

# Compressed Natural Gas Passenger Vehicle Development – Issues and Challenges

Barkawi Sahari<sup>1</sup>, Yusoff Ali<sup>2</sup>, Fakhru'l-Razi Ahmadun<sup>1</sup>, Shahrir Abdullah<sup>2</sup>,  
Masjuki Hj. Hassan<sup>3</sup>, Ishak Aris<sup>1</sup>, Muhamad Adlan Abdullah<sup>4</sup>, Mohd. Fauzy Ahmad<sup>5</sup>,  
V. Chelliah<sup>4</sup>, Zahari Taha<sup>3</sup>, Abd. Rashid Aziz<sup>6</sup>, Md. Nor Musa<sup>7</sup>, T. G. Chuah<sup>1</sup>,  
Norman Mariun<sup>1</sup>, Ku Halim Ku Hamid<sup>8</sup>, V.R. Radhakrishnan<sup>6</sup>

<sup>1</sup>Universiti Putra Malaysia (UPM), <sup>2</sup>Universiti Kebangsaan Malaysia (UKM),

<sup>3</sup>Universiti Malaya (UM), <sup>4</sup>Petronas, <sup>5</sup>Proton Berhad,

<sup>6</sup>Universiti Teknologi Petronas (UTP), <sup>7</sup>Universiti Teknologi Malaysia (UTM),

<sup>8</sup>Universiti Teknologi Mara (UiTM),

**Abstract:** The research and development of automotive vehicle has always been influenced by the availability and the form of fuel. The oil reserves are depleting by the day. This will affect the automotive designs, research and development, particularly, the engine and transmission, fuel storage and the vehicle body. For passenger car, either an alternative fuel need to be sought and utilised fully and/or new fuel need to be developed. In either cases, technological research and development on the engine and transmission, fuel storage and the vehicle body need to be carried out extensively. For this purpose, collaborative efforts between the Universities, Research Institutes and Industries and strong funding are required. This paper presents the results of the research and development program for the development of a Compressed Natural Gas (CNG) Direct Injection (DI) vehicle sponsored by the Ministry of Science, Technology and Innovation (MOSTI) under the Intensification of Research Priority Areas (IRPA) mechanism. It is a collaborative research program involving UPM, UM, UKM, PRSS, UTM, UiTM, UTP and PROTON. This paper also discusses the issues arising from the implementation of the programme, the challenges faced and the way forward for the CNG vehicle.

**Keywords:** Natural Gas Vehicle, Compressed Natural Gas, Direct Injection

Communicating Author:

Prof. Ir. Dr. Barkawi Sahari,  
Advanced Automotive Technology Laboratory,  
Institute Teknologi Maju (ITMA)  
Universiti Putra Malaysia,  
43400 UPM SERDANG, SLANGOR

Tel: 03-89467536

Fax: 03-89467536

e-mail: barkawi@eng.upm.edu.my

## 1 Introduction

The research and development (R and D) of automotive vehicle has always been influenced by the fuel availability and its form. We have seen the changing of car design from the era of horses and cows, coal and liquid petrol. The oil reserves are reduced by the day. This will affect the automotive designs, research and development activities, particularly, alternative fuel, engine and transmission, fuel storage and vehicle body. For passenger car, either an alternative fuel need to be sought and utilised fully and/or new fuel need to be developed. In either case, technological research and development on the engine, transmission, fuel storage and the vehicle body need to be carried out extensively. The focus areas of R and D in automotive differs from country to country, from region to region (such as EU, ASEAN) and from one economic grouping to another (such as AFTA). The choice of focus mostly depends on the national interest, regional interest and some also depends on the technical consultants and advisors of the government. For automotive sector, international regulations related to the environment (such as EURO 3 and EURO 4) and guidelines related to passenger safety (such as NCAP) has a very much influenced on the research focus. This paper intends to provide an overview of automotive research, particularly the focus areas of research, mechanisms and management of research activities, challenges that might be faced and become hindrance to and issues related to procurement for public sector automotive R and D. The paper is divided into several parts, namely; energy scenario, engine technology, focus areas of importance, research works on natural gas vehicle, and issues and challenges. The later part of the paper will propose practical mechanisms for automotive R and D.

## 2 Background motivation

There are three factors that motivate the present research. The first is the fuel availability, cost and supply. Studies on the energy demand for the 21<sup>st</sup> century has been conducted by World Energy Council (1, 2, 3, 4) and a summary of the energy availability is shown in Fig. 1 (1). From Fig. 1, it can be seen that during the period of 2005 to 2050, the use of oil is less compared to the use of Natural Gas (NG). Also, during this period, the use of oil is decreasing whereas for NG it remains almost constant. Therefore, NG is the fuel of choice for at least the next 50 years. Malaysia currently produced 39.8 million tonnes oil equivalent (mtoe) of NG and consumes only 19.5 mtoe (6). Hence, there is plenty of NG available for automotive use. To utilise NG for automotive, a number of issues need to be addressed. These are technological, economical and political. This paper focuses on the technology aspect only. The main concern for using NG for automotive is the safety, storage and refuelling infrastructure. NGV also has less emission level as set out by the EURO 3 and EURO 4 requirements. Table 1 shows the results of test on two types of fuel compared to the standards requirement as reported by Middleton and Neumann (9). It can be seen that NGV comply all the requirements of the standards. Other alternative fuels are electric, hydrogen, propane, alcohol, bio-based, fuel cell and nuclear. However, these alternative fuels are still being researched.

The second motivation is the industrial supports. For this case, Proton has given the full support in terms of base body, engine, research expertise and information. Industrial support and commitment are very important for the success of the research.

The third motivation is the market potential. Table 2 shows the population of NGV of some selected countries. Argentina ranks the top as far as number of vehicles of nearly 1.5 million vehicles followed by Brazil and Pakistan. The number of NGV in Malaysia is still very low with only 15,600 units. Therefore there is plenty of market potential for NGV. With the high price of gasoline, NGV offers a cheaper fuel alternative.

## 3 Research Work on Compressed Natural Gas Vehicle

As regard to the mono-fuel passenger vehicle, UPM, UM, UKM, PRSS, UTM, UiTM, UTP and PROTON together, carry out a program to develop the Compressed Natural Gas vehicle (CNGV) sponsored by (MOSTI) under the Intensification of Research Priority Areas (IRPA) mechanism (10). The program covers natural gas storage (UPM), fuel system and injectors (UKM, UM), combustion and ignition (UKM, UPM, UTP), electronic control unit and diagnostic kit (UPM), performance and emission (UM, UiTM), vehicle body architecture (UPM) and refuelling technology (PRSS, UTM, UTP). PROTON is involved in every project. It is a collaborative effort between the Universities, Research Institutes and Industries with strong funding.

The program used the 1.6 liter CAMPRO as the base engine as shown in Fig. 2 and the Proton Waja vehicle platform as shown in Fig. 3 as the base platform. The research methodology is shown Fig. 4. The development include the vehicle platform, fuel storage tank, fuel system, ignition system, cylinder head, exhaust, electronic control unit, fuel injectors and the refueling equipment; compressor and dispenser.

The fuel storage is cylindrical tank with an aluminium liner wound with carbon fibre. The pressure capacity is 200.0 bar. Three tanks are fitted to provide a predicted range of 300.0 km. A new cylinder head was designed to fit the injectors and fuel rail to the CAMPRO engine block. To achieve good combustion characteristics, a longer spark plug is used. The arrangement of tank, fuel systems and injector and fuel systems configurations is shown in Fig. 5. An Electronic Control Unit (ECU) included the hardware, software and diagnostic kit was designed and calibrated. The program also takes into account the exhaust emission and in particular NO<sub>x</sub>. To achieve this, a catalytic converter was designed. The vehicle platform was developed to adapt the CNG tanks with the main consideration included safety, tank shape, number and weight, mileage and refueling time. An important design criteria was platform structural safety during crash and these were simulated using various designs of structural reinforcements, weights and tank mountings. For the refuelling work, the compressor and dispenser are also being designed. Because of the high pressures involved, rigorous analysis such as mode shape and stress analyses were performed on the components to ensure safety. A prototype refueling station was constructed. The CNG/DI prototype vehicle is as shown in

Fig. 6.

## 4 Challenges and difficulties faced.

In executing the program, there are a number of difficulties faced. They can be divided into three categories; technical, institutional and industrial supports.

The technical part of the program requires major design, analysis, fabrication and testing. Highly skilled manpower for a specified period is required. Such people are difficult to get because most prefer jobs on a permanent basis. For the CNG project, this is possible through collaborations of a number of institutions. Another difficulty is in the fabrication of prototypes. Rapid prototyping is usually needed. For epoxy type, it can be done either in house or done by a third party within the country. However, for more delicate and complex components and metal rapid prototyping, usually third party from outside Malaysia is required. It costs more and it took longer. Researchers also have to be aware of intellectual property and the disclosure of technical information that might jeopardize patent filing. On the supplies side, technically competent suppliers in providing technical information, equipment, software, testing and fabrication works, raw materials, electronic components and specialist consumables should be readily available. Provision of good support from suppliers is crucial to the success of the research work.

The second challenge is the support from the research institutions, particularly, during the kick off and the early stage. It includes administrative and suitable space. The timeliness in personnel recruitment, procurement of equipment and materials is crucial. In this regard, a suitable procurement procedure conducive for research works that will reduce if not eliminate unnecessary delay is needed.

The support from the automotive industry is as important as that from the institutions. This could be in kind such as base vehicle, base engine, information or data, expertise, fabrication and testing standards, procedures and services. For the CNG program industry support is obtained from Proton.

## 5 Concluding remark

From the above retrospect, we can conclude that:-

- a) R and D in automotive, depends on the two main factors, namely the available fuel and the market potential. The present program's main focus is to utilise the NG to its fullest and to meet the standards with regard to environment,
- b) Natural gas seems to be the fuel of choice. It is abundant, clean and within means of storage and distribution. Hence R and D on NGV should continue to be given priority especially in the development of Original Equipment (OE) and commercialise and promoting NGV.
- c) In terms of mechanism and management of research in automotive, a multi institutional collaboration that comprises of the Universities, Research Institutes and the Industry appears to be necessary to utilise fully all the available resources and expertise in the respective institutions.
- d) A special procedure for procurement of equipment and services is very much needed to reduce unnecessary delay.
- e) Three main issues and challenges has been identified; namely technical, institutional and industrial supports, These issues need to be addressed properly especially in formulating research proposal and its implementation.

## 6 References

1. Nakicienovic N., Grubler A., McDonald, (editors), "Global energy perspectives". Cambridge University Press, UK, 1998, p299.
2. WEC (World Energy Council), "Energy for tomorrow's world", St. Martin's Press, USA, 1993, 320p.
3. WEC (World Energy Council), "New renewable energy resources: A guide to the future", Kogan Page, London (UK) 1994, 391p.
4. Brundtland G.H., "Our common future", Oxford University Press, UK, 1987, 400p.
5. Durell E, Law D, Allen J, Heath J., "Emissions Results from Port Injection and Direct Injection Bi-fuel (Gasoline and CNG) Engines", Lotus Engineering. Hargrave, Loughborough University.
6. IANGV Newsletter, <http://www.iangv.org/default.php?PageID=132>
7. IANGV Newsletter, <http://www.iangv.org/default.php?PageID=130>
8. Mohd. Ghazali Daud, "Experience and challenges in the implementation of NGV/CNG as a clean fuel of choice for Malaysian Transportation Sector", Paper 1, Proceedings, ANGVA 2005, 1<sup>st</sup> Conference & Exhibition, 26 – 28 July 2005, Kuala Lumpur.

9. Middleton, A., Neumann, B., "CNG engine technology for fleets – performance, emissions and cost effectiveness", Paper 9, Proceedings, ANGVA 2005, 1<sup>st</sup> Conference & Exhibition, 26 – 28 July 2005, Kuala Lumpur.
10. Barkawi Sahari, Yusoff Ali, Fakhru'l-Razi Ahmadun, Shahrir Abdullah, Masjuki Hj. Hassan, Ishak Aris, Muhamad Adlan Abdullah, Mohd. Fauzy Ahmad, Chelliah, V, Zahari Taha, Abd. Rashid Aziz, Md. Nor Musa, Chuah, T.G., Norman Mariun, Ku Halim Ku Hamid, Radhakrishnan, V.R., "A Compressed Natural Gas Direct Injection Vehicle (CNGDIV) Development Program – A Malaysian Initiative", Paper 7, Proceedings, ANGVA 2005, 1<sup>st</sup> Conference & Exhibition, 26 – 28 July 2005, Kuala Lumpur.

## 7 Acknowledgements

The author would like to acknowledge the following organisations and their staff for their contributions, commitment and assistance; Ministry Of Science Technology and Innovation, Ministry Of Finance, Universiti Putra Malaysia (UPM), Universiti Kebangsaan Malaysia (UKM), Universiti Malaya (UM), PRSS, PROTON, Universiti Teknologi Petronas (UTP), Universiti Teknologi Malaysia (UTM), Universiti Teknologi Mara (UiTM).

## 11. List of Tables

Table 1: Comparison of emission level against standard (9) (Units: grams/kilowatt hour)

	CO	NMHC	CH4	NOX	PM
EURO 3 limit	5.45	0.78	1.6	5.0	0.16
EURO 4.1 limit	4.0	0.55	1.1	3.5	0.03
NGV test results G20 gas	0.131	0.011	0.156	3.09	0.006
NGV test results G25 gas	0.134	0.020	0.459	2.88	0.007

Table 2: The number of NGV and refuelling stations for selected countries (7).

Country	Number of Vehicles (NV)	Number of refuelling stations (NRS)
Argentina	1,459,236	1,400
Brazil	1,035,348	1,176
Pakistan	850,000	828
India	204,000	198
Iran	91,314	120
Bangladesh	44,534	106
Malaysia (8)	15,600	40
USA	130,000	1,340
Japan	25,000	289

## 12. List of Figures

Fig. 1: The availability of fuel and usage

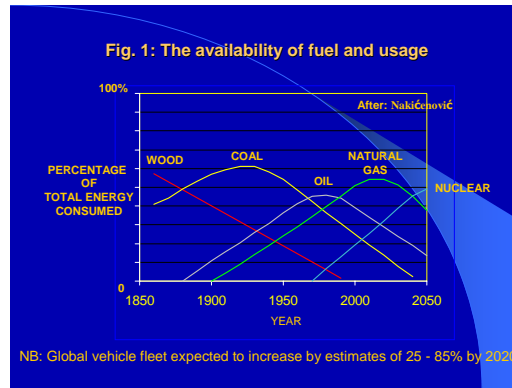


Fig. 2: The PROTON CAMPRO engine



Fig. 3: The PROTON WAJA Body Platform

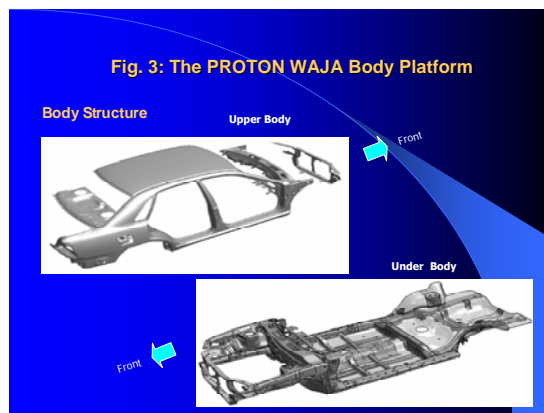
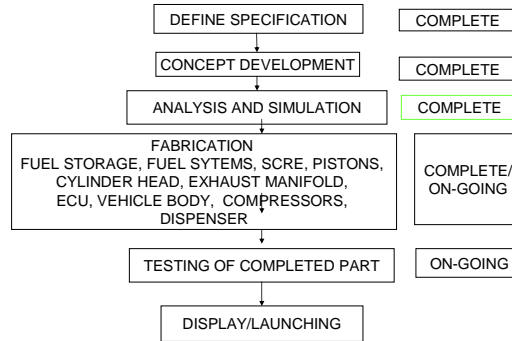
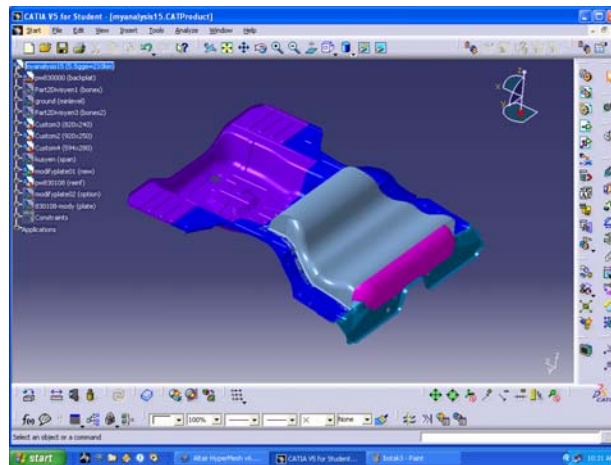


Fig. 4: The Research Methodology

**Fig. 4 PROGRAM METHODOLOGY**



**Fig. 5: The tank, fuel systems and injector arrangement**



**Fig. 6: The CNG vehicle**