However, attention as to the GHG reduction benefits require further research, as well as ensuring that they meet the sustainability criteria set.

Another alternative fuel under examination by the Ministry of Energy and Water (MOEW) for passenger cars is the natural gas (NG). NG is being used in some cities worldwide in the compressed gas form...
(CNG) for passenger cars, vans and buses, and liquefied form (LNG) for long range trucks. NG vehicles are well known for the air quality benefits rather than GHG and energy consumption reductions, as illustrated in Figure 15 and Figure 16.

Figure 14. WTW energy change of BEV relative to average consumption of the Lebanese cars fleet of 2007. (Reference: Technology Needs Assessment, 2012)

Figure 15. WTW energy changes of NGV, gasoline HEV and BEV relative to the average consumption of the Lebanese cars fleet of 2007. (Reference: Technology Needs Assessment, 2012)

Figure 16. WTW pollutants change of NGV, gasoline HEV and BEV relative to the average emissions of the Lebanese cars fleet of 2007. (Reference: Technology Needs Assessment, 2012)
Adopting the ASI strategy for a more sustainable transport sector in GBA

Based on the prevailing conditions in the Lebanese road transport sector, several factors need to be considered for mitigation from a sustainability perspective: (1) reduce the number of passenger cars, (2) reduce the number and length of trips, (3) increase the vehicle occupancy rates, (4) increase mass transit means, (5) improve the vehicle efficiency, (6) increase the use of low carbon fuels, (7) increase urban average traffic speed.

Considering the suggested Avoid-shift-Improve approach to promoting sustainability and providing mitigation strategies, it is clear that no one measure will provide the solution, and action is needed simultaneously through a combination of different mitigation strategies, as summarized in Figure 17.

Priority strategies identified for consideration in the GBA seek to:

- Promote/modernize the bus mass transit system, operable on dedicated lanes.
- Create a market for hybrid electric vehicles and promote fuel efficient gasoline-powered vehicles, in order to renew the existing car fleet through a scrappage program.

The two prioritized mitigation strategies are identified using a Mutli-Criteria Analysis decision-making exercise, where transport experts and stakeholders assessed the identified mitigation technologies based on their importance in meeting national mitigation goals in terms of minimizing the GHG and pollutant emissions for the transport sector and maximizing the environmental, social, and economic development benefits, on the short- and long-terms.

The selection process, selection criteria and prioritization results are fully detailed in the Technology Needs Assessment (TNA) report, prepared by the Ministry of environment and UNDP Lebanon (Technology Needs Assessment, 2012).

Figure 17. Hierarchical process to setting up mitigation strategies for a sustainable mobility sector in GBA based on the ASI approach.

An approach for developing preliminary programme deployment of the prioritized strategies is presented in the TNA as well. The approach entailed (1) the market analysis for identifying the market chain actors and assessment of the addressable market, (2) barrier analysis to the deployment of the prioritized mitigation strategies, including financial, policy, legal, market failures, and institutional analysis, (3) setting up an enabling framework for overcoming financial and non-financial barriers, and (4) cost benefit analysis of the required incentives for deployment success of the mitigation strategies, from the government and passengers’ perspective. Outcomes are detailed in the TNA and summarized in Figure 18 and Figure 19 for both promoting bus mass transit strategy and renewing passenger cars fleet with HEV and fuel-efficient gasoline vehicles.
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<thead>
<tr>
<th>Type</th>
<th>Priority sequence</th>
<th>Measures</th>
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<tbody>
<tr>
<td>Economic and financial measures</td>
<td>1. Develop supply chain</td>
<td>Design a bus network covering all boroughs within GBA and reserve lanes for bus operation</td>
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<tr>
<td></td>
<td>2. Shift travel demand</td>
<td>Establish smart card ticketing schemes with appropriate reduced tariffs</td>
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<td></td>
<td>3. Deploy effective infrastructure</td>
<td>Optimize the operation management of the bus transit system conserve a clear and regular bus operation, implement real-time information system, deploy personalized travel planning tools, implement transit signal priority, set up stringent maintenance cleanliness program, construct relevant maintenance and repair workshops</td>
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<tr>
<td>Policy, legal and regulatory</td>
<td>4. Set regulatory framework</td>
<td>Set clear regulations specifying the operation manoeuvres of private bus operations and taxi owners</td>
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<td></td>
<td>5. Manage demand</td>
<td>Draft new amended laws for increasing parking space and reserving lanes for buses</td>
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<tr>
<td>Institutional / organizational capacity</td>
<td>6. Stimulate passengers</td>
<td>Develop technical expertise among TMC staff and high level management</td>
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<tr>
<td>Social awareness</td>
<td>7. Monitor the progress</td>
<td>Provide information on CO2, fuel and cost savings comparing to passenger cars</td>
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<tr>
<td>Project monitoring and validation</td>
<td></td>
<td>Create Mobility Monitoring Indicators (MMI) framework</td>
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Figure 18. Action plan for promoting bus mass transit systems on dedicated lanes. (Reference: Mansour, 2013)

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<thead>
<tr>
<th>Type</th>
<th>Priority sequence</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic and financial measures</td>
<td>1. Create market Give incentives</td>
<td>Exemption from custom excise fees, registration fees, and road usage fees at registration</td>
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<td>2. Stop the bleed</td>
<td>Payment of min. salvage value (2000 USD) x down payment for car loan &gt; Extension of loan period to 5 years. Reduce loan interest</td>
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<td></td>
<td>3. Remove old cars</td>
<td>Reduce gradually max age of imported pre-owned vehicles to 3 years with mileage lower than 100,000 km</td>
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<tr>
<td>Policy, legal and regulatory</td>
<td>4. Regulate car imports</td>
<td>Create a car scrappage program based on swapping current passenger cars with hybrid and fuel efficient cars</td>
</tr>
<tr>
<td>Institutional / organizational capacity</td>
<td>5. Close the tap</td>
<td>Update decree 6603 / 1995 relating to standards on permissible levels of exhaust fumes and exhaust quality to cover all types of vehicle</td>
</tr>
<tr>
<td>Social awareness</td>
<td>6. Reform wrong perception</td>
<td>Update the vehicle inspection requirements taking into consideration special requirements for hybrid cars' inspection, in addition to mandating the presence of catalytic converters on conventional gasoline vehicles</td>
</tr>
<tr>
<td>Project monitoring and validation</td>
<td>7. Monitor the progress</td>
<td>Establish awareness campaign</td>
</tr>
</tbody>
</table>

Figure 19. Action plan for renewing passenger cars fleet with HEV and fuel efficient gasoline vehicles. (Reference: Mansour, 2013)
CONCLUSION

The long list of problems and the diverse set of challenges facing the land transportation sector in Lebanon, as discussed in this Exchange, are only the manifestations of one primary root cause: the lack of a national transportation strategy that can begin to organize the sector into a sustainable one. Such a strategy is long overdue given the current state of mobility in the country and the projected magnitude and speed of future growth in demand. The need for a comprehensive strategy is made even more pressing by the fact that the system has been left to emerge in an ad-hoc way with relatively minimal oversight for decades now, and what limited development has been done to-date has been exclusively focused on building more road capacity based on the wrong precept that capacity expansion is the solution for improving mobility. As a result, all indications are that further delay in enacting such a strategy will severely restrict future options for sustainability. Indeed, if we were to only consider the many years it takes to design and implement strategy at a national level, it would become clear how high and imminent the risk is of reaching a point of no return where we end up with a system that is continuously in “firefighting” mode, struggling to stay functional rather than evolving to be sustainable.

The lessons learned from successful experiences in transportation planning around the world lead us to the conclusion that a national strategy for sustainable transportation in Lebanon should necessarily be based on the integration of a carefully designed portfolio of policies, mitigations, incentives and other instruments as those discussed under the avoid-shift-improve approach. It then follows that a comprehensive strategy for Lebanon should have for basic building blocks those major pillars encompassing the majority of instruments available and most critical in the Lebanese case, namely:

- Infrastructure development: the need for a modernized, inter-modal transportation system in Lebanon has been detailed in this Exchange. What remains to be emphasized is the urgent need for concurrent land-use planning in order to build the right infrastructure in the right place and to ultimately use it in a sustainable way. Attention should also be given to the speeding up of the execution of key projects since the development of the system has been exceptionally slow. For example, Public-Private Partnerships financing public works are now being explored in several cities worldwide based on the precept that transport projects bring large benefits to the economy and therefore present an incentive for industry to share in the financial responsibilities of building them quickly and efficiently.

- Systems management: the lack of regulation and planning in the transportation sector in Lebanon and the resulting chaotic state of mobility make the system an ideal candidate for “smart” management of both the technical and human parts of the system. This can be implemented with the host of options available under the “Avoid-Shift-Improve” strategies discussed previously. On the technical side, these options include the incorporation of new technologies at the vehicle level (powertrain, chassis, fuel) and the transport network level (transportation demand management, intelligent transportation systems, among others). On the user side, mechanisms for improving behaviour range from shifting demand towards more efficient modes or routes, to overcoming cultural barriers and changing driver habits.

- Administrative reform: there is no lack of government bureaucracy involved in the transportation sector in Lebanon; however, the many inefficiencies of this bureaucracy as already illustrated in this Exchange, raise a deep and immediate concern for administrative reform. Here all the typical mechanisms for transforming organizations and reducing waste in processes apply, with special emphasis on the need for inter-organizational coordination to address the deep fragmentation of responsibilities and authority between agencies, and the urgent need for a transparent process for citizen participation in transportation planning.

An illustration of the building blocks of a sustainable national strategy is shown in Figure 20:
Figure 20. Building blocks of a national strategy for sustainable transportation in Lebanon.

References


1 Introduction

Air transport plays a vital role in supporting economies and societies that are increasingly interconnected by globalization. It is one of the world’s fastest-growing industries today, however there are unprecedented levels of popular and scientific concern about the environmental impacts of air transport. Emissions from aircraft and airports contribute to climate change and to localized air pollution, and aircraft noise affects communities adversely in the vicinity of airports. These environmental impacts are already acute and are likely to increase in scale and scope as the demand for air transport grows.

In the EU for example, the transport sector has the second biggest greenhouse gas (GHG) emissions, second only to energy industries, which contribute to the rise of Earth’s temperature. Although more than two thirds of transport-related GHG emissions are from road transport (Fig. 1), emissions from the aviation and maritime sectors are also significant especially that these sectors are experiencing the fastest growth in emissions (Fig. 2).

GHG emissions in sectors other than transport decreased 15% between 1990 and 2007 but emissions from transport, including aviation, increased 36% during the same period (Fig.2). This increase has happened despite improved vehicle efficiency because the amount of personal and freight transport has increased. Global emissions from transport of CO2, a GHG with a long-lifetime in the atmosphere, are expected to continue to grow by approximately 40% from 2007 to 2030 (ITF 2010).

Balancing the tradeoff between the growing demand for air transport and its environmental impacts presents policymakers and the aviation industry with a major challenge.
In this Exchange, we address the challenges of making aviation sustainable in the long term and we review the measures undertaken by the international community to respond to these challenges through policy development and international treaties and through the advancement of aircraft and fuel technology to offset aviation environmental impacts. The material presented is based on a review of the academic literature and on primary research into aviation environmental impacts undertaken between 2006 and 2010, with a focus on how Middle East Airlines (MEA), the national air carrier of Lebanon, and the Civil Aviation Authority of the Lebanese government are responding to issues of global climate change and other environmental impacts of civil aviation.

**Key issues in sustainable aviation**

As with many other environmental issues, debates about the environmental impacts of air transport are often framed within wider discussions of sustainable development. Sustainable development, defined simply, entails balancing the economic, social and environmental benefits, and costs of development both for people living now and for future generations (Upahm et al. 2003).

Air transport makes a substantial contribution to local, regional and national economies in its own right: by adding to gross domestic product (GDP), by creating direct and indirect employment, by raising productivity, by exporting goods and services, by contributing taxes and through investment in the supply chain. It is the sheer scale of aviation growth,
however, that requires special attention as to its' environmental impacts. In 1999, following a request from the United Nations (UN) International Civil Aviation Organization (ICAO) and the parties to the Montreal Protocol on Substances that Deplete the Ozone Layer, the UN Intergovernmental Panel on Climate Change (IPCC) published an important report on the atmospheric impacts of aviation (IPCC, 1999). In this report, the IPCC noted that aviation has experienced rapid expansion as the world economy has grown (IPCC, 1999). Passenger traffic (expressed as revenue passenger-kilometers) has grown since 1960 at nearly 9% per year, 2.4 times the growth rate of the global average gross domestic product (GDP). Freight traffic, approximately 80% of which is carried by passenger aircraft, has also grown over the same time period. By 2050, air passenger traffic is expected to have increased five-fold from 1995 levels (IPCC 1999).

In summary and during the last 40 years, air transport, at the global level, has grown twice as fast as global GDP. The growth is far from saturating in developed countries, and is markedly strong in emerging countries. In the case of MEA, MEA has witnessed an average 4% growth over the past 4 years. The growth of air transport will transform the industry from being currently a modest contributor to climate change to a relatively more substantial polluter.

**Noise control and Local environmental impacts of aviation**

In 1992, ICAO compiled an inventory of environmental problems associated with civil aviation (see Table 1). Locally, aircraft and airport operations generate noise from take-off and landings, engine testing, ground support equipment (GSE) and airport construction, so that noise is widely considered to be one of the most serious environmental problems of aviation. Although perception of noise is subjective, it can contribute to sleep disturbance problems and other related physiological and psychological effects for individuals living in the vicinity of airports and beneath their arrival and departure routes.

<table>
<thead>
<tr>
<th>Environmental Impact</th>
<th>Examples</th>
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<tbody>
<tr>
<td>Aircraft noise</td>
<td>Aircraft operations</td>
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<td></td>
<td>Engine testing</td>
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<td></td>
<td>Airport sources</td>
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<td></td>
<td>Sonic boom (due to supersonic aircraft)</td>
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<td>Local air pollution</td>
<td>Aircraft engine emissions</td>
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<td>Emissions from airport access traffic</td>
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<td>Emissions from airport motor vehicles</td>
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<td>Emissions from other airport sources</td>
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<td>Global phenomena</td>
<td>Long-range air pollution (e.g. acid rain)</td>
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<td>The greenhouse effect</td>
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<td>Stratospheric ozone depletion</td>
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<td>Airport/infrastructure construction</td>
<td>Loss of land</td>
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<td>Soil erosion</td>
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<td>Impacts on water tables, river courses and field drainage</td>
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<td></td>
<td>Impacts on flora and fauna</td>
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<tr>
<td>Water/soil pollution</td>
<td>Pollution due to contaminated run-off from airports</td>
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<td></td>
<td>Pollution due to leakage from storage tanks</td>
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<tr>
<td>Waste generation</td>
<td>Airport waste</td>
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<td>Waste generated in-flight</td>
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<td>Toxic materials from aircraft servicing and maintenance</td>
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<td>Aircraft accidents/incidents</td>
<td>Accidents/incidents involving dangerous cargo</td>
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<tr>
<td></td>
<td>Other environmental problems due to aircraft accidents</td>
</tr>
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<td></td>
<td>Emergency procedures involving fuel dumping</td>
</tr>
</tbody>
</table>

Table 1. ICAO inventory of aviation environmental problems  (Source: Adapted from Daley (2010))
Airports also have other localized environmental impacts including habitat modification and destruction, land contamination, waste production, water consumption and water pollution. At the global scale, concerns about the environmental impacts of aviation now focus sharply on the issue of climate change. Aircraft and airports generate air pollution, especially due to the emission of nitrogen oxides (NOx) and particles. These emissions and their impact locally and globally on climate change are covered in the next section.

**Impact of aviation on atmospheric conditions and global warming**

At the global scale – and increasingly at the scale of individual airports the impact of aircraft emissions far outweighs any other aviation environmental effect in its magnitude and significance. Therefore, an understanding of aircraft emissions is crucial to any discussion of aviation environmental impacts.

Modern commercial aircraft are powered by the combustion of kerosene in turbofan or turboprop gas turbine engines. In ideal conditions the combustion of kerosene produces several GHG’s including carbon dioxide (CO2), water vapor (H2O) and a small proportion of sulfur dioxide (SO2). In addition, many other substances are emitted as a result of the incomplete combustion of the fuel like nitrogen oxides (NOx, the sum of NO+NO2) and sulphur oxides (SOx) which gives rise to particulate matter (PM), carbon monoxide (CO), and hydrocarbons (HCs). The atmospheric effects of aircraft emissions are markedly different at typical cruising levels from the effects of the same substances at ground level. At cruising levels, aviation emissions have several significant effects: they change the concentration of atmospheric greenhouse gases, including CO2, ozone (O3) and methane (CH4); they can cause condensation trails (contrails) to form in certain conditions; and they can increase cirrus cloud coverage (IPCC 1999). Aircraft emissions also have several effects closer to the ground during the landing and take-off (LTO) cycle as they alter local concentrations of NOx, O3 and particles in addition to their more general effect of elevating CO2 concentrations.

The emissions of greenhouse gases by aircraft absorb infrared radiation from the earth’s surface and help retain heat in the atmosphere. Changes in the radiative properties of the atmosphere are known as radiative forcing.

The US Environmental Protection Agency (EPA) was first to legislate against aircraft emissions during the 1970s. This early legislation, local to the US, later gave rise to the engine emission certification requirements of the International Civil Aviation Organization (ICAO) on unburned hydrocarbons (UHCs), nitrogen oxides (NOx) and carbon monoxide (CO) (ICAO 2005).

The IPCC report published in 1999 provided a detailed assessment of the nature and severity of the atmospheric impacts of aircraft – and of the magnitude of projected future impacts – and it established an influential framework for further research into aviation environmental issues. Since the publication of this ‘authoritative’ report, other important documents have been produced that explored the relationship between air transport and sustainable development and the various options for mitigating the effects of aviation emissions on climate change (Upham et al. 2003, Daley, 2010), as detailed in the following sections.

**International treaties to combat climate change and their impact on aviation**

Aviation emissions are currently regulated through the ICAO engine certification process, which requires that engines meet relatively stringent standards for emissions of four pollutants (NO, HCs, CO and particle emissions) over the aircraft LTO cycle. The ICAO certification standards, however, are “manufacturing standards and not an in-service compliance regime”. Hence those standards do not take into account the decline in engine and airframe performance and thus the increased emissions generated over the service life of an aircraft. More significant also is the fact that CO2 emissions are not regulated by the ICAO certification process, since those certification standards were originally developed in response to concerns about local air pollution – and CO2 has no effect on local air quality. Besides the ICAO certification standards, no other form of direct regulation of aircraft emissions exists. Success in responding to the challenge of climate change depends upon the development of effective international climate change agreements. Some progress has been made in the form of the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, and in the various negotiations to cover the post-Kyoto period from 2012. The international community also faces the urgent challenge of creating a transparent,
comparable carbon price signal worldwide, which is necessary for mitigation as it would generate incentives for producers and consumers to invest in low-carbon products, technologies and processes (Daley 2010). The next sections shed the light on the existing international treaties to combat climate change and the range of policy instruments needed to encourage new technology development and change in consumption patterns of aviation.

**The United Nations Framework Convention on Climate Change**

The United Nations Framework Convention on Climate Change (UNFCCC) joined countries in an international treaty in 1992, to cooperatively consider what they could do to limit average global temperature increases, and to cope with whatever impacts were, by then inevitable. By 1995, countries realized that emission reductions provisions in the Convention were inadequate and, two years later, adopted the Kyoto Protocol. The Protocol legally bound developed countries to emission reduction targets. However, the treatment of international aviation and shipping GHG emissions, due to the difficulty in allocating emissions from these global sectors, have not been addressed in Kyoto GHG reduction targets of the first commitment period which started in 2008 and ended in 2012.

The IPCC assessment reports, used as baseline by the UNFCCC in making science-based decision relevant to climate change, acknowledged that improvements in Air Transport Management (ATM) and other operational systems and procedures could reduce aviation fuel consumption by 8 to 16%, leading to the reduction of emissions levels (IPCC 1999). Improvements in the efficiency of the ATM system depend upon the creation of the necessary institutional frameworks at an international level, such as the implementation of the Single European Sky initiative (EUROCONTROL 2007; IPCC 1999).

The IPCC also highlighted the following policy options to reduce emissions: a) more stringent aircraft engine emissions regulations, b) removal of subsidies and incentives that have negative environmental consequences, c) market-based options such as environmental levies (charges and taxes) and emissions trading, d) voluntary agreements, e) research programs, and f) substitution of aviation by other transport modes. However, not all of these options have been fully investigated or proven in relation to aviation (IPCC 1999).

The Kyoto protocol

The Kyoto Protocol in its second commitment period that began in 2013 and extends until 2020 addresses emissions from fuel used for international aviation in its Article 2, paragraph 2. The article states that Annex I Parties shall pursue limitation or reduction of emissions of greenhouse gas emissions not controlled by the Montreal Protocol from aviation, working through the International Civil Aviation Organization (ICAO). Domestic aviation CO2 emissions are counted as “transport emissions” and are included in national inventory totals and reported to UNFCCC in the context of national carbon allowances, while emissions from international aviation are reported separately and do not count towards national GHG totals.

Lebanon ratified the Kyoto Protocol on 13 November 2006 to benefit from the Clean Development Mechanism (CDM). CDM is one of three market-based mechanisms that help Parties to the Protocol meet their emission targets through emission-reduction projects that stimulate green investment in developing countries like Lebanon. Lebanon’s contribution to global GHG emissions is considered insignificant. For example, in 2000, CO2 emissions in the UK reached 553,046,000 tonnes compared to Lebanon’s 18,507,000 tonnes (UNFCCC); the per-capita contribution to CO2 emissions in Lebanon is significantly lower than in the UK (4.6 tonnes of CO2 per capita per year in Lebanon versus 8.9 tonnes CO2/capita/year in the UK) [State and Trends of the Lebanese Environment, 2010].

Turkey, Saudi Arabia, and Iran from the MENA region ranked among the top 10 non-ITF (International Transport Forum) CO2 emitting countries. Data on their CO2 emissions in millions of Tonnes (Mt) from aviation between 1990 and 2007 to UNFCCC are shown in Table 2 (ITF, 2010). It is worth noting that Saudi Arabia witnessed a reduction in CO2 emissions from international aviation during this period while emissions in Turkey have increased five folds during the same period.

The regulation of CO2 emissions arising from international aviation raises three main issues: a) the difficulty of producing adequate and consistent emission inventories, b) the difficulty of allocating emissions to countries, and c) the difficulty in devising suitable policy measures to control emissions. The four basic allocation options identified by UNFCCC that have been explored are: a) no allocation to national inventories, b) allocation according to the
county where the fuel is sold, c) allocation according to the nationality of the airline/aircraft operator or aircraft registration, and d) allocation according to the country of departure or destination of the aircraft (Yamin and Depledge 2004).

Hence, in relation to the issue of climate change, international aviation currently remains exempted from any fixed limits or caps of its greenhouse gas emissions under the Kyoto Protocol. As a result, limited progress has been made in managing the greenhouse gas emissions of the sector since the Kyoto Protocol was signed. Discussions are ongoing to determine the potential for aviation to be subject to emissions limits in an international post-2012 climate agreement.

Under the Kyoto Protocol, the use of tradable permits within emissions trading schemes is evolving as an important element of international climate policy and is discussed in the following section. The largest scheme in the world is the EU Emissions Trading Scheme (ETS), currently in its third trading period covering the period from January 2013 to December 2020. Emissions trading schemes represent one preferred route by which international aviation CO2 emissions could be brought under the Kyoto Protocol.

The European Union Emissions Trading System (EU ETS)

The EU ETS is a market-based policy instrument that works on the «cap and trade» principle. Like other tradable permit schemes, it operates on a simple principle: a) a total level of pollution is defined for a specific region, b) permits totaling that level are distributed amongst polluters in the region, and c) those permits are then traded, either amongst polluters or between the operational sites of individual polluters. The overall level of emissions for the industry is fixed (as with a regulatory standard), but, once the market is operating, the distribution of permits – and thus of emissions – is determined by the polluters trading in the market.

The overall volume of greenhouse gases that can be emitted by the power plants, factories and other fixed installations covered by the EU ETS is limited by a «cap» on the number of emission allowances. A separate cap applies to the aviation sector. Both caps are set at EU level. Within these Europe-wide caps, companies receive or buy emission allowances which they can trade as needed. They can also buy limited amounts of international credits from emission-saving projects around the world.

Aviation was not included in the first ETS trading period, however, in December 2006, the European Community adopted a proposal to include aviation within the EU ETS. That proposal aims to bring aviation into the trading scheme in two stages, commencing in 2011 with intra-EU flights (domestic and international flights between EU airports) and then expanding in 2012 to include all international flights arriving or departing from EU airports (CEC 2006). This scheme has been suspended for one year, pending the possibility of having a global system for these emissions established.

The aviation sector cap in the European Economic Area has been provisionally set at 210,349,264 aviation allowances per year for the 2013-2020 trading period, which is 5% below the average annual level of aviation emissions in the 2004-2006 calculated at 221,420,279 tonnes. Free aviation allowances were allocated to more than 900 aircraft operators who applied for free allocation by reporting their verified tonne-kilometre data for 2010 («tonne-kilometre» means a tonne of payload carried a distance of one kilometre where “payload” includes the total mass of freight, mail, passengers and baggage carried onboard the aircraft during a flight). A total of 82% of the allowances were granted for free to aircraft operators and 15% were auctioned. The balance of 3% is held in a special reserve for later distribution to fast growing aircraft operators and new entrants in the market.

In the United Kingdom, the government set a new target for CO2 emissions from UK aviation in 2009, which requires them to be no higher than 2005 levels in 2050. This target incorporates emissions from both domestic and international aviation (DoT, 2009).

The free allocation is calculated on the basis of benchmark values established in European Commission and EEA Joint Committee decisions taken in 2011. The benchmark was calculated by dividing the total annual amount of free allowances available by the sum of tonne-kilometre data included in applications by aircraft operators submitted to the Commission. The submissions by aircraft operators were based on independently verified tonne-kilometre activity data recorded throughout the 2010 calendar year. In phase three, an airline receives 0.6422 allowances per 1,000 tonne-kilometres flown.

Each aircraft operator is administered by a single
Member State. Aircraft operators based in the European Economic Area (EEA) are administered by the Member State that issued their operating license. In all other cases, the operator is administered by the state with the greatest estimated attributed aviation emissions from that operator in the base year. The allocation of free allowances to each aircraft operator is carried out by Member States. Allocations are calculated by multiplying the benchmark by the verified 2010 tonne-kilometre data of each eligible aircraft operators who applied. In the case of MEA which submitted its fleet list consistent with EU-ETS requirements, France serves as its administering Member State.

A range of logistical issues remains to be resolved for aviation emissions trading schemes, particularly in relation to trade rights, the initial allocation of permits, the avoidance of 'windfall' benefits due to the over-allocation of permits, the coverage of the scheme, and the possible use of a factor to account for the non-CO2 climate effects of aviation (Daley 2010).

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<td>SAUDI ARABIA</td>
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<tr>
<td>IEA CO2 from transport fuel combustion (Mt) *</td>
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<td>65.05</td>
<td>72.38</td>
<td>86.55</td>
<td>104.28</td>
<td>71%</td>
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<td>30.10%</td>
<td>27.50%</td>
<td>25.90%</td>
<td>28.00%</td>
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<tr>
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<td>2.05</td>
<td>1.9</td>
<td>1.91</td>
<td>1.74</td>
<td>1.88</td>
<td>-8%</td>
<td>-0.51%</td>
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<tr>
<td>International Aviation (Mt)</td>
<td>6.14</td>
<td>5.71</td>
<td>5.72</td>
<td>5.22</td>
<td>5.64</td>
<td>-8%</td>
<td>-0.50%</td>
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<td>ISLAMIC REPUBLIC OF IRAN</td>
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<tr>
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<td>41.79</td>
<td>59.36</td>
<td>76.51</td>
<td>105.45</td>
<td>109.71</td>
<td>163%</td>
<td>5.84%</td>
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<td>116%</td>
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<tr>
<td>IEA CO2 from transport fuel combustion (Mt) *</td>
<td>28.66</td>
<td>36.49</td>
<td>37.59</td>
<td>43.71</td>
<td>54.02</td>
<td>88%</td>
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<td>Transport* as a percentage of total</td>
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<td>0.78</td>
<td>1.54</td>
<td>3.21</td>
<td>3.42</td>
<td>545%</td>
<td>11.59%</td>
</tr>
</tbody>
</table>

* includes emissions from international aviation and international maritime bunkers - there is no internationally agreed allocation mechanism for these and totals are indicative of the scale of these emissions, not of their national “ownership”.
** available years

### Current trends towards sustainable aviation

Sustainable aviation depends not only on the introduction of effective policy measures but also on the achievement of major technological and operational improvements in the environmental performance of aircraft to reduce aviation environmental impacts.

In general, technological responses to the challenge of reducing the environmental impacts of air transport have focused on achieving improvements in engine and airframe design and performance, and on developing alternative aviation fuels (Thomas and Raper 2000) while operational improvements have focused on the development of more efficient Air Traffic Management and the use of noise abatement procedures.

### New Technology in Fuel, Engine and Airframe

Improvements in engine design and performance focused on maximizing the fuel efficiency of aircrafts, both by reducing the weight and drag of airframes and by maximizing the energy conversion efficiency of engines. At present, the most fuel-efficient aircraft engines are high-bypass, high-pressure-ratio gas turbine engines, and the prospects for developing viable alternatives remain elusive (Lee 2004).

One important consideration in this respect is that
aircraft engine design may be optimized for fuel efficiency to minimize CO2 emissions but this improvement comes at the expense of increased NO production (IPCCC 1999). Indeed, while CO2 and H2O emissions increase in direct proportion to fuel consumption and their emission factors are constant, NOx is produced more abundantly at high power settings for a fixed quantity of fuel burned, and its emission factor increases with a range of other variables, like the ambient temperature, pressure and humidity, the aircraft forward speed, and the extent of engine and airframe deterioration (Curran 2006). Studies have shown that efforts to improve the fuel efficiency of aircraft engines have prompted the use of greater engine pressure ratios, which in turn have led to higher temperatures and pressures in the combustors, and thus to increased NO production (Rogers et al. 2002). Aircraft NOx emissions have been forecast to increase by a factor of approximately 1.6 over the period 2002–2025 which prompted policymakers to call for simultaneous reductions in aircraft NO emissions and fuel efficiency improvements (Lee 2004, ACARE 2004). The drive to limit NOx emissions now focuses on the development of new combustor technologies.

Improvements in airframe performance is sought through improved aerodynamic designs, innovation in control and handling systems, the development of radical aircraft designs such as the blended-wing body, and the use of advanced materials such as the use of engine turbine blade made of carbon ceramic material that is four times lighter than the metal equivalent part and withstands temperatures higher than the melting point of the special turbine metal alloys. This technology effort that started in the 1980’s is expected to reach the market around 2020 and is expected to bring about 3% reduction in fuel burn.

In parallel, technological improvements have focused on researching alternative aviation fuels. This effort led to the development of low sulphur fuels, which have reduced emissions of sulphur oxides (SOx). Recent research has also investigated the potential for biofuels or hydrogen to supplement or replace fossil jet fuel. The options to deploy cost-effective biojet fuels on a global scale, however, are limited by several factors such as technical constraints, significantly higher production costs, price and competing uses for feedstock which represents 50 to 90% of biojet fuel price, limited availability of residues and waste as feedstock, limited production capacity, and the lack of policy incentives to bring the cost of biojet fuel closer to the cost of fossil jet fuel.

All in all technological improvements – both those relating to aircraft design and performance and to aviation fuels – improved aircraft fuel efficiency, measured as fuel efficiency per passenger-kilometre, by around 70% since 1960. Overall, however, technological improvements require substantial investment and are likely to yield benefits only in the long term.

**Operational improvements undertaken by civil aviation worldwide to comply with EU climate policy for combating climate change and the Kyoto protocol**

Operational improvements in the environmental performance of aircraft are based on the principle of maximizing fuel efficiency by a variety of means: reducing aircraft weight, increasing load factors, ensuring high levels of aircraft maintenance, minimizing route distances, optimizing cruising speeds and levels, and maneuvering aircraft more efficiently (IPCC 1999).

Increasing the load factor of a flight can be achieved by eliminating non-essential weight and by maximizing the payload (IPCC 1999). In this way, maximum utility can be obtained for a given level of environmental impact. Efficient loading of aircraft can be increased by avoiding tankering – the practice of enplaning more fuel than a particular flight requires so that it can be used for subsequent flights. Carrying surplus fuel occurs for commercial or operational reasons. The commercial reasons are due to the fact that substantially higher fuel costs at the destination airport which offset the cost of the increased fuel burn (Zouein et. al 2002) and for operational reasons such as the desire to minimize turnaround time, to make an allocated runway slot, or to avoid refuelling in places where fuel availability or quality is not assured. The effect of tankering however, is to increase aircraft mass and thus fuel consumption and emissions. British Airways estimated that additional fuel burn due to tankering is around 0.5 per cent of total aircraft fuel consumption, although this depends on the aircraft type, on the flight distance, and on how many tankering flights are flown in sequence.

Accelerating the rate of fleet renewal and carrying more frequent aircraft maintenance (especially engine maintenance) is another measure recommended by IPCC (1999) that could reduce environmental impacts since it helps ensuring that fuel efficiency is maximized throughout the service
Environmental impacts may also be reduced through the use of revised Air Traffic Management (ATM) procedures such as reduced cruising speeds, flight level optimization for emissions reduction, arrival management (AMAN) and departure management (DMAN) systems, continuous descent approaches (CDAs) and ‘low-power, lowdrag’ (LP/LD) approaches, which may reduce aircraft emissions and noise levels in the vicinity of airports, and expedited climb departure procedures which could allow aircraft to climb rapidly to their optimal cruising levels (Dobie and Eran-Tasker 2001; ICAO 2004). The use of hub-bypass route planning and the use of fixed electrical ground power (FEGP) in preference to auxiliary power units (APUs) may also help reduce environmental impacts (Morrell and Lu 2006).

The effects of relatively simple changes in operational practices have been investigated in the EC TRADEOFF project. For example, the complex effects of flying at higher or lower altitudes on contrail formation, on CO2 and NOx emissions, and on ozone enhancement, have been estimated by various authors (Upham et al. 2003). Flying at lower speeds also offers a potential means of achieving emissions reductions, although this involves compromising journey times and customer service levels. Eliminating periods of holding, a feature of congested airspace in which aircraft are directed into holding patterns (‘stacks’) during approach until a landing slot becomes available. Holding is usually a temporary effect affecting only the busiest airports at certain times of the day; nevertheless, British Airways reported that the additional fuel burned during holding around three major UK airports over a one-year period from 2000–2001 amounted to 1.2 per cent of total fuel consumption by the airline (Eyers et al. 2004).

Another improvement of the ATM system was the reduction of the vertical separation of air traffic in European airspace and in the North Atlantic Flight Corridor (NAFC) from 2,000 feet to 1,000 feet. That innovation has increased the capacity of the airspace and, in principle, allowed aircraft to fly closer to their most fuel-efficient cruising levels. However, by increasing the vertical concentration of air traffic, the coverage of contrails may have increased as more aircraft are now likely to fly in contrail-forming conditions (Lee 2004).

Other operational improvement measures to reduce fuel consumption and specific emissions involved limiting the number of pieces passengers can carry on board of the plane for free. Making passengers who want to carry more than one piece over long hauls, pay extra, forces passengers to think twice before carrying an extra piece and pack lightly. Passengers on some domestic flights in the United States for example have to pay for pieces that go in suite; only carry-on are free of charge (Upham et al. 2003).

Despite the various ways in which operational procedures have been or could be revised, their potential to reduce the environmental impacts of aircraft is relatively modest and these kinds of operational measures will not offset the impact of the forecast growth in air travel. If the environmental impacts of air transport are not sufficiently mitigated by those measures and by new aircraft and fuel technology – and if environmentalist concerns continue to deepen – then policymakers will face intense pressure to curb the growth of the air transport industry.

A Survey of Green Initiatives Undertaken by MEA

MEA is the national air carrier of Lebanon. It employs around 1,900 employees and flies to 21 countries serving a total of 30 different airports with 62 departures daily (data based on SRS Analyser™ database on 31 December 2013). It has a fleet consisting mainly of A320s and A330s that stands at 18 aircrafts operating at 60% capacity according to the following figures on Available Seat Kilometres (ASK), Available Tonnes Kilometres (ATK) and Total Revenue Passenger-Kilometres (RPK).

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<td><strong>Traffic</strong></td>
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<tr>
<td>Total RPK (mil)</td>
<td>3,865</td>
<td>3,952</td>
<td>2.2%</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td></td>
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<tr>
<td>Total ASK (mil)</td>
<td>5,944</td>
<td>5,794</td>
<td>-0.8%</td>
</tr>
<tr>
<td>Total ATK (mil)</td>
<td>821</td>
<td>812</td>
<td>-1.0%</td>
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MEA has witnessed on average a 4% growth in tonne-kilometres moved, but has maintained roughly the same rate of emissions per tonne-kilometres as conveyed by the data shown in Table 3 for the past 4 years. The table shows for each year, reported figures on 1) Tonne-Kilometre flown (one «tonne-kilometre» is a tonne of payload carried a distance of one kilometer), 2) total fuel consumed, and 3) estimated CO2 emissions based on a factor of 3.15 as recommended by EU regulations.
It is worth noting that there is no domestic aviation in Lebanon which limits MEA and aviation environmental impacts mainly to the area in the vicinity of the single international airport in Beirut (Rafic Hariri International Airport) and to global atmospheric emissions. Furthermore, the layout of the airport's runways are such that aircraft are oriented away from land, with all takeoffs and landings occurring over water, which serves to mitigate local environmental impacts on nearby residences such as noise and soot particle deposits.

The environmental affairs unit at MEA was established in 2009. In 2010, the unit ran an organization-wide awareness campaign which was known then as the Tonne-Kilometre movement to heighten the level of awareness about global regulations regarding monitoring and reporting of GHG emissions and the initiatives undertaken by civil aviation worldwide to cut down on their emissions in compliance with these regulations. The unit used workshops and focus group meetings involving pilots and head of units in the commercial and operations department of MEA to make them aware of the need of introducing operational improvements to prepare the ground for compliance with emerging international regulations, namely the reporting of yearly data on Tonne-Kilometres and CO2 emissions to the Direction générale de l’aviation civile (DGAC) the authority designated by the administering member state, France in compliance with Directive 2009/28/EC and EU Commission Regulation No 601/2012 (Article 66 of OJ L 275, 25.10.2003, Article 67 of OJ L 140, 5.6.2009).

Operational improvements towards maximizing fuel efficiency already attempted at MEA were two folds: one that focused mainly on minimizing takeoff weight by minimizing the unusable fuel carried and the fuel consumed during flight and the second by renewing their fleet and self-mandating frequent aircraft maintenance. For the purpose of minimizing fuel consumption during flight, MEA monitors and keeps records of flight plans for each flight including cruising speed and levels, descent and takeoff approaches, maneuvering of the aircraft, and the amount of additional fuel requested by pilots. These flight plans are monitored for compliance with best practices and optimized ATM procedures for emissions reduction. Consistent deviations from standard procedures are followed up on for corrective action in particular when additional fuel is consistently requested by a pilot or when the flying style of a pilot consistently deviates from ATM procedures and flight plan.

For the purpose of minimizing takeoff weight by minimizing the unusable fuel carried, efforts were deployed to ensure that all concerned departments in the company provide timely and accurate estimates of the mass of freight, mail, passengers and baggage carried onboard of the flight few hours before scheduled flight departure. Accurate estimates of payload are essential for optimizing the amount of fuel uplifted. It is worth noting that MEA was commended for being 100% compliant for accuracy and completeness in emissions reporting at a recent meeting of the Arab Air Carrier Organization (AACO), according to MEA’s own environmental affairs manager Captain Said El-Hage. MEA is represented on the environmental policy team of AACO which is a Regional Association of Arab Airlines whose role,

<table>
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<tr>
<th>Reporting year</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
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</thead>
<tbody>
<tr>
<td>Revenue Tonne-kilometres</td>
<td>429,693</td>
<td>453,305</td>
<td>463,312</td>
<td>470,641</td>
</tr>
<tr>
<td>Total fuel consumed (Tonnes Reported)</td>
<td>176,509.26</td>
<td>183,966.95</td>
<td>184,624.78</td>
<td>185,854.10</td>
</tr>
<tr>
<td>Total CO2 emissions (Tonnes Estimated)</td>
<td>556,004</td>
<td>579,496</td>
<td>581,568</td>
<td>585,440</td>
</tr>
</tbody>
</table>

Table 3. MEA Tonne-Kilometres and CO2 emissions over the past 4 years

This effort has further evolved into one of compliance with emerging international regulations, namely the reporting of yearly data on Tonne-Kilometres and CO2 emissions to the Direction générale de l’aviation civile (DGAC) the authority designated by the administering member state, France in compliance with Directive 2009/28/EC and EU Commission Regulation No 601/2012 (Article 66 of OJ L 275, 25.10.2003, Article 67 of OJ L 140, 5.6.2009).
among others, is to transfer “the industry’s best practices and up-to-date products” to its member airlines.

The second operational improvement was in renewing its fleet of aircraft leading to reduced emissions. In fact MEA acquired a total of 11 new A320 and 4 new A330 and phased out 3 old A330 and 4 old A321 aircraft over the last 5 years. And in terms of future plans, another noteworthy achievement by MEA on the path of sustainable aviation came in January 2013 when the Lebanese Ministry of Environment (MOE), in cooperation with the United Nations Development Program (UNDP), awarded MEA the “National Green Award” for its green corporate growth strategy. Specifically, the award recognized MEA’s planned acquisition of 10 new fuel-efficient aircraft (5 A320neo and 5 A321neo) expected to enter into service in 2017 with a potential of up to 15% in fuel savings over 2013 consumption, leading to a reduction of CO2 emissions of an estimated 87,816 tonnes of CO2 per year.

**Climate policy for civil aviation in Lebanon**

The Lebanese Directorate General of Civil Aviation (DGCA) is responsible for supervising the air transportation sector and for promulgating and implementing laws concerning aircraft operation. The DGCA was established through Decree 1610 of 26 July 1971 to manage the aviation sector in Lebanon under the jurisdiction of the Ministry of Public Works and Transport (MPWT).

One of the DGCA’s principal responsibilities is for the management of the Beirut Rafic Hariri International Airport (RHIA). The DGCA has invested heavily in airport infrastructure at RHIA and has adopted modern technologies and procedures to automate its passenger processing operations.

A draft law has long been passed authorizing the creation of a Civil Aviation Authority (CAA) to replace the DGCA (Law number 481 dated 2002) as a public organization with administrative and financial autonomy. The objective of creating the CAA is to develop the sector of civil aviation through a restructuring of the administrative, supervisory and control bodies governing the sector, the organization of the aviation community and the encouragement of investment in the industry and related sectors. However, this law has yet to be implemented by the government due to chronic political infighting which has crippled the enactment of new laws and frozen the appointment of civil servants in top government positions.

A direct consequence of this political struggle is the lack of active legislation in the aviation industry in general and in the environmental sector in particular, with the only prominent examples being the MPWT’s Article 51 titled “Environmental Protection” under the Civil Aviation Reform Law Act No. 663 titled “Civil Aviation Safety” and dated 10 February 2005 which states:

“No aircraft should fly over Lebanon unless it is subject to the provisions of the regulations issued by the Civil Aviation Administration and related to noise, engine smoke, gaseous emission, fuel ventilation and other issues related to environmental protection from aircraft operation.”

While no provisions were further developed to enforce this article, the Act No. 663 still ensures compliance of all aircraft operating in Lebanon with international regulations through its Article 9 titled “Implementation of the provisions of international conventions in current effect in Lebanon” which states:

“…the provisions of effective international conventions in Lebanon shall be applicable to aircraft […]”

This approach is evidence that the primary role of the civil aviation authority in Lebanon today is one of compliance with international laws rather than active development of national aviation legislation and strategies.

These high-level legislative efforts by the MPWT are matched by a similar level of legislation by the Ministry of Environment (MOE) which can be largely summarized by the Environmental Protection Act (law no. 444), which set only basic principles and general provisions to regulate environmental protection, without being specific about standards and provisions for different sectors and industries, including the aviation industry. The MOE prepared in 2005 another draft law on the protection of air quality (The Clean Air Legislation) that covers the specifics and mechanisms for environmental protection in 34 articles related to ambient air pollution (including fixed and mobile sources), monitoring air pollutants (through a series of mechanisms including a national program for ambient air quality monitoring, a national network for ambient air quality monitoring, a national emissions inventory, and a national report on the ambient air quality), assessment of their levels in the Lebanese atmosphere (setting standards and
thresholds of ambient air pollutants including CO, NOx, O3, Particulate Matter, SOx, NMVOC and Lead, emission standards for fixed and mobile sources, specifications of harmful material in fuel, among others), and the prevention, control and surveillance of the ambient air pollution resulting from human activities. However, this law still awaits formal approval by the Lebanese Parliament.

Another way the local civil aviation authorities attempt to control aviation for safety and environmental impact is through the aircraft registration process. According to Mr. Ali E-Chaar, coordinator in Aviation Environment Affairs at the DGCA, no aircraft can be registered in Lebanon if it is more than 15 years old. This ensures that the fleet of aircraft with Lebanese registration is equipped with the latest environmentally-compliant engine technology, and that both the engines and the mainframe of Lebanese aircraft are in relatively new condition that they would still be operating at peak performance, thus maintaining their ratings of reduced emission levels.

On the regional level, the only noted legislative efforts have been through the Committee for the Environment of the Arab Civil Aviation Commission (ACAC), an arm of the Arab League, where Lebanon’s DGCA has played a key role in the development of a unified environmental strategy.

**Gap analysis and recommendations**

At the MENA region level, there is a concerted effort, in particular by the ACAC to transfer technology to the civil aviation community in the Arab world as well as to adopt and enforce ICAO standards and regulations and initiatives to reduce emissions and noise.

At the national level, the national air carrier, MEA, showed openness and receptiveness in adopting new technology in aircraft and new aviation fuels as they become well established and proven efficient globally. At the operational level, every effort is being deployed to create an awareness and to monitor and control the unusable fuel carried and to encourage best practices and compliance with optimized ATM procedures leading to reduced emissions.

What is lacking however, both at the national and the regional levels, is an enabled legislative body to regulate environmental impacts from aviation in a way that best serves the needs of these countries. Strategies and policies developed so far are still at an embryonic stage. This follows the fact that emissions from aviation have only recently been included in the international treaties on climate change and caps on emissions are binding for Annex I parties only. In fact, only Annex I Parties to the Kyoto protocol are mandated to report their CO2 emissions from international aviation fuels in their annual national inventories, while Non-Annex I Parties, Lebanon being one of them, “should” report international aviation emissions “to the extent possible, and if disaggregated data are available”.

Aside the regulatory venues other voluntary-based initiatives need to be investigated. Current voluntary measures relative to aviation and climate policy focus on the use of carbon offsetting, commitments to achieve “carbon neutrality” and the adoption of a range of broader corporate responsibility initiatives – including “eco-labelling” initiatives. For example, in 2006, an estimated 1.5 million people in the UK paid to offset the emissions of a flight (New Scientist, 24 February 2007). Another example is in December 2007 when the UN committed to pay $100,000 to offset the CO2 generated by its delegates attending the climate summit in Indonesia (New Scientist, 12 December 2007). Many issues though are associated with carbon offsetting and these are mainly related to the measurement of emissions and to the permanence and credibility of offsets. As a small airline in a developing country, MEA is a cautious follower of international trends, rather than being a trend setter reflecting the local culture and that of the bulk of its passenger.

How to best mitigate aviation environmental impacts requires concerted action at national and international levels. Proposals to cap aviation emissions, to impose taxes and emissions charges, to introduce or remove subsidies, to issue tradable permits for aviation emissions or to encourage the use of voluntary agreements, have been widely debated and contested (Bishop and Grayling 2003, IPCC 1999, Upham et al. 2003). In general, however, regulatory approaches face the problem that air transport is an international industry that spans national jurisdictions, and that nations vary in their capacity to monitor and enforce environmental standards. Voluntary approaches on the other hand face the criticism that they are too weak to catalyze the profound behavioral change that is required to align air transport with the principles of sustainable development. The varying effectiveness, geographical applicability, complexity, and political acceptability of the different policy instruments means that no single instrument appears to be ideal, and the use of a
combination of regulatory, market-based and voluntary approaches will probably be required in future aviation environmental policy (Daley 2010).

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