CHAPTER 1

INTRODUCTION

1.1 Background of Study

The reduction of CO_2 emission is probably one of the most talked about topics of this 21st century. This is due to its effect on climate change and global warming. From Previous research and studies by government and NGO's, the world is dying as a result of various Greenhouse gases (GHG) emission (IPCC, 2007b; IPCC, 2007a; NAS, 2008; Theseira, 2010). CO_2 is a greenhouse gas (GHG) and its increase, intensify the average surface temperature of the earth affecting the ecosystems, sea levels, water resources, agriculture, and global climate (CEC, 2002). In 1999, Malaysia became a signatory to the Kyoto Protocol and declares the country's agreement of the Protocol on 2002 under the UNFCCC (UN, 1998). However, as a developing country, Malaysia had no quantitative commitments under the Kyoto Protocol (Selamat & Abidin, 2010). Then in 2009 the United Nations organized a world climate summit, held in Copenhagen. In the summit, a Malaysian conditional proposal to reduce its CO_2 emission to 40% by the year 2020 as compared to its 2005 level was presented (Gruber, 2011; Mohamad, 2009). Nevertheless, to reach this predicted CO_2 reduction level, extensive action has to be taken in all contributing sectors. According to a report released by the Malaysian Department of Environment (MDOE) in 2010, the transport sector is one of the major contributing sectors estimated to contribute about 45% of CO_2 emission to the environment (Gallo, 2011). This could be attributed to the social demographic and behavioral patterns of the human luxurious lifestyle especially in Transportation; consistently this has resulted in a momentous burning of fossil fuel (Schipper, et al., 1989; NAS, 2008). Taking into consideration that the modes of transportation in Malaysia consist of buses; LRT monorail and airport express rail link, taxis and commuter rail. The emissions are evenly distributed, especially on the road sector, which dominates the mode of transport (National, 2008).

"Dato" Hajah Rosnani Ibarahim Director General, Department of Environment, Malaysia as at 2006" said**,** meeting the 40% target depends on domestic environmental awareness and individual compliance (Ang, 2010 ; Theseira, 2010). To this end, the Malaysian Road Transport Department (JPJ) considers CO_2 emission a potential threat to its vision of a sustainable environment by 2020. CNG fondly called NGV (Natural Gas Vehicles) in Malaysia is seen as a potential alternative fuel to gasoline, and from studies, Natural gas now powers more than 12 million vehicles globally and about 53,783 vehicles locally (Hasim, 2005; IANVG, 2011; ANGVA, 2013), Apart from Natural gas being relatively low cost than gasoline or diesel fuel. Natural gas vehicles show an average reduction in ozone-forming emissions of 80 percent compared to gasoline vehicles (MMD, 2009; IPCC, 2006). Shell Malaysia chairman Mohd Anuar Taib in one of his awareness campaign speeches said, emissions from fossil fuels are currently responsible for 60% of the world's total GHG emissions (Daud, 2005). To this end, the use of CNG vehicles on the Malaysian road as an alternative fuel to Gasoline seems to be a step in the correct direction.

1.2 Problem Statement

The use of CNG vehicles as a means of transportation in Malaysia, is hoped to reduce CO_2 exhaust emission, however, since its inception only few outcomes (results) on exhaust emission levels have been achieved.

The International Energy Agency (IEA, 2010c) released data shows that Global CO_2 emissions is on the increase and developing countries like Malaysia is seen as a major culprits of this increasing trend (IEA, 2010a). Malaysia a developing country with about 28.318 million people (MDS, 2010) has one of the highest carbon emission intensity due to rapid rise and robust expansion in its power, industrial, automotive and other sectors (Canadel, et al., 2010).

CO_2 is a Greenhouse gas and its increasing concentration contributes to global warming, examples of which Malaysia has experienced some significant increase in temperature and rainfalls as a side effect. However, Gasoline (Petrol) that contains high carbon content producing high amount of CO2 emissions to the environment is still the major fuel used on cars in Malaysia. According to JPJ (2012), the number of vehicles on the Malaysian road has been on the rise over the past eight years. This is on an average of approximately 520,000 new cars annually i.e. about 45 - 50% of which 90% are petrol fueled cars, but the increases in CNG fueled cars is still between 3 to 5% (MAA, 2013).

1.3 Objectives of Research

This study is conducted to buttress the fact that CNG fueled cars, produces less CO_2 exhaust gas emission as compare to Petrol cars. To this end, The Study focuses on two main objectives:

1. To study the significant difference in CO_2 emission from CNG and Petrol Vehicles operating on the Malaysian road.
2. To investigate the optimum performance level of CO_2 emission from cars reducible by the year 2020.

1.4 Scope and Limitations of Study

The focus of this study is on the amount of CO_2 emission reduced using CNG fuel on vehicles. This research focuses only on Cars (Commercial and passenger cars) excluding Motorcycles. It is also limited to cars running on petrol and CNG fuel excluding diesel.

This study was conducted experimentally on a Petrol fueled engine in comparison with a CNG fueled engine. For this purpose, Information's and results were collected from books, journals, Internet sources and some relevant Malaysian government bodies like Department of Statistic, Department of Environment and Department of Road transportation.

The experiments were conducted at the University Kuala Lumpur Malaysia, France Institute Automotive/Mechanical Engineering workshop in Bangi area during the spring of 2013. The experiments were carried out on two (2) vehicle engine types, the 4g15-carburetor engine and the 1.6 CAMPRO IAFM injector engine while a Bosch- BEA 050 exhaust gas analyzer was used to experimentally determine the amount of CO_2 emitted from the exhaust. Both the 4g15-carburetor engine and the 1.6 CAMPRO IAFM injector engine has been modified to run in the bi-fuel engine.

The study used the significant difference in CO_2 emission from CNG and Petrol Vehicles operating on the Malaysian road to investigate the optimum performance level of CO_2 emission reducible by year 2020.

1.5 Significance Of The Study

The Malaysian transportation industry considers CO_2 emission a potential threat to its vision of a sustainable environment by 2020 (JPJ, 2012).As a developing nation, the rapid level of Modernization, urbanization and industrialization has resulted in the transportation industry accounting for about 45% percent of all carbon dioxide (CO_2) emissions in Malaysia (Bari, et al., 2011; Wee, et al., 2008; Wei, et al., 2005), CNG vehicles in Malaysia is seen as an alternative fuel to Gasoline, majorly because CNG costs about 50% less than gasoline, emits up to 80% fewer emissions than gasoline and many more advantages (Bakar, 2008). However, since its inception, it is yet to achieve its full essence. Although, findings shows the Malaysian interest in CNG is gradually increasing especially among the road transportation sector (public transport like Taxis and Busses). United Nations data shows Malaysia's carbon emissions in year 2006 stood at 187 million tonnes or 7.2 tonnes from each Malaysian (Mohamad, 2009) while the numbers of NGV in Malaysia is still below 100,000 as against 12,139,275 total vehicles in Malaysia (excluding Motorcycles) with 174 stations as at June 2013 (ANGVA, 2013). Currently, there are several dedicated AFV options in existence, however, In Malaysia; CNG stands out with some significant qualities, this makes it a realistic option for large-scale deployment in the reduction of CO_2emission especially in the Transport sector. From a Global perspective, many countries like the United States, Ireland, China and India aim to reduce it greenhouse gas (GHG) emissions to a minimum level by year 2020 (G8, 2007). Natural gas stands the chance of being the initial fuel source to best achieve a sustainable energy future in Malaysia; due to its huge reserved availability which saw an increased from 315 billion cubic feet (cu ft) in 1990 to more than 1,260 cu ft as at 2010 (Chin, 2012). The International Energy Agency reported that the emission from fossil fuels is affecting the world Climatic condition, so managing CO_2 emissions especially from fossils fuel is essential in tackling climate change and should be done from all contributing sector (IEA, 2010b). According to Andrew Chan the executive director of PwC Advisory Services Malaysia, he points out that the first step in carbon management is to establish a baseline inventory, that is, to determine the level of carbon emitted to the atmosphere (Bari, et al., 2011). This will allow the transport industry to strategically identify and manage its carbon emissions considerably.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter talked about previous studies and researches relevant to this topic. It begins with the Malaysian concern on CO_2 emission in proper context with global initiatives; it explains how CO_2 emission relates to transportation as a contributing sector. Thereafter, CNG as an alternative fuel to petrol was reviewed as studied by other concerned researchers, government and NGO's Agencies.

2.2 CO_2 Emission Footprint In Malaysia

Malaysia as a developing country has one of the highest carbon emission intensity of GDP 1.4 million metric tons (MT) as at 2008 (MDOE, 2010)with about 28.318 million people its emissions growth is one of the fastest (MDS, 2010); it grew by 221 per cent from 1990 to 2004 accounting for about 0.6 per cent total share of global carbon emissions While its CO_2 emissions per capita (tCO_2) was at 7.5 per cent (UN, 2010). This rapid rise is as a result of the robust expansion in its power, industrial and automotive sectors together with the over dependence on fossil fuel as its Total Primary Energy Supply (TPES) (Canadel, et al., 2010). In 2009, the world climate summit, organized by the United Nations in Copenhagen saw about 200 nations and some other 45,000 participant at the sidelines gathered for two weeks attempting to forge a legally binding international environmental agreement with the goal of hammering out a meaningful and fair part to a carbon-free world. Though, not entirely successful, the end of the meeting saw leaders of the US and the BASIC group of countries (Brazil, South Africa, India and China) battering out a dramatic last-minute deal, which on the final day of the summit, produced, what became known as, the ‘Copenhagen Accord’ (UNFCCC, 2010). The Copenhagen Accord is noted as an informal setting, where each country says what it is prepared to do. Though non-binding and non-formal, it must be regarded as an important step forward because “Better a declaration than none at all”. The Malaysian Prime Minister Datuk Seri Najib Tun Razak delivered in the summit a Malaysian proposal to reduce its CO_2 emission to 40% by the year 2020 as compared to its 2005 level, subjected to assistance from developed countries in the form of technology transfer and adequate financing (Mohamad, 2009; Ang, 2010 ; ACIR, 2010, May 25). CO_2 emission; since becoming a subject of global interest has witness a high level commitment and development, gaining momentum amongst governmental and NGO’s in setting motion initiative targeted towards a carbon-free world. To this effect, most of the research done by automotive manufacturers, universities or research organizations has focused on how to reduce the CO_2 emission by improving the gasoline/diesel fuel engines (Bakar, et al., 2007c). However, its level of pollutant still threatens the main fabric of life in this planet. From a Global perspective, China and India aim to reduce emissions by up to 45% and 25% respectively by 2020 (A.D., 2005; UNEP, 2008). Some other countries like Ireland are imposing carbon taxes others like the United States and some European countries are intensifying their effort to make greenhouse gas (GHG) emission disclosure mandatory (G8, 2007) (Wee, et al., 2008). According to Andrew Chan the executive director of PwC Advisory Services Malaysia (Bari, et al., 2011), the first step in carbon management is to establish a baseline inventory; to this end, a paper has been written and presented on this topic ‘the reduction of CO_2 emission in Malaysia transport industry: using compressed natural gas as alternative fuel as shown in Appendix 3.

2.3 Carbon Dioxide (CO_2) Emission

CO_2 is one of the largest suppliers to greenhouse effect and this is due to cellular respiration and burning of fossil fuels by humans. According to NIOSH standards CO_2 is a naturally occurring atmospheric gas that is considered safe at levels below 0.5% (CCOHS, 2005; NIOSH, 1997.). This is because as a product, it is a colorless, odorless and a non-flammable gas with a molecular weight of 44.01g/mol (Shah, 2011). Although, without CO_2 and its greenhouse activity, the earth would be too cold to support life, however, Small changes in atmospheric CO_2 leads to much larger changes in the amount of energy trapped through greenhouse activity (Nelson, 2000) and external air factors are mostly related to the fact that CO_2 is denser than ambient air so therefore, tends to accumulate near the ground surface (Farrar et al. 1999). Thus, Control of the emission of CO_2 is taken as an important issue. The International Energy Agency (2010) released data shows that global CO_2 emissions is on the increase by 0.4 Gt CO_2 between 2007 and 2008, which represented a growth rate of 1.5%. According to the report, the culprits of this increasing trend are the developing countries like Malaysia (IEA, 2010a). United Nations shows that at 2006, Malaysia's annual CO_2 emissions stood at 187 million metric tons and it is equivalent to7.2 metric tons per capita per year (MDOE, 2010; Mohamad, 2009). According to the data, it shows that Malaysia is the third highest emitter in the Southeast Asian region behind Indonesia with 333 million metric tons and Thailand with 273 million metric tons. On per-capita basis, Malaysia also placed third in the SEA region with Brunei topped the list at 15.5 metric tons and followed by Singapore at 12.8 metric tons per capita (Netto, 2009). Over the past 100 years, the number of anthropogenic greenhouse gases emissions in the atmosphere is increasing yearly particularly carbon dioxide (CO_2) (Humlum, 2011).

2.4 Main Contributing Sector To Co_2 Emissions In Malaysia

The International Energy Agency (IEA, 2010c) released data shows that global CO2 emission is on the increase by 0.4 Gt CO_2 between 2007 and 2008, which represented a growth rate of 1.5%. And according to the report, the culprits of this increasing trend are the developing countries, of which Malaysia is not left out (IEA, 2010a). Human activity through industrialization, agriculture activity, power generation, and transportation are believed to be the main contributor of CO_2 emissions to the atmosphere (IPCC, 2007a). (Beniston, 2002). In 2011 further energy report shows that the energy sector contributed the largest anthropogenic carbon dioxide emissions with 41% of the entire world CO_2 emissions annually. Transportation sector comes next with 23%, industry and manufacturing sector with 20%, residential area with 6% and others at 10%(IEA, 2011b; Wee, et al., 2008). With emphasis on the 23% global CO_2 emissions by the transport sector, a recent OECD study reported that the global CO_2 emissions from transport grew by 45% from 1990 to 2007 and are expected to continue to grow by approximately 40% from 2007 to 2030 – though this is lower than pre-crisis estimates (National, 2008). Others includes commercial/public services, agriculture/forestry, fishing, energy industries and others too neumerous to mention (index, 2012). According to the Malaysian Department of Environment (MDOE), the Malaysia transport sector contributes 40% CO_2 emission to the environment due to consistent burning of Fossil fuel. This sector accounts for approximately 15% of overall greenhouse gas emissions (MDOE, 2010). 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. As reported by the Department of Environment Malaysia, only in 1996, the percentage of the emission loads from different sources to its air 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 (DOE, 2001). Obviously, huge number of passenger cars in use was the main source of atmospheric pollution in Malaysia.

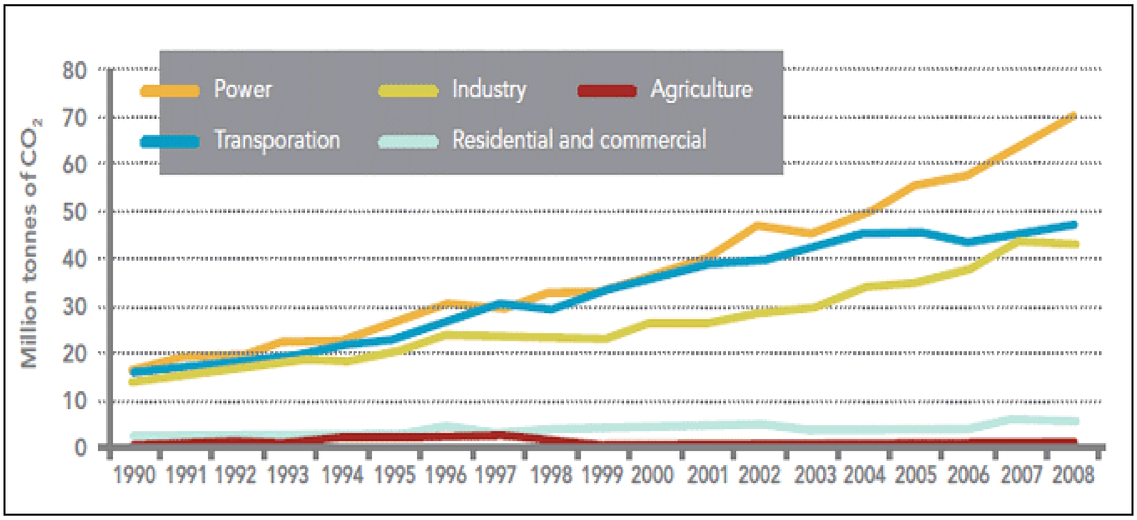

Figure 1: CO_2 emissions in Malaysia by sector, 1990-2008

Source: (Green Tec, 2008)

As distinctively shown in Figure 1, the breakdown of CO_2 emission by sector shows that transportation seconds the list by 45% of increasing from year 1990-2008. In 2005, Malaysia became a net emitter of greenhouse gases (Al-Mofleh, et al., 2009). The energy sector is the biggest source of emissions, with fugitive emissions from oil and gas systems accounting for 10 per cent of total emissions. Transportation generation is the largest emitting sector, accounting for 43 per cent of total emissions, and it is estimated that, without mitigation measures, 286 million tons of CO_2 will be emitted in 2020.

2.5 Environmental And Health Effects Associated With CO_2

2.5.1 Global Warming/ Climate Change Effects On Malaysia

Malaysia also has experienced some significant increase in temperature as a side effect of global warming. This could be as a result of Greenhouse gases (GHG) emission like CO_2, SO_2, NOx, CO and HC which aids in insulating the atmosphere thus depriving reflected gas energy from escaping the surface-troposphere system back to space resulting in "global warming/climate change" (Shah, 2011). The Climate Change report by IPCC (2006) stated that, since 1900, the global temperature has increased by 0.7°6C and It is predicted to continue with an increase of about 2°C between 1990 and 2100 (O'Sullivian & & Morrall, 1996). According to the Malaysian Meteorological Department, the mean temperature recorded between 1998 and 2007 saw an average upsurge of 0.5°C to 1.5°C recorded in Peninsular Malaysia, and an average upsurge of 0.5°C to 1.0°C in East Malaysia (BERNAMA, 2013). With this continual increase, the temperature is projected to increase further with an elevation of about 3.5°C by the end of the 21st century (MMD, 2009). Consequently, series of Floods were experienced in 2005, 2006 and 2007 hitting a few states that were not prone to flood until recent years, such as Johor and Sarawak with an estimated losses of about RM4 billion. According to national news agency BERNAMA (2013), the flood situation in Pahang, Johor and Terengganu had worsened with more than 9,000 people evacuated to Flood Relief Centers (FRC) These events could be linked to flared gases such as carbon dioxide (CO_2), methane (CH_4), Nitrous oxide (N_2O), sulfur hexafluoride (SF_4), Hydro fluorocarbons (HFCs), and Per fluorocarbons as a resultant agent (PFCs) (IPCC, 2006a; IPCC, 2007a). Although, from previous studies, carbon dioxide is not the most potent GHG among the list, but it is one of the largest generated anthropogenic source, which contribute to the issue of global warming and climate change.

2.5.2 Environmental Air Pollution In Malaysia

In Malaysia, emissions from motor vehicles have been 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). The Department of Environment Malaysia, in 1996, Reported a breakdown per sources in percentage, of the total emission exposed to the atmosphere, of the list was, 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 (MDOE, 1996). Obviously, from the list, huge number of motor vehicles in use was the main source of atmospheric pollution. These vehicles also discharge about 75 percent of the total CO and 76–79 percent of the oxides of sulfur and nitrogen. This resulted in the establishment of the Environmental Quality (Control of Emission from Petrol Engines) Regulation 1996 P.U. (A) 543/96 and Environmental Quality (Control of Emission from Diesel Engines) Regulation P.U. (A) 429/96 (MDOE, 1996). 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 (Afroz, et al., 2003). However, the amount of greenhouse gases emission by transportation sector has not yet been analyzed. 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. So in terms of reduction, Malaysia needs to reduce up to at least 38 million metric tons of carbon annually to achieve the 40% target by the Prime Minister (Ang. 2010).

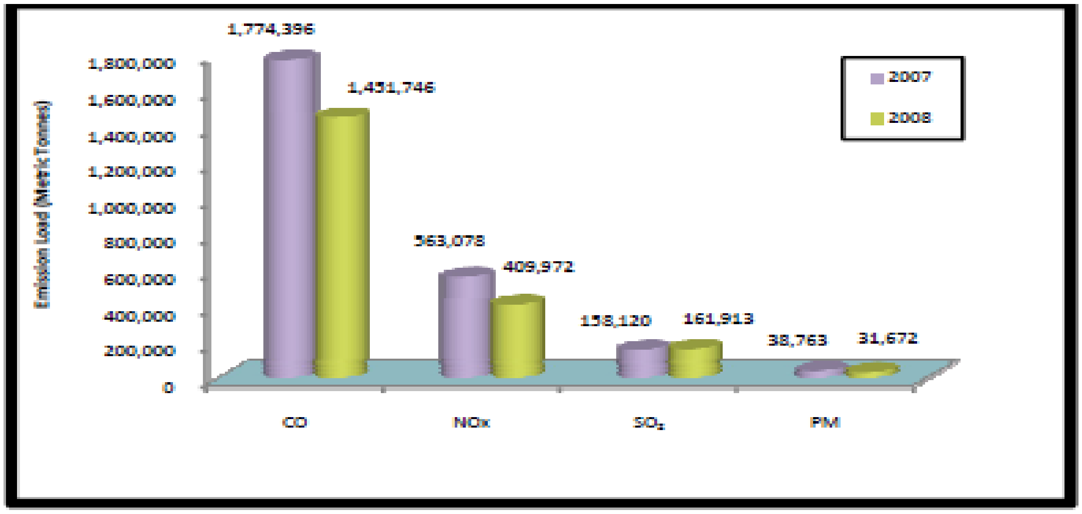

Figure 2: Malaysian Air Pollutant Emission Load from All Sources, 2007-2008)

(Sources: National, 2008)

The Malaysian government recognizes the extent, to which climate change would affect its citizen's wellbeing as well as threatened the sustainability of it natural resources, to this end, the governments are encouraging the use of alternative fuels in motor vehicle engines, and compressed natural gas CNG has proven a viable alternative fuel (Nylund, et al., 2002).

2.5.3 Human Health Effects Associated With CO_2 Exposure

In the atmosphere, CO_2 is present at 0.035% (350 ppm) and this poses no threat to human health, however, considerably higher concentrations produce adverse effects (Aerias, 2005). Preliminary evaluation of CO_2 effects in human populations suggests that acute exposure to CO_2 concentrations and prolonged exposure to concentrations may significantly affect the human health in a general population (Rice S.A., 2004; Nelson, 2000). A value of 40,000 ppm is considered immediately dangerous to life and health. Based on this fact, a 30-minute exposure to 50,000 ppm produces intoxication, and concentrations greater than that, produce unconsciousness, Coma, convulsions and death (NIOSH, 1997; IPCC, 2007).

2.6 Chronological Framework Of CNG Vehicles In Malaysia

2.6.1 Introduction of CNG as Alternative Motor Fuels in Malaysia

CNG also referred to as NGV (Natural Gas Vehicles) in Malaysia; was initiated during the late-1990s by PETRONAS. In 1984, PETRONAS NGV Sdn Bhd, a subsidiary of the state-owned Malaysian oil and Gas Company started the research and development of natural gas, by carrying out a feasibility study specifically to assess the viability of utilizing natural gas in the transportation sector (Daud, 2005; Das, et al., 2000). The study identified several benefits amongst which were its secured supply and environmental friendly characteristics to the country and consumers (Daud, 2005). Furthermore, between1986-1988; a pilot programme was formally initiated at the Gas Processing Plant in Kertih, Terengganu to help lay the structure for a commercial programme. Thereafter, One NGV refueling outlet was constructed and 21 PETRONAS owned vehicles were converted to bi-fuel operation (Daud, 2005). The result of the pilot programme proved successful that Natural Gas Vehicles (NGV) can operate favorably under the Malaysian condition with several benefits. Due to this great discovery, in 1991 the Government gave an approval to PETRONAS, encouraging the starting up of a Commercial Programme in Klang Valley to further improve the efficiency for a wider implementation of NGV in the country (Daud, 2005). Although as at then, there were little or no awareness, Six (6) stations natural gas refueling station under the Mother-daughter concept were established in the Klang Valley through the Natural Gas Distribution System (NGDS), supplied from the Peninsular Gas Utilization (PGU) project. At the same time, due to the limited gas network distribution in the country, a conventional station was established in Mire and by mid-1992, there were about seven fully operational stations and also a total of 930 vehicles were converted to bi-fuel operation, thereby monopolizing the provision of CNG to road users but as at then, marketing NGV was a big challenge due to customer's acceptance of the product. This was as a result of some sense of comfort with the traditional fuels and skepticisms on whether NGV is a reliable product as promoted. But later on, with various awareness campaigns and incentives placed on NGV by the government, the erroneous perception that NGV was "dangerous" was appropriately corrected. Although yet to have a total level of acceptability, the use of CNG in the Transport industry is still generally seen amongst taxicabs predominantly in the Klang Valley, Johor Bahru and Penang (EIA, 1998).

2.6.2 Development of Natural Gas in Malaysia

Natural gas production in Malaysia has been rising steadily in recent years; reaching about 1.89 Tcf in 2003.This is due to the fact that it has about 75 trillion cubic feet Tcf of proven natural gas reserves (Sun, et al., 1998). Also, Natural gas consumption is on the rise, in 2003 it was estimated at 1.008 Tcf, with LNG exports of around 0.882 Tcf mostly to Japan, South Korea, and Taiwan (EIA, 2005) (Aldrich & Chandler, 1997). 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 (Bakar, et al., 2007a). Construction began in 2002, and the delivery of natural gas into Malaysia began in the first quarter of 2005. Malaysia accounted for approximately 14% of total world LNG exports in 2003. In February 2000, PETRONAS signed a contract with a consortium headed by Kellogg Brown and Root for construction of the Malaysian LNG Tiga facility in Bintulu, Sarawak. Two LNG liquefaction trains and a total capacity of 7.6 million metric tons 370 Bcf per year were built and completed in April 2003. The Bintulu facility as a whole is now one of the largest LNG liquefaction center in the world, with a total capacity of 23 million metric tons 1.1 Tcf per year. In 2004, Shell brought two additional fields online, Jintan and Serai 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. As such this should serve as an incentive for further growth of NGV in Malaysia (Bakar, et al., 2007a).

2.6.3 Overview Of Compressed Natural Gas (CNG) As Fuel

CNG is one of the forms of Natural Gas used on vehicles that operates on natural gas as opposed to fuel-powered vehicles. There are typically two forms of natural gas: Compressed Natural Gas (CNG) and Liquefied Natural Gas (LNG) (Bakar, et al., 2009). Although all vehicles can run on both forms, most light to medium duty vehicles use the gaseous compressed form (CNG) since it is the most common form on-board storage of natural gas while Heavy-duty NGVs prefer LNG which allows them to store more fuel on board with less tank weight (Aldrich & Chandler, 1997). CNG occurs naturally and requires very little processing before use. From the gas field to the vehicle's engine, natural gas requires very little processing to make it suitable for use as a fuel. Gasoline and diesel must be processed from crude oil in large and complex oil refineries. After water vapor, sulfur and heavy hydrocarbons are removed, natural gas flows by pipeline directly to the central fueling station where it is compressed for use (Bakar et al., 2007b; Ismail et al., 2007).

Chemically, CNG is a naturally occurring mixture of hydrocarbon and non-hydrocarbon gas found in porous geologic formations; normally it consists of approximately 80 to 90 percent methane (CH_4) in gaseous form with other smaller amounts of ethane, propane, butane, carbon dioxide and other trace gases (Bakar, 2008) (Shasby, 2004). CNG is made by compressing natural gas to less than 1% of its volume at standard atmospheric pressure thus making it much safer than other fuels in the event of a spill. Noting that, pure methane contains a very high octane rating (120-130) and low carbon content this in turn results in low carbon produced during combustion.

Table 1: Natural Gas composition

(Source: Shasby, 2004; Bakar, 2008)

Composition	Formula	Volume Fraction (%)			
		Ref. 1	**Ref. 2**	**Ref. 3**	**Ref. 4**
Methane	CH_4	94.00	92.07	94.39	91.82
Ethane	C_2H_6	3.30	4.66	3.29	2.91
Iso-Butane	$i\text{-}C_4H_{10}$	0.15	0.21	0.11	-
Propane	C_3H_8	1.00	1.13	0.57	-
N-Butane	$n\text{-}C_4H_{10}$	0.20	0.29	0.15	-
Iso- Pentane	$i\text{-}C_5H_{12}$	0.02	0.10	0.05	-
N-Pentane	$n\text{-}C_5H_{12}$	0.02	0.08	0.06	-
Nitrogen	N_2	1.00	1.02	0.96	4.46
Carbon dioxide	CO_2	**0.30**	**0.26**	**0.28**	**0.81**
Hexane	$C_6+(C_6H_{14})$	0.01	0.17	0.13	-
Oxygen	O_2	-	0.01	<0.01	-
Carbon Monoxide	CO	-	<0.01	<0.01	-
Total	-	100	100	100	100

2.6.3.1 Advantageous Properties Of CNG Over Gasoline

CNG is a more environmentally clean fossil fuel to gasoline fuel, colorless, odorless, tasteless, non-poisonous, non-corrosive, inflammable and lighter than air (Bakar, 2008). CNG being lighter than air, tends to disperses and dissolve quickly when released therefore maintaining a concentration of 5% to 15% to trigger an explosion which is considered safe. It is also non-toxic, and has no potential for ground or water contamination in the event of a fuel release (Bakar, 2008; Yusaf, et al., 2010). Vehicles using CNG emits roughly 20% less carbon dioxide (CO_2) to an equivalent gasoline vehicle, this is due to its low volumetric energy density estimated to be about 25% that of Diesel fuel, CNG is compressed to a pressure of about 3000 to 4000 psi, or 205 to 275 bar and a temperature around -160°C to enhance the vehicle on-board storage in a cylinder (Aldrich & Chandler, 1997). Natural gas vehicles have an excellent safety record for two primary reasons: the properties of the fuel itself and the integrity of the natural gas vehicle when relating to its combustion properties (Kalam, 2007).

Table 2: Combustion related properties of gasoline & CNG

(Source: Bakar, et al., 2007a; Bakar, 2008)

Properties	**Gasoline**	**CNG**
Motor octane number	80-90	120
Research octane number	92-98	120
Flammability limits (volume % in air)	1.3-7.1	4.3-15
Density (kg/m^3)	1.38	1.24
Flammability limits (Ø)	1.3-7.1	0.4-1.6
Autoignition temperature in air (0C)	480-550	723
Minimum ignition energy (mJ)[b]	-	0.28
Flame velocity (ms^{-1})[b]	-	0.38
Quenching distance (mm) b	-	2.1
Adiabatic flame temperature (K)[b]	-	2214
Stoichiometric air-fuel ratio	14.6	16.79
Stoichiometric volume fraction %	-	9.48
Heat of combustion (MJ/kg_{air})[b]	2.83	2.72
Lower heating value (MJ/kg)	43.6	45.8
Molar mass (kg/mol)	110	16.04

2.6.3.2 Types of CNG in Malaysia

Currently, most of the CNG engine vehicles in Malaysia are converted from the gasoline engine; though fully made CNG vehicles are available, there are 3 main type of CNG fuel engine (Kalam, 2007).

1. **Bi-fuel CNG engine:** This is the most popular type of CNG engine use by taxis in Malaysia. It is developed from a conventional gasoline fuel engine and modified with ability to run on either CNG or gasoline/diesel (Kalam, 2007).
2. **Dual fuel CNG engine:** This type of engine can run on natural gas plus pilot oil or on diesel only. It can also switch back to conventional diesel operation. This is used in heavy-duty vehicle such as urban buses. However, this also contributes to high amount of emission due to the stop and start nature of urban buses (Kalam, 2007).
3. **Mono fuel CNG engine/ Dedicated CNG engine:** This type is designed to run solely on CNG. It is designed to optimize the advantages of using only natural gas as fuel. It has a better performance and lower emissions than bi-fuel vehicles (Kalam, 2007).

2.6.4 Current Research On CNG Fuelled Engine

A lot of theoretical researches, practical analysis have been carried out in the quest to further improve and encourage the use of CNG, however, the performance parameters of a four-cylinder diesel engine still stands out as a disturbing factor for CNG. Yusaf (2010) studied on the engine performance and emission of CNG and gasoline of a retrofitted car engine. From the results, at 80% throttle position, the CNG fuel produced 10.86% less brake power when compare to gasoline. Also discovered was that, the specific fuel consumption (SFC) for CNG fuel was always lower than that for the gasoline due to the slow burning and higher heating value of the CNG. The exhaust gas temperature of CNG was 24.21% higher than gasoline at 80% throttle conditions. This is because of the higher heating value and ignition temperature of the CNG compare to gasoline (Yusaf, et al., 2010), (Jahirul, et al., 2010). Consequently, from the research, focusing on the performance analysis of a 4-stroke SI engine using CNG, the volumetric efficiency of CNG fuelled engine was lower about 12.3% than petrol engine (Yusaf, et al., 2010; Shamekhi & Khatibzadeh, 2008) thereby leading to a reduction in the amount of oxygen in each cycle, therefore causing a lower engine torque and power compare to gasoline as fuel. This was due to the higher heating value and leaner combustion of CNG compared to gasoline but the thermal efficiency when using CNG as fuel shows an increase value of 32% at 2000rpm. This was caused by the higher CNG calorific value and lower engine fuel consumptions (Yusaf, et al., 2010). He also studied on the effect of fuel density on the performance of a CNG fuelled engine. Based on the result, they found that the CNG fuelled engine produced lower brake power compared with gasoline fueled engine. The power loss is due to low density of natural gas where gaseous form of fuel occupies a larger volume per unit energy than a liquid fuel. Other reasons were the low flame speed, lower cylinder pressure and high CNG temperature (Yusaf, et al., 2010). But generally the CNG vehicles now have specific lower fuel consumption and higher thermal efficiency, which serves as an advantage to diesel and gasoline (Jahirul, et al., 2010). In 1998, PETRONAS jointly manufactured 1000 monogas vehicle (dedicated CNG vehicle) and Enviro 2000 NGV taxis with the cooperation from MATRA of France (Daud, 2005). The engine and the CNG equipment's including the composite cylinder were proven to withstand the hot and humid climate and the traffic condition in Malaysia. A test was conducted and found that the emissions from the vehicles that have operated more than 400,000km are still able to meet Euro 2 standard (Ganesan, 2003). It was also explained that the specific fuel consumption varies with the load and speed. The overall performance of the engine depends on the inter-relationship between power output, speed and the specific fuel consumption.

2.6.5 NGV Usage Around the world

The use of natural gas began in the 1930s at a major geographical location called Po River Valley of Italy (Sperling, et al., 2009). As at 2011 the number of natural gas vehicles Worldwide has risen to about 14.8 million, The Asia-Pacific region foremost with about 5.7 million NGVs, followed by Latin America with almost 4 million vehicles (Mostafa, et al., 2005; Hasim, 2005).

Table 3: Number of NGV in Asia pacific

Source: (ANGVA, 2013)

S/n	Country	Total Vehicles	No. Of Station	Remarks
1	Iran	3,300,000	1,992	Apr'13
2	Pakistan	2,790,000	2,997	March '13
3	India	1,500,000	724	Feb ' 12
4	China	1,577,000	2,800	May '13
5	Bangladesh	220,000	585	Apr '13
6	Uzbekistan	450,000	213	June '13
7	Thailand	396,513	487	March '13

Table 3 continued: Number of NGV in Asia pacific

Source: (ANGVA, 2013)

8	Japan	42,590	314	March '13
9	Malaysia	53,783	174	June '13
10	Korea	35,872	190	Jan '12
11	Myanmar	30,005	51	May '12
12	Tajikistan	10,600	53	Dec '07
13	Kyrgyzstan	6,000	6	Dec '07
14	Australia	2,825	47	Jan '09
15	Indonesia	5,690	9	Dec '12
16	Singapore	5,522	4	Dec '11
17	United Arab Emirates	2,801	17	Apr '13
18	New Zealand	201	14	Dec '10
19	Philippines	71	3	Oct '11
20	Vietnam	462	7	July '12
21	Kazakhstan	3,200	2	July '12
		10,433,135	**10,689**	

From the Table 1 above, it can be deduced that half of the world natural gas vehicles and stations are in Asia Pacific and Top 10 NGV countries worldwide, 5 from Asia Pacific, with Iran leading the table with about 2.86 million NGVs and 1820 refueling station of about 1999 million. According to (Mostafa, et al., 2005), the growth in Iran's NGV market is as a result of its government policy to reduce the effect of sanctions on Iran and make the nation's domestic market less dependent on imported gasoline. The government plans to have a number of 4500 CNG refueling station in Iran by 2020 (Mostafa, et al., 2005). Although Malaysia seems to be in the list, it is seen that the numbers of NGVs in Malaysia still hasn't gotten up to 100,000.

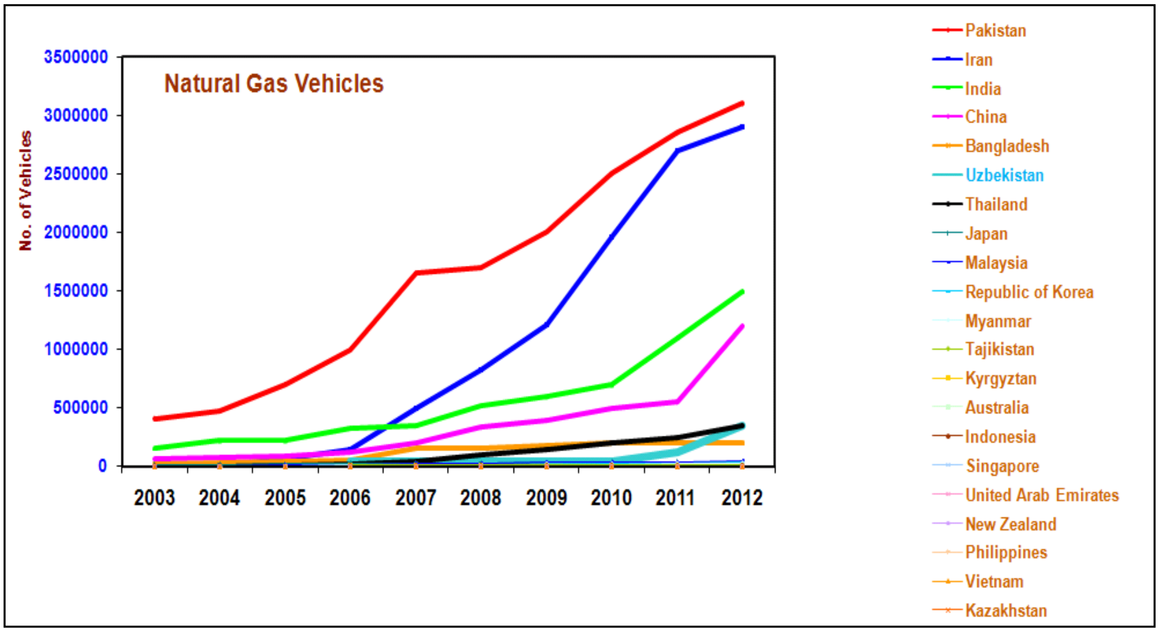

Figure 3: NGV Growth in Asia Pacific. 2003 – 2012

Source: (ANGVA, 2013)

From the Figures 3, 4 and 5, it can be seen that Asia pacific regions have drastically growth in the number of NGV at an average rate 24 % per annum of as well as the numbers of CNG refueling station with a 19% increase per annum. Asia pacific countries have turned to natural gas as the major alternative fuel in automotive sector due to its high natural gas reservoir in these countries (Hasim, 2005; ANGVA, 2013). Apart from the high natural reservoir, the main reason NGV is popular in this region is to reduce the air pollution from the emission of pollutants such as NOx, CO_2 and CO. Energy researchers found that there is a positive correlation between better lifestyle and higher energy consumption for individuals (Al-Mofleh, et al., 2009). Economic growth, social development and environmental protection are interdependent components sustaining developments and as well contributing to CO_2 emissions increase because as economies grow, the consumption of energy and resources grows (Beniston, 2002).

2.7 CNG Vehicle Usage In Malaysia Transport Industry

2.7.1 Number of Total Vehicles on the Malaysia Road

The number of vehicles on the road in Malaysia has been on the rise over the past eight years as shown in Table 3. On an annual average, there are approximately 520,000 new cars and 480,000 new motorcycles registered with the Malaysian Road Transport Department i.e. about 45 - 50% increase in vehicles (MAA, 2013; JPJ, 2012). In 2010, the then Transport Minister Datuk Seri Kong Cho Ha said, in total, the number of vehicles in Malaysia increased from 19,016,782 in 2009 to about 21.25 million in 2010 (NGV, 2012). This increase has resulted to a more demand on fuel usage and air pollution increased (EIA, 1998).

Table 4: Total Motor Vehicles in Malaysia year 2012

Source: (JPJ, 2012)

State	*Motorcycle*	*Motorcar*	*Bus*	*Taxi*	*Hire & Drive Car*	*Goods Vehicle*	*Others*	*Total*
PERLIS	66,684	21,055	208	199	5	1,865	1,430	91,446
KEDAH	773,671	292,997	3,334	3,739	775	36,275	20,156	1,130,947
PULAU PINANG	1,226,223	1,000,131	6,131	3,931	499	68,381	20,920	2,326,216
PERAK	1,190,091	687,213	4,982	4,518	73	66,323	39,055	1,992,255
SELANGOR	1,150,029	1,052,353	7,798	11,581	257	161,874	82,223	2,466,115
WILAH PERSEKUTUAN	1,536,607	3,332,767	20,112	39,394	15,586	222,683	153,413	5,320,562
NEGERI SEMBILAN	481,513	309,135	2,860	2,162	15	41,876	8,244	845,805
MELAKA	402,740	303,162	2,076	1,838	49	25,419	6,703	741,987
JOHOR	1,574,475	1,312,016	10,548	12,392	120	131,007	54,398	3,094,956
PAHANG	499,887	345,883	2,099	2,670	16	40,365	15,011	905,931
TERENGGANU	320,658	183,793	1,178	1,099	16	20,300	7,565	534,609
KELANTAN	452,800	267,542	2,055	2,006	13	26,731	8,300	759,447
SABAH	276,278	570,267	6,902	5,124	1,282	107,406	59,608	1,026,867
SARAWAK	638,162	676,364	3,253	2,387	590	81,499	62,823	1,465,078
MALAYSIA	**10,589,818**	**10,354,678**	**73,536**	**93,040**	**19,296**	**1,032,004**	**539,849**	**22,702,221**

From the ministry of transport Malaysia as stated in Table 4, the total numbers of automobile as at 31st December 2012 shows that there are about 22.7 million automobiles on Malaysian road i.e. to say, out of the 28.318 million Malaysians from statistics, there is one vehicle for every 1.2 Malaysians. Due to urbanization, these vehicles are concentrated in high-density locations such as the Federal Territories (Wilayah Persekutuan) recording the highest number of registrations of 5,320,562 vehicles in total, followed by Johor (3,094,956) and Selangor (2,466,115). Although Penang came fourth on the list with a total 2,326,216 vehicles, places like Perak and Sarawak, Sabah and Kedah seems to be increasing at a fast pace with each registering above 1 million vehicles as at 31st (JPJ, 2012). December 2012.Although the final listing for the year 2013 is yet to surface since the year hasn't ended, however, According to the Malaysian Automotive Association (MAA), As at September 2013, There were a total of 487,970 added new vehicles registered in the country as stated in Table 4.while statistical comparison between 2013 and its preceding year shown in Table 3 that the production and sales of both passenger vehicles and commercial vehicles witnessed some increase in variance (MAA, 2013)

Table 5: Production & Sales for September 2013

Source: (MAA, 2013)

Segment	**September**			**Year to Date September**		
	2013	**2012**	**Variance**	**2013**	**2012**	**Variance**
Passenger vehicles	48,411	40,235	1.20	430,488	403,890	1.07
Commercial vehicles	6,534	5,690	1.15	57,482	54,581	1.05
Total	54,945	45,925	1.20	487,970	458,471	1.06

The Malaysian Automotive Association (MAA) also gave a press release on the market performance, in September 2013;the Sales volume was 3,839 units or 8% higher than the previous month. YTD September 2013 TIV registered a growth of 29,499 units or 6% higher compared to similar period in 2012 (MAA, 2013).

According to 1Gas Malaysia, it was estimated that these various vehicles run on the various amount of fuel per year, so going by their estimate.

Table 6: Review of New P&C Vehicles registered in Malaysia as at Sept. 2013

Source: (MAA, 2013).

Year	Passenger Vehicles	Commercial Vehicles	4x4 Vehicles	Total Vehicles
2005	416,692	97,820	37,804	552,316
2006	366,738	90,471	33,559	490,768
2007	442,885	44,291	-	487,176
2008	497,459	50,656	-	548,115
2009	486,342	50,563	-	536,905
2010	543,594	61,562	-	605,156
2011	535,113	65,010	-	600,123
2012	552,189	75,564	-	627,753
YTD SEPTEMBER 2013	430,488	57,482	-	487,970

Note:

1. Passenger Vehicle industry reclassified in January 2007 and includes all passenger carrying vehicles. I.e. Passenger Cars, 4WD/SUV, Window Van and MPV models.

2. Commercial Vehicles also reclassified on 1 January 2007 and include Trucks, Prime Movers, Pick-up, Panel Vans, Bus and Others (MAA, 2013).

From **Table 6,** Sales of passenger vehicles in September 2013 recorded a considerable increase number of 430,488 units so also was the Sales of commercial vehicles of about 57,482 units as compared to the total sales in 2009 Meanwhile, the Malaysian Automotive Association (MAA) said year-to September 2013, the total industry volume registered a growth of 29,499 units, or 6% higher compared with the similar period last year. This increase was due to the launches of new models vehicles and market conditions returning to normalcy (MAA, 2013). MAA said, the sales volume was expected to be higher as the year progresses to an end due to year-end promotions and campaigns.

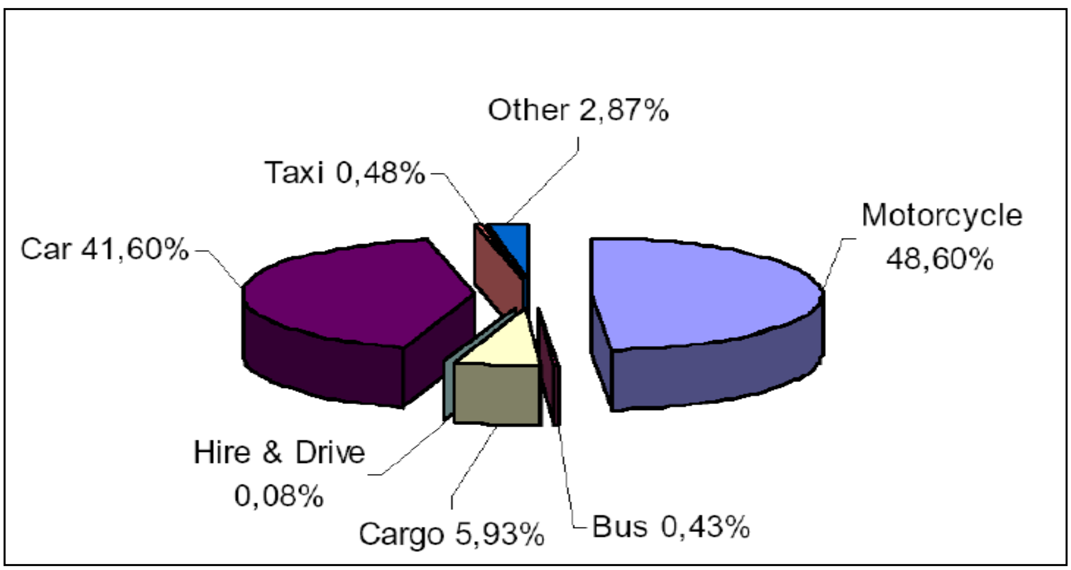

Figure 4: Types of vehicles usage in transportation sector of Malaysia

Source: (Masjuki, et al., 2005)

Figure 5 shows that of the total number of vehicles in Malaysia, majority proportion of vehicles stands at 48.60 percent motorcycles and 41.60 percent passenger cars.

However, fuel consumption of motorcycles is much lower than that of passenger cars and CNG is not yet been used in motorcycle engine.

Table 7: Average of fuel usage per Vehicle in Malaysia

Source: (ONE gas NVG, 2009)

No.	**Type of Vehicle**	**Average of fuel use per vehicle per year**
1.	Cars	25,000 litres/year
2.	Buses	43,000 litres/year
3.	Dump Truck	27,000 litres/year
4.	Long Haul Truck	80,000 litres /year
5.	Rim pull Truck	1,500,000 litres/year

According to the Annual Average fuel usage per vehicle stated in Table 7, it would be appropriate to multiply the average amount of fuel used per vehicle yearly to the numbers of vehicles available in Malaysia because this could help to ascertain and calculate the level of CNG fuel consumed over the years and also helps to determine an estimated amount of CO_2 emission from gasoline and NGV fuel vehicles till the vision is meant at 2020.nevertheless, in this study, a vivid experimental resolution would be achieved to help justify the expected reduction level.

2.7.2 Number of NGV on the Malaysia Road

The number of natural vehicles in Malaysia is gradually but slowly increasing; this is due to the rising price of gasoline. Late this year, the price of gasoline was increased from RM 1.95 to RM2.10 (lee yen mun, 2013). The Malaysian government has also implemented a few components to encourage the use of CNG as alternative fuel but the commercialization of CNG vehicles in Malaysia is far behind compare to other country like Argentina, Brazil and Pakistan. As fuel subsidies were gradually removed in Malaysia starting June 5, 2008, the subsequent 41% price hike on petrol and diesel led to a 50% increase in the number of new CNG tanks installed (Bakar, 2008). National carmaker Proton Snd. Bhd. considered fitting its Waja, Saga and Persona models with CNG kits from Prins Auto gas system by the end of 2008 (Durell, 2010). According to Dr Xander Thong, CEO of Hijau MOG Sdn Bhd, NGV conversion company, he said as at 2008,his office received almost 1,000 calls and the demand for system conversion showing an increase of about by 500% due to the propose gasoline fuel price rise (Durell, 2010). Therefore to ascertain the level of growth of NGV's in Malaysia, it would be nice considering the total number of NGV's to the Total number of vehicles in Malaysia as shown in Table 4.Currently, there are over 50,000 NGV vehicles (ANGVA, 2013). This shows quite a level of acceptance, although most of the NGV in Malaysia are mainly being operated on Bi-fuel CNG engine converted from conventional gasoline engine. The main users are generally taxis and busses.

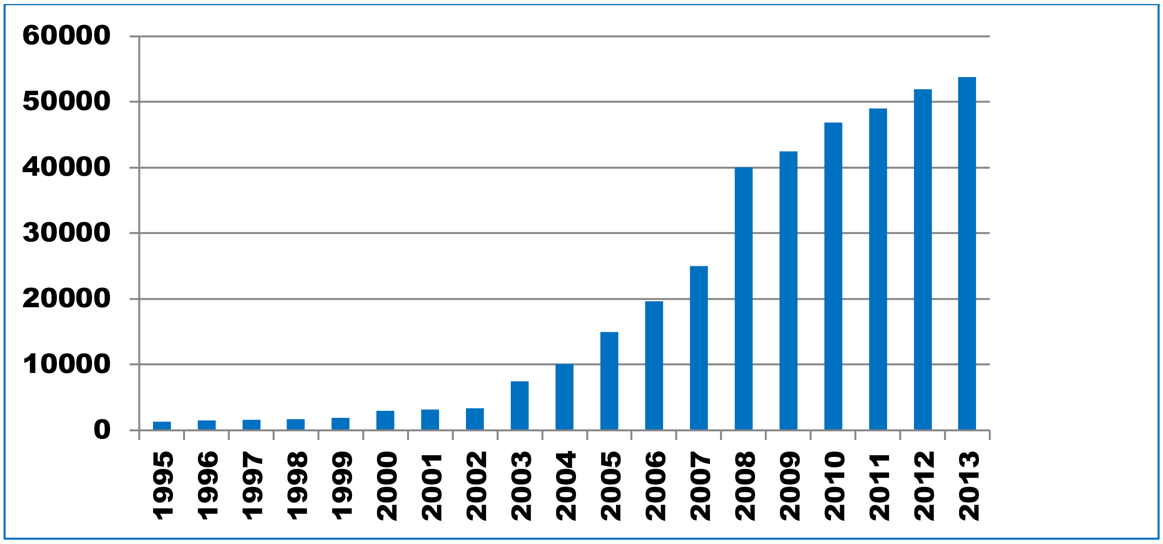

Figure 5: The total number of NGV used in Malaysia from 1995 to 2013

Source: (ANGVA, 2013; ONE gas NVG, 2009)

As shown in Figure 6, the estimated numbers of NGV in Malaysia is still below 100,000 though growing at approximately 5% per annum of which 90% are taxis (NGV, 2012). The Deputy Minister of Domestic Trade, Cooperatives and Consumerism, Rohani Karim said as at May 2011, there were only 46,000 motor vehicles using NGV in peninsular Malaysia. In June 2012, PETRONAS NGV Sdn Bhd organized an NGV PETRONAS Safety Awareness Campaign with the cooperation of the Domestic Trade, Cooperatives and Consumerism Ministry. there the CEO of PETRONAS NGV Sdn Bhd, Akhbar Md Thayoob said The use of NGV in the country increases by five per cent each year and as at 2012,the country has about 50,000 vehicles running on Natural gas with 90 per cent comprising of taxis (Star, 2011).

2.7.3 Government Incentive & Legislations To Encourage NGV Usage

The government of Malaysia supports NGV with incentives, policies and legislation to encourage its owners. As a result of energy security and improved emissions discovered from CNG'Vs, in 1993 and 1995, the government implemented various incentive programs to make ownership of CNG'Vs more appealing and less expensive (Bakar, et al., 2009; Afroz, et al., 2003).

1. The price of NGV cannot exceed 50% on the price of premium grade petrol
2. There would be import duty and sales tax exemption on conversion kits in other to ensure a reasonable price of conversion kits.
3. Execution of 25% reduction of road tax for bi-fuel and dual fuel vehicles
4. Execution and implementation of 50% reduction of NG fuel price to premium grade petrol for monogas vehicles (Daud, 2005).

In 2005, The Commercial Vehicle Licensing Board also passed a regulation that 25% of new taxi fleets (with new permits) have to be on NGV and new taxis (replacing old taxis) are compulsory to be on NGV.A certification program was established for NGV technician reinforcing the advantage of environmental friendliness (Bakar, et al., 2009; Daud, 2005).

2.7.4 NGV Price to Gasoline Price Comparison

Malaysians are gradually beginning to realize the impact CNG vehicles contributes towards Carbon Dioxide (CO_2) reduction in Malaysia, but the main motivating factor and reason Malaysians uses CNG as alternative fuel is its reduced price as compare to petroleum. As on date the price of petrol in Malaysia is RM 2.10 per liter and the price of NGV Gas is RM 0.68 cent/liter (lee yen mun, 2013).

There is a clear difference of 65 % between the two fuels. So, the simplest way to calculate the amount of money that you can save by converting your vehicle to NGV is to multiply the amount of money that you spend on petrol by 65 %. For example, if you spend about RM 500 on petrol every month, then you save RM 325 (500 x 65 %) per month on your fuel bill. For every year you save RM 3900 (325 x 12). (Bakar, et al., 2009).

Table 8: Fuel Expenses for 3,000 KM

Source: (NGV, 2012)

COMPARISON	PETROL	NGV GAS	SAVE (RM)
Price(RM/Liter)	RM 2.70	RM 0.68	RM 2.02
Costs of Fuel	RM 810.00	RM 204.00	RM 606.00

Table 9: Total saves in RM

MONTH	TOTAL SAVE (RM)
12 Months	RM 4,464

2.7.5 CNG Refueling Stations in Malaysia

As the consumption of CNG increases nationwide, the fueling infrastructure for natural gas vehicles continues to grow. Currently, there are about 174 NGV refueling stations to cater for more than 50,000 NGV vehicles across in Malaysia (ANGVA, 2013). The natural gas is supplied to NGV stations through natural gas pipeline (conventional system) or trailers (mother-daughter systems) made possible by PETRONAS. Where there was limited availability of natural gas pipelines in strategic areas, the Mother – daughter NGV refueling system caters for these areas. According to (BERNAMA, 2013), The Malaysian government plans to have 200 natural gas vehicle filling stations operative throughout the country by 2014 (NNA, 2011a). also reported as at 2012 is that PETRONAS NGV Sdn Bhd, is to open 10 more natural gas vehicle (NGV) refueling stations, planned for completion by 2014, this announcement was made by PETRONAS NGV CEO Akhbar M Thayoob at a PETRONAS NGV Safety Awareness Campaign event co-hosted by the Ministry of Domestic Trade, Cooperatives and Consumerism Ministry (Ministry) at an NGV station in Berendam, Melaka on 28 September (NNA, 2011a) (NGV, 2012). According to Petekma (association for taxi drivers and taxi/limousine operators) deputy president Mohd Shahrir Abd Aziz,he said as at 2008,because of the monopoly enjoyed by PETRONAS in selling natural gas there are limited number of stations supplying gas for cars (Rashvinjeet, 2008). On consideration, The Malaysian NGV Sdn Bhd with plans to open 200 CNG stations nationwide with a brand name of "1Gas Tenaga Bersih Untuk Semua" or 1Gas Clean Energy For All, was given a permit to market and distribute NGV in Malaysia (ONE gas NVG, 2009), Under this 1Gas station concept, the managing director of 1Gas Stesen NGV, Rahmat Ahmad said investing is open to the public and Landowners with a strategic land measuring more than 33,000 sq ft in encouraging them to participate as entrepreneurs with an estimated monthly income of RM30,000 to RM50,000. (NNA, 2011a) (BERNAMA, 2013).

2.7.5.1 Home refueling options for CNG

In 2005, the Fuel Maker Corporation of California produced a home refueling appliance named "Phill". In that year, Waterland, L.R.; Powars made a Safety Evaluation of the Fuel Maker Home Refueling Concept. It was found safe according to the report, Although not implemented yet in Malaysia, it is Seen as a mile stone achievement because with device like this, CNG vehicle owners can refuel their vehicles overnight in their own home, therefore it is getting popular around the world in places like the united states of America and Germany who are potential high users of NGV's. (Waterland, et al., 2005).

2.7.6 CNG Vehicles Conversion

Most of the NGV in Malaysia are converted from conventional gasoline vehicles to bi-fuel vehicles. To date, 110 service centers for NGVs are in operation nationwide currently 60% of total taxis in Klang Valley have been converted (Bedi., 2008-06-08). About 300 conversions are recorded every month and the numbers are on the rise. It is targeted for all taxis and heavy-duty market in Klang Valley, Penang and Johor to be converted by Year 2020 (Daud, 2005) (Vinesh, 2008-06-25) (Perumal, 2008-06-13). Though all gasoline-based or diesel based engine cars can be fitted with the NGV system, you would need the right components for each particular vehicle models since no major modification is done on the engine. During conversion, the main factors to consider before conversion are the costs associated with the conversion and the expected gains. This usually cost between RM3000 to RM5000 covering the cost for Components as shown in figure 7.but before that, one must go through the first and second stage as shown in Figure 6.

1. **First Stage**

2. **Second stage**

Figure 6: Natural Gas Installation Procedure Flowchart

Source: (Suria NGV, 2012)

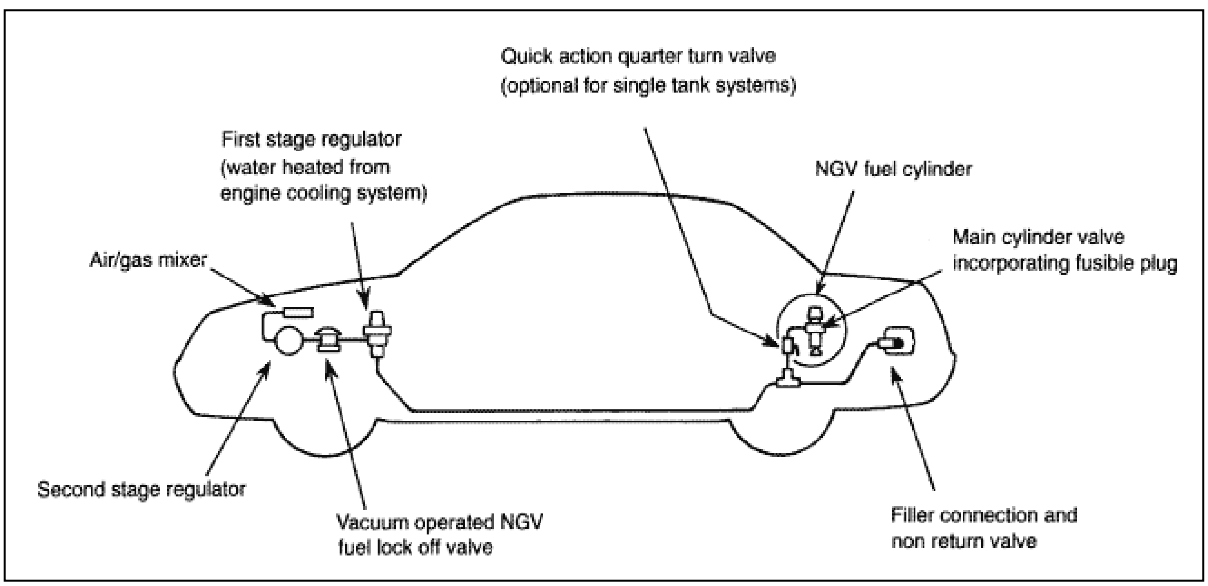

Figure 7: Showing components of an NGV vehicle

Source: (Suria NGV, 2012)

The six main component parts fitted to the vehicle are:

1. The filler connection, which incorporates a non-return valve.
2. The NGV storage cylinder together with a cylinder valve fusible plug.
3. A first stage regulator reducing the pressure from 20MPa to approximately 0.7MPa.
4. A vacuum fuel lock-off valve, which stops the fuel flow when the engine stops.
5. A second stage regulator, which further reduces the pressure.
6. An air/gas mixer that measures airflow of gas into the engine.

There are three types of conversion kit technology system on vehicles (Suria NGV, 2012; Bakar, et al., 2009).

1. Carburetor kit System – This is an Electronic CNG kit for carburetor cars, consisting of electronic CNG converter, switches with gas starting automatic priming and gas level indicator, petrol solenoid valve, manometer, filling valve, and pipe set (NGV, 2012).
2. Catalyzed Injection kit System - Electronic CNG kit for catalyzed injection cars, consisting of electronic CNG converter, switch with petrol starting with selectable acceleration and deceleration change and gas level indicator, gas control mechanism, manometer, filling valves, and pipe set.
3. Sequential Injection kit System- Sequential injection gas conversion system is designed to fuel motor vehicles with CNG in gaseous state. It can be used for both “full group” and “phased” systems. The electric injector control, whether single or multiple, is automatically determined by the control system during the adjustment

phase. This product is the most modern and technologically advanced system today available on the market (Bedi., 2008-06-08; Star, 2008a).

More importantly, it should be noted that, CNG on vehicles works best in an injector fuel engine because it has a longer mixing time. CNG is also occasionally mixed with hydrogen (HCNG) to increase the H/C ratio of the fuel, raising the flame speed eight times higher than CNG. Though, this alternative needs further technical improvement; the use of natural gas in internal combustion engine is relatively mature (Bakar, 2008; Star, 2011a).

2.8 Vehicle Engine combustion and Exhaust Emissions

2.8.1 Vehicle Exhaust Emissions

Vehicle exhaust gas emissions are results from fuel engine combustion (Crypton, 2012). There are two types of engine combustion namely:

1. Complete (Good) combustion
2. Incomplete (bad) combustion

Figure 8: Showing vehicle exhaust smoke

Source: (MAI, 2013)

1. Complete (Good) combustion. The design is to accurately burn up all the petrol inside the combustion chamber, using various hydrocarbons (combinations of hydrogen and carbon atoms), Together with lots of air, which contains oxygen and mainly nitrogen of about 78%. The air expands with the heat, assisting to push down the piston. Thereafter, the combustion chamber brings out carbon dioxide, water and nitrogen. CO_2 (contains one carbon atom in combination with two oxygen atoms). The water is represented by H_2O, two hydrogen atoms combined with one oxygen atom. And then all the nitrogen that came in is puts out (Crypton, 2012).

In troubleshooting, the complete chemistry combustion equation is consists of Fuel (hydrogen, carbon, sulphur) = Air (nitrogen, oxygen) = Carbon dioxide + water vapour + oxygen + carbon monoxide + hydrocarbon + oxides of nitrogen + sulphur oxide which is simply represented as:

$$Complete\ Combustion = \mathbf{HC + O_2 + N_2 = H_2O + CO_2 + N_2}$$

2. Incomplete (bad) combustion: This is where the wrong things happen, and the by-products of combustion produce gases, which contribute to air pollution or other problems. In practice it’s impossible for even the best-tuned engines to obtain Complete Combustion, so Incomplete Combustion is inevitable. Incomplete Combustion produces raw gasoline of HC, which goes in, then comes out, and isn't burnt up in the process. Another example is Carbon Monoxide (CO). It doesn't create smog, but it's deadly. A third example is Oxides of Nitrogen (NOx). It helps create out brown smog (Crypton, 2012).

2.8.2 Exhaust Greenhouse Gas Emission

Exhaust greenhouse gases exposed to the atmosphere are carbon dioxide CO_2, sulfur dioxide SO_2, nitrogen oxide NOx, carbon monoxide CO and hydrocarbons HC. The Use of a Gas Exhaust Analyser can help troubleshoot emissions concerns. The analyser's measures five exhaust emissions gasses which are: HC, CO, CO_2, O_2, and NOx. The estimated amount of CO_2, SO_2, NOx, CO and HCs generated from petrol, diesel and natural gas by passenger cars per day have been calculated by (Jahirul, et al., 2007). Using the exhaust analysis, he looked at what came out of the car exhaust to figure out what caused those emissions. From clues and patterns of exhaust readings, the exhaust analyzer could be used to figure out if there are problems in areas like: Air/Fuel Ratio, Combustion, Ignition and Emission Control Devices before running a diagnosis and functional tests. Emission factors of fuel production and combustion on vehicles is collected from earlier works by Masjuki (2005) and tabulated in tables 10 for one kg of fuel use. Also calculated were the estimated amount of CO2, SO2, NOx, CO and HCs generated from petrol, diesel and natural gas by passenger cars per day Jahirul (2007).

Table 10: Exhaust gas emissions by cars using three different fuel types

Source: (Masjuki, et al., 2005; Jahirul, et al., 2007)

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

Demand of petrol and diesel fuels was calculated for the predicted number of passenger cars from period 2006 to 2020.The Fuel use per vehicle kilo-meter and mean trip length of a vehicle per day in km was assumed constant as 17.2 km per day According to HNDP study (Masjuki, et al., 2005). From table 10, NG equivalents to petrol fuel consumption has also been estimated based on lower heating value of the respective fuels. The lower heating values of petrol and diesel were considered 44.5 MJ/kg and 42.0 MJ/kg respectively and that of NG was 43.6 MJ/kg. Form finding as shown in table 11, the total estimated emission from petrol, diesel and NG per day have been calculated separately and then added for year 2010 with an assumption of 60 percent replacement of the petrol and diesel by NG.

Table 11: A sample calculation of Fuel used by three different fuel types

Source: (Jahirul, et al., 2007; Masjuki, et al., 2005)

No of cars	Estimated Total	Petrol (99.6%)	Diesel (0.4%)	Equivalent NGV & NG fuel consumption
	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	$N_p \times V_{km} \times F_{km} \times S_P$ = 42382.7 kg	$\frac{W_P \times H_P}{H_{NG}} + \frac{W_D \times H_D}{H_{NG}}$ = 9434378.66 kg
Fuel used 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 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				

2.8.3 Gases Measured By The Gas Analyzer

There are six gasses measured by a gas analyzer as discussed below.

1. HC (Hydrocarbons)

Hydrocarbons (HC) are produced as a result of unburned fuel due to incomplete combustion. The rate of HC release is caused by the molecular weight of the particular 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 with high combustion efficiency (Crypton, 2012). An HC emission happens due to gas CH4 losses during production and distribution process (Lewis, 1997). All HC components, except CH4 reacts with atmospheric gases and forms photochemical smog but the HC emissions from NGVs mainly CH4 is not harmful to that is caused by HC emitted from liquid fuels.

2. CO (Carbon Monoxide)

Carbon monoxide is a colorless and odorless poisonous gas produced inside the engine by Partially Burned fuel, i.e. the fuel combust but not completely. As a result, an overly rich mixture preparation of an excessive CO content is formed. The CO should have become CO_2 but due to lack of time or insufficient O2 to become real CO_2, it is exhausted as CO instead.) 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 (Crypton, 2012). 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 (Bakar, et al., 2007a).

3. CO_2 (Carbon Dioxide)

Carbon dioxide is also a colorless and odorless poisonous gas as stated above but this is produced from Completely Burned fuel. This represents the engine combustion efficiency of how well the air/fuel mixture is burned. It is commonly 1-2% higher at 2500 RPM than at idle speed. This is due to improved gas flow consequential to better combustion efficiency. Maximum is around 16%. Therefore, as the growing number of motor vehicles using liquid fuels increases, the amount of CO_2 in the atmosphere continues to grow. Related researches done earlier have shown that NG produces much less amount of CO_2 20% compared to the liquid fuels (Bakar, et al., 2007c). 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 estimated amount of CO_2 emission per day will be around 41.79 kton. (Jahirul, et al., 2007)

4. O_2 (Oxygen)

O_2 occurs in the exhaust when there is an excess of air in the mixture. In combustion, O_2 content increases sharply as soon as Lambda rises above 1. Oxygen content is a clear indicator of the transition from rich to lean mixture range, or leaks in the manifold or exhaust systems as a result of combustion failures (Crypton, 2012). With rich mixture most of the O_2 is burned during combustion except some very lean O_2 which escapes "un-combusted".

5. NOx (Oxides Of Nitrogen)

NO*x* is a collective term used to describe oxides of nitrogen, namely nitric oxide NO with a mixture of nitrogen dioxide NO_2 and other nitrogen-oxygen combinations. NOx emissions rise and fall in a reverse pattern to HC emissions. As the mixture becomes leaner more of the HC's are burnt, but at high temperatures and pressures (under load) in the combustion chamber there will be excess O_2 molecules which combine with the nitrogen to create NOx (Crypton, 2012). This gas is related to the exhaust gas detoxification and recirculation systems. NO_2 is harmful to the human lungs and other biological tissues (Willard W, 2004). NOx emission increases with the increasing use of liquid fuels in transportation.

6. A/F Ratio Or Lambda

Air/Fuel Ratio or Lambda value is calculated based on the concentrations of HC, CO, CO_2 and O2. The stoichiometric (ideal) A/F is 14.7 liters air to 1 liter fuel or 14.7/1. The ideal Lambda value is 1(one) and below that the A/F mixture is rich and if above, it is lean. For example, lambda=0.6 corresponds to an air/fuel ratio of (0.6x14.7): 1=8.82:1 (e.g. lambda 0.6 = A/F ratio of 8.82/1 or very rich air fuel mixture) (Crypton, 2012). An ideal mixture is 14.7 pounds of air to 1 pound of gasoline for the cleanest burning. 14.7:1 stoichiometric ratio is the air to fuel ratio at which there is enough air to completely burn certain amount of fuel.

2.8.4 Other Gases Not Measured By The Gas Analyzer

There are a few other exhaust components which impact driveability and/or emissions diagnoses that are not measured by workshop Gas analyzers. They are: Water vapour (H2O), Sulphur Dioxide (SO2), Hydrogen (HO), Particulate carbon soot (C) (Crypton, 2012).

2.8.5 General Rules of Emission Analysis

1. If CO increases, O2 decrease, and conversely if O2 increases, CO decreases. This is because CO readings indicate a rich running engine while O2 readings indicate a lean running engine. So also, if HC goes up as a result of a lean misfire, O2 goes up
2. Due to an air/fuel imbalance or misfire, CO2 will decrease in any of the above cases.
3. If CO goes up, this does not necessarily mean HC will increase. However an Added HC will only be formed at the point where rich misfire begins (3% to 4% CO)
4. High O2, high HC and low CO at the same time show a misfire due to lean diluted mixture. Then, if O2, HC, CO are all high ,it shows a misfire due to rich mixture
5. Mechanical engine problem or ignition misfire normally leads to high HC, slightly low CO and high O2 (Exaust A, 2010).
6. The graph below examines the effects A/F mixture has on exhaust gas Output level.

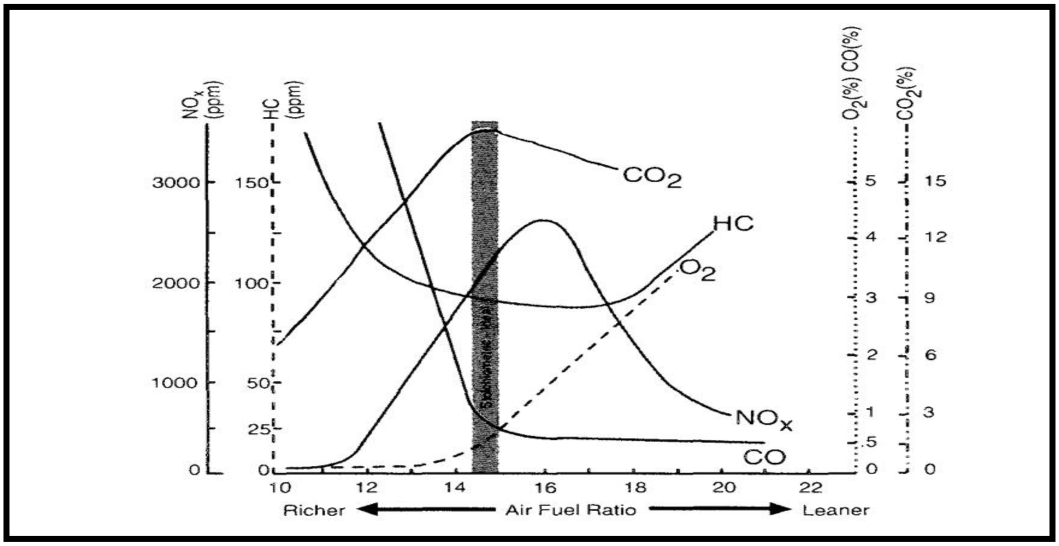

Figure 9: Effects of A/F Ratio on Engine-Out Gases

Source: (Exaust A, 2010)

The diagram represents the Exhaust Gases relationship to the Air/Fuel ratio that enters the engine and the Power output of the engine. Ideal Air/Fuel Ratio is 14.71/1 (for petrol) and not consequently this is where the CO_2 is at about its highest percentage and the HC at its lowest. The Power graph highest point is also almost there, so these should be guidelines. Also notice that the CO and O2 have almost the same (low) values at the "ideal" point (the grey area on the diagram). All the gases relate to one another so if one is out of range it will reflect on the others too (Exaust A, 2010).

2.9 Safety, Health and Environmental Benefits And Drawbacks Of CNG

2.9.1 Benefits

There are various benefits as well as advantages of using CNG as an Alternative fuel to petrol, discussed below are some notable points.

1. **Lower Emission Quality:** Compressed natural gas vehicles (CNGVs) have good combustion characteristics and dramatically lower exhaust gas emissions due to lead and sulphur free character, making it a green fuel (Bakar, et al., 2007c). CNG Low engine exhaust emission as compared to gasoline makes its appropriate to run in lean burn operation and therefore it burn cleaner than most of the fuel. Hence, the engine emission gases like NOx, CO_2, CO that pollutes the air are drastically reduced in percentage.

Emissions like:

A. Reduces carbon dioxide (CO_2) emissions by 20% to 30%.
B. Reduces carbon monoxide (CO) emissions up to 75%, 78 and 25.8 grams.
C. Reduces nitrogen oxide (NOx) emissions by approximately 50%.
D. Reduces up to 95% of particle matter (PM) emissions.
E. Reduces volatile organic compound (VOCs) emissions by 55% (Aldrich & Chandler, 1997).

2. **Low Flammability:** CNG is less likely to auto-ignite on hot surface, it has a high auto-ignition temperature of about 540 degrees centigrade and narrow range inflammability of about 5% to15% (Das, et al., 2000). It means that if CNG concentration in the air is below 5% or above 15%, it will not burn. This high

ignition temperature and limited flammability range makes accidental ignition or combustion very unlikely. CNG is lighter and tend to dissipates in the air, so, explosion can only occur if the concentration is high. Although CNG is flammable, it has a narrow flammability range which makes it an inherently safe fuel according to the U.S. Environmental Protection Agency (Schipper, et al., 1989). CNG disperses rapidly, minimizing ignition risk when compared to gasoline. Natural gas is lighter than air and will not pool as a liquid or vapor. Nevertheless, indoor leaks can form a flammable mixture in the vicinity of an ignition source and can kill if it is present in large concentrations in which is reduces the amount of oxygen in the air to sustain life. Gasoline and diesel burn at much lower concentrations and ignite at lower temperatures. Although it takes very little energy to ignite a flammable mixture of air and natural gas, gasoline, or diesel, natural gas burns at a somewhat lower temperature (Nylund, et al., 2002; Aslam, et al., 2006).

3. **Less Pollutant to the Environment:** CNG fuel systems are sealed, which prevents any spill or evaporation losses, but In the event of a spill or accidental release, CNG poses no threat to land or water, as it emits significantly less pollutants and nontoxic. It is lighter and dissipates quickly (Bakar, et al., 2009). Being a gaseous fuel, CNG mixes easily and evenly in air to reduce toxicity.

4. **More Engine Mechanical Power**: CNG has a higher octane number in the range of 120 to 130 as compare to a range of 93 to 99 octanes for gasoline. This makes the CNG fuel possible to run at high compression ratio engine without any knocking phenomena. A high compression ratio is desirable because it allows an engine to extract more mechanical energy from a given mass of air-fuel mixture due

to its higher thermal efficiency (Hasim, 2005). This occurs because internal combustion engines are heat engines, and higher efficiency is created because higher compression ratios permit the same combustion temperature to be reached with less fuel, while giving a longer expansion cycle, creating more mechanical power output and lowering the exhaust temperature.

5. **Availability Of Reserve Of Natural Gas**: Despite increase rates in natural gas consumption, According to the most recent USGS estimates, released in the World Petroleum Assessment 2000, The mean worldwide-undiscovered natural gas is estimated at 4,301 trillion cubic feet, which is approximately twice the worldwide cumulative consumption forecast from 2002 to 2025 (IEO, 2005). 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. (IEO, 2005). The ratio of proven reserves to production of natural gas was estimated to be 39 years while gasoline only 11 years (Chin, 2012). Therefore, natural gas will be the best choice for the fuel in next 30 years. Also, besides being made from fossil fuel, natural gas can also be made from agricultural waste, human waste and garbage.

6. **Low Operational Cost:** As discussed early in this chapter, one of the advantages of using CNG as an alternative is low cost. The low costs are in production, storage, maintenances and price of the fuel. Currently, the price of the fuel in Malaysia is govern by the rules and regulation of government (ONE gas NVG, 2009), which state the price of CNG cannot exceed 50% of the premium grade of petrol; therefore cost saving in price of the fuel is justified. The operational

cost of vehicles running on CNG is about 68% lower than petrol and 36% lower than diesel.

7. **Easy Maintenances:** CNG has lower maintenances cost; this is because CNG as an engine fuel has a lean burn lower flame speed operation giving it a higher durability of engine lubricant. E.g. it can be half of gasoline oil changed in more than every 15-30,000 km drive (NNN, 2011). The lubricating oil used on CNG vehicles does not contaminate and dilute the crankcase oil (Sun, et al., 1998). Being non-corrosive and due to the absence of any lead or benzene content in CNG, spark plugs used for carburetor engine are not easy contaminated creating longevity of spark plugs (Das, et al., 2000).

2.9.2 Drawbacks

To everything with an advantage, there is most probably a disadvantage to it, however in this case; there is not so much a sustainable disadvantage but a drawback due to various reasons.

1. **Acceptability:** One of the biggest challenges faced in the marketing of NGV in the early days of its introduction was the sense of comfort with traditional fuel skepticisms; whether NGV is a reliable product as promoted. To this end, PETRONAS then focused on taxis as the targeted main customer, using a strategy that provide financing package to taxis driver with the cooperation of two financial institutions, and since then, it has remained majorly accepted by taxis drivers but relatively low acceptability amongst the general public in Malaysia (Daud, 2005).

2. **Lower Engine Performance**: The use of CNG as fuel will cause the lower engine performance by comparison to the gasoline. This is due the low density of natural gas where gaseous fuel occupies a larger volume per unit energy than a liquid fuel said gasoline (Bakar & Mardani, 2001).

3. **Fueling Stations Availability:** Limited availability of natural gas pipelines in strategic areas. Consequently, PETRONAS have to use Mother – daughter NGV refueling at the strategic areas that without pipelines (NGV, 2012a).

4. **Large Pressurized Fuel Storage Tank:** The high pressure of the storage tank causes some safety issues. Compressed natural gas vehicles require a greater amount of space for fuel storage than conventional gasoline powered vehicles (Durell, 2010). Since it is a compressed gas, rather than a liquid like gasoline, CNG takes up more space for each gasoline gallon equivalent (GGE). Therefore, the tanks used to store the CNG usually take up additional space in the trunk of a car or bed of a pickup truck which runs on CNG. This problem is solved in factory-built CNG vehicles that install the tanks under the body of the vehicle, leaving the trunk. They were concern about the loss of boot space with the installation of NGV cylinder, the increased in weight of vehicle after conversion (Durell, 2010).

5. **Cost Of Conversion**: This is a barrier for CNG use as fuel and explains why public transportation vehicles are early adopters, as they can amortize more quickly the money invested in the new (and usually cheaper) fuel. In spite of these circumstances the number of vehicles in the Malaysia that use CNG has grown steadily at a 0.03 percent annual rate (Nylund, et al., 2002). However, the focus is

now on the hybrid or electric car, the power to weight ratio of internal combustion engine (including the tank and fuel) is much more higher than the battery powered or fuel cell operated vehicles (Das, et al., 2000).

6. **Greater Breaking Distance:** greater breaking distance due to increased fuel storage system weight. This is a relatively small concern, however, because the fuel system is a small fraction of a vehicles' total weight, CNG vehicles also might accelerate more slowly than their diesel counterparts (Bakar & Mardani, 2001).

7. **High Methane Quantity:** CNG is primarily over 90% methane, which is a greenhouse gas that could contribute to global climate change if leaked. Methane is slightly soluble in water and under certain anaerobic conditions does not biodegrade. However, natural gas has a high content of methane (another greenhouse gas), so this could affect CNG fuel's advantage somewhat (Bakar, 2008). Therefore, while CNG vehicles are not likely to offer the sole solution to reducing carbon dioxide emissions and subsequent potential effect on climate change, they do have significant advantages over traditional gasoline fueled vehicles.

CNG usage as a vehicle fuel has greatly increased over the last few years. Due to its advantageous properties as a fuel, various studies are been carried out regularly with the support of some international organizations like IANGV (International Association for Natural Gas Vehicles), ANGVA (Asian pacific natural Gas Association) and ENGVA (European Natural Gas Vehicle Association) (ANGVA, 2013). CNG safety record as compares to other alternative fuels available today remains favorably high.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter studies the amount of CO_2 emission that can be reduced using CNG vehicles, since the transportation department is estimated to produce nearly 45% of CO_2 emission (Salahudin, et al., 2013; National, 2008). This experimental carried out to review a gasoline fueled engine in comparison with a CNG fueled engine. The analysis in this study is also generally based on experimental evaluation and modeling methodologies, done to ascertain the amount of gases emitted from cars running on gasoline and CNG fuel in Malaysia by 2020. For this purpose, Information's and results has been collected from books, journals, Internet sources and some relevant Malaysian government bodies like Department of Statistic and Department of Road transportation. Some of the Information's used were readily available but others were calculated with respect to the trend of fuel usage by passenger cars. Furthermore, this study based its results analysis and presentation scenario on the constant increase of vehicles using CNG on the Malaysian road, while using Schwartz scenarios which states that, despite not presenting an accurate picture at the end-result, projecting views about alternative future environments is most likely to be a better decision than any other because this can provide a good ground for better decision making (Schwartz, 1996). The experiments were conducted at the University Kuala Lumpur Malaysia, France Institute Automotive/Mechanical Engineering workshop in Bangi area during the spring of 2013.

3.2 Experimental Set-up

The experiments were carried out on Two (2) Vehicle engine types, the 4g15-CARBURETOR engine and the 1.6 CAMPRO IAFM Injector engine while we used a Bosch- BEA 050 exhaust gas analyzer to experimentally determine the amount of CO_2 emitted from the exhaust. Both the 4g15-CARBURETOR engine and the 1.6 CAMPRO IAFM Injector engine has been modified to run in the bi-fuel engine. A CNG Conversion kit has also been installed to adjust the engines operating condition so the engines can both easily run in gasoline and CNG fuel. The kit composes of a gas-air mixer unit, two electrically operated solenoid valves for gasoline and CNG cut-off, a timing advance processor to adjust the CNG and gasoline ignition timing and gas pressure regulator.

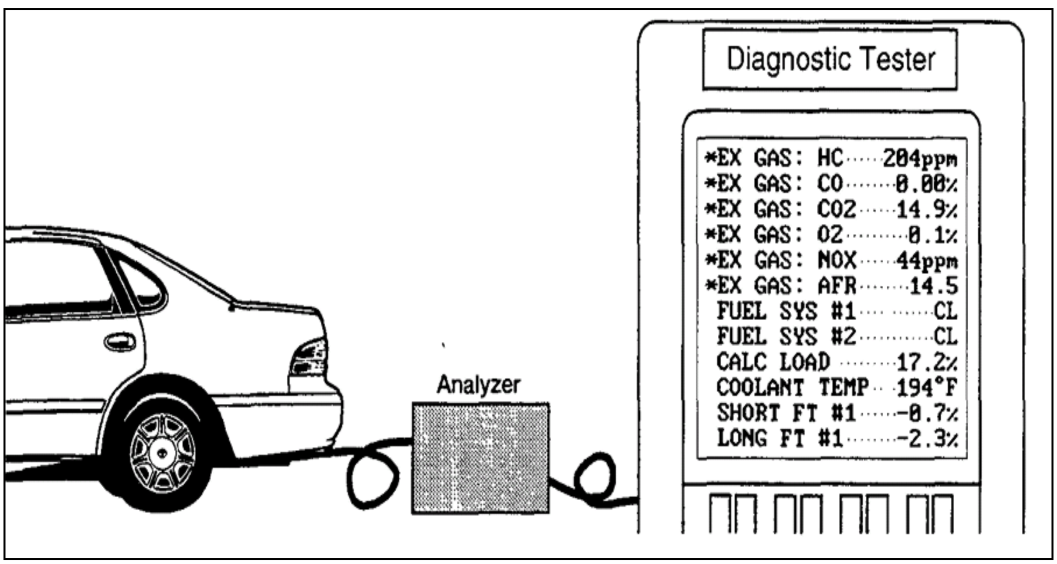

Figure 10: Showing Diagnostic Tester of an exhaust gas analyzer

Source: (Bosch, 2013)

3.3 Application

The Bosch- BEA 050 exhaust gas analyzer is fitted with a spark-ignition engines which helps to facilitate operator-friendly performance of exhaust-gas measurements on vehicles (Bosch, 2013). The test is conducted to include the entire range of the vehicles emission measuring exhaust-gas components like, hydrocarbon (HC), carbon monoxide (CO), carbon dioxide (CO_2), oxygen (O_2) and nitrogen oxide (NO_x) as well as lamda. The A/F ratio lambda calculation is based on the measured exhaust-gas values. The non-dispersive infrared method (NDIR non-dispersive infrared spectroscopy) is used for the measurement of CO, CO_2 and HC percentages. An electro-chemical acting sensor determines the oxygen content. It has been calibrated to perform and to comply with statutory regulations that can only be used in combination with Bosch test systems and the Emission System Analysis program. The Emission System Analysis program consists of: A computer PCB and spark-ignition exhaust-gas analyzer module (AMM).

Figure 11: BOSH Exhaust Analyzer (BEA 050)

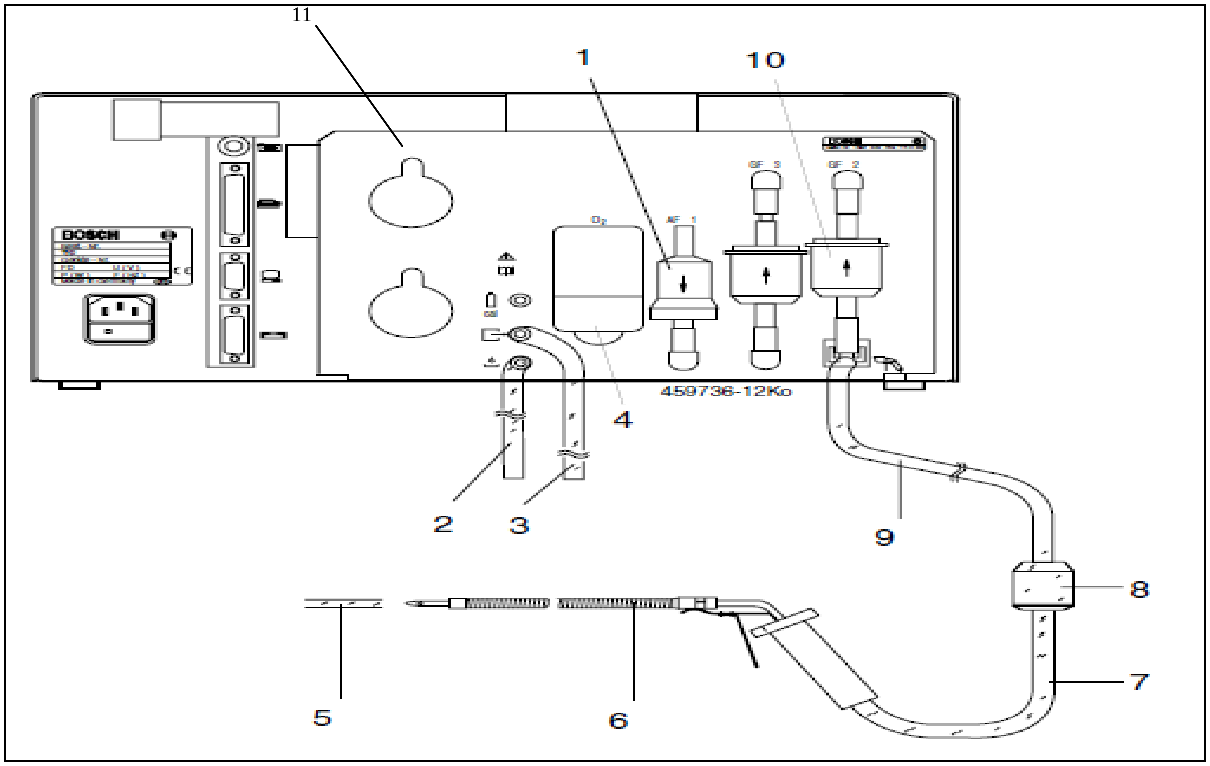

Figure 12: Rear view of BEA 050(with AMM)

Source: (Bosch, 2013)

1. Activated carbon filter
2. Gas and condensation output (140 cm PVC transparent hose)
3. Measurement gas exhaust (140 cm PVC transparent hose)
4. O2 sensor (The illustration may differ from the original)
5. Plastic hose for leakage test
6. Exhaust-gas sample probe
7. 30 cm viton hose (black)
8. GF1 filter
9. 8 m hose line
10. GF2 input filter
11. Spark-ignition exhaust-gas analyzer module (AMM)

3.4 Engine Specifications

As mentioned in the earlier part of this chapter, the experiments were carried out on Two (2) Vehicle engine types, the 4g15-CARBURETOR Engine and The 1.6 CAMPRO IAFM Injector Engine.

Table 12: Engine specification for 4g15-CARBURETOR gasoline bi-fuel engine

No	Description	4g15-CARBURETOR Engine
1.	Valve Mechanism	16 Valve IAFM DOHC
2.	TYPE	In-line OHV,SOHC
3.	Total displacement dm3	1,468
4.	Piston Stroke (mm)	82
5.	Compression Ratio	9
6.	Horse Power	100Hp(78kW) @ 5800rpm
7.	Torque	148 Nm @ 4000rpm

Table 13: Engine specification for 1.6 CAMPRO IAFM Engine

No	Description	1.6 CAMPRO IAFM Engine
1.	Valve Mechanism	16 Valve IAFM DOHC
2.	Total Displacement	1597cc
3.	Stroke (mm)	88
4.	Fuel Type	Multi Point Injection Petrol
5.	Compression Ratio	10
6.	Horse Power	110Hp(82kW) @ 6500rpm
7.	Torque	148 Nm @ 4000rpm

3.5 Experimental Procedures

3.5.1 Starting up

The engine was run until it reaches the steady state condition (warm-up), i.e. run-up before taking readings because if cold, it would give a hard start and that could affect the engine as well as give wrong readings. The experiments started with 1000 revolution per minute (rpm) engine speed, at this stage, the Bosch - BEA 050 spark-ignition engine exhaust-gas analyzer was connected to the RTM 430 and a Bosch test system. From the system, the power supply is established by way of the lighting line (Bosch, 2013). Noting that the BEA 050 is set at ex-factory to 230 V, 50/60 Hz, before starting up care was taken to ensure that the lighting line's voltage matches the configured voltage of the BEA 050. Also, since the BEA 050 is operated in the open workshop, a power source that is protected by an FI circuit breaker was used (Bosch, 2013).

3.5.2 Switching Device On

The BEA 050's power plug was plugged into the plug-socket strip on the Bosch test system and then switched on at the same time as the test system is switched on. Reading (results) was collected at interval and test was repeated for different speeds in the range of 1500 to 3000 rpm. At the end of each experiment, the results were taking from the Computer screen at the various stipulated speed limit but the focus was specifically on the amount of CO_2 emitted. Were the typical readings are compared if the values gotten are standard reading or not. The experiments lasted at about forty-five minutes to one-and-a-half hours. Copies of the Experimental pictures can be found in the Appendix 2.

3.5.3 Switching Device Off

After exiting the exhaust-gas test step and experiments, it was necessary to wait until the pump stopped running thereafter the test system was switched off. In order to keep the level of contamination in the BEA 050 as low as possible and safe for future usage, the exhaust-sample probe was left open while pump was ran to purge the BEA 050 of residual gas before switching it off.

Figure 13: showing the exhaust gas analyzer probe in the exhaust

3.6 Test Procedures

The test procedures were conducted in accordance with the Fifth schedule (regulation 11) of the environmental quality act 1974 amendment 1996.stating that;

The engine should be accelerate to a moderate speed with no load, maintain for at least 15 seconds then return the engine to idle speed. Thereafter, while the engine idles, insert the sampling probe into the exhaust pipe as deeply as possible but in any case for not less than 300mm and then wait for at least 20seconds before the reading are taken from the analyzer display unit. (IPCC, 2007b; MDOE, 2010).

3.7 Methodology for CO_2 Emissions Calculation

This calculation is carried According to PUSPAKOM (Malaysia Automobile Computerized Testing Centre) and DOE standard (JPJ, 2012). In calculating for CO_2 emissions from fuel combustion, this can be done in three different levels of details as suggested in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2007a). They are: referred to as Tiers 1, 2 and 3 (IPCC, 1996).

Tier 1: Production-based Average Emission Factors Approach. This method depends on estimating the emissions from the carbon content of fuels supplied to the country as a whole. UN gives an accurate estimation of national CO2 emissions.

Tier 2: Mass Balance Approach. This method may be regarded as that dividing fuel consumption on the basis of sample engineering knowledge between technology types that are sufficiently homogenous to permit the use of representative emission factors.

Tier 3: Rigorous Source-Specific Evaluation Approach. This method generally estimate emissions from activity figures (km travelled or ton x km carried, not fuel consumption) and specific fuel efficiency or fuel rates or, alternatively, using an EF expressed directly in terms of a unit of activity.

From the polynomial method of description by Jahirul (2010), we used the Tire 2 to develop a regression Equation that we then used to analyzed and develop a model historical data on the number of passenger cars and fuel consumption from year 2013 to 2020 (Jahirul, et al., 2010; JPJ, 2012).

CHAPTER 4

RESULTS AND ANALYSIS

4.1. Introduction

This chapter presents the results obtained from the various text actions carried out. The data's of the measured exhaust constituent were interpreted by simple computer display system, specifying the gases in their various units. Not forgetting, the main aim of this research is to facilitate the implementation of CNG in the Transport industry. Besides that, the purpose of this study is to verify the significant difference in CO_2 emission from two different Vehicles engines operating on CNG and Petrol. Results collected from this study were implemented to reduce further emission from CO2 exhaust gas.

4.2. Specified range of Exhaust Constituents

As discussed in chapter 2, the ideal expected range of the various exhaust constituent as measured by a Gas analyzer, are displays in the tables below (Crypton, 2012).

Table 14: An Ideal Exhaust constituent of a Carburetor and Injector Petrol Engine

Source: (Exaust A, 2010)

	Carburetor Petrol Engine	**Injector Petrol Engine**
CO	1 ~ 3% *high mix rich, low mix lean	0.5 ~ 1.5 %
CO_2	>13% *higher is O.K	>14%
HC	<400 ppm *lower is O.K	<200 ppm
O_2	<2% *lower is O.K	<1%

With input parameters like: CNG quantity and quality, engine oil level, throttle position, throttle vale, rate of variation, pressure stability, operating timing being monitored.

4.3. Test Results

For the first objective of this research, it is important to know the amount of the various exhaust gas emitted. Focusing on the two-test subject (The Injector Engine and Carburetor Engine), the presentations of these data's are displayed in tabular forms that will be explained later.

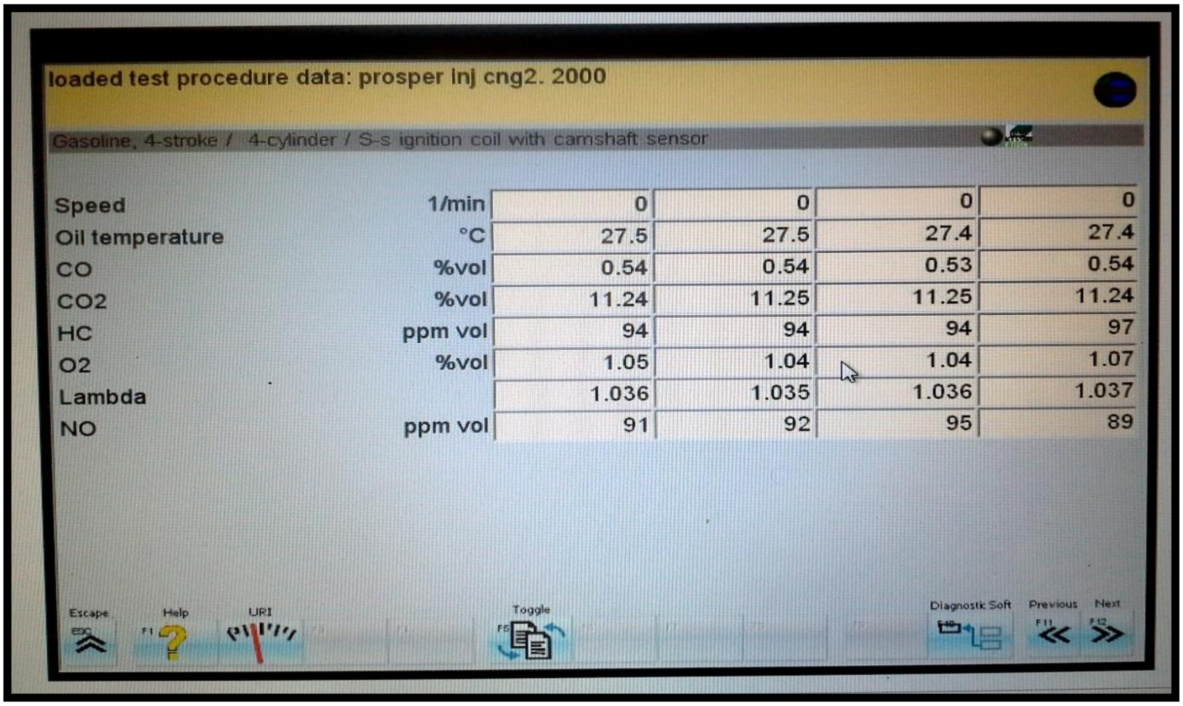

Figure 14: Result Screen display of the Bosh gas Analyzer

4.4. Test Results Presentation

4.4.1 Test Procedures on Vehicle Injector System

This test procedure comprises of the two main fuel categories:

Category A: Petrol Fueled Injector engine

Category B: CNG Fueled Injector engine

A. Petrol Fueled Injector Engine

Table 8 shows the result presentation of the experiments conducted. This experiment was conducted Three times at each designated speed range, and then the average value is evaluated to be the most accurate.

Table 15: Result Presentation for Petrol Fueled Injector Engine

Measure ment result	Speed	Oil temperature	CO	CO_2	HC	O2	Lambda	NO
Unit	**1/min**	**Oc**	**%vol**	**%vol**	**Ppm**	**%vol**		**Ppm vol**
Measured at speed range 1000rpm	1007	27.7	0.93	**13.76**	214	1.44	1.029	64
	1000	27.6	0.93	**13.77**	223	1.47	1.030	67
	1008	27.6	0.93	**13.78**	224	1.45	1.028	67
Average Measured		27.6	0.93	**13.77**	220	1.45	1.029	66
Measured at speed range 1500rpm	1500	27.8	0.90	**13.90**	169	1.45	1.033	172
	1503	27.8	0.96	**13.88**	161	1.48	1.027	162
	1499	27.9	0.95	**13.88**	154	1.35	1.028	137
Average Measured		27.8	0.94	**13.88**	161	1.43	1.029	157
Measured at speed range 2000rpm	2000	27.4	0.86	**14.10**	135	1.09	1.018	154
	2013	27.5	0.86	**14.10**	135	1.09	1.018	146
	2009	27.5	0.86	**14.10**	135	1.09	1.018	142
Average Measured		27.47	0.86	**14.10**	135	1.09	1.018	147
Measured at speed range 2500rpm	2500	27.7	0.82	**14.25**	105	1.01	1.018	189
	2497	27.7	0.82	**14.25**	102	1.00	1.017	189
	2500	27.6	0.82	**14.25**	100	1.00	1.017	191
Average Measured		27.7	0.82	**14.25**	102	1.00	1.017	190
Measured at speed range 3000rpm	3000	27.9	0.78	**14.30**	115	0.98	1.017	262
	3000	28.0	0.76	**14.32**	111	0.95	1.016	261
	2997	28.0	0.75	**14.33**	106	0.95	1.017	262
Average Measured		28.0	0.76	**14.31**	111	0.96	1.017	262

B. CNG Fueled Injector Engine

As demonstrated in Table 9, this experiment was also conducted Three times at each different designated speed range, and then the average value was evaluated to be the most accurate.

Table 16: Result Presentation for CNG Fueled Injector Engine

Measurement result	Speed	Oil temperature	CO	CO_2	HC	O2	Lambda	NO
Unit	**1/min**	**Oc**	**%vol**	**%vol**	**Ppm**	**%vol**		**Ppm vol**
Measured at speed range 1000rpm	1000	27.6	0.63	**10.83**	272	1.70	1.060	48
	1000	27.6	0.62	**10.86**	266	1.65	1.058	44
	1000	27.7	0.64	**10.85**	228	1.62	1.058	39
Average Measured		27.6	0.63	**10.84**	255	1.66	1.059	44
Measured at speed range 1500rpm	1500	27.7	0.60	**11.08**	136	1.25	1.043	73
	1496	27.7	0.60	**11.09**	131	1.24	1.042	64
	1500	27.6	0.61	**11.08**	124	1.27	1.044	57
Average Measured		27.7	0.60	**11.08**	130	1.25	1.043	65
Measured at speed range 2000rpm	2000	27.5	0.54	**11.25**	94	1.04	1.035	92
	2000	27.5	0.53	**11.25**	94	1.04	1.036	95
	2000	27.4	0.54	**11.24**	97	1.07	1.037	89
Average Measured		27.5	0.54	**11.25**	95	1.05	1.036	92
Measured at speed range 2500rpm	2530	27.3	0.57	**11.28**	68	0.95	1.030	124
	2500	27.3	0.57	**11.27**	71	0.98	1.032	135
	2498	27.4	0.58	**11.25**	74	1.00	1.033	136
Average Measured		27.3	0.57	**11.26**	71	0.98	1.032	132
Measured at speed range 3000rpm	3009	28.1	0.55	**11.31**	79	0.92	1.029	158
	3010	28.0	0.55	**11.31**	76	0.92	1.029	155
	3000	28.0	0.55	**11.32**	75	0.91	1.028	174
Average Measured		28.0	0.55	**11.31**	77	0.92	1.029	162

After recording the various values form the two test categories, it was better to convert form percentage volume to a more generally accepted value as it relates to fuel consumption (CATERPILLAR, 2007),

This is done using the various conversation formulas as stated in the formulae table.

1. From % vol to PPM = x 10^4
2. 1 PPM = 1 Mg/L
3. From Mg/L to Kg/L = x 10^{-6}
4. CO_2 emission (Kg/L)

Since the two different fuel seem to be the driving force behind the increase and decrease in the various exhaust gas emission, it would be better to represent the data's in the form of Kg/L, i.e. converting from %Vol to Kg/L (Supple, 2010) as shown in table 17 below.

Table 17: Converting Injector Emission Results form %Vol to in Kg/L

Measurement result	**Total Average Measured result** (%Vol)		**Total Average Measured result (%ppmVol)**		**Total Average Measured result (kg/L)**		**Co2 Amount Reduced**
Speed (Rpm)	**Petrol (CO_2)**	**CNG (CO_2)**	**Petrol (CO_2)**	**CNG (CO_2)**	**Petrol (CO_2)**	**CNG (CO_2)**	**(Kg/L)**
1000	**13.77**	**10.84**	137,700	108,400	2.70	2.13	0.57
1500	**13.88**	**11.08**	138,800	110,800	2.73	2.18	0.55
2000	**14.10**	**11.25**	141,000	112,500	2.77	2.21	0.56
2500	**14.25**	**11.26**	142,500	112,600	2.79	2.21	0.58
3000	**14.31**	**11.31**	143,100	113,100	2.81	2.22	0.60
AVERAGE					**2.75**	**2.20**	**0.55**

From the table 10, it can be seen that the Petrol injected engine seems to produce more CO_2 of about 2.77 Kg/L than the CNG injected engine of 2.21 Kg/L, This is further subtracted to displayed the amount of CO_2 reduced. As a form of further clarity, a graph is drawn showing the significant reduction between this two fuel conditions.

4.4.2 Test Procedures on Vehicle Carburetor System

This test procedure also comprises of the two main fuel categories that we classified as:

Category C: Petrol Fueled Carburetor engine

Category D: CNG Fueled Carburetor engine

C. Petrol Fueled Carburetor Engine

Table 8 shows the results presentation of the experiments conducted Three times at each designated speed range, and then the average value was evaluated to be the most accurate.

Table 18: Result Presentation for Petrol Fueled Carburetor Engine

Measurement result	Speed	Oil temperature	CO	CO_2	HC	O2	Lambda	NO
Unit	**1/min**	**Oc**	**%vol**	**%vol**	**Ppm**	**%vol**		**Ppm vol**
Measured at speed range 1000rpm	1007	32.0	1.47	**13.27**	476	1.16	1.043	87
	1000	32.3	1.49	**13.30**	455	1.22	1.042	84
	1008	32.2	1.49	**13.26**	449	1.17	1.044	89
Average Measured		32.2	1.48	**13.28**	460	1.18	1.043	87
Measured at speed range 1500rpm	1500	32.5	1.42	**13.39**	345	1.33	1.043	103
	1503	32.4	1.42	**13.38**	334	1.29	1.042	111
	1499	32.5	1.39	**13.38**	334	1.35	1.044	156
Average Measured		32.47	1.41	**13.38**	338	1.32	1.043	123

Table 18 continued : Result Presentation for Petrol Fueled Carburetor Engine.

Measured at speed range 2000rpm	2000	32.6	1.40	**13.53**	226	1.41	1.043	121
	2013	32.6	1.40	**13.49**	245	1.40	1.042	127
	2009	32.7	1.39	**13.50**	239	1.43	1.044	129
Average Measured		32.63	1.40	**13.51**	237	1.41	1.043	126
Measured at speed range 2500rpm	2500	32.6	1.41	**13.76**	215	1.64	1.029	164
	2497	32.4	1.40	**13.74**	214	1.67	1.030	167
	2500	32.7	1.39	**13.74**	224	1.75	1.028	167
Average Measured		32.6	1.40	**13.75**	218	1.69	1.029	166
Measured at speed range 3000rpm	3000	32.7	1.37	**13.80**	212	1.85	0.920	172
	3000	32.6	1.35	**13.82**	205	1.98	1.001	162
	2997	32.5	1.38	**13.83**	209	1.95	0.989	137
Average Measured		32.6	1.37	**13.82**	209	1.93	0.970	157

D. CNG Fueled Carburetor Engine

Just like that of category B, this experiment is conducted on a CNG converted carburetor Vehicle engine. As demonstrated in Table 9, the experiments were conducted Three times at each different designated speed range; thereafter the average value was evaluated to be the most accurate.

Table 19: Result Presentation for CNG Fueled Carburetor Engine

Measurement result	**Speed**	**Oil temperature**	**CO**	**CO_2**	**HC**	**O2**	**Lambda**	**NO**
Unit	**1/min**	**Oc**	**%vol**	**%vol**	**Ppm**	**%vol**		**Ppm vol**
Measured at speed range 1000rpm	910	32.5	1.29	**9.58**	525	1.66	1.497	60
	1150	32.7	1.25	**9.07**	484	1.35	1.493	63
	1160	32.5	1.29	**9.01**	484	1.12	1.521	64
Average Measured		32.6	1.28	**9.89**	498	1.38	1.504	62

Table 19 continued: Result Presentation for CNG Fueled Carburetor Engine

Measured at speed range 1500rpm	1500	32.5	1.24	**9.33**	392	1.28	1.362	89
	1480	32.4	1.24	**9.30**	390	1.29	1.357	86
	1530	32.6	1.23	**9.31**	453	1.27	1.364	87
Average Measured		32.5	1.24	**9.31**	412	1.28	1.361	87
Measured at speed range 2000rpm	2000	32.5	1.20	**10.02**	304	1.24	1.262	94
	1980	32.5	1.18	**10.01**	271	1.17	1.257	94
	2030	32.5	1.19	**10.03**	275	1.25	1.264	94
Average Measured		32.5	1.19	10.02	283	1.22	1.261	94
Measured at speed range 2500rpm	2500	32.6	1.15	**10.95**	230	1.02	1.139	108
	2510	32.4	1.15	**10.96**	229	1.07	1.147	116
	2420	32.4	1.12	**10.96**	236	1.25	1.151	120
Average Measured		32.5	1.14	10.96	232	1.11	1.146	115
Measured at speed range 3000rpm	3020	32.5	1.07	**11.29**	216	0.96	1.097	122
	2980	32.3	1.06	**11.31**	205	0.98	1.093	129
	3010	32.5	1.09	**11.30**	201	1.02	1.021	125
Average Measured		32.4	1.07	11.30	207	0.99	1.070	125

We also converted form %Vol to Kg/L. see formulae table for further conversion.

Table 20: Converting Results in Kg/L form %Vol Carburetor Engines

Measurement result	**Total Average Measured result** (%Vol)		**Total Average Measured result (%ppmVol)**		**Total Average Measured result (kg/L)**		**Co2 Amount Reduced**
Speed (Rpm)	**Petrol (CO_2)**	**CNG (CO_2)**	**Petrol (CO_2)**	**CNG (CO_2)**	**Petrol (CO_2)**	**CNG (CO_2)**	**(Kg/L)**
1000	**13.28**	**9.89**	132,800	78,900	2.61	1.76	0.85
1500	**13.38**	**9.31**	133,800	83,100	2.63	1.77	0.86
2000	**13.51**	**10.02**	135,100	90,200	2.65	1.78	0.87
2500	**13.75**	**10.96**	137,500	99,600	2.69	1.81	0.88
3000	**13.82**	**11.30**	138,200	103,000	2.71	1.82	0.89
AVERAGE					**2.65**	**1.78**	**0.9**

From the Test results in the four categories (Category A to D), it could be seen that the Values are quite in close range, however, we consider the Using the Average values from Table 12.which is then displayed in table 13.

Table 21: Amount of CO_2 emission produced by both vehicle Engine types

UNIT	**Production Of CO_2 Emission In Kg/Liter**			
	Petrol (carburetor)	**Petrol (Injector)**	**CNG**	**TOTAL CO_2 REDUCTION**
Kg/Liter	2.65 kg/litre		1.78 kg/litre	0.87 kg/litre
		2.77 kg/litre	2.21 kg/litre	0.56 kg/litre

Table 11 shows that by converting from petrol (carburetor) system to NGV system, CO_2 emission from vehicles could reduce up to 0.9 kilograms for one Liter of NGV usage. Meanwhile, conversion from Petrol (injector) system to NGV system, up to 0.6 kilograms CO_2 reduction per one liter could be achieved. This shows that before conversion, the Petrol (injector) engine with Euro4 standard of emission already produced more CO_2 compared to petrol (carburetor) system. Therefore, the focus would be on the carbureted engine vehicle because the more fuel they burn the more polluted our environment would be, resulting to the various effects as discussed earlier in Chapter 2.see table 22 for a clearer view.

Table 22: Amount of CO_2 emission produced and reduced by Petrol and CNG vehicle

PRODUCTION OF CO_2		
PETROL	**CNG**	**TOTAL CO_2 REDUCTION**
2.6 Kg/L	1.7 Kg/L	0.9 Kg/L

4.5 CALCULATIONS AND ANALYSIS

4.5.1 Statistical Considerable facts

1. Currently, in Malaysia there are approximately 23,000,000 vehicles on the road (JPJ, 2012).

2. As at June 2013, an estimated 53,783 vehicles in Malaysia were running on natural gas (i.e. 1 of 200 vehicles using CNG) (ANGVA, 2013).

3. The Expected progressive increase in the Number of new cars added to the Malaysian road as well as the Number of new NGV following a similar projected increase of 5.7%, 6.0%, 6.5% & 7.0%, 7.5%, 8.0%, 8.5% & 9.0% (MAA, 2013).

4. The Road Transport Department records that about 99.6 percent of the total passenger cars in Malaysia use petrol fuel while the others use diesel and CNG (Masjuki *et al*, 2005; MMA). Based on this observation, an estimated increasing pattern of passenger cars has been generated for the period of year 2013 to year 2020 as in Table 24.

5. The statistical percentage of total number of vehicles in Malaysia, shows that motorcycles are foremost with 48.60 percent while passenger cars stands at and 41.60 percent see figure 5 (Masjuki, et al., 2005), However, fuel consumption of motorcycles is much lower than that of passenger cars and motorcycle engine does not move on CNG yet, so this study emphasized on passenger cars only.

6. Standard Value show that each vehicle on the road consumes more than 5Litres per day on a 10-kilometer journey per day (FCE, 2010).

4.5.2 Estimated Projections

1. This study estimates a 15% increase by NGV users in comparison with the total numbers of vehicles in Malaysia from 2013-2020. Hence, giving a high impact on CO_2 emission reduction in Malaysia's atmosphere.

2. This calculation is done on the value estimated by Highway Network Development Plan (HNDP) that about 80 % of 25.8 million person-trips per day would be on passenger cars by year 2020 (Masjuki *et al*, 2005).

3. According to the annual average fuel usage per vehicle stated in Table 5 by 1Gas Stesen NGV, it would be appropriate to multiply the average amount of fuel used per vehicle yearly to the numbers of vehicles available in Malaysia because this could help to ascertain and calculate the level of CNG fuel consumed over the years and also helps to determine an estimated amount of CO_2 emission from gasoline and NGV fuel vehicles till the vision is meant at 2020 (ONE gas NVG, 2009).however, a vivid experimental resolution would be achieved to help justify the expected reduction level.

4. We also used data's from MAA to analyzed the number of passenger cars and fuel consumption from year 2013 to 2020 (MAA, 2013)

Table 23: Forecast number of new NGV and total Vehicles from year 2013 -2020

Year	No. Of New NGV Vehicles	Rate Increase	Total No. Of NGV Vehicles	No. Of New Vehicles	Rate Increase	Total No. Of Vehicles
	(Unit)	%	(Unit)	(Unit)	%	(Unit)
2010	1806	4.3	45,000	605,156	5.5	10,279371
2011	2200	4.8	47,200	600,123	5.8	10,884527
2012	3700	7.8	50,900	627,753	5.5	11,484650
2013	2883	**5.7**	53,783	654,625	**5.7**	12,139,275
2014	3228	**6**	57,029	728,357	**6**	12,867,632
2015	3707	**6.5**	60,736	836,396	**6.5**	13,704,028
2016	4252	**7**	64,988	959,282	**7**	14,663,310
2017	4874	**7.5**	69,862	1,099748	**7.5**	15,763,060
2018	5589	**8**	75,451	1,261,045	**8**	17,024105
2019	6413	**8.5**	81,864	1,447,049	**8.5**	18,471,154
2020	7368	**9**	89,232	1,662,404	**9**	20,133,558

NOTE:

The Total Numbers of Vehicles estimated are without Motorcycles.

Table 23, shows the forecasted projections of car increase rate based on the previous constituent increase from 2010 to 2013. Going by the expected increase in the additional number of new cars annually, if new cars are added at an annual average of 6 to 7% i.e. about 600,000 vehicles per year, while that of new NGV is approximately 5% per annum of about 2000-6000 yearly. Therefore, it is logical to project on a trend of 1 to 1.5% increases in between each year. The predictable increase in percentage from 2013 would likely follow a procession of 6 to 9%.This we used to calculate the Numbers of Vehicles obtainable by 2020. From the table, it can also be seen that should the Numbers of vehicles in Malaysia increases at the expected pace, there would only be a slight percentage increase of 9% resulting to an estimated 20,133,558 vehicles by year 2020.i.e. excluding Motorcycle. So also, by year 2020, there would only be 89,232 NGV vehicles in Malaysia.

4.6 CO_2 Emission Calculations

Based on the predicted percentage increase, two areas of calculations are being considered.

1. Calculation On CO_2 Emissions from petrol fuel cars by year 2020
2. Calculation On CO_2 Emissions Reduction using CNG fuel cars by year 2020

4.6.1 Calculation On CO_2 Emissions Produced From Petrol Fuel Cars By year 2020

To calculate how much CO_2 emission that would be contributed from petrol cars by year 2020, we would treat it from two angles.

1. We subtracted the estimated Total number of NGV from The Total number of Vehicles obtainable at year 2020 as shown in table 14.

Solution:

Total Vehicle by year 2020 - Total NGV vehicle by year

(20,133,558) - 2020 (89,232) = 20,044326

Therefore, as at year 2020 there would be about 20,044326 cars still running on gasoline (fuel)

2. We now determine the Amount of CO_2 emission that would be generated by the Remaining Cars not running on NGV by 2020.Assuming that the 20,044326 cars where running on gasoline.

Solution:

If 1 car producing 2.6 kg/liter is estimated to travels on an average of 5 liters per day,

1 day journey = 2.6 x 5 = 13 kg/L daily

1 year journey = 13 x 365 = 4745 kg/L Annually

So, by year 2020, If 20,044326 cars are still running on gasoline (fuel),

1 car journey per year produces 4745 kg/L $CO_{2.}$

Then the Amount of CO_2 emitted by vehicle as at year 2020, would be.

20,044326 x 4745 = 9.5 x $10^{10\ kg}$/L CO_2 or 95,110,327 Tones CO_2

This then leads to the next phase of our projection.

From the calculation above, the increase in rate of new cars seems to affect the amount of CO_2 produced, because, the more the petrol fuel cars the more the CO_2 emissions.

4.6.2. Calculation On CO_2 Emissions Reduced Using CNG Fuel Cars By 2020

Currently, in Malaysia there are approximately 23,000,000 Total vehicles and an estimated 53,783 NGV. (JPJ, 2012) i.e. about 0.03% meaning only 1 of 200 vehicles uses CNG, but in other countries like Iran and Pakistan their percentages are quite high of about 12 and 15%. Taking notice of this, we estimated that an increase by 15% of the present numbers of cars in Malaysia would have a great impact in the effort to reduce CO_2 by year 2020.This would also see Malaysia reach the same number of NGVs like Iran and Pakistan as of now. To this end, Table 15 shows the probability of an increase rate in NGV usage that would lead to a 15% increase of the present number of vehicles in Malaysia.

Table 24: Forecast rate of new NGV vehicles from year 2013 –2020

Year	% Of New NGV Vehicles	No. Of New NGV Vehicles	Total No. Of NGV Vehicles
2013	1.6	**53,783**	53,783
2014	1.5	**182,089**	235,872
2015	2.0	**242,786**	478,658
2016	3.25	**394,526**	873,184
2017	3.75	**455,223**	1,328,407
2018	4.25	**515,919**	1,844,326
2019	4.75	**576,616**	2,420,942
2020	5.55	**637,312**	3,058,254
Total		**3,058,254**	

NOTE:

The Total Numbers of Vehicles estimated are without MOTOCYCLES.

Therefore as shown in table 14, 15 % of the proposed Total Number of Vehicles in Malaysia would then be:

$$\frac{15}{100} \times 20{,}133{,}558 = 3{,}020{,}034 \text{ Vehicles}$$

Looking at table 24, it shows that the total achievable number of new NGV by 2020 following a procession of 1.5, 2.0, 3.25, 3.754.25, 4.75, 5.55, would be 3,058,254 which is a little bit higher than the proposed 15% increase of about 3,020,034 vehicle by 2020.So therefore, from the estimated projection in 15% increase Of New NGV Vehicles, to calculate for the reduction of CO_2 emission by year 2020, we would use a generated equation from Tier 2 (IPCC, 1996).

$$\mathrm{CO2}\ Emission\ Reduction = \sum \mathrm{NV_x} \times \mathrm{LS_a} \times \mathrm{ER_b} \times \mathrm{VR_c}$$

Where,

NV_x = Nos. of New Vehicles or New NGV Vehicles

LS $_a$ = Amount of liter spent per year (5 x 360)

ER $_b$ = Emission reduction (kg/L) (0.9 kg/L)

VR $_c$ = 80% of total vehicles on the Road (All vehicle type except Motorcycles)

Also, Taking Note That the calculation is based on 80 % of total vehicle on the road and each Vehicle is presume to consumes 5 Liters per Day while referring to table 45 for the amount of CO_2 emission that can be reduced by 1 car.

Example:

<u>For Year 2013</u>

53,783 cars x 5 x 365 days/Year x 0.09kg/L of CO_2 x 0.8

= 70,671000 kg CO_2 = 70,671Tones.

With this method, we calculated for the rest values shown in table 26 below.

Table 25: CO_2 reduction per vehicle Projected from year 2013 – 2020

Year	No. Of New NGV Vehicles	Total No. Of NGV Vehicles	Reduction In CO_2 Emission (Tons)							
			2013	2014	2015	2016	2017	2018	2019	2020
2013	**53,783**	53,783	70,671	70,671	70,671	70,671	70,671	70,671	70,671	70,671
2014	**182,089**	235,872		239,265	239,265	239,265	239,265	239,265	239,265	239,265
2015	**242,786**	478,658			319,021	319,021	319,021	319,021	319,021	319,021
2016	**394,526**	873,184				518,407	518,407	518,407	518,407	518,407
2017	**455,223**	1,328,407					598,163	598,163	598,163	598,163
2018	**515,919**	1,844,326						677,918	677,918	677,918
2019	**576,616**	2,420,942							757,673	757,673
2020	**637,312**	3,058,254								837,428
Total	**3,058,254**		**70,671**	**309,936**	**628,957**	**1,147,364**	**1,745,527**	**2,423,445**	**3,181,118**	**4,018,546**

From table 25, it can be seen that should there by a continuous increase in the number of new NGV in Malaysia, there would be a Amount of CO_2 emission reduced and by year

2020, there would have been a reduction of about 4,018,546 Tons CO_2 emission. The table projection is based on a target of 15% reduction of CO_2 emission as against the present number of cars in Malaysia.

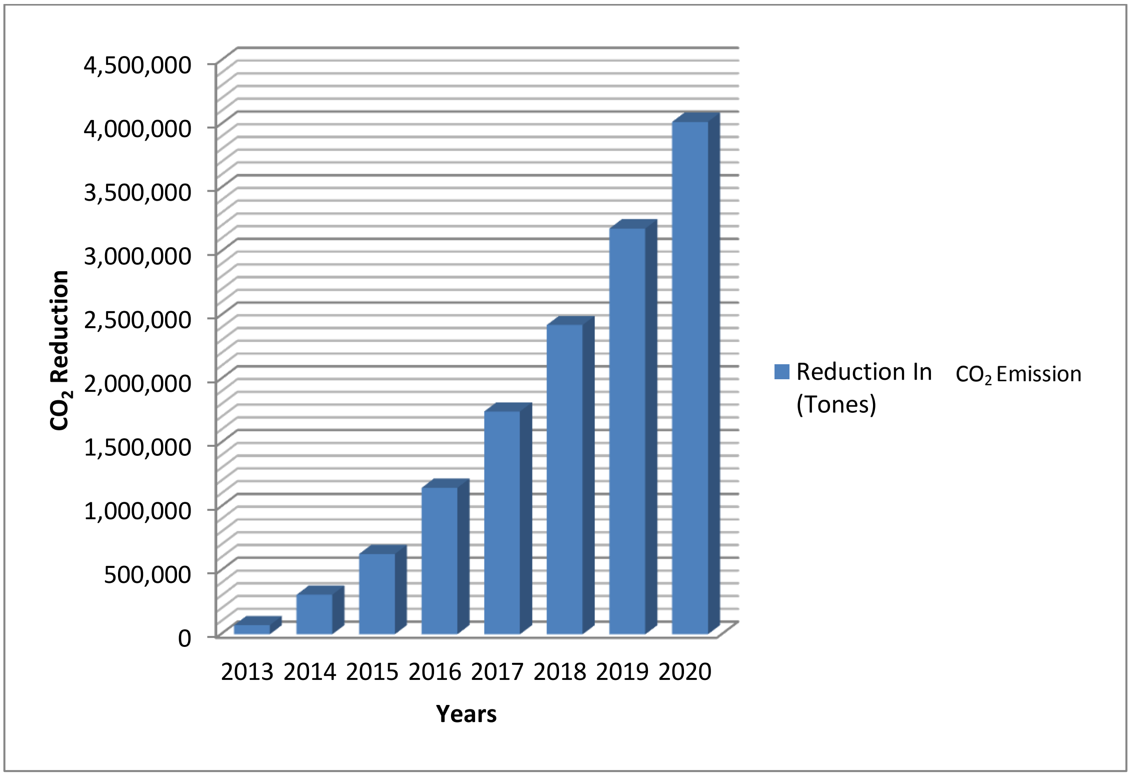

Figure 15: Graph showing the Reduction in CO_2 of 15% Increase in CNG cars

From table 25, the graph is drawn representing the reduction in CO_2 Emission of 15% Increase in CNG cars. If the increase rate take the path as predicted, it would definitely mean a significant land mile in the quest to reduce the amount of CO_2 emission by 2020.from the graph, the increase CNG cars is climbing high on a gradual pace showing that, other consideration could be given along the way to the 15% goal, however with continuous improvements on CNG, It would be an achievable target.

CHAPTER 5

DISCUSSION

5.1 Introduction

This chapter discusses the results and findings of this study. The chapter begins with the discussion of CO_2 emission results gotten from the performance test; stressing the significant difference in CO_2 emission from Vehicles operating on CNG and Petrol. Besides this, the highest point was to identify and described the amount of CO_2 emission reducible by year 2020. Furthermore, contributing to this subject matter, the discussion is based on the estimated increase in cars and the considerable amount of CO_2 produce by 2020. Highlighted were the calculated values achieved from the forecast increase in percentage rate of the new NVG added each year from 2013 to 2020. This chapter ends up with a certain level of job satisfaction providing a guide for further studies of CNG as a viable AFV to gasoline fuel among cars in Malaysia.

5.2 Discussion on CO_2 emission Performance test results

From the Performance tests, it was found that the amount of CO_2 emission slightly increased along the different speed range. i.e. the faster the car the more CO_2 it emits. It was also recognized that the two different fuel types plays part of this increase and decrease in the various exhaust gas emission. From the result of the Performance tests, the petrol fueled injector engine produced more CO_2 emission, having its highest value at 14.31% Vol. Though this is consider ok for an injector engine it is due to a complete combustion process, as Shown in table 17.

The injector CNG fueled engine produced less CO_2 emission as shown in table 4.5 above. The difference was quite significant of about 0.56 to 0.6 kg/L reduction when compare to its injected petrol counterpart. As a form of further clarity, a graph is drawn below showing the significant reduction between this two fuel conditions.

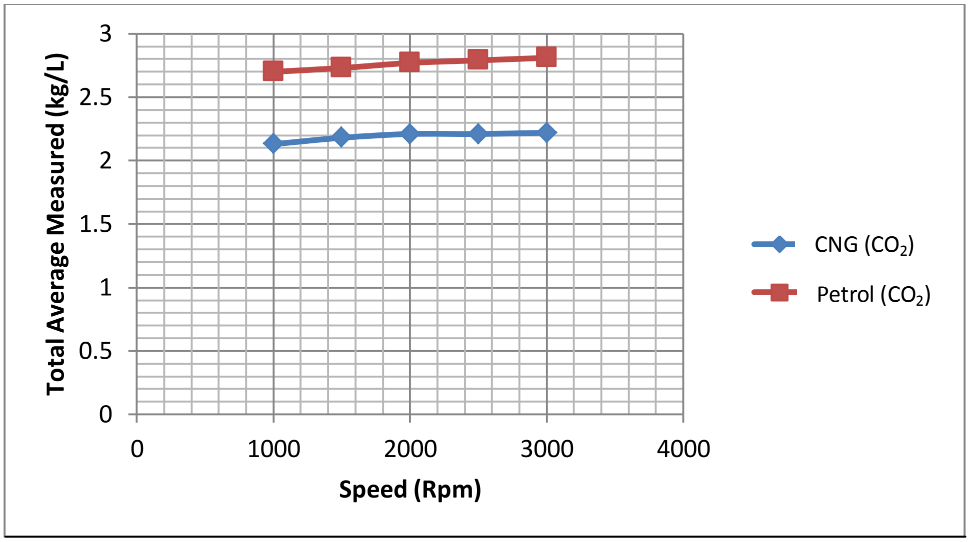

Figure 16: Graph showing the graphical represent of petrol and CNG injector engine

In addition, the results collected from the performance test on the carburetor engine showed quite a high number of CO_2 emissions, although it still wasn't high as compare to the injector engine. This could be due to a well-tailored combustion process by the injector engine. Taking note that, the better the engine combustion performance, the higher the amount of CO_2 emission. However the conversion to CNG saw a considerable decrease in the amount of CO_2 emitted as displayed in the graph below.

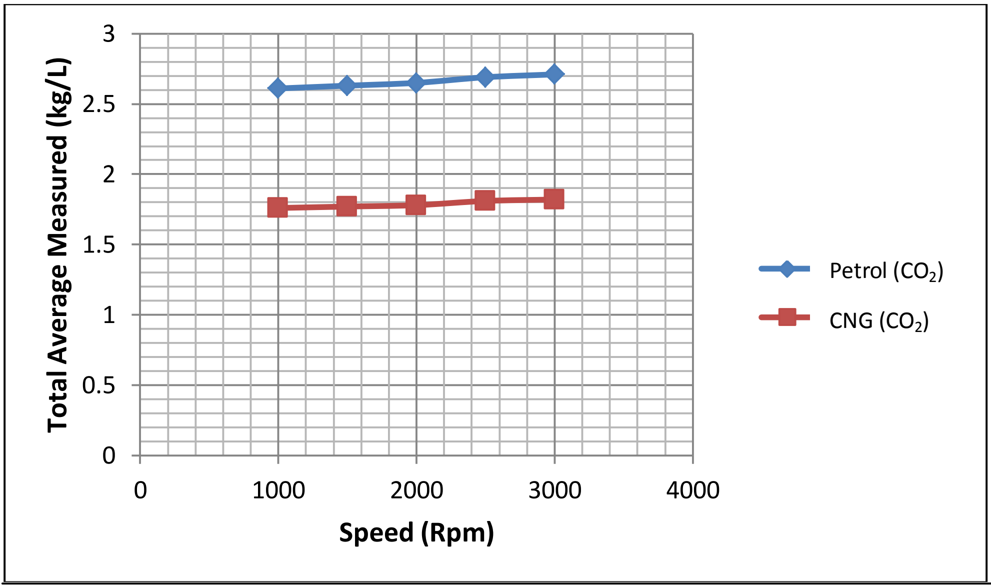

Figure 17: Graph showing the graphical represent of petrol and CNG

The Graph shows that in the two categories, from the start of the engine, as you accelerate further, the conversion takes effect and as the speed increases the difference in the reduction of CO_2 emission begins to manifest.

5.3 Comparing the Petrol Fueled Engine to the CNG fueled engine

In comparing the both test subject and their different categories, the carburetor engine seems to produce the more amount of CO_2 emission reduction than the injected engine. This is due to the adaptation of the Carburetor engine to CNG conversion and probably some other numerous qualities. This produced a specific increase of 0.9 kg/L as compare to the injector of 0.6 kg/L. With this finding, our further consideration and calculation was based on the fact that the best quality of reduction could be attended to in other to encourage the phasing out of petrol usage in the transport industry. In addition, it was found from the performance test of both test engines, that, the use of CNG generally brings about a reduction of CO_2 (Jahirul, et al., 2010).

5.4 Discussion on Co_2 emission reduction analysis

In this section, the data's gotten from the performance test is consider and analyzed with the help of various estimation and projections models. From the calculations, projecting from year 2013 to year 2020 (IPCC, 1996; MAA, 2013), the possible significant amount of CO_2 emission that could be produced using petrol fuel on cars, was found to be quite high according to the various statistical facts stated in number 4.5.1.The consideration was based on all the facts but most especially was the approximate amount of vehicles on the Malaysia road, also considered was the estimated 53,783 numbers of NGV in Malaysia (ANGVA, 2013).From all the assumption and calculations done in this study, the most important fact was the exclusion of Motorcycles from the list of vehicles in Malaysia. Although Motorcycles occupies about 48.6 % of the Malaysia vehicle, motorcycles do not run on CNG, so it wasn't necessary considering it in our study (Masjuki, et al., 2005). As at 2012, the numbers of vehicles excluding motorcycles in Malaysia was about 12, 139, 275, considering that the increase rate is about 0.5 to 1.5 % amongst the numbers of new numbers NGV cars and total numbers of Cars in Malaysia (MAA, 2013). Then, with these estimations, table 14 was drawn forecasting and projecting an expected increase in the numbers of cars on the Malaysian road, which is from year 2013 following the same procession of percentage increase through to year 2020.form the calculated projection, it was found that if all goes by the expected increase in the additional numbers of new cars annually, table 24 reflects that there would be a slight percentage increase projection to 9% increase rate of about 20,133,588 vehicles by year 2020.so it was also for the number of total NGV following the same expected percentage increase, this would by year 2020 amount to about 89,223 numbers of Vehicles in Malaysia.

Considering this forecast, the two expected outcomes showed that by year 2020 the numbers of NGVs would still be below 100,000 units i.e. in ranges of 0.05 to 1 % of the total Number of Vehicles in Malaysia by year 2020.Although; this would be about 1-2% of the present day total number of cars in Malaysia. With these understanding established, we then calculated for Two Conditions.

1. Calculation On CO_2 emissions from petrol fuel cars by year 2020
2. Calculation On CO_2 emissions Reduction using CNG fuel cars by year 2020

5.4.1 Discussion On CO_2 Emissions Produce Using Petrol Cars

Under the first Condition, we subtracted the estimated total Number of NGV from the Total Number of Vehicles and in doing this, it was discovered that by year 2020, the number of cars still running on petrol would be about 20,044,326 units. Thereafter, with this number, we were able to calculate the Amount of CO_2 emission that would be generated in year 2020.stating that:

If 1 car producing 2.6 kg/liter is estimated to travels on an average of 5 liters per day,

1 day journey = 2.6 x 5 = 13 kg/L daily

1 year journey = 13 x 365 = 4745 kg/L Annually

So, by year 2020, If 20,044326 cars are still running on gasoline (fuel),

1 car journey per year produces 4745 kg/L $CO_{2.}$

Then the Amount of CO_2 emitted by vehicle as at year 2020, would be 95,110,327 Tones CO_2

5.4.2 Discussion On CO_2 Emissions Reduction Using CNG Cars

The second Consideration was that, as at present the number of NGV is about 0.03 % of the total car in Malaysia. Taking note of this, we estimated that a 15% increase of NVG by year 2020 would have a great impact in the effort to reduce CO_2 emission in Malaysia. This would also see Malaysia grow to almost reach the same numbers of NGVs like Iran and Pakistan as of now. Table 26 showed the calculation with a total number of new NGV at 3,058,254 vehicles by year 2020.However, table 25 shows that, in other to achieve this total number of new NGV by 2020,the increase rate has to follow a procession of about 1.5, 2.0, 3.25, 3.754.25, 4.75, 5.55, which would produce about 3,058,254 units of vehicle. Then comparing to the proposed 15% increase of about 3,020,034 vehicles by 2020, this seems a little bit higher and ok. So therefore, from the estimated projection of 15% increase in new NGV Vehicles, we then calculated for the amount of CO_2 reduced by the year 2020.We found out that if the trend of new numbers of NGV in Malaysia starting from 2013 should increase in the procession as estimated, there would be a total of about 4,018,546 tones CO_2 emission reduced by 2020.also shown was the amount of CO_2 emission reduced each year. This is used further to derive the amount of reduction per day as shown in Table 26.

Table 26: Vehicle Unit and CO_2 Emission reduced from year 2014 – 2020

Year	No of Vehicles	Petrol CO2	CNG CO2	Reduction Emission CO2/Litre	Reduction Emission CO2/Day	Reduction Emission CO2 / Year.
	Unit	Kg/litre	Kg/litre	Kg/litre	Tonnes	Tonnes
2014	**182,089**	**2.6**	**1.7**	**0.9**	**656**	**239,265**
2015	**242,786**	**2.6**	**1.7**	**0.9**	**874**	319,021
2016	**394,526**	**2.6**	**1.7**	**0.9**	**1,420**	518,407
2017	**455,223**	**2.6**	**1.7**	**0.9**	**1,639**	598,163
2018	**515,919**	**2.6**	**1.7**	**0.9**	**1,857**	677,918
2019	**576,616**	**2.6**	**1.7**	**0.9**	**2,076**	757,673
2020	**637,312**	**2.6**	**1.7**	**0.9**	**2,294**	**837,428**

From the table 26, the estimated CO_2 emission reduced per day will be around 2,294tonCO_2 for using NGV fuels or about 3,058,254 units. This would be good a step for a fast developing country like Malaysia. Table 25 and Table 26, evidently shows that this amount of CO_2 can gradually be reduced with the increasing use of CNG fuel instead of petrol. I.e. if About 15 percent of The Present total Number of cars in Malaysia is running on CNG fuel. Based on this study, we were able to:

1. Verify its objectives of establishing the already estimated fact that the use of CNG vehicles reduces car exhaust CO_2 emission of about 0.9 kg/L when compared to petrol.
2. Substantiate the possible significant amount of CO_2 emission that can be reduced by year 2020 with a projected increase in CNG fuel usage.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter wraps up this study regarding CNG usage and CO_2 emission in the Malaysia Transport industry. The study achieving its main objective could help meet the Malaysian target of CO_2 emission reduction to 40% by year 2020 as compared to its 2005 level (Mohamad, 2009). In addition this study suggested some recommendation for future research to reducing the amount of CO_2 emission by year 2020.

6.2 Conclusion

On a whole, while this report generally documented the use of CNG on vehicles as an alternative to petrol, the main focus is that it would reduce the amount of CO_2 emission in the transport sector which could in turn lead to a sustainable and carbon free Malaysia by year 2020. The 45% of CO_2 emission from the transport sector can be effectively tackled with the use of more CNG vehicles on the Malaysian road instead of Petrol. From the performance tests conducted on the carburetor and injector car engine, using both petrol and CNG fuel discretely, a proposed CNG takeover of the total vehicles on the Malaysian road by 2020 is worth the consideration, taking note that using CNG as an alternative fuel to petrol reduces about 0.9kg/L of CO_2 exhaust gas emission. This means that the amount of CO_2 emission in the Malaysia road transport sector can gradually be reduced with the increasing use of CNG fuel instead of Gasoline (petrol). Also, from the analysis, the possible amount of CO_2 emission that can be reduced with the increasing use of CNG vehicle by year 2020 would be about 4,018,546 tones as against an estimated 3,058,254 cars. With this level of increase Malaysia could meet up with other higher NGV users around the world, taking Iran and Pakistan as a point of reference (Mostafa, et al., 2005). also, while taking every other estimation into consideration, there are other car powered sources that produces' less CO_2 emissions in use e.g. Electric, Hybrid, Bio-fuel and others, but in all, considerations should be given to the normal expected increase in general car numbers, which would be about 20,133,558 units by year 2020. Finally, from the study, it is presume that CNG fuelled engines has a great prospect as compare to gasoline since it has a clearly defined advantage in the reduction of CO_2 emissions.

6.3 Recommendations

This report has generally acknowledged the use of CNG on vehicles as an alternative to petrol, however, it is important to carry out continuous research on this and other energy saving technologies in other to simultaneously reduce the amount of CO_2 emission in other producing sectors such as industrial, commercial and residential using CNG.in contrast, the various estimation and accuracy of the result was based on the availability and accessibility of the CO_2 emission result. So, as a part of research fundamentals, results should be made available and be periodically updated so that researchers could look at these data and extract meaningful information from them. Additionally, the Malaysian government has to play some few more roles in its efforts to meeting the 40% CO_2 reduction target by 2020 (Mohamad, 2009). Either by the effecting more policies to further cut down gasoline usage in the transport sector or Make CNG a must use fuel. This write-up serves as a preliminary report toward integrating CNG and its CO_2 emission reduction benefits to transportation, thus, a holistic analysis and clear understanding of how the CNG engine performance relates to CO_2 emission reduction in the transport sector as a whole is required. Researches could also be done on the other GHG emitted from the car exhaust. More emphases on the importance and safety in using CNG should be highlighted to the public, in other to fulfill the vision of a 40% CO_2 reduction by 2020 (Mohamad, 2009).In addition, This same procedure could be followed to predict the emission for non-conversion, full conversion and partial replacement of petrol fuels driven cars by NGVs. Finally, although there are many strategies in general that can reduce CO_2 emissions in the Transport sector, the Author suggests CNG as a viable alternative to Gasoline fossil fuel for the case of Malaysia.

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REFERENCES

Afroz, R., Nasir, M. & Akma, N., 2003. *Review of air pollution and health impacts in Malaysia. Environmental Research,* Volume 92, p. 71–77.

Air Quality Science IAQ Resource Center (Aerias) 2012. *Environmental Research on Carbon Dioxide: A Common Indoor Air Pollutant* in Malaysia.

Aldrich, B. & Chandler, C., 1997. The ABCs of AFVs – *A Guide to Alternative Fuel Vehicles. The California Energy Commission.United Sates.*

Al-Mofleh, A., Taib, S., Mujeebu, M. A. & Salah, W., 2009. *Analysis of sectoral energy conservation in Malaysia.Energy*. 6(34), pp. 733-739.

Asia Pacific Natural Gas Vehicles Association (ANGVA). 2013. *Status of NGV in Asia Pacific (Dec '12).* http://www.angva.org/?page_id=256.

Aslam, M.U., Masjuki, H.H., Maleque, M.A., Kalam,M.A., Mahlia, T.M.I., Zainon, Z., 2003. *Introduction of natural gas fueled automotive in Malaysia. Proc. TECHPOS'03; 160.* University of Malaya, Malaysia.

Aslam, M.U., Masjuki, H.H., Kalam, M.A., Abdesselam, H., Mahlia, T.M.I., and Amalina. M.A. 2006. *An experimental investigation of CNG as an alternative fuel for a retrofitte gasoline vehicle.* Fuel, Volume 85, pp. 717-724.

Bakar, R. A. & Mardani, A. S., 2001. *The Realization Of Optimum CNG Engine:It's Implication On Engine Design", Advances in Malaysian Energy Research,.* UKM, 29 October 2001.

Bakar, R. A. S., 2008. *A Technical Review of Compressed Natural Gas as an Alternative Fuel for Internal Combustion Engines*. American Journal of Engineering and Applied Sciences, 4(1 ISSN 1941-7020), pp. 302-311.

Bakar, R., Idris, A. & Semin., 2009. *An Overview of Compressed Natural Gas as an Alternative Fuel and Malaysian Scenario*. European Journal of Scientific Research, 34(1), pp. 6-15.

Bakar, R., Semin. & Ismail, A., 2007a. *The Internal Combustion Engine Diversification Technology And Fuel Research for the Future.* A Review, Proceeding of AEESEAP Symposium, Kuala Lumpur, Malaysia, p. 57 – 62.

Bakar, R., Semin., Ismail, A. & Ali, I., 2007b. *Computational Modeling of Compressed Natural Gas as an Alternative Fuel for Diesel Engines, Proceeding of 2nd ANGVA Conference.* Bangkok, Thailand.

Bari, M.A., R.A. Begum, A.H. Jaafar, R.D.Z.R.Z. Abidin and J.J. Pereira, 2011. *Future Scenario of Residential Energy Consumption and CO2 Emissions in Malaysia.* Universiti Kebangsaan Malaysia, Bangi.

Beniston, M., 2002. Climatic change: possible impacts on human health. *Swiss medical weekly,* Volume 132, pp. 332 -337.

Biello, D., 2010, July 22. *The new normal: Average global temperatures continue to rise. Scientific American.*

Bosch,2013.*MTS 1100 Gas analyser. Retrieved 24 September 2013 from*: http://www.boschdiagnostics.com/parts/diagnostics/MTS1100/Pages/MTS1100.aspx.

Burniaux, J. & Chateau, J., 2011. *Mitigating potential of removing fossil fuel subsidies: A general equilibrium assessment (OECD Economics Department Working Paper No. 853).*

Cable, J., 2004. *NIOSH report details dangers of carbon dioxide in confined spaces. Occupational Hazards.*

Canadel, J. et al., 2010. *Interactions of the carbon cycle, human activity, and the climate system: a research portfolio. Current opinion in environmental sustainability,* 2(4), pp. 301-311.

CATERPILLAR, 2007. *Application and installation guide:Gas ENGINE EMISSION.* pp. 7-11.

Ching, G., 2005. *China NGVs as a solution to energy security concerns in China and beyond, in Proceedings of ANGVA 2005, July 26-28.* Kuala Lumpur,Malaysia..

Chowdhury, A.D. (2005), *CNG programme for commercial vehicles in India, in Proceedings of ANGVA 2005*, July 26-28, Kuala Lumpur, Malaysia.

Chyi, S.C. (2010).*Review on Malaysia's national energy developments: Key policies, agencies, programmers and international involvements; Renewable and Sustainable Energy Reviews,* Volume14.Issue9 pp, 2916-2925.

Crypton, 2012. *Understanding EXHAUST EMISSIONS. Retrieved 3 December 2013 from*: http://www.crypton.co.za/Tto%20know/Emissions/exhaust%20emissions.html.

Das, M. L., Gulati, R. & Gupta, K. P., 2000. *A comparative evaluation of the performance characteristics of a spark ignition engine using hydrogen and compressed natural gas as alternative fuels. International Journal of Hydrogen Energy,* Volume 25, (2000), 783-793.

Daud, M., 2005. *Experience and challenges in the implementation of NGV/CNG as a clean fuel of choice for malaysian Transportation Sector in Proceedings of ANGVA,* 26-28 July, p. Paper 1, Kuala Lumpur, Malaysia.

Department of Environment, Malaysia. (2001). *Clean Air Regional Workshop Fighting Urban Air Pollution: From Plan to Action,Department of the Environment, Malaysia,* KL,Malaysia. http://www.doe.gov.my/portal/

Department of Environment, Malaysian. MDOE (2010). Retrieved 16 Novenmber 2013, from Department of *Environment* Malaysia .http://www.doe.gov.my/portal/

Department of Statistics. (2010a). Population and housing census of Malaysia 2010 *Population distribution and basic demographic characteristics*. Putrajaya, Malaysia.

Department of Statistics. (2010b). Population, household & living quarters, Malaysia. Retrieved 13 September 2011, from Department of Statistics Malaysia http://www.statistics.gov.my/portal/download_Population/files/BPD/population_quarters_2010.pdf

Durell, Elizabeth, Allen, Jeff., Law, Donald.,Heath, John., 2000. *Installation and Development of a Direct Injection System for a Bi-Fuel Gasoline and Compressed Natural Gas Engine, Proceeding ANGVA 2000 Conference,.* Yokohama, Japan.

Energy Information Administration (EIA). 2005. *Malaysian Country Analysis Brief.* Washington, DC., Office of Energy Markets and Use.

Exaust A, 2010. *Exhaust Analysis Using 4 and 5 Gas Analyzers EMISSIONS #2 . Retrieved 23 November 2013 from:www.autoshop101.com/forms/h56.pdf.*

G8, 2007. *Chair's Summary. Heiligendamm: G8 Summit 2007 Heiligendamm. http://www.g-8.de/Webs/G8/EN/G8Summit/SummitDocuments/summit documents.html*

Gallo, M., 2011. A fuel surcharge policy for reducing road traffic greenhouse gas emissions. *Transport Policy*, 38(18(2)), pp. 413-424.

Ganesan, V., 2003. Internal combustion engines. In: s.l.:Tata McGraw Hill, pp. ISBN 0-07-0494576.

Green Tech Malaysia (2008). CO2 emissions by sector from Global Perspective. Retrived 4 June 2013 from: http://www.greentechmalaysia.my/.

Gruber, G., 2011. *Combating climate change.* Available at: www.thestar.com.my [Accessed 17 November 2013].

Hasim, A. R., 2005. *Natural gas for vehicle – the fuel of choice for Asia pacific - status, challenges and the way forward, in Proceedings of ANGVA 2005, July 26-28,*. Kuala Lumpur, Malaysia.

Hubacek, K., Guan, D. & Barua, A., 2007. Changing lifestyles and consumption patterns in developing countries: a scenario analysis for China and India.. *Futures,* 39(9), pp. 1084 - 1094.

International Energy Agency (IEA), 2010. *International Energy Agency:Working together to ensure reliable, affordable and clean energy.* http://www.prb.org/pdf11/2011population-data-sheet_eng.pdf

International Energy Agency (IEA), 2011. *CO2 emissions from fuel combustion 2011 high lights.index,Malaysia-CO2emissions.*http://www.indexmundi.com/facts/malaysia/co2-emissions

Intergovernmental Panel on Climate Change (IPCC). 1996. *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventory*.. Montreal.

Intergovernmental Panel on Climate Change (IPCC). 2001. *Climate Change 2001: The Scientific Basis. Geneva: Intergovernmental Panel on Climate Change*.

Intergovernmental Panel on Climate Change (IPCC).2004.*16 Years of Scientific Assessment In Support of the Climate Convention: Intergovernmental Panel on Climate Change*.. Geneva.

Intergovernmental Panel on Climate Change (IPCC).2006.*Intergovernmental Panel on Climate Change. 2006 IPCC guidelines for national greenhouse gas inventories.: National Greenhouse Gas Inventories Programme*.. Kanagawa, JAPAN.

Intergovernmental Panel on Climate Change (IPCC).2007a. *IPCC Special Report on Carbon Dioxide Capture and Storage Climate Change.Working Group III of the Intergovernmental Panel on Climate Change.* Geneva.

Intergovernmental Panel on Climate Change (IPCC).2007b.*Climate Change:Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*.. Geneva.

Jahirul, M.I.; Saidur, R.; Hasanuzzaman, M.; Masjuki, H.H.; Kalam, M.A. (2007). A comparison of the air pollution of gasoline and CNG driven car for Malaysia. International Journal of Mechanical and Materials Engineering, 2 (2). pp. 130-138. ISSN 18230334.

Jahirul M. I., Masjuki H. H., Saidur R., Kalam M. A., Jayed M. H., & Wazed M. A. (2010).Comparative engine performance and emission analysis of CNG and gasoline in a retrofitted car engine. *Applied Thermal Engineering*, *30*(14-15), 2219-2226.

Kalam M., 2007. *Performance and simulation study of a new Direct Injection (DI) compressed natural gas (CNG) engine.(Unpublished PhD's thesis).* University of Malaya, Kuala Lumpur.

lee yen mun, 2013. *RON95 petrol, diesel up 20 sen from midnight (Update).* Available at: http://www.thestar.com.my/News/Nation/2013/09/02/ron95-up-20-sen.aspx

Malaysia Automotive Association (MAA) 2013.*: Summary of Sales & Production Data.* Available at: http://www.maa.org.my/info_summary.htm [Accessed 10 May 2013].

Malaysia Environmental Quality Report, *(*MDOE) (1996).Malaysia Ministry of Science, Technology and Environment.

Malaysian Meteorological Department. (MMD) (2009). Climate change scenarios for Malaysia. *Petaling Jaya, Selangor, Malaysia: Malaysian Meteorological Department.,* pp. 2001 -2099.

Malaysian Road Transport Departmen JPJ, R., 2012. *Vehicle and driver statistics:Road Transport Department Malaysia.June 2013.*

Masjuki H., Rehan M. & Mahlia T., 2005. *Energy use in the transportation sector of Malaysia. A danida-funded project on renewable energy and energy efficiency..* Consultancy unit university of Malaya.

Mohamad M., 2009. *Malaysian Prime Minister at COP15. Retrived 5 June 2013 from:* http://www.demotix.com/news/malaysian-prime-minister-cop15#media-207416.

Mohan M., 2008. Addressing the sustainable development and climate change challenges together: Applying the sustainomics framework. Procedia social and behavioral science 41 (2010); 6634-6640.

Mostafa S., Ghoresihi S. & Maryam H., 2005. *Iran's NGV road-map; Technology, policy and marketing, in Proceedings of ANGVA.* Kuala Lumpur, Malaysia.

National, E. B., 2008. *Energy statistics from Energy Commission Retrived 8 June 2013 from:*http://www.st.gov.my/index.php?option=com_content&view=article&id=5437%3Aenergy-statistics&catid=837&Itemid=1749&lang=en .

National Institute for Occupational Safety and Health (NIOSH).(1976). *Criteria for a Recommended Standard, Occupational Exposure to Carbon Dioxide.*

National Institute for Occupational Safety and Health. NIOSH, 1997. *NIOSH Pocket Guide to Chemical Hazards. DHHS (NIOSH) publication no. 97-140. US Government Printing Office, Washington, DC .* Available at: http://www.cdc.gov/niosh/npg/npg.html

National News Agency of Malaysia BERNAMA, 2011. *Malaysia on Target for 200 NGV filling Stations Nationwide.* http://www.namnewsnetwork.org/v3/read.php?id=MTYwNTcz

National News Agency of Malaysia BERNAMA, 2013. *Flood Situation Worsen In Pahang, Johor And Terengganu. Retrieved 3 May 2013 from:* http://www.bernama.com/bernama/v7/newsindex.php?id=998168

Nam News Network (NNN), 2012. *Petronas To Have 184 NGV Stations Nationwide By 2014Source: Nnn-Bernama.* http://www.namnewsnetwork.org/v3/read.php?id=MjA3NjM0

Nelson L., 2000. Summary of physiological effects and toxicology of CO2 on humans. *Carbon Dioxide Poisoning. Emerg. Medicine*, 32(5), pp. 36-38.

Netto A., 2009. *Copenhagen talks create hardlya ripple in malaysia, Inter Press Service. Retrived* 4 October *2013 from*: http://ipsnews.net/news.asp?idnews=49744.

NGV Global News, 2012 Malaysia's Petronas to Add 10 More NGV Refueling Stations by 2014. Retrived 14 may *2013 from*: http://www.ngvglobal.com.

Nylund N., Laurikko J. & Ikonen M., 2002. *Pathways for natural gas into advanced vehicles. IANGV International Association for Natural Gas Vehicle, Edited Draft Report 2002; Version 30.8.2002.*

O'Sullivian S. & & Morrall J., 1996. Walking distances to and from Light-Rail Transit stations. *Transportation Research Record* , Volume 1538, pp. 19 -26.

ONE gas NGV,2009. Retrived 6 May May from:http://www. malaysiangv.com/station.html

Perumal E., 2008-06-13. *Rush to fit natural gas gadget". The Star Online.* Available at: http://www.thestar.com.my/story.aspx?file=%2f2008%2f6%2f13%2fcentral%2f21532553&sec=central [Accessed 7 September 2013].

Rahnama A., 2007. *The Great Progress in CNG, A Giant Leap in Iran, 2nd ANGVA Conference,.* Bangkok, Thailand, R BAIRWA.

Ramhee E. & Reddy, K. V. K. (2011). Performance analysis of a 4-stroke SI engine using CNG as an alternative fuel. Indian *Journal of Science and Technology, 4*(7), 801-804.

Rice S.A., 2004. *Human health risk assessment of CO2: survivors of acute high-level exposure and populations' sensitive to prolonged low level exposure. Poster 11-01 presented at 3rd Annual conference on carbon sequestration,* Alexandria.

Safaai S., Noor Z.Z., Hashim H., Ujang Z., & Talib J. (2010**).** *Projection of CO2 emissions in Malaysia. Environmental Progress & Sustainable Energy.*

Saidur R. , Jahirul, M., Moutushi T., Imtiaz H., Masjuki H. (2007). Effect of partial substitution of diesel fuel by natural gas on performance parameters of a four cylinder diesel engine.. *Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy*, 221(1), pp. 1-10.

Salahudin, S. N., Abdullah, M. M. & Newaz., N. A., 7 July 2013.. Emissions: Sources, Policies And Development In Malaysia,. Volume 1.

Sanquist, T. F., Orr, H., Shui, B. & Bittner, A. C., 200. Lifestyle factors in U.S. residential electricity consumption. *Energy Policy,* 42(2012), pp. 354-364.

Schipper, L., Bartlett, S., Hawk, D. & Vine, E., 1989. Linking life-styles and energy use: A matter of time?. *Annual Review of Energy,* 14(1), pp. 273-320 .

Schipper, L., Saenger, C. & Sudardshan, A., 2011. Transport and carbon emissions in the United States: The long view.. *Energies,*, 4(4), pp. 563 -581.

Schwartz, S. H. (1996). Value priorities and behavior: Applying of theory of integrated value systems. In C. Seligman, J. M. Olson, & M. P. Zanna (Eds.), The Psychology of Values: The Ontario Symposium, Vol. 8 (pp. 1–24). Hillsdale, NJ: Erlbaum.

Selamat & Abidin, 2010. *Renewable Energy and Kyoto Protocol: Adoption in Malaysia*. Available at: http://publicweb.unimap.edu.my/ppkas/home/index.php/news/articles/29.

Shah, A., 2011. *Climate change and global warming introduction. Global Issues website:*. http://www.globalissues.org/article/233/climate-change-and-global-warming-introduction.

Shamekhi, A. H. & Khatibzadeh, N., 2008. A Comprehensive Comparative Investigation of Compressed Natural Gas as an Alternative Fuel in a Bi-Fuel Spark Ignition Engine.. *Iranian Journal of Chemistry & Chemical Engineering,* 27(1), pp. 73-83.

Shasby, B., 2004. Alternative Fuels: Incompletely Addressing the Problems of the Automobile, MSc Thesis, USA. *Virginia Polytechnic Institute and State University*, 19 May, pp. 5-13.

Sperling, Daniel & Gordon, D., 2009. Two billion cars driving toward sustainability. New York: Oxford University Press, ISBN 978-0-19-537664-7., p. 93–94.

Sun, Xiaobo., Lutz, Alwin., Vermiglio, Ezio., Arold, Mark., 1998. Wiedmann, Tom, *The development of the General Motors 2.2L CNG bifuel passenger cars,* s.l.: SAE Technical Paper (982445).

Suria NGV, 2012.Save Fuel Cost up to 80%.Retrived 6 July 2013 from: http://suprongv.com/v1/index.php?option=com_content&task=blogsection&id=8&Itemid=28

Tangang, F., 2007. *Climate change and global warming: Malaysia perspective: Malaysia perspective and challenges. Lecture note.,* Universiti Kebangsaan Malaysia.: School of Environmental and Natural Resource Sciences, Faculty of Science & Technology.

Theseira Gary W., T., 2010. How can the 40% carbon (intensity) reductions can be achieved?. *ENSEARCH,* Issue Waste Management 2010 Conference.

UN, 1998. *Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC)* 1998. New York, United Nations.

UN, 2008. *Kyoto Protocol to the United Nations Framework Convention on Climate Change.,* New York: United Nations.

UNFCCOCC, 1997. *United Nations Framework Convention on Climate Change: Kyoto Protocol to the United Nations Framework Convention on Climate Change.*

United States Department of Transportation,*National Highway Traffic Safety Administration (2010),Factors and Considerations for Establishing a Fuel Efficiency* FCE,2010.

United States National Academy of Sciences (NAS) 2008. "Most scientists agree that the warming in recent decades has been caused primarily by human activities that have increased the amount of greenhouse gases in the atmosphere.

Waterland, L., Powars, C. & Stickles, P., 2005. *Safety Evaluation of the Fuel Maker Home Refueling Concept", Final Report, NREL/SR-540-36780NREL, Colorado, USA.*

Wee, K., Matsumoto, H., Chin, S. & Yu, F., 2008. Energy consumption and carbon dioxide emission considerations in the urban planning process in Malaysia. *Planning Malaysia 6*, pp. 99-128.

Wei, Y., Liu, L., Fan, Y. & Wu, G., 2005. The impact of lifestyle on energy use and CO2 emission: An empirical analysis of China's residents.. *Energy Policy,* 35(1), pp. 247-257.

Yusaf, T. F., Buttsworth, D. R., Saleh, K. H. & Yousif, B. F., 2010. CNG-diesel engine performance and exhaust emission analysis with the aid of artificial neural network. *Applied Energy,* 8(5), pp. 1661-1669.

APENDIX 1

BOSH Gas Exhaust Analyzer Operating Principle

1. Warm-up period

The device's warm-up period amounts to approximately 1 minute. At this period it is not possible to perform a measurement.

2. Null balance at start of measurement

After switching on the pump, for period 30 seconds the zero point of the analysis system is automatically compensated for with ambient air (zero gas).

3. Null balance during measurement

After a measurement has been started, the BEA 050 performs an automatic system check using ambient air .The BEA 050 then switches a solenoid valve to ambient air for the system check. Zero gas is then purged for a period of 30 seconds. The ambient air intake is then cleaned of hydrocarbons by an activated-carbon filter.

Check (inspect) the system before any experiment.

1. **Exhaust Sample System Tightness:** It is essential that the exhaust sample system does not have any leakages if it is to measure exhaust gas accurately. So before the experiment, make sure a tightness test (leakage test) is performed.

2. **Exhaust Sample Probe:** Make a Visual inspection of the exhaust-gas sample probe keeping the opening at the tip of the probe clean. Check for any signs of HC residue and

condensation, if found, disconnect the exhaust sample probe from the hose and blow it out in the opposite direction to the intake flow using compressed air.

3. **Exhaust Sample Hose:** Check whether both PVC hoses are connected to the gas exhausts, check for signs of damage. If there are any signs of HC residue and condensation disconnect the exhaust sample probe from the hose and blow it out in the opposite direction to the intake flow using compressed air.

4. **Filter:** Check the downstream measuring chambers if damaged by corrosion residue (e.g. rust particulates through metal-filter inserts). Also check if the measuring gas is cleansed of particulates (e.g. dust and soot) and aerosols by a cascade of filters. In order to prevent any damage occurring to the exhaust-gas analyzer, it is necessary to ensure that the correct type of filter is used and that it is replaced according to the schedule.

5. **Checking Display Stability:** Disconnect the exhaust sample hose from the measurement input on the BEA 050. In the Emission System Analysis program in your Bosch test system call up the Diagnosis / Gas values menu. After the system balance (null balance and HC residue test) the device will display the current measured values. Observe the display for approx. 2 minutes checking limits and stability.

Error limits for fluctuations (noise):

Display	**Value**	**Fluctuation**
CO	0 %Vol	± 0,005 %Vol
CO2	0%Vol	± 0,02 %Vol
HC	0 ppm Vol	± 0,12 %Vol
O2	20,9 % Vol	± 0,4 %Vol

The HC display stabilize at a value < 12 ppm vol after approx. 2 minutes.

APENDIX 2

Experimental Pictures

CAMPRO IAFM Engine

A change over switch and the exhaust probe in the exhaust

The RPM clip, for taking the readings

The BOSH 050, gas analyzer during experiment

APENDIX 3

Conference Paper

Odeta P., Edilan M.M., Hossain A., Bakar M.A. (2013). *Reduction of CO_2 Emission in Malaysia Transport Industry: Using Compressed Natural Gas (CNG) as Alternative Fuel.* Science & Engineering Technology National Conference 2013, Bangi, Malaysia, 3rd – 4th July 2013.

Reduction of CO_2 Emission in Malaysia Transport Industry: Using Compressed Natural Gas (CNG) as Alternative Fuel

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Abstract

Compressed Natural Gas (CNG) fuel has long been used in the Malaysia transport industry due to its numerous advantageous properties. CNG fuel engine considered a low carbon dioxide (CO_2) emission producer presents itself a viable alternative to gasoline/ diesel fuel engines. From the literature, it is found that the transport industry contributes 45% of CO_2 emission to the environment. Therefore, this study presents the investigation of CO_2 emission in the Malaysia transport industry by using CNG as an alternative fuel. Data has been collected from the previous research, experimental resolution and field survey which has been used for verifying and validating the possible outcomes of CNG engine performance on CO_2 reduction as well as the impact of constant increase of vehicles using CNG. In this study an elevated performance implementation has been achieved in other gases but the target was on CO_2 emissions at its minimal stage, noting the risk involve as well as encouraging the total acceptability of the CNG fuel in the Malaysia society. It is therefore proposed that any adjustment or improvement result in CO_2 emissions reduction will save the world environmental climate change.

Keywords: Compressed Natural Gas; CO_2 emission; Environment; Transport industry.