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A COMPARISON OF THE AIR POLLUTION OF GASOLINE AND CNG DRIVEN CAR FOR MALAYSIA

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ABSTRACT

In order for saving the constrained resources and preservation of environment, the natural gas is a proven low cost and low emission alternative fuel to petroleum fuels for all types of motor vehicles. It is being widely used throughout the globe. In Malaysia, still millions of vehicles are plying on use of petroleum fuels. These fuels release huge emissions to the environment. Definitely, this adversely affects the natural ecosystem. In this backdrop, a study is felt important to predict the trend of emissions of anti-body gases released by cars in Malaysia for use of liquid fuels and natural gas between 2006 and 2020. The growth of vehicles demand has been considered alongside. The study reveals that current emission levels of different anti-body gases are huge and these can be significantly reduced by converting liquid fuel based engine into the natural gas based engine.

Keywords: Liquid fuels; Natural Gas NG; Emission; Passenger Cars; Alternate Fuel.

1. INTRODUCTION

Increasing concentration of greenhouse gases like carbon dioxide CO_2, sulfur dioxide SO_2, nitrogen oxide NO_x, carbon monoxide CO and hydrocarbons HC in the atmosphere has already warned the concerned engineers, scientists and environmentalists to stand on it. Nevertheless, a huge amount of these gases are generated by vehicles using the foretold liquid fuels. In the 1990s, the transportation sector saw the fastest growth in carbon dioxide emissions of any major sector of the US economy. And the transportation sector is projected to generate nearly half of the 40% rise in US carbon dioxide emissions forecast for 2025 (Joseph R. 2006).

Claude Mandil, Executive Director of the International Energy Agency IEA, said in May 2004, ''In the absence of strong government policies, we project that the worldwide use of oil in transport will nearly double between 2000 and 2030, leading to a similar increase in greenhouse gas emissions'' (IEA, 2004). In Malaysia, emissions from motor vehicles were the main source of air pollution, burdening to at least 70–75 percent of the total pollutants during last 5 years (Afroz, *et al*., 2003). Reported by the Department of Environment Malaysia, only in 1996, the percentage of the emission loads to its air from different sources were, motor vehicles, 82 percent; power stations, 9 percent; industrial fuel burning, 5 percent; industrial production processes, 3 percent; domestic and commercial furnaces, 0.2 percent; and open burning at solid waste disposal sites, 0.8 percent (Department of the Environment, Malaysia. 1996). Obviously, huge number of passenger cars in use was the main source of atmospheric pollution in here. These vehicles also discharge about 75 percent of the total CO and 76–79 percent of the oxides of sulfur and nitrogen (Department of the Environment, Malaysia. 2001).

In recent years, the environmental legislations exerted a notable influence to hold pollutant gas emissions from vehicles. In January 2000, the European regulation EURO-III came into force and promulgated severe limits to the allowable exhaust pipe emissions from vehicles. Widely known as the Kyoto protocol, signed by EU in December 1997 states that greenhouse gases should be reduced by 8 percent within 2012 from the level recorded in 1990. Malaysia is one of the 160 countries that have accepted this protocol. However, the amount of greenhouse gases emission by transportation sector has not yet been analyzed in here. On the other hand, due to rapid economic growth and infrastructure development, the usage of petrol and diesel fuels in transportation sector has rather increased tremendously. As a result, Malaysia's oil reserve fallen rapidly in the past decade. It could be assumed that each year huge amount of greenhouse gases have been released to the environment. The necessity has gain the ground to apply a suitable energy policy for transportation sector in order to balance the demand and supply of energy and to contain the overall release of greenhouse gases. This effort would lead to the conservation of limited nonrenewable energy resources and preservation of environment. It is the responsibility and probably would be remarkable contribution of the present people to future generations.

Energy policy and planning with that orientation has become a very important public agendum of most developed and developing countries today. As a result, the governments are encouraging the use of alternative fuels in motor vehicle engines as well. Compressed natural gas CNG has appeared as a proven alternative fuel. The advantages of CNG as an automotive fuel over conventional fuels are quite many, and these are broadly stated by Nylund *et al*.(2002) and Aslam *et al*. (2003). Emissions from CNG using vehicles are in general are lower than emissions from petrol and diesel operating vehicles and thus after conversion, the expected emission levels would be lower (Aslam *et al*. 2006).

This study on natural gas vehicle NGV has been undertaken to identify the deficiencies of and scope of improvement to the previous policies. Another matter that has been considered to reduce pollutant emissions from motor vehicles is the conversion of motor vehicles being operated on petrol and diesel fuels to CNG vehicles. The main factors that should be taken into account when considering the conversion are in the costs associated with the conversion and the expected gains in terms of reduction of the emissions of all the pollutants that pose environmental or health risks. Appreciably, Malaysia has planned to reduce the production of CO_2, SO_2, NO_x, CO and HC but the data on their emission levels are not readily available. Therefore, this study attempts to estimate potential production of these gases from transportation sector, particularly from the use of passenger cars in this country. Having known the accurate figures on their emissions, the relevant agencies can take the appropriate measures in order for prudent use of limited energy resources and conservation of environment.

2. NATURAL GAS RESERVE

2.1 World Reserve

Natural gas is projected to be the fastest growing component of world primary energy consumption. Consumption of natural gas worldwide increases at an average rate of 2.3 percent annually from 2002 to 2025 compared with projected annual growth rates of 1.9 percent for oil consumption and 2.0 percent for coal consumption (BP, 2005). From 2002 to 2025, consumption of natural gas is projected to increase by almost 70 percent, from 92 trillion cubic feet to 156 trillion cubic feet and its share of total energy consumption on a Btu basis is projected to grow from 23 percent to 25 percent. Natural gas is projected to increase by a more modest annual average of 1.6 percent from 2002 to 2025, with the largest incremental growth in the mature market economies projected for North America, at 11 trillion cubic feet.

The world NG reserves were estimated at 6,040 trillion cubic feet as shown in Table 1. The former Soviet Union FSU, in particular, accounts for around 6 per cent of world reserves but nearly 40 percent of proven gas reserves, most of which 27.8 per sent of world reserves is located in Russia. The Russian reserves are largest in the world; almost double the second-largest volume in Iran. Russia, Iran, and Qatar combined account for about 58 percent of the world's natural gas reserves. Reserves in the rest of the world are fairly evenly distributed on a regional basis.

Table 1 World Natural Gas Reserves by Country as of January 1, 2005

Country	Reserves Tcf	Percent of World Total
World	6,040	100.0
Top 20 Countries	5,391	89.3
Russia	1,680	27.8
Iran	940	15.6
Qatar	910	15.1
Saudi Arabia	235	3.9
U.A.E	212	3.5
United States.	189	3.1
Nigeria.	176	2.9
Algeria	161	2.7
Venezuela	151	2.5
Iraq	110	1.8
Indonesia.	90	1.5
Malaysia	75	1.2
Norway	75	1.2
Turkmenistan	74	1.2
Uzbekistan	71	1.2
Kazakhstan	66	1.1
Netherlands	65	1.1
Canada	62	1.0
Egypt	57	0.9
Ukraine	40	0.7
Rest of World	649	10.7

Despite high rates of increase in natural gas consumption, particularly over the past decade, most regional reserves-to-production ratios have remained high. Worldwide, the reserves-to-production ratio is estimated to be 66.7 years (IEO, 2005). Central and South America has a reserves-to-production ratio of 55.0 years, the FSU 77.4 years, and Africa 96.9 years. The Middle East's reserves-to production ratio exceeds 100 years.

According to the most recent USGS estimates, released in the World Petroleum Assessment 2000, a significant volume of natural gas remains to be discovered. The mean estimate for worldwide-undiscovered natural gas is 4,301 trillion cubic feet, which is approximately double the worldwide cumulative consumption forecast from 2002 to 2025 in IEO2005. Of the total natural gas resource base, an estimated 3,000 trillion cubic feet is in "stranded" reserves, usually located too far away from pipeline infrastructure or population centers to make transportation of the natural gas economical. Of the new natural gas resources expected to be added over the next 25 years, reserve growth accounts for 2,347 trillion cubic feet. More than one-half of the mean undiscovered natural gas estimates is expected to come from the FSU, the Middle East, and North Africa; and about one-fourth 1,065 trillion cubic feet is expected to come from a combination of North, Central, and South America (IEO, 2005).

2.2 Natural Gas in Malaysia

Malaysia contains 75 trillion cubic feet Tcf of proven natural gas reserves. Natural gas production has been rising steadily in recent years, reaching 1.89 Tcf in 2003. Natural gas consumption in 2003 was estimated at 1.008 Tcf, with LNG exports of around 0.882 Tcf mostly to Japan, South Korea, and Taiwan (EIA, 2005).

One of the most active areas in Malaysia for gas exploration and development is the Malaysia-Thailand Joint Development Area JDA, located in the lower part of the Gulf of Thailand and governed by the Malaysia-Thailand Joint Authority MTJA. The two governments for joint exploration of the once-disputed JDA established the MTJA. The JDA covers blocks A-18 and B-17 to C-19. A 50:50 partnership between Petronas and Amerada Hess is developing block A-18, while the Petroleum Authority of Thailand PTT and Petronas also share equal interests in the remaining blocks. PTT and Petronas announced an agreement in November 1999 to proceed with development of a gas pipeline from the JDA to a processing plant in Songkla, Thailand, and a pipeline linking the Thai and Malaysian gas grids. Malaysia and Thailand will eventually take half of the gas produced, though initial production will go just to Malaysia. The project had been controversial in Thailand, facing opposition from local residents in Songkla along the pipeline route. In May 2002, the Thai government announced a final decision to commence construction on the project later in 2002, through the pipeline route was altered slightly to avoid some populated areas. Construction has begun, and the delivery of natural gas into Malaysia is scheduled to begin in the first quarter of 2005.

Malaysia accounted for approximately 14% of total world LNG exports in 2003. After much delay, Malaysia is proceeding with a long-planned expansion of its Bintulu LNG complex in Sarawak. In February 2000, Petronas signed a contract with a consortium headed by Kellogg Brown and Root for construction of the Malaysian LNG Tiga facility, with two LNG liquefaction trains and a total capacity of 7.6 million metric tons 370 Bcf per year, which was completed in April 2003. The Bintulu facility as a whole is now the largest LNG liquefaction center in the world, with a total capacity of 23 million metric tons 1.1 Tcf per year. Most of the production from the new LNG trains will be sold under term contracts to utilities in Japan. Tokyo Electric Power TEPCO, Tokyo Gas, and

Chubu Electric all import LNG from the project. BG signed a contract on August 2004 for supplies over a 15-year period to the United Kingdom, to begin in 2007 or 2008. Shell brought two additional fields online in 2004, Jintan in March, and Serai in September, both of which feed into the Bintulu export terminal.

Malaysia holds the world NG reserves of about 1.2% and the largest NG producer in South East Asia region. Malaysia has about 75 Tcf of NG reserve. As such this should serve as an incentive for further growth of NGV in Malaysia. Petronas is spear heading the Malaysian NGV industry development. Petronus primary focus is to convert commercial vehicles, particularly the petrol and diesel taxi to NGV taxi.

3. METHODOLOGY

This study used the scenario approach of data analysis and presentation. Schwartz (1996) states that scenarios are tools for projecting views about alternative future environments despite the end-result might not present an accurate picture. This can, however, provide a good ground for better decision. No matter how things might actually turn out, both the analysts and the policy makers can have a scenario that resembles a given future and that can help them think about the opportunities and the consequences of the future.

The analysis in this study is generally based on modeling methodologies to figure out the potential emissions from passenger cars using liquid fuels petrol and diesel and CNG fuel in Malaysia between 2006 and 2020. For this purpose the types of fuel used for passenger cars have been identified. Information has been gathered from books, journals and Internet sources. The data has been collected from the relevant Malaysian government bodies like Department of Statistic, Department of Road and Transportation and other government agencies. Some of the data were already available but others were calculated with respect to the trend of fuel consumption by passenger cars. Polynomial curve fitting method has been employed to analyze and predict unavailable data. The best fit from these methods was used for this study.

The polynomial method was an attempt to describe the relationship between a variable *X* as the function of available data and a response variable *Y*. Mathematically, a polynomial of order *k* in *X* is expressed in the following form (Klienbaum, D.G., 1998).

$$Y = C_0 + C_1X + C_2X^2 + ... + C_kX^k \quad 1$$

To develop the model, historical data on the number of passenger cars and fuel consumption from year 1990 to 2004 has been analyzed and shown in Table 2. Using Equation 1 and the data in Table 2, a regression Equation 2 shown below that can be used to predict the total number of passenger cars in Malaysia between 2006 and 2020.

$$Y_1 = -4.28E + 08 + 243309\ X, R^2 = 95.6\% \quad 2$$

And fuel use per vehicle kilometer in liter in Malaysia from the year 2006 to 2020 can be predicted by the following equation:

$$Y_2 = -12.366 + 0.0132X - 3E - 06X^2, R^2 = 80\% \quad 3$$

The results of the predicted number of total passenger car and fuel use per vehicle kilometer in liter based on Eqs. 1 and 2 from the year 2006 to2020 are shown in Table 3.

The results of the estimated number of passenger cars and fuel use are shown in Table 3.

Based on the model from 'Highway network development plan HNDP' study in 1993, a trip generation model has been developed for this study. Using this model it has been forecasted that more than 25.8 million person-trips per day would be used by year 2020 and around 80 percent would the passenger cars (Masjuki *et al.*, 2005). Figure 1 show that 41.60 percent vehicles are passenger cars and 48.60 percent are motorcycles. Together these constitute the majority proportion of vehicles in Malaysia. Nevertheless, fuel consumption of motorcycles is much lower than that of passenger cars. CNG is not yet used in motorcycle engine. Therefore, this study emphasized on passenger cars only.

From the historical record available with the road transport department, it is observed that about 99.6 percent of the total passenger cars in Malaysia used petrol fuel and the rest used diesel (Masjuki *et al.,* 2005). Based on this observation the estimated patterns of passenger cars for the aforesaid period have been shown in Table 3.

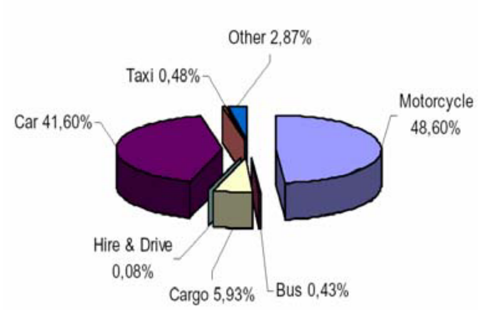

Figure 1. Percentage of different types of vehicles usage in transportation sector of Malaysia (Masjuki *et al.*, 2005)

3.1 Emission Calculation.

The estimated amount of CO_2, SO_2, NOx, CO and HCs generated from liquid fuels petrol & diesel and the natural gas by passenger cars per day have been calculated. Emission factor of fuels production and combustion on vehicles is collected from earlier works (Masjuki *et. al.,* 2005, Hampden *et. al.*, 2004 & Lewis, C.A., 1997) and is tabulated in Tables 4 and 5 for one kg of fuel use. Demand of petrol and diesel fuels have been calculated for period 2006 to 2020 for the predicted number of passenger cars. Fuel use per vehicle kilo-meter and mean trip length of a vehicle per day in km has also been shown. According to HNDP study, the mean trip length for the total vehicle population is 17.2 km per day (Masjuki *et al.,* 2005), which has been assumed constant for 2006 to 2020 in this study.

Table 2 Number of Passenger rcars and Fuel Use per Vehicle-km in Malaysia from 1990 to 2004. (Masjuki *et al.,* 2005)

Year	Passenger Car	Fuel Use per Veh-km Liter
1990	1709754	0.1162
1991	1858123	0.11139
1992	1977612	0.11222
1993	2126578	0.11472
1994	2344751	0.11354
1995	2600381	0.11133
1996	2936021	0.11077
1997	3322597	0.10941
1998	3507442	0.10883
1999	3842673	0.10986
2000	4202134	0.10707
2001	4614571	0.01772
2002	5059339	0.10704
2003	5347927	0.10635
2004	5591236	0.10568

Table 3 Forecasted Numbers of Passenger Cars and Fuel Used per Vehicle-km.

Year	Passenger Cars	Petrol Car	Diesel Car	Fuel Use per Veh-km Liter
2006	6077854	6054576	23278	0.10430
2007	6321163	6296953	24210	0.10363
2008	6564472	6539330	25142	0.10295
2009	6807781	6781707	26074	0.10227
2010	7051090	7024084	27006	0.10159
2011	7294399	7266461	27938	0.10091
2012	7537708	7508839	28869	0.10023
2013	7781017	7751216	29801	0.09956
2014	8024326	7993593	30733	0.09888
2015	8267635	8235970	31665	0.09820
2016	8510944	8478347	32597	0.09752
2017	8754253	8720724	33529	0.09684
2018	8997562	8963101	34461	0.09617
2019	9240871	9205478	35393	0.09549
2020	9484180	9447856	36324	0.09481

Table 4 Total CO_2, SO_2, HC, NO_x and CO emission from per kg of fuels production and distribution

Fuels	Emission				
	CO_2 g/kg	SO_2 g/kg	HC g/kg	CO g/kg	NOx g/kg
Petrol	418.30	2.79	0.77	0.24	2.03
Diesel	294.00	1.89	0.66	0.21	1.64
NG	178.80	0.73	9.75	0.06	0.46

Table 5 CO_2, SO_2, HC, NOx and CO emission from per kg of fuels used by passenger cars

Fuels	Emission				
	CO_2 g/kg	SO_2 g/kg	HC g/kg	CO g/kg	NOx g/kg
Petrol	3,183	0.0994	4.00	152.20	59.68
Diesel	3,145	0.0995	6.50	4.34	12.09
NG	2,553	0.0000	2.00	10.14	23.12

Natural gas NG equivalent to liquid fuel consumption has been estimated based on lower heating value of the respective fuels. The lower heating values of petrol and diesel have considered 44.5 MJ/kg and 42.0 MJ/kg respectively and that of NG is 43.6 MJ/kg (Aslam *et. al*. 2006). Calculations of emission for using 100 percent liquid fuel then gradually substituting the liquid fuels by 20, 40, 60, and 80 percent NG have also been made. Emission patterns of full substitution by NG for passenger cars have been shown. For finding the total emission per day, the estimated emissions from petrol, diesel and NG have been done separately and then added. Total emissions calculated for year 2010 with an assumption of 60 percent replacement of the liquid fuels petrol, diesel by NG are shown in Table 6.The same procedure have been followed to predict the emission for non-conversion, full conversion and partial replacement of liquid fuels driven passenger cars by NGVs for year 2006 to 2020. The results are shown in Figures 2-6.

Table 6 Sample of emission calculation

	Estimated Total	Petrol 99.6%	Diesel 0.4%	Equivalent NGV & NG fuel
No of cars	7,051,090	7,022,886	28,204	7,051,090
Fuel consumption		$N_P \times V_{km} \times F_{km} \times S_P$ = 9203569.35 kg	$N_D \times V_{km} \times F_{km} \times S_D$ = 42382.7 kg	$\frac{(W_P \times H_P)}{H_{NG}} + \frac{(W_D \times H_D)}{H_{NG}}$ = 9434378.66 kg
Fuel use after 60% replacement	-	3681427.74 kg	16953 kg	5660626.8 kg
Where, H_p, H_D and H_{NG} are the lower heating value of petrol, diesel and NG respectively. Vehicle-km per day V_{km} = 17.2 km. Fuel use per vehicle-km F_{km} = 0.102 liter. (Table. 2) Specific Gravity of petrol S_P = 0.75. Specific Gravity of petrol S_D = 0.86				
Using the emission factors from Tables 3 and 4: CO_2 Emission = 28.78 kton; SO_2 Emission = 14.84 kg; HC Emission = 84.23 ton; CO Emission = 619.02 ton; NO_X Emission = 360.92 ton				

4 RESULTS AND DISCUSSIONS

4.1 CO_2 Emission

Out of all the gases being produced by human activities, the largest supplier to the greenhouse effect is CO_2. Because of the growing number of motor vehicles using liquid fuels, the amount of CO_2 in the atmosphere continues to grow. Control of the emission of CO_2 is thus an important issue. The most effective way to reducing the amount of CO_2 is to burn less liquid fuels and replace it by NG fuel. From the related works done earlier, it is obvious that NG produces much less amount of CO_2 20% compared to the liquid fuels. NG gas principally contains CH_4 and liquid fuels contain hydrocarbon. From the concept of chemical equilibrium, it is confirmed that for higher hydrogen to carbon ratio H/C of a fuel, the amount of CO_2 release is lower. CNG fuel has much higher ratio.The predicted amount of CO_2 emission from passenger cars per day using liquid fuel is shown in Figure 2. For year 2020, estimated CO_2 emission per day will be around 41.79 kton for using liquid fuels, which is simply huge for a fast developing country like Malaysia. Figure 2 evidently shows that this amount of CO_2 can gradually be reduced with the increasing use of NG fuel instead of petrol and diesel. About 23 percent of CO_2 emission can be reduced from operating passenger cars plying in Malaysia if all of them are converted to NGVs.

4.2 SO_2 Emission

A colorless gas SO_2 belongs to the family of oxides of sulfur SO*x*. It is the key pollutant that causes acid rain. Fossil fuel combustion is the main source of SO_2 emission. Many countries have enacted laws restricting the amount of sulfur to be allowed in a fuel, and the laws are continuously and more stringent updated. Petrol and diesel contain large amount of sulfur, which gets oxidized and produces SO_2. SO_2 combines with water that forms a sulfuric acid aerosol. The amount of sulfur contains in natural gas is almost nil. Therefore, use of natural gas as a viable alternate fuel is the most effective way of minimization of acid rain and other problems to the environment caused by sulfur. For uses of liquid fuels, passenger cars in Malaysia are producing huge amount of SO_2 everyday and it is increasing day by day. The predicted SO_2 emissions per day by passenger cars from 2006 to 2020 in Malaysia have shown in Figure 3. If the current rate of SO_2 emission continues, it will create a serious environmental problem in the near future. One of the best ways to save environment from this problem is to increase the uses of natural gas in transportation sector. Figure 3 also shows that significant amount of SO_2 emission can be reduced by fractional conversion of liquid fuel driven passenger cars to NGVs.

4.3 *N*O_x Emission

NO*x* is a collective term used to describe oxides of nitrogen, namely nitric oxide NO with a small amount of nitrogen dioxide NO_2 and traces of other nitrogen-oxygen combinations. NO_x is mostly created from nitrogen constituent in air. Presence of NO_x is one of the primary causes of photochemical smog, which has become a major problem in many large cities of the world. NO_2 plays a major role in the atmospheric reactions that produces ozone. Ground-level ozone is harmful to lungs and other biological tissues. It is also harmful to trees and plants, and causes billions of dollars of crop loss each year throughout the world (Willard W, 2004). Tables 3 and 4 shows that use of petrol in passenger cars produces large amount of NO_x compared to diesel fuel and natural gas. NG as a low emission fuels can play an important role to keep NO_x emission in lowest level. NO_x emissions per day produced by passenger cars have predicted for the period 2006 to 2020 and are shown in Figure 4. It is clear that NO_x emission is increasing with the increasing use of liquid fuels in transportation sector in Malaysia. This can be controlled by changing liquid fuel vehicles to NG vehicles. Figure 4 also shows the change of future NO_x emission scenario with the changed fuel mood. It is possible to reduce as high as 65 percent NO_x emission produces from passenger cars in Malaysia by converting conventional liquid fuel vehicles to natural gas vehicles.

4.4 CO Emission

Carbon monoxide is a colorless and odorless poisonous gas. It is produced inside the engine when there is not enough oxygen to convert all carbon to CO_2. Unburnt fuel produces CO. This CO emission has terrible impact on environment and human health. CO damages coronary arteries in the heart and cerebral arteries in the brain. Recent studies have proved that even a low concentration of CO can decrease the pregnancy rate. Table 4 also shows that emission factor of CO for production and distribution of petrol fuel is high 0.2403 g/kg compared to diesel 0.21 g/kg and NG 0.061 g/kg. Table 5 also shows that emission factor of CO for combustion of petrol fuel is very high 152.20 g/kg compared to NG 10.14 g/kg and diesel 4.34 g/kg. Reported earlier that as many as 99.6 percent of the total passenger cars in Malaysia use petrol as fuel. So, huge amount of CO is released to air every day. The emission of CO is increasing day by day because of the increasing number of passenger cars in use. Figure 5 exhibits that if the present state of use of liquid fuels continues; CO emission will reach to 1,761.41 ton per day in the year 2020. This figure is definitely frightening for environment and human life. The best solution to this problem is to reduce the use of petrol in motor vehicles. CO emissions from passenger cars for the uses of natural gas have also been estimated and are shown in Figure 5. The result shows that using natural gas as an alternate fuel can reduce CO emissions to an enormous extent about 93%.

4.5 HC Emission

Hydrocarbons HC, more appropriately organic emissions, are also the consequence of incomplete combustion of the hydrocarbon fuel. Table 3 shows that maximum HC emission caused from diesel vehicles 6.5 g/kg followed by petrol 4g/kg and natural gas 2 g/kg vehicles through combustion process. The rate of HC release is caused by the molecular weight of the respective fuel. The molecular weight of diesel 170-200 or petrol 110 is much higher than NG 16.04 (Heywood, 1988). Being lightweight fuel, NG can form much better homogeneous air-fuel mixture and NG engine runs with high combustion efficiency. On the other hand, Table 4 shows production and distribution emission of HC 9.7533 g/kg from NG is much higher than petrol 0.7743 g/kg and diesel 0.6594. HC emissions are mainly occurred due to gas CH_4 losses during production and distribution process (Lewis, C.A., 1997). As a result total HC emission will increase with use of NG in passenger cars. The future aspect of HC emission formed by passenger cars in Malaysia has been predicted and is shown in Figure 6. Study shows that HC emission will be about 2.5 times higher through 100 percent conversion of passenger cars from liquid fuels to natural gas. All HC components, except CH_4 reacts with atmospheric gases and form photochemical smog but the HC emissions from NGVs mainly CH_4, which is not harmful to the extent that is caused by HC emitted from liquid fuels.

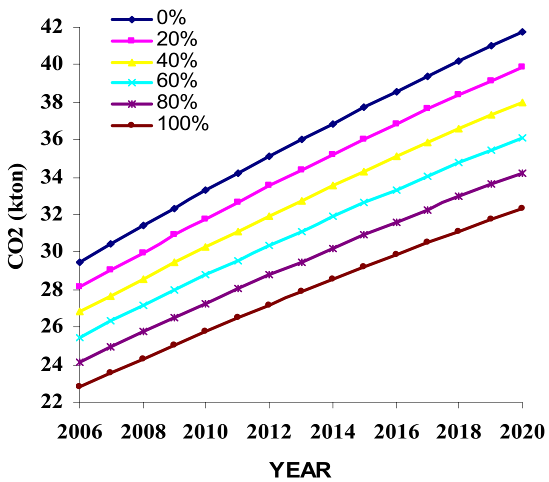

Figure 2. CO_2 emission pattern use of different percentage of NG.

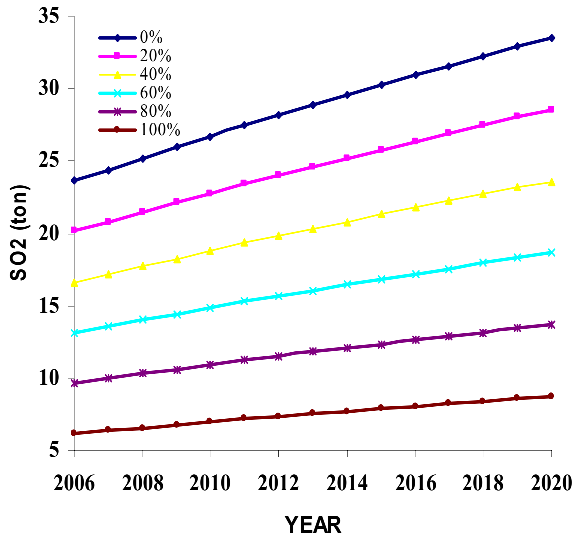

Figure 3 SO_2 emission pattern use of different percentage of NG

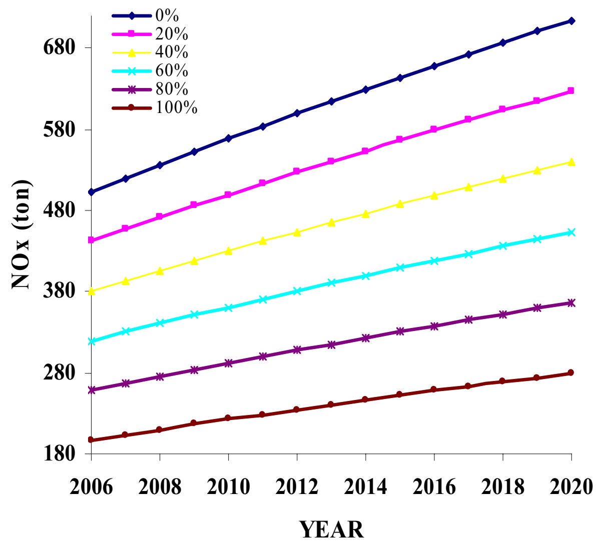

Figure 4 NO_x emission pattern use of different percentage of NG

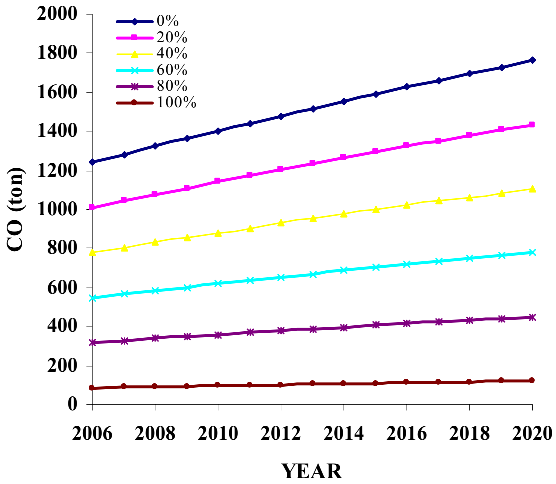

Figure 5 CO emission pattern use of different percentage of NG

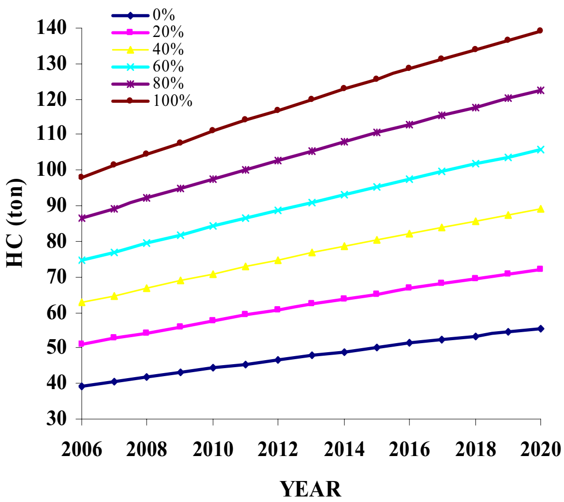

Figure 6 HC emission pattern use of different percentage of NG

5 CONCLUSIONS

Air pollution is a global concern. Malaysia, being one of the largest automobile manufacturers and users in Asia, the consumption of conventional fuels by motor vehicles such as diesel and petrol would significantly donate to air pollution in this country. The use of natural gas would provide a way to reduce the emission of air pollutants. Natural gas is a very environment friendly alternative car fuel. Besides, the use of natural gas as the future motor fuel will help the country's economy significantly, since Malaysia ranks twelfth in the world as per as natural gas reserve is concerned. Both the government and private sectors can increase their investments in improving infrastructures, and also to conduct more awareness campaigns regarding NGV benefits.

The results obtained in this study show that NG has much lower emission levels than gasoline or diesel fuels. The study revealed that from the use of NG as motor fuel, the air pollution reduction can be as high as 90 percent from passenger cars in Malaysia. This reduction would create a tremendous direct impact on the cleanliness of Malaysian air. This indication should be good enough for its policymakers to consider the use of NGVs.

However, more research should go on board in this area before it can be fully exploited. Typically, when a new idea is put forward, it takes a long time to disseminate the information to the public.

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