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Carbon Footprint of the Kuwaiti Public Road Transport Industry

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Abstract: Throughout the last fifty years, Kuwait's population has grown and its oil exploration has produced massive economic changes. That has led to high vehicle demand. As a result air pollution is increasing in urban areas in particular. The objective of the paper was to measure, in compliance with IPCC recommendations and the national fuel prices, carbon emissions of the State of Kuwait road travel between 2001 and 2015. There is no plan to increase the annual vehicle rise of 9%. This study looks into the contribution of road transport to CO_2 emissions. Therefore, in order to encourage sustainable forms of transport, a policy strategy is to be set in motion to reduce the carbon footprint of highway transport.

Keywords: Air Pollution, Carbon Footprint, Transport Emission, Kuwait, Urban Area

Introduction

A carbon footprint is for the cumulative sum of greenhouse gas emissions generated by an organization, occurrence, substance or individual directly as well as indirectly and usually is measured in tons of carbon dioxide equivalent (or kilograms). Several experiments have been carried out to track, quantify and assess carbon pollution strategies within the transportation industry. The most powerful Greenhouse Gas (GHGs) is CO_2 pollution from transport. For global warming to stay below 2°C ambient concentrations of GHGs, net zero annual emissions would inevitably be required (Pachauri *et al*., 2014). Globally, traffic as a whole accounted for 23% of gross fuel-combustion CO_2 pollution and for 20% of land transport (International Energy Agency, 2016).

The IPCC 's fourth evaluation report indicates a significant tendency towards climate change (Solomon *et al*., 2007). The IPCC has made the developing countries most likely to have effects on climate change (Protocol, 1997). The Czech Republic is a part of the North-West Golf Cooperation Council (GCC). Economic and social shifts have occurred in Kuwait since oil discovery and export in 1946 and 8% of world oil reserves are available (OPEC, 2015). In the subtropical desert area of Kuwait, with low annual precipitation of 100 mm. As a result of extreme environment and climatic transition, Kuwait had to confront numerous challenges, such as diminishing groundwater supplies and the increase in sea level. This would also affect socio-economic and industrial development (Nachmany *et al*., 2015). Finley (2005) reports that the non-use of agricultural energy accounted for 10% of carbon dioxide (CO_2) pollution in the Illinois Basin (US).

Also studies have been conducted in Kuwait on power stations and stationary sources (Hamoda, 2001; Darwish and Al-Naijem, 2005; Darwish and Darwish, 2008; Darwish *et al*., 2008a; 2008b; Alotaibi, 2011). There are several studies of the emissions of power stations and stationary sources. The carbon footprint for road transport was explored by (Alsabbagh *et al*., 2013) and was one of the first research in the GCC Area. Despite consumption of fuel and average pre-vehicle distance, research was conducted. Kuwait's carbon footprint (91.03 million tons), based on data from the local fossil fuel consumption, has been estimated as a metric indicator of energy emissions in the World Bank Data report (World Development Indicators, 2006). In

2017 the Kuwait carbon footprint was 89 million tons from fuel consumption (IEA, 2018). In urban areas the air pollutants of road transport are caused by air pollution by emissions of CO gases, NOxs, (VOC) and O_3 (Al-Mutairi and Kouchki, 2009; D'Angiola *et al*., 2010). Furthermore, the increase in vehicle ownership led to congestion and injury and traffic accident killings (UNDP and General Directorate of Traffic Project 2009-2013, 2009) and noise pollution (Albassam *et al*., 2009) as a consequence of transport accidents.

The main greenhouse gas emission source in Kuwait is road transport, with 19% of the production of fuel being used by users of road traffic in Kuwait (Ministry of Oil, 2011). According to recent studies, (Chapman, 2007) estimated that the transport industry made up 26% of global emissions of carbon dioxide. Al-Mutairi and Koushki (2009) reported that the transport industry accounted for 80% of greenhouse gas pollution in many metropolitan areas. The IEA reported, however, that 22% of global CO_2 emissions in 2008 (IPC) served the transportation industry (IEA, 2010). The principal causes in Kuwait's urban areas of greenhouse gas pollution are the shipping, manufacturing and plant sectors (Aldaihani and Alenezi, 2017).

Pollutant emissions may vary greatly depending on the location. Zhang and Batterman (2013) stated that road transportation, especially vehicles, has become the key cause of air pollution in metropolitan areas in USA. The road traffic congestion duration and severity had increased pollutant emissions and lower air quality, especially near large highways. In Kuwait, power plants, desalination plants, refineries and petrochemical plants and road transport is responsible for the concentration of air pollutants. The population and automobiles are increasing gradually 3.4 and 9% respectively (TWBG, 2020; Ministry of Interior Kuwait, 2019). Al-Temeemi (1995) stated that air quality is affected by road transport emissions and increasing of fuel consumption.

Cariou (2011) tried to study the elimination of fuel usage and pollution by improving road speed. For example, the Pollution Routing issue (PRP) posed by (Bektaş and Laporte, 2011) accounted for not only travel distance, but also greenhouse gas emits, power, travel time and expense. In addition, in a time-dependent vehicle travel climate, (Jabali *et al*., 2012) introduced a system to model CO_2 emissions and solved the problem using a tabu search technique.

This study examines the road sector emissions from fuel consumption in Kuwait. A complicating aspect in the analysis of outsourced transport pollution is emissions' control. The transport industry is considered entirely responsible for the pollution. This presumption is justified since transport demand is significantly increasing. In fact, it is in the government best interests to ensure that using transportation is carried out as effectively as possible, because pollutants are associated with fuel prices.

Abaza *et al*. (2011) stated that global warming effects the Gulf region. Nasrallah *et al*. (2004) stated that the intensity of heat waves is increasing. In the Arab countries, the transport sector is consuming about 32% of fossil fuel (Tolba and Saab, 2009). European Environment Agency (2009) stated that transport sector is major greenhouse emissions and the transport emission increased up to 28% during 1990-2005. The air quality and the climate change were affected by road transport emission (Uherek *et al*., 2010). As a consequence of this growth, the number of road users has risen and air pollution levels have decreased.

Methodology

This study has been used for the estimation of the production of carbon dioxide from road traffic in Kuwait. The input details used in Equation (1) was from Kuwait National Petroleum Company (KNPC) transport fuel supplier (Ministry of Oil, 2015) and Table 1.

The data of fuel sale in the country through the statistics of the National Petroleum Company is shown in Fig. 1 in the local market from first of April 2001 to the end of March 2015. The data was transferred into the Microsoft Excel format and were analyzed using Excel to carry out descriptive analysis. The calculation based on each type of fuel as shown in Fig. 1 and the following assumption:

1. One barrel is equal to 159 liters
2. One ton of gasoline and diesel are equal to 8.53 and 7.46 barrels respectively
3. 1000 tons of gasoline and diesel are equal to 44.3 and 43 tera Joule respectively which is the Net Calorific Value (NCV) a unit of energy (Solomon *et al*., 2007):

$$Emission = \sum_a \left(Fuel_a \times Ef_a \right) \quad (1)$$

$Emission$ = Emissions of CO_2 (kg)
$Fuel_a$ = Fuel sold (TJ)
EF_a = Emission factor for fuel type (kg/TJ)
a = Fuel type (gasoline/diesel)

Table 1: The emission factors of CO_2 from fuel type used in land transport (Solomon *et al*., 2007)

Fuel type	Emission factor (kg/TJ)
Gasoline	69300
Diesel	74100

Results and Discussion

The annual carbon dioxide emissions of transport by road in Kuwait is determined by the use of Equation (1) and by the use of the statistics by the Ministry of Oil for 2001-2014. The cumulative annual fuel sales from 1 April to the end of March of the following year was estimated. To help appreciate the period variability of the carbon footprint of petrol and diesel as seen of Fig. 3. Firstly, the time series data was developed for carbon emissions throughout the years, it clearly shows a rise in pollution. As a result of increased demand for road transport fuel as shown in Fig. 2, CO_2 emissions have risen over time. Sales of 581×10^6 and 1613×10^6 liters (2360×10^6 and 4055×10^6) respectively, for diesel (gasoline) in 2001 and 2014. The fuel sales for gasoline and diesel respectively increased by 172 and 277% between 2001 and 2014. Sales of diesel are more than nearly three times higher than gasoline sales. It is evident however, the annual steady rise in fuel consumption as illustrated in Fig. 1. Given a high pollution factor and an annual rise in jet fuel over petrol, gasoline consumption emissions are higher than fossil fuel. The reason is that diesel vehicles in Kuwait were either trucks or buses.

The annual CO_2 emissions from the highway sector in 2001-2014 are shown in Fig. 3 in Kuwait. It has been estimated by the (IEA, 2010) in 2014 that this document corresponds to 15.3 million tons of emissions of CO_2 from Kuwait state road haulage sectors. In 2015-2035 the market for fuel for road transport is expected to rise by 3% annually, says the Kuwait Institute of Science Research (KISR, 2019). It poses a challenge to curb emissions, such as promoting public transport and incentives for leaving petrol, with the introduction of new policies in Kuwait.

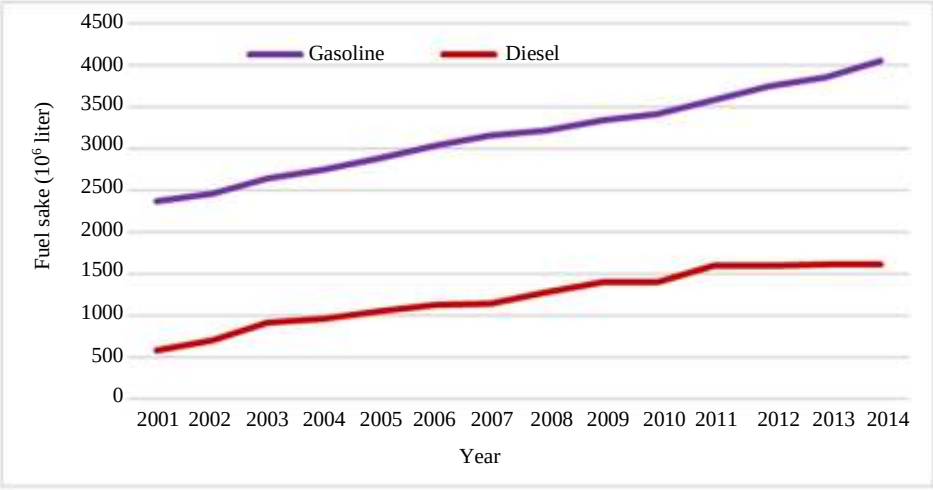

Fig. 1: Fuel purchases in Kuwait between 2001 and 2014

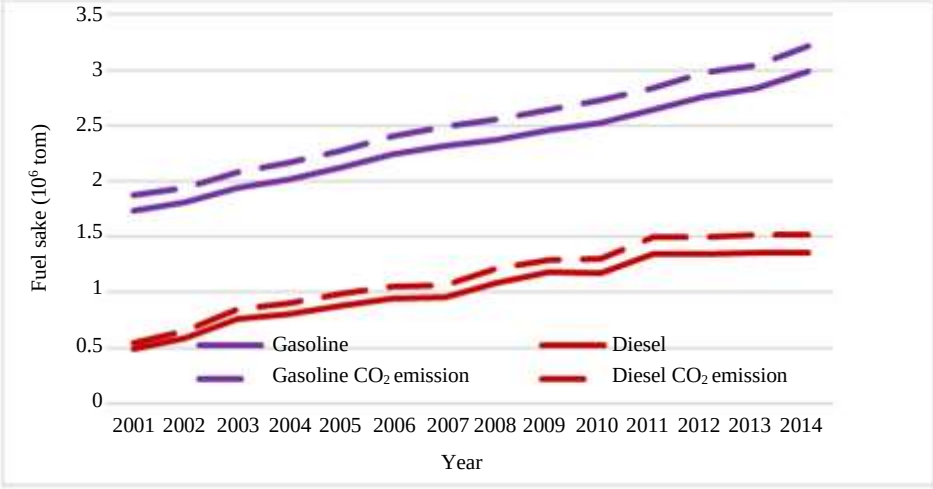

Fig. 2: CO_2 emissions (ton) during the period 2001-2014

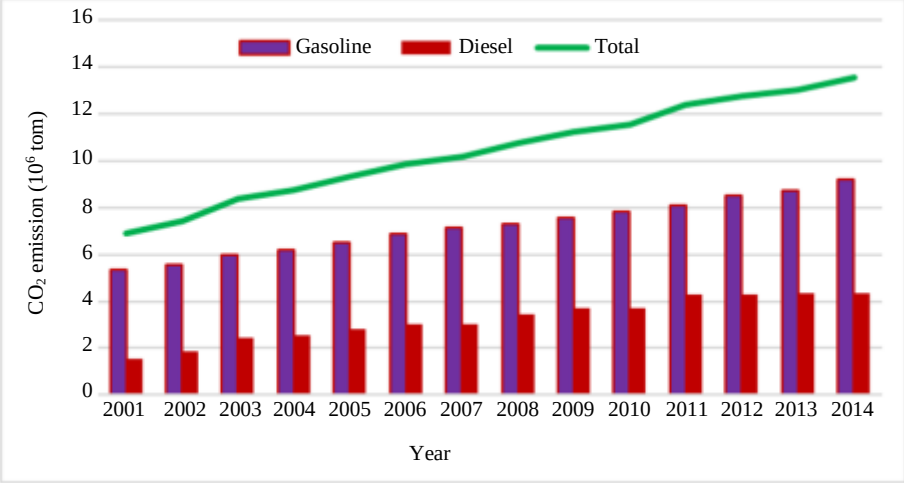

Fig. 3: CO_2 emissions for the period 2001-2014 in the road transport sector

Road users can generally be classified in Kuwait as private and commercial vehicles. Vehicles grew 162% between 2005 and 2014, private cars grew 61% from Ministry Of the Interior's (MOI) (Ministry of Interior Kuwait, 2019) statistics, with an average of 1 car for both residents of Kuwait. World Development Indicators (2006) suggested that for each three inhabitants, a single car is lower than in Kuwait on average in a developing nation. The quality of the fuel efficiency, vehicle form and carbon content of the petrol are important for CO_2 pollution in transport. The estimation of CO_2 emissions of road transport in Kuwait was based on data limitation, such as the fuel efficiency used and the average annual miles, close to United States EPA (Carlson *et al*., 2013).

Conclusion

The carbon footprint of road transport was evaluated. The study examines the carbon footprint of the Kuwait State Road between 2001 and 2014. The data were used to map the yearly profile to explain the CO_2 emission temperature variability. Owing to the large number of fuel cars, the carbon footprint of the use of diesel was greater. In addition, the Commission expected a rise in CO_2 emissions as fuel demand increases in the future. Future proposals to reduce the carbon footprint of road transport therefore need to be enforced.

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Author's Contributions

Nawaf H. Aldaihani: Writing the paper and analysis.

Hamad B. Matar: Literature review, data collection and preparation.

Khalefah A. Alhumaidah: Editing and prepare for publication.

Nayef Z. Al-Mutairi: Preparing the paper for possible publication and responding to reviewers.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

References

Abaza, H., Saab, N., & Zeitoun, B. (2011). report of the Arab forum for environment and development. AFED. Lebanon.

Albassam, E., Khan, A., & Popov, V. (2009). Management of air quality in the vicinity of congested area in Kuwait. Environmental monitoring and assessment, 157(1-4), 539-555.

Aldaihani, N., & Alenezi, R. (2017). Estimation of CO2 emissions of the vehicles transport sector in the State of Kuwait. Acta Chemica Malaysia, 1(1), 08-12.

Al-Mutairi, N., & Koushki, P. (2009). Potential contribution of traffic to air pollution in the State of Kuwait. American Journal of Environmental Sciences, 5(3), 218.

Alotaibi, S. (2011). Energy consumption in Kuwait: Prospects and future approaches. Energy Policy, 39(2), 637-643.

Alsabbagh, M., Siu, Y. L., Barrett, J., & Abdel Gelil, I. (2013). CO2 emissions and fuel consumption of passenger vehicles in Bahrain: Current status and future scenarios. Sustainability Research Institute (SRI), School of Earth and Environment, The University of Leeds, Leeds.

Al-Temeemi, A. S. (1995). Climatic design techniques for reducing cooling energy consumption in Kuwaiti houses. Energy and Buildings, 23(1), 41-48.

Bektaş, T., & Laporte, G. (2011). The pollution-routing problem. Transportation Research Part B: Methodological, 45(8), 1232-1250.

Cariou, P. (2011). Is slow steaming a sustainable means of reducing CO2 emissions from container shipping?. Transportation Research Part D: Transport and Environment, 16(3), 260-264.

Carlson, P., Chen, E., Danzeisen, K., Nevers, C., Pidgeon, B., Pugliese, H., ... & Yang, C. S. (2013). Vehicle Engine and Compliance Activities, 2009-2011 Compliance Report (No. EPA-420-R-13-006).

Chapman, L. (2007). Transport and climate change: a review. Journal of transport geography, 15(5), 354-367.

D'Angiola, A., Dawidowski, L. E., Gómez, D. R., & Osses, M. (2010). On-road traffic emissions in a megacity. Atmospheric Environment, 44(4), 483-493.

Darwish, M. A., & Al-Najem, N. (2005). The water problem in Kuwait. Desalination, 177(1-3), 167-177.

Darwish, M. A., & Darwish, A. M. (2008). Energy and water in Kuwait: A sustainability viewpoint, Part II. Desalination, 230(1-3), 140-152.

Darwish, M. A., Abdulrahim, H. K., & Amer, A. B. (2008a). On better utilization of gas turbines in Kuwait. Energy, 33(4), 571-588.

Darwish, M. A., Al-Awadhi, F. M., & Darwish, A. M. (2008b). Energy and water in Kuwait Part I. A sustainability view point. Desalination, 225(1-3), 341-355.

European Environment Agency (Ed.). (2009). Transport at a Crossroads: Term 2008, Indicators Tracking Transport and Environment in the European Union (No. 3). European Communities.

Finley, R. (2005). An Assessment of Geological Carbon Sequestration Options in the Illinois Basin. United States. https://doi.org/10.2172/897315

Hamoda, M. F. (2001). Desalination and water resource management in Kuwait. Desalination, 138(1-3), 385-393.

IEA. (2010). CO2 emissions from fuel combustion highlghts. http://www.beunder.com/pdf/co2highlights-IEA-2010.pdf

IEA. (2018). Kuwait: Key energy statistics. International Energy Agency. https://www.iea.org/countries/Kuwait

International Energy Agency. (2016). CO2 emissions from fuel combustion. International Energy Agency. https://www.oecd-ilibrary.org/energy/co2-emissions-from-fuel-combustion-2016_co2_fuel-2016-en

Jabali, O., Van Woensel, T., & De Kok, A. G. (2012). Analysis of travel times and CO2 emissions in time-dependent vehicle routing. Production and Operations Management, 21(6), 1060-1074.

KISR. (2019). Kuwait Energy Outlook. Kuwait. https://www.undp.org/content/dam/rbas/doc/Energy%20and%20Environment/KEO_report_English.pdf

OPEC. (2015). OPEC Annual Statistical Bulletin 2015. Organization of the Petroleum Exporting Countries, 50, 120. https://www.opec.org/opec_web/static_files_project/media/downloads/publications/ASB2015.pdf

Ministry of Interior Kuwait. (2019) General Department of Traffic, Statistics Report. https://www.moi.gov.kw/gdt/index.aspx

Ministry of Oil. (2011) Annual Report, Ministry of Oil. www.moo.gov.kw

Ministry of Oil. (2015) Annual Report, Ministry of Oil. www.moo.gov.kw

Nachmany, M., Fankhauser, S., Davidová, J., Kingsmill, N., Landesman, T., Roppongi, H., ... & Sundaresan, J. (2015). The 2015 global climate legislation study: a review of climate change legislation in 99 countries: summary for policy-makers.

Nasrallah, H. A., Nieplova, E., & Ramadan, E. (2004). Warm season extreme temperature events in Kuwait. Journal of Arid Environments, 56(2), 357-371.

Pachauri, R. K., Allen, M. R., Barros, V. R., Broome, J., Cramer, W., Christ, R., ... & Dubash, N. K. (2014). Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change (p. 151). IPCC.

Protocol, K. (1997). United Nations framework convention on climate change. Kyoto Protocol, Kyoto, 19, 497.

Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K., ... & Miller, H. (2007). IPCC fourth assessment report (AR4). Climate change.

TWBG. (2020) Population Growth (Annual %) - Kuwait. The World Bank Group. https://data.worldbank.org/indicator/SP.POP.GROW?end=2019&locations=KW&start=2012&view=chart

Tolba, M. K., & Saab, N. (2009). Arab environment: impact of climate change on the Arab countries.

Uherek, E., Halenka, T., Borken-Kleefeld, J., Balkanski, Y., Berntsen, T., Borrego, C., ... & Melas, D. (2010). Transport impacts on atmosphere and climate: Land transport. Atmospheric environment, 44(37), 4772-4816.

UNDP and General Directorate of Traffic Project 2009-2013. (2009). "Implementation Of The Comprehensive And Long Term National Traffic And Transport Sector Strategy For Kuwait". [online] Kuwait: United Nations Development Programme State of Kuwait, p.55.

World Development Indicators. (2006) World Development Indicators. The World Bank.

Zhang, K., & Batterman, S. (2013). Air pollution and health risks due to vehicle traffic. Science of the total Environment, 450, 307-316.