**Fuel Economy and CO2 Emissions of Light-Duty Vehicles in Bahrain**

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## Introduction

The transport sector is responsible for 27 % of the world energy consumption (IEA, 2012a). This proportion has increased from 23% in 1973 (IEA, 2011) and contributes to 22 % of total CO2 emissions (IEA, 2012b).

Many countries worldwide have fuel economy or CO2 emissions standards in place to improve vehicle efficiency. A number of initiatives around the world are also introduced to help countries with regard to fuel economy standards, data availability and calculation methodologies. The Global Fuel Economy Initiative (GFEI) – for example - comes as an effort of five organizations[[1]](#footnote-1) to promote improvements in vehicle fuel economy. This initiative aims to achieve 50 % improvements by 2050 in all vehicles globally compared to that in the year 2005. The initiative’s main activities include: data development and analysis, policy support, and awareness raising (GFEI, 2013a).

In Bahrain, as in most other countries, road transport sector is one of the highest energy consuming sectors. It consumes around 22 % of its total energy (IEA, 2012a) and is responsible for a significant share of the CO2 emissions. According to Bahrain’s Second Communication to the United Nations Framework Convention on Climate Change (UNFCCC), the CO2 emissions from transport sector has been increasing over the period 2000 - 2010 by 5.5 % in average (PMEW, 2012). This is due to the rapid increase in the number of the passenger vehicles (7.3 % per year on average) (General Directorate of Traffic, 2012) which resulted in an accelerated rise in fuel consumption (5.7 % per year on average) (CIO, 2012) in addition to the increase in the carbon emissions. Fuel consumption and CO2 emissions of passenger vehicles in Bahrain are projected to double in the year 2030 compared to 2010 (Alsabbagh et al., 2013).

Sustainability and energy efficiency issues receive considerable attention from policymakers in Bahrain. These issues are stated in the National Environment Strategy, the Economic Vision 2030, and the Second Communication Report to the UNFCCC. However, no specific targets or action plans have been developed yet. There is no car manufacturing industry in the country, and Bahrain still has not introduced any CO2 emissions or fuel economy standards yet.

Fuel economy and CO2 emissions are recognized as missing indicators for vehicles in Bahrain (Alsabbagh et al., 2013). Hence, this paper aims to achieve three main objectives: firstly, it supplies information on two important indicators, namely average fuel economy and CO2 emissions of new Light Duty Vehicles (LDVs) in Bahrain in 2005, 2008, 2010 and 2012. Secondly, it analyzes the fuel economy trends of new LDVs. Thirdly, this study conducts comparisons between fuel economy of new LDVs in Bahrain and that of other countries.

This report consists of five sections. Section 2 of the report sheds light on transport sector in Bahrain, while the methodology is explained briefly in the subsequent section. The study results and discussion are presented in section 4 and finally, section 5 states the main conclusions along with some recommendations.

## Transport Sector in Bahrain

Since 2000, the total vehicle number in Bahrain has grown dramatically to reach 501,481 vehicles in 2012 with an average annual growth rate of 7.3 % (General Directorate of Traffic, 2012). This is a result of the rapidly increasing population (average annual growth rate of 7.1 %) (CIO, 2011; CIO, 2012) and Gross Domestic Product (GDP) (average annual growth rate of 6%) (MOF, 2011) between 2000 and 2010. Figure 1 provides a significant, positive and very strong correlation[[2]](#footnote-2) between the passenger vehicle number, the population size (R2=0.99) and the real GDP (R2=0.94) in Bahrain during the period between 2000 and 2010.

**2000**

**2010**

**Figure 1: Passenger vehicle number vs. population size and real GDP in Bahrain between 2000 and 2010**

Source: CIO, 2011; CIO, 2012; MOF, 2011

Despite the upward trend in vehicle ownership (366 vehicles per 1000 population in 2010), this is relatively low when comparing this statistic to that in countries worldwide (e.g. Australia 688, UK 523, USA 802 vehicles per 1000 population). However, this trend in Bahrain is higher than that of some neighboring countries (e.g. Saudi Arabia 192, and Oman 215 vehicles per 1000 population) (IRF, 2011).

Vehicles in Bahrain rely heavily on gasoline. In 2010, more than 93% of the total vehicles have gasoline engines whilst the remaining percentage uses diesel. Therefore, gasoline usage has experienced an increase in local consumption with an average annual growth rate of 5.7% during the last decade (Figure 2). This increase was a result of the dramatic increase in the number of passenger vehicles, as shown in Figure 3 (CIO, 2012).

Figure 2: Gasoline consumption in Bahrain between 2000 and 2010 (TJ)

Source: BAPCO, 2010

Figure 3: Total number of registered vehicles in Bahrain between 2000 and 2012

Source: General Directorate of Traffic, 2012

The nearly complete reliance on gasoline has resulted in an average annual increase of 5.5 % in CO2 emissions between 2000 and 2010 (Figure 4) (PMEW, 2012; own calculations). Despite the relatively low share of the carbon emissions from transport sector at 6.8% of the country’s total emissions in 2000 (PMEW, 2012), this rate has been gradually increasing since 1994. Therefore, this emissions rate is one of a high priority to be controlled and managed.

Figure 4: Carbon emissions from transport sector in Bahrain between 2000 and 2010

Source: PMEW, 2012; own calculations.

## Methods

Methodology suggested by the Global Fuel Economy Initiative (no date) to construct a baseline that tracks trends in the fuel economy and CO2 emissions of new light-duty vehicles (LDVs) is used to carry out this study. LDVs include mini, small, compact, family and big cars in addition to light vans and sport utility vehicles (SUVs) (Annex 1).

 The new LDVs data are compiled from the General Directorate of Traffic – Ministry of Interior for the years 2005, 2008, 2010 and 2012. A sample of the data set is presented in Annex 2. The data set includes the following vehicle characteristics:

* Vehicle make and model
* Model production year
* Year of first registration
* Fuel type
* Engine size (in cubic meters – cc)
* Curb weight (in kilograms – kg)
* Number of cylinders
* Body type
* Registration plate type / use of the vehicle

A number of tasks involved with data processing and management were undertaken. Details on the sources contacted and data cleaning are available in Annex 1. It is worth noting in this context that more than 50 % of accurate emission factors and fuel economy was achieved.

Details are available in Annex 1.

## Results and Discussion

The fuel economy of new LDVs in Bahrain has improved in 2012 by 1 liter per 100 km compared to the year 2005. However, the detailed figures indicate a slight decrease in the fuel economy numbers in 2008 and 2010 matching a similar trend in non – OECD countries[[3]](#footnote-3) (GFEI, 2013b).

Figure 5: Average fuel economy (L/100km) and CO2 emissions (g/km) for new LDVs in Bahrain

When compared to the fuel economy trend of new vehicles in the USA[[4]](#footnote-4), the gap widens over time in favor of the USA as shown in Figure 6. The US fuel economy standards are set at 7.2 l/100 km for passenger vehicles manufactured in the year 2012, and at 9.3 l/100km for light trucks manufactured in the same year (RITA, 2013). These standards ensure improvements in the vehicle fuel economy unlike the case of Bahrain. The fuel economy figures for Bahrain are also higher than that of the Organization for Economic Co-operation and Development (OECD) countries, and non-OECD countries (Figure 7).

Figure 6: A comparison between the average fuel economy of new LDVs registered in Bahrain and USA in 2005, 2008, 2010 and 2012 (L/100 km, CAFE)

Source: RITA, 2013

Figure 7: : A comparison between the average fuel economy of new LDVs registered in Bahrain, OECD, and non-OECD countries in 2005, 2008, 2010 and 2012 (L/100 km, NEDC)

Source: GFEI, 2013b

The study also reveals that the average CO2 emissions for new LDVs in Bahrain has decreased by 7% in 2012 compared to 2005 (Figure 5). However, a slight increase in the emissions has again occurred in 2005 and 2008.

Figure 8 shows that apparent variations exist between the EU figures and Bahrain’s calculated numbers. The calculated numbers for Bahrain are considerably higher than that of the EU (EEA, 2013). This could be a result of number of factors that affect the engine size and performance including dissimilar weather, consumption patterns, alternative modes of transportation, and CO2 emissions standards.

Figure 8: A comparison between the average CO2 emissions from new models of passenger vehicles in the EU and Bahrain in 2005, 2008, 2010 and 2012 (g CO2/km)

Source: EEA, 2013

The study results show that the number of new vehicles in Bahrain has grown by 19.8 % in 2012 compared to 2005 with LDVs making 82 % in average (Figure 9). New LDVs in Bahrain rely heavily on gasoline as it makes more than 99 % of the total number, while the remaining share uses diesel.

Figure 9: Total new LDVs and other types in Bahrain in 2005, 2008, 2010 and 2012

The average curb weight of new LDVs has increased over the study period reaching 1718 kg in 2012 compared to 1685 kg in 2005 (Figure 10). These figures indicate that the new LDVs in Bahrain are growing in weight as predicted by Alnaser (1995) and Eltony (1996) and evidenced by Alsabbagh et al. (2013).

Figure 10: Average curb weight and engine size of new LDVs in Bahrain in 2005, 2008, 2010 and 2012

The majority of new LDVs in Bahrain are first registered at the vehicle year of manufacture (Figure 11). A considerable number of LDVs is registered a year before that, while only a small fraction is registered after the vehicle year of manufacture. One implication that can be drawn is that most LDVs in Bahrain are new imported vehicles.

Figure 11: Number of new LDVs per year of first registration

## Conclusions

This study aims to provide a clear picture of the fuel economy and CO2 emissions trends of LDVs in Bahrain. Having a clear understanding of these indicators is crucial to informing effective policies. Analysis shows an improvement in vehicle fuel economy in 2012 compared to the base year 2005. However, an increasing trend towards buying large vehicles can be observed. This implies that the increase in the vehicle weight has offset the potential of significant savings gained from the wide distribution of small and more efficient vehicles.

Although this could be a common problem that may possibly be found in other countries, it is of special importance to Bahrain. There are no restrictions in Bahrain on new vehicles with respect to fuel economy or CO2 emissions. Furthermore, environmental labeling, emission reduction targets and action plans are yet to be developed for the country. Hence, this denotes abundant objectives for focusing policy framing and research to encourage the use of more efficient vehicles and the introduction fuel economy standards.

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## Annex 1: Methodology

## Obtain vehicle registration data:

* The data are compiled from the General Directorate of Traffic –Ministry of Interior.
* The collected data for Bahrain are extracted from the on-road registered vehicles in 2013 data set. The new LDVs data could not be obtained directly due to IT system change in the General Directorate of Traffic.
* The collected data contains the following information and specifications:
	+ Year of manufacture
	+ First registration date
	+ Vehicle make code and name
	+ Vehicle model code and name
	+ Engine capacity (cc)
	+ Weight (kg)
	+ Fuel type
	+ Vehicle type code and name
	+ Plate type code and name
	+ Number of axles
	+ Number of cylinders
* The database does not indicate whether the vehicle is imported as a new or used vehicle. However, estimates can be obtained from the comparison between the year of manufacture and the first registration year. If the car is registered three years or more after the year of manufacture, it can be assumed that it was imported as a used vehicle.

## Cleaning data:

* Vehicles not classified as LDVs are removed. Types of vehicles classified as LDVs are presented at Table 1 (GFEI, no date).

Table 1: Types of LDVs

|  |  |
| --- | --- |
| Vehicle Segment | Examples |
| A: Mini / Micro / Small town car*Smallest cars, with a length between 2.50m to 3.60m.* | Citroën C1 Fiat PandaSmart Fortwo |
| B: Small compact*Slightly more powerful than the Minis; still primarily for urban use; length between 3.60m and 4.05m* | Mitsubishi Colt Opel Corsa Suzuki Swift |
| C: Compact*Length between 4.05m – 4.50m* | Mazda 3 Subaru ImprezaVolvo S40 |
| D: Family cars*Designed for longer distance; fits 5- 6 people; length is 4.50m to 4.80m* | BMW 3 series Chrysler Sebring Lexus IS |
| Light vans*Size is similar to D, but interior volume is maximized to accommodate larger families* | Chevrolet Uplander Ford GalaxyVolkswagen Sharan |
| Big / Full size cars*Have generous leg room; can comfortably transport 5 - 6 people; generally haveV8 engines and are 5m or longer in length* | Cadillac DTS Jaguar XJ Mercedes-Benz E Class |
| SUV / All terrain*The original cars were utility cross-country vehicles with integral transmissions like the Jeep* | Dodge Durango Jeep Grand Cherokee Nissan PatrolToyota Land Cruiser |

Source: GFEI, no date

* Correct data entry errors.

## Structure the data set:

* New LDVs data are extracted from the data set based on the year of manufacture (2005, 2008, 2010, 2012).
* Find fuel economy and CO2 emission factors for Bahraini LDVs. Data sources and contacts are briefed in Table 2.

Table 2: Data sources and contacts

|  |  |  |
| --- | --- | --- |
| Country | Source | Comments |
| USA | DoE / EPA Fuel Economy ratings[www.fueleconomy.gov/](http://www.fueleconomy.gov/)  | This website is used to obtain fuel economy and CO2 emissions data |
| China | [www.gzly.miit.gov.cn:8090/datainfo/miit/babs2.jsp](http://www.gzly.miit.gov.cn:8090/datainfo/miit/babs2.jsp)  | Couldn’t use and couldn’t use Google Translate |
| UK | Car Fuel Data Booklet<http://carfueldata.direct.gov.uk/search-new-or-used-cars.aspx>  | Different from Bahraini vehicle types |
| France | Consommationconventionnelles de carburant et émissions de gazcarboniquewww2.ademe.fr/servlet/getDoc?cid=96&m=3&id=52820&p1=00&p2=12&ref=17597  | Different from Bahraini vehicle types |
| Australia | Green Vehicle Guide Factsheets[www.greenvehicleguide.gov.au](http://www.greenvehicleguide.gov.au)  | No assessment yet, sent an email to ask for database and they replied after submitting the report. Nevertheless, they mention data duplication which means more time is required for cleaning the data. |
| Japan | JIDOSHA NENPI ICHIRAN (in Japanese)[www.mlit.go.jp/jidosha/jidosha\_mn10\_000001.html](http://www.mlit.go.jp/jidosha/jidosha_mn10_000001.html)  | Couldn’t use and couldn’t use Google Translate |
| Mexico | Indicadores de EficienciaEnergética y EmisionesVehiculares[www.ecovehiculos.gob.mx/](http://www.ecovehiculos.gob.mx/)  | Couldn’t use and couldn’t use Google Translate |
| South Africa | National Association of Automobile Manufacturers of South Africa<http://www.naamsa.co.za/ecelabels/>  | Doesn’t show the year of manufacture and when contacted, they sent emission factors for BMW only. |
| Swiss | Automobil Revue catalogue (not official this one, but good compilation of worldwide vehicle production[www.katalog.automobilrevue.ch/](http://www.katalog.automobilrevue.ch/)  | Different from Bahraini vehicle types |
|  | Major car manufacturers | Data for 2013 models only were received |
|  | The Next Green Car <http://www.nextgreencar.com/>Car Emissions <http://www.car-emissions.com/> CO2 Emissions Calculator <http://www.falconsolution.com/co2-emission/index.php?Year=0&Make=ACURA&Model=0&Distance=100&DrivenCase=2>  | Couldn’t use because of data reliability concerns |

## Estimate baseline fuel economy and CO2 emissions

* Vehicles data obtained for the fuel economy and CO2 emissions (called here reference data) are coded based on the vehicle model codes used in the Bahraini registration system. With regard to the fuel economy data, the reference data includes city MPG, highway MPG, and combined MPG. The last one is used for the calculations
* Four main elements of the Bahraini LDVs data set are utilized to obtain fuel economy and CO2 emissions for new LDVs, namely the vehicle make, model, year of manufacture, and the engine size.
* The percentage of Bahraini vehicles that match specifications of reference data has exceeded 50 % (Table 3). However, some of the data are removed in order to represent all categories. The removal process is based on the engine capacity to allow a satisfactory weight distribution of the sample and to well represent the entire population (Table 3).

Table 3: Total number of LDVs used for the calculations

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Year | LDVs | LDVs with calculated fuel economy | % | LDVs with calculated fuel economy (after data refinements) | % |
| 2005 | 25,019 | 11,015 | 44.0 | 7,853 | 31.4 |
| 2008 | 32,229 | 14,553 | 45.2 | 9,404 | 29.2 |
| 2010 | 20,479 | 9,256 | 45.2 | 4,018 | 19.6 |
| 2012 | 28,552 | 15,012 | 52.6 | 7,610 | 26.7 |

* Pivot tables are then created to calculate the weighted average fuel economy and CO2 emissions of new LDVs in Bahrain using the following equations (GFEI, no date):





* The fuel economy estimate is then converted from Corporate Average Fuel Economy (CAFE) to New European Driving Cycle (NEDC) using the Test Cycle Conversion Tool: <http://www.theicct.org/sites/default/files/info-tools/GlobalStdReview_Conversionfactor_May17_v1.xlsx> .

## Annex 2: Sample of the data

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## Annex 3: Tables

**Table 4: Passenger vehicle number vs. population size and real GDP in Bahrain between 2000 and 2010.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Year** | **Vehicles** | **Population** | **Real GDP** **(BD Million)** |
| 2000 | 216679 | 637,582 | 2996.9 |
| 2001 | 229780 | 661,317 | 2981.5 |
| 2002 | 250978 | 710,554 | 3192.6 |
| 2003 | 273230 | 764,519 | 3665 |
| 2004 | 293801 | 823,744 | 4224.5 |
| 2005 | 314033 | 888,824 | 5060.6 |
| 2006 | 337545 | 960,425 | 5960.3 |
| 2007 | 366732 | 1,039,297 | 6945.6 |
| 2008 | 399546 | 1,106,509 | 8328.8 |
| 2009 | 428957 | 1,178,415 | 7377.5 |
| 2010 | 452222 | 1,234,571 | 8245.6 |

Source: CIO, 2011; CIO, 2012; MOF, 2011

Table 5: Gasoline consumption in Bahrain between 2000 and 2010 (TJ)

|  |  |
| --- | --- |
| **Year** | **Gasoline consumption** |
| 2000 | 3014350 |
| 2001 | 3143120 |
| 2002 | 3429410 |
| 2003 | 3639380 |
| 2004 | 3837740 |
| 2005 | 3933800 |
| 2006 | 4232630 |
| 2007 | 4303160 |
| 2008 | 4681990 |
| 2009 | 4945000 |
| 2010 | 5157350 |

Source: BAPCO, 2010

Table 6: Total number of registered vehicles in Bahrain between 2000 and 2012

|  |  |
| --- | --- |
| **Year** | **Vehicles number** |
| 2000 | 216679 |
| 2001 | 229780 |
| 2002 | 250978 |
| 2003 | 273230 |
| 2004 | 293801 |
| 2005 | 314033 |
| 2006 | 337545 |
| 2007 | 366732 |
| 2008 | 399546 |
| 2009 | 428957 |
| 2010 | 452222 |
| 2011 | 475150 |
| 2012 | 501481 |

Source: General Directorate of Traffic, 2012

Table 7: Carbon emissions from transport sector in Bahrain between 2000 and 2010

|  |  |
| --- | --- |
| **Year** | CO2 emissions |
| 2000 | 1462.61 |
| 2001 | 1500.09 |
| 2002 | 1712.48 |
| 2003 | 1863.74 |
| 2004 | 2021.64 |
| 2005 | 2350.25 |
| 2006 | 2458.99 |
| 2007 | 2587.22 |
| 2008 | 2906.78 |
| 2009 | 2928.59 |
| 2010 | 2905.25 |

Source: PMEW, 2012; own calculations.

Table 8: Average fuel economy (L/100km) and CO2 emissions (g/km) for new LDVs in Bahrain

in 2005, 2008, 2010 and 2012

|  |  |  |  |
| --- | --- | --- | --- |
| Year | Average fuel economy (CAFE) | Average fuel economy (NEDC) | Average CO2 emissions (g/km) |
| 2005 | 10.5 | 12.1 | 247.1 |
| 2008 | 10.6 | 12.2 | 249.0 |
| 2010 | 10.7 | 12.2 | 251.0 |
| 2012 | 9.6 | 11.1 | 229.6 |

Table 9: A comparison between the average fuel economy of new LDVs registered in Bahrain, USA, OECD, and non-OECD countries in 2005, 2008, 2010 and 2012 (L/100 km, CAFE)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **2005** | **2008** | **2010** | **2012** |
| Bahrain | 10.5 | 10.6 | 10.7 | 9.6 |
| USA\* | 7.8 | 7.5 | 7 | 6.6 |

Source: \*RITA, 2013

Table 10: A comparison between the average fuel economy of new LDVs registered in Bahrain, OECD, and non-OECD countries in 2005, 2008, 2010 and 2012 (L/100 km, CAFE)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **2005** | **2008** | **2010** | **2012** |
| Bahrain | 12.1 | 12.2 | 12.2 | 11.1 |
| OECD\* | 8.1 | 7.6 |  |  |
| Non-OECD\* | 7.5 | 7.6 |  |  |

Source: \*GFEI, 2013b

Table 11: A comparison between the average CO2 emissions from new models of passenger vehicles in the EU and Bahrain in 2005, 2008, 2010 and 2012 (g CO2/km)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **2005** | **2008** | **2010** | **2012** |
| EU\* | 162.4 | 153.6 | 140.3 | - |
| Bahrain | 248.5 | 250.4 | 252.4 | 230.9 |

Source: \*EEA, 2013

Table 12: Total new vehicles, new LDVs and gasoline LDVs in Bahrain in 2005, 2008, 2010 and 2012

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Year | Total new vehicles | New LDVs | % | Gasoline LDVs | % of LDVs |
| 2005 | 29395 | 25019 | 85.1 | 24946 | 99.7 |
| 2008 | 40395 | 32229 | 79.8 | 32161 | 99.8 |
| 2010 | 24939 | 20479 | 82.1 | 20439 | 99.8 |
| 2012 | 35219 | 28552 | 81.1 | 28439 | 99.6 |

Table 13: Average curb weight and engine size of new LDVs in Bahrain in 2005, 2008, 2010 and 2012

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Item | 2005 | 2008 | 2010 | 2012 |
| Average curb weight (kg) | 1685 | 1753 | 1731 | 1718 |
| Average engine size (cc) | 3191 | 3417 | 3061 | 2955 |

Table 14: Number of new LDVs per year of first registration

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Item | 2005 | 2008 | 2010 | 2012 |
| Registered a year before the year of manufacture | 5444 | 5669 | 3390 | 5216 |
| Registered at the year of manufacture | 13327 | 22550 | 14931 | 21143 |
| Registered between one and three years after the year of the manufacture | 2912 | 2769 | 2156 | 2191 |
| Registered at more than three years after the year of the manufacture | 3294 | 1174 | 0 | 0 |
| N.A. | 42 | 67 | 2 | 2 |
| Total | 25019 | 32229 | 20479 | 28552 |

1. **FIA Foundation, International Energy Agency (IEA), International Transport Forum (ITF), United Nations Environment Programme (UNEP), and the International Council on Clean Transportation (ICCT).** [↑](#footnote-ref-1)
2. The correlation is significant at the 0.01 level (2-tailed) [↑](#footnote-ref-2)
3. With regard to 2008 models [↑](#footnote-ref-3)
4. For passenger vehicles only [↑](#footnote-ref-4)