

An Assessment of Hydrogen Fuel Cell Vehicles in Malaysia

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Abstract

Hydrogen Fuel Cell Vehicles (HFCV) as a backstop technology has the potential to meet energy security needs especially in the transportation sector of the economy. A good number of studies assessing the acceptance of HFCV as a renewable energy source in relation to other economic factors indicate that HFCV can meet increasing energy consumption needs, significantly reduce CO₂ emission and increase energy security of a country. Scientific evidence has shown that the adoption of hydrogen pathway is expected to have beneficial economic and environmental impact. The momentum of current research in this area is focused on optimizing the potential benefits. This article highlights issues and prospects, energy security, economic and environmental impact of HFCV in the Malaysian context. Key methods and assumptions of the literature are duly discussed to lessen these concerns and to help the research community towards the development of HFCV that is expected to benefit and bring forth effective prospects to Malaysia and elsewhere.

Key words: Hydrogen fuel cell vehicles, transportation, energy security, backstop technology, technological change, energy policy, Malaysia

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1. Introduction

Energy price volatility, scarcity and environmental degradation have been driving major initiatives in energy policy reform around the world. A good number of scientific references show concern in indicating the energy policy, environmental concern, economic activities, carbon emission and global warming (Nordhaus, 1994; McKibbin & Wilcoxon, 2002; Beccherle and Tirole, 2011; Rosen and Guenther, 2015). Recent literature supports that

economic activities and welfare of individuals become increasingly vulnerable as global warming intensifies (IPCC, 2007; Stern, 2007). The transportation sector being predominantly reliant on fossil fuel is a significant contributor to the global warming and CO₂, and one of the few industrial sector emissions that is still growing (Chapman, 2007). Climate change and energy policy efforts need to come to terms to special problems associated to decarbonising transportation sector. It is projected that globally CO₂ emission from transportation accounts 14% of greenhouse gas emissions (Stern, 2006) and expected to increase by more than 80% by 2050 (EC, 2011; IEA, 2011). Global energy futures is of increasingly concern as the issue is alarming; however, how energy demand and growth need to be managed with renewable and sustainable energy source is still a fundamental question (Solomon & Banerjee, 2006). Consequently, a significant amount of research is on-going toward renewable and sustainable energy and toward the global warming and carbon emission reduction. Although recently many alternative sustainable energy pathways may emerge, hydrogen economy in particular has received much attention. It is noted that hydrogen energy system is able to safely meet sustainability needs efficiently with possible and useful option in various applications (Dunn, 2002; Barreto, Makihira & Riahi 2003; Ogden, 1999).

Renewable and alternative energy can replace fossil fuels efficiently through the introduction of environment friendly technologies also known as backstop technologies¹, a term attributed to (Nordhaus, 1973). It refers to a technology that is readily available but is not yet viable due to high cost. Backstop technology is an important concept to the discussion of feasibility of HFCV and energy system transition to effectively decarbonize transport sector. This is because the problem of which alternative technology should be considered as backstop technology in transport sector is at the centre of this debate. More importantly the prospect of overcoming energy security risks associated to supply side shocks because by definition backstop technology is free from factor market volatility (Liski & Murto, 2006). The notion of hydrogen economy motivated beyond clean fuel and environmental concerns is also explained by (Rifkin, 2003), “Hydrogen, because of its universalities, offers the prospects that, we might be able to, at long last, to democratise energy and empower every human being on earth”. The hydrogen non-polluting renewable energy needs a breakthrough and transportation is maybe where it starts (Hoffmann, 2012). This is an important implications for Malaysia that has been a net crude oil exporter since 1970s but has been declining and expected to be a net exporter by 2020 (Vigliasini, 2012). This holds great promise for future energy policy design to strengthen energy security.

It is not surprising then that many countries are introducing alternative vehicle technologies like hydrogen fuel cell vehicles (HFCV) to effectively to reduce CO₂ emission and increase energy security by reducing fossil fuel dependence and reduce risk and vulnerabilities of energy demand (Hoffman, 2012; Berry, Pasternak, Rambach, Smith, & Schock, 1996). As emission related energy policy has direct and indirect impacts on the economy; integrated evaluation through quantitative modelling is addressed by many studies to evaluate alternatives such as introduction of HFCV using energy economy models (Wang, 2011; Kim & Moon, 2008; Nakata, 2003).

¹ Backstop technologies provide carbon-free energy and are not subject to any scarcities.

Technological innovation alone without policy interface and influence is unlikely to bring desired sustainable solutions. In the past explicitly linking policy to technological improvements has not been common in climate policy models until recent times. In the case of oil endowments and energy security (Kim, 2014) find that alternative vehicle innovation are not countries with large oil endowments. Therefore environmental and energy policies can induce technological change that also has the effect of making emissions reduction less costly.

Given the complexity of energy policy dimensions and its path dependence requires that policy makers must be able to foresee these opposing dimensions and approach it from sustainability angle (Goldthau & Sovacool, 2012). Especially because prioritizing of competing energy policy is necessary, important interdependencies and interconnections are sometimes missed that give rise to other unintended issues. Strategy for affordability cannot be achieved when reducing oil dependence is the objective (Sovacool & Saunders, 2013). There is no doubt that energy security is essential to economic growth and development (Stern, 2004). In order to discuss what may enable successful transition to sustainable energy pathways, the evolution of technological change of a country and proper association to energy requirement and security needs to be understood (Rosenberg, 1982). IEA defines energy security as “the uninterrupted availability of energy sources at an affordable price” (IEA, 2014). However, the body of literature on technology innovation does not explicitly consider energy security (Kim, 2014). This is because energy security in energy policy has almost exclusively focused on securing supply. However with recent energy policy, there is a shift from the old thinking of energy security to include broader comprehensive concerns that include environment, economic and international considerations (Hippel, Suzuki, Williams, Savage, & Hayes, 2011).

Many studies have addressed energy policy and rethinking of energy security and alternative sources of energy and green economic system such as solar and hydrogen energy by looking at future economic and environmental sustainability (Timilsina et al., 2009). Thus, the concept of green economic system is not new; however, the concept of green and smart transportation systems by alternative vehicle technologies is a new area to be explored more as the transportation is primarily responsible to CO₂ and global warming. Additionally, green and smart transportation expected to become critical as it is a new initiative in the most developing countries. Likewise, a number of technological shuffling is required to develop the new transportation infrastructure and structure. The issues are much important for advance developing countries particularly for a country like in Malaysia because, there are a number of factors² involved with adoption issues to the alternative vehicle technologies and hydrogen energy roadmap and fundamental challenges that need to be addressed. The national economy thus related to domestic macroeconomic issues and developmental concerns should be taken into account, and this is an underlying concern for policy makers in adopting alternative feasible options such as hydrogen fuel against conventional fossil fuel economy. It is evident that there are significant hurdles that stand in sustainable means of producing and commercializing hydrogen fuel as developing this technology requires extensive infrastructure as well (Lovins, 2005). Some studies indicate that hydrogen would not provide an immediate solution to reducing global warming risks and energy security, and climate crises; however it has potential as a long-term solution (Chu and Majumdar, 2012;

² The factors importantly are (a) coast-to-coast delivery, (b) consumer-affordable levels of mass production, (c) expensive to manufacture, and (d) fuel storage and delivery methods.

Farrell, Keith, & Corbett, 2003). However, these concerns should be put forward as the sustainability and environmental issues need to be addressed in the present precisely because of future long-term benefits.

Policy decisions are required so that negative impact of transportation on the environment can be minimized and depleting natural resources conserved. The other alternatives to fossil fuels focused by the researchers such as for solar, biofuels or biodiesel energy for the transportation system. There are some progresses made in biofuels compared to solar as an alternative sources notably its position as a palm oil related biodiesel product (Lim and Lee, 2012). Some countries that have explored utilization of biodiesel for their vehicles include USA, Germany, Japan, Brazil, India (Basha et al, 2009). However, the shortcoming of such fuel sources is their low volatility and insufficiency in term of quantity to replace fossil fuels. Such problems strongly stimulate other research of alternative energy source which also have technical feasibility, economic competitiveness, environmentally friendly and acceptable and readily available (Enweremadu and Mbarawa, 2009). With that in mind there are various alternative choices have emerged including hydrogen, natural gas, and liquefied petroleum gas (LPG), Fischer–tropshy fuel, and solar fuels. However, compared to other energy sources, hydrogen is recognized as the most viable and long term renewable alternatives to fossil fuel after solar energy (Martinot, et al. 2007). Although, solar energy is preferred but the concern of its power and efficiently to replace the conventional energy in the transportation systems has deterred further progress and consequently hydrogen fuel, apart its source being abundant and available, it is still potentially the most viable alternative energy source.

However, the task of developing a hydrogen fuel economy with planned infrastructure need to be envisioned with long-term national planning. Energy policy ultimately depends on country specific energy security needs based on specific vulnerabilities and natural resources endowment. The transition to hydrogen energy systems can increase energy security of a country in either or both stationary power plant and automotive vehicles applications (Ren, Andreasen, & Sovacool, 2014). Like other advance and developing nations Malaysia is also looking into the consideration of transition to hydrogen energy systems; however, how to overcome the current drawbacks by considering the trade-off between hydrogen economy and conventional energy system is a question mark. The aim of this article is to highlight those issues and prospects, with the introduction of HFCV in the Malaysian context. Importantly, this article reviews Malaysian energy policy in response to energy security concerns with particular focus on transportation sector. This article additionally reviews backstop technology, induced technological change (ITC)³ and related sustainability considerations.

2. Hydrogen Fuel Cell Vehicles

2.1 Vehicles and energy sources

Many studies have been done on hydrogen application in fuel cell technologies however, very few that address changes in developing countries (Solomon & Banerjee, 2006; Bader, Bleischwitz, Fuhrmann, Madsen, Andersen, 2008). As the urgency for this technology is evident in many developed countries, car manufacturers have developed and are testing

³ Induced technological change (ITC) is endogenous and technological change in policy scenario may exceed (or fall short of) its extent in the baseline, i.e. Policies induce additional technological change.

HFCV on the road. HFCV leads as viable alternative to replace combustive engines. Tesla and Toyota have turned technology patents on its head by allowing other car makers to use their patents on HFCV. This is done to boost commercialisation of zero emission vehicles within the automotive industry (Forbes, 2014). Technological adoption and alternative vehicle technologies, particularly roadmap for the transportation dynamics for the hydrogen choices are still challenge in the developing countries (Mytelka and Boyle, 2008). While radical technological adoption within the automotive industry is rare; however, in recent years focus on HFCV has been notable (Van den Hoed, 2007). Why is the focus on HFCV given many other alternative energy efficient vehicles? Many factors have pushed recent interest on HFCV to the forefront especially application for transportation sector. These include the state of rising urban air pollution, pushing demands for low or zero-emission vehicles, the need to reduce dependence on imported oil, CO₂ emissions from fossil fuel being main cause of global climate change and the need of alternative renewable energy supplies (Solomon & Banerjee, 2006). In this regard, HFCV is seen by many analysts most viable for transportation sector even though the application for hydrogen is not limited to it (Cropper, Geiger & Jollie, 2004).

Hydrogen fuel cell vehicle, unlike mechanical energy created in conventional combustion of fossil fuel, uses electricity from the chemical reaction of hydrogen and oxygen instead, with water being the by-product of this chemical reaction instead of emitting harmful particulates and gases such as sulfur dioxide (SO_x), oxides of nitrogen (NO_x) and CO₂ (Kang & Par, 2011). Hydrogen itself is not an alternative to fuel, but an energy carrier that has to be produced by using energy and naturally available sources. The majority of hydrogen source globally is abundant but predominantly produced from fossil fuel sources (Harvey, 2010). In 2006 the world hydrogen production is 50 million tonnes of which 48% produced from natural gas, 30% from oil, 18% from coal and only 4% from renewable sources (Srinivasan, 2006). However, hydrogen is not readily available and is subject to extraction and production methods which are expensive. Steam reforming is the most common form of extraction, using methane (CH₄), where water is heated to high temperature (roughly 1000 °C) which reacts with the hydrogen (cultivated for use) and carbon monoxide (emitted as GHG). Alternatively the cleanest extraction is through breaking water molecules into hydrogen and oxygen using process of electrolysis. The main drawback is that it takes more energy to create the hydrogen than what is actually produced, making it even more expensive and not feasible⁴.

Hydrogen and electricity can be interconverted by electrolysis and fuel cells specifically in the transportation sector (Armaroli and Balzani, 2011). Other issues related to capacity of the tank, safety of refuelling or reliability of the fuel cell under extreme temperature conditions seem to be solved or at least solvable in the near future (Schwoon, 2006). There are various alternative vehicles that serve as solution to the problem such as hybrid vehicles, bio fuel vehicles, battery electric vehicles and fuel cell electric vehicles. There is no clear answer as to which one could dominate the future low carbon vehicle market. Many automobile companies have an equal interest in all four power-trains and scholars broadly agree that all currently viable technologies are likely to play a part in a future sustainable transport system (Contestabile, Offer, Slade, Jaeger and Thoennes, 2011). Growing

⁴However, several hydrogen economy pathways presently exist. A hydrogen system based on nuclear electricity has related risks such as radioactive waste, natural disaster. Other renewable energy sources in principle have potential such as wind and solar but the technologies are still underdeveloped and unviable for application.

international concerns with climate change and oil import dependence has led to great interest in demonstrating the market viability of hydrogen energy. According to IEA Technology Roadmap national targets 7 million vehicles sales are expected by 2020.

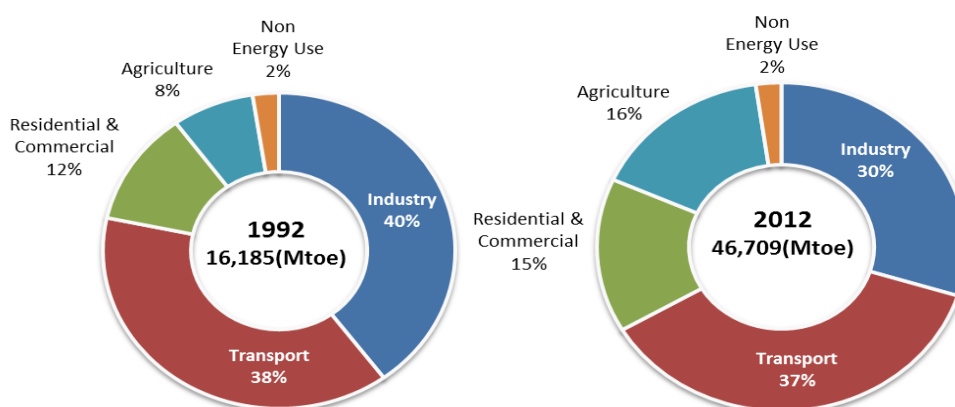
3. Drivers of hydrogen fuel cell vehicles in Malaysia

3.1 Transportation and Emission

In Malaysia, transportation is the leading energy consuming sector surpassing industrial sector since 2011. The energy use has increased at 5.9% annually and is expected to grow as vehicles ownership increases (Indati & Bekhet, 2014). Table 1 shows latest national energy consumption by sector in Malaysia from 16.2 Mtoe in 1992 to 46.7 Mtoe in 2012. Transportation sector is the highest consumer at 37% followed by industrial sector at 30%. The share of petroleum products will remain highest in the span of 2010 to 2020 whereby almost 100% of the private cars are fuelled by petrol, while about 74% of commercial vehicles such as busses and lorries consumed by diesel (Tye, Lee, Abdullah & Leh, 2011). Although Malaysia is an oil producer, it is still reliant on imported oil to satisfy the demand in transportation sector. Consequently, the development of renewable energy policies and technologies towards introduction of alternative fuels like hydrogen, ethanol and biodiesel will reduce the dependence on imported fuel sources and emissions contribution (Kamarudin, Daud, Yaakub, Misron, Anuar & Yusuf, 2009).

Table 1: Energy Consumption by Sector in Malaysia (1992-2012)

Sector	1992(Mtoe)	Share (%)	2012(Mtoe)	Share (%)
Industry	6,455	40	13,919	30
Transport	6,226	38	17,180	37
Residential & Commercial	1,891	12	7,064	15
Agriculture	1,222	8	7,494	16
Non Energy Use	391	2	1,052	2
Total	16,185	100	46,709	100



Source: National Energy Balance (2014)

Malaysian economic growth has been dependant on fossil fuels. In 2012 fossil fuel or petroleum products amounted to 53% of total energy demand, followed by natural gas at 21.8%, electricity at 21.4% and 3.7% for coal and coke (National Energy Balance, 2014).

High levels of fuel subsidy due to domestic retail price stabilization and reform difficulties faced was substantial. Malaysia had the third highest per-capita basis fuel subsidies spending USD 199.6 per person in 2009 out of 12 economies in the APEC forum which in total account for an estimated quarter of global subsidies. Malaysia also spent 2.4 % of GDP on fossil fuels behind Vietnam with the highest spending 2.8% of GDP (IEA, 2011). The lack of effective subsidy reform implementation is reflected in increasing annual subsidy expenditure. The weak fiscal reforms resulted in Malaysian credit rating from stable to negative by global rating agencies (Fitch, 2013). Federal Government debt rose to 53.3% of GDP in 2012, up from 51.6% in 2011 and 39.8% in 2008. According to Fitch, the general government budget deficit also widened to 4.7% of GDP in 2012 from 3.8% in 2011. Following several years of high fiscal burden, Malaysia is prioritizing implementation of fuel subsidy reform, moving away from price stabilization and subsidies to market-based fuel pricing. This is timely given that international crude oil prices have dropped below \$55 per barrel. However, historically there are no indications that prices will stay low.

High consumption of energy in Malaysia is expected to persist especially in the transport sector. Risks and uncertainties with absence of more viable alternatives to fossil fuels are further intensified. It is acknowledged that fuel price in developing countries are inelastic and a high price does not mean a decline in consumption due to lack of substitutes to petroleum products. This has important implications to emission reduction goals for climate change as Malaysian pledged for voluntary reduction of up to 40% by 2020. Malaysian greenhouse gases (CHG) is predicted to rise from 189 (Mtoe) in 2005 to 382 (Mtoe) in 2020 (Shamsuddin, 2012). However a key challenge on voluntary emission reduction pledged nationally is on meeting global goal of keeping the temperature rise below 2°C.

In the past industrialised countries have been known to be major CHG emitters. However, rapidly growing developing countries' emissions surpassed industrialised countries. The collective emission of developing countries is expected to surpass developed countries and responsible for over 75% of global emission by 2030 (Stern 2007). There are considerable problems in coordinating global response to meet challenges of global warming and climate change. Given that not all countries prioritize nor are equally determined in reducing emissions. The move towards low-carbon economies, mitigation efforts is not enough to only be realize in developed countries, but in developing countries as well. (Yandle, Vijayaraghavan, and Bhattarai, 2002).

In this context it is important to trace developing countries' readiness to switch from fossil fuels to low-carbon pathways. For this purpose the next section is a review on Malaysian energy security and policy developments to gain insight for future energy policy planning.

3.2 Energy Security and policy development in Malaysia

Following the 1970s oil price countries embarked on in energy diversification initiatives to reduce overdependence on fossil fuel. Malaysian government introduced various major energy policies summarized in Table 2. In 1974, Petroleum Development Act and Regulation (PDA) were introduced to regulate petroleum industry in Malaysia. PETRONAS the Malaysian National Oil Company was given exclusive rights to explore, develop and produce the entire petroleum resources in Malaysia. In 1975, the Government introduced the

National Petroleum Policy to regulate the downstream sector of the oil and gas industry under the Ministry of International Trade and Industry (MITI) and The Ministry of Domestic Trade and Consumer Affairs (MDTCA) (EPU, 2015). In pursuit of the supply objective, policy initiatives such as Fuel Diversification Policy and the National Depletion Policy were introduced to reduce dependence on oil and extending the life of domestic depleting energy resources particularly crude oil and gas, respectively (Jafar, Al-Amin, & Siwar, 2008). The National Depletion Policy was launched in 1980 to prolong the lifespan of Malaysia's oil reserves for future security and stability of supply.

Table 2: Summary of Energy Policies in Malaysia

National Petroleum Policy (1975) Petroleum Development Act 1974	<ul style="list-style-type: none"> • Efficient Utilization of petroleum resources • Management and operation of the petroleum industry
National Energy Policy (1979) Petroleum Development Regulation 1979	<ul style="list-style-type: none"> • Supply Objective : Ensure adequate, secure and cost effective energy supply • Utilization Objective : Efficient utilization of energy and eliminate wasteful and non-productive usage • Environmental Objective : Minimize negative impact to environment
National Depletion Policy (1980)	<ul style="list-style-type: none"> • To prolong the life span of nation's oil and gas reserves
Four Fuel Policy (1981) (7 th Malaysian Plan)	<ul style="list-style-type: none"> • Aimed at ensuring reliability and security of supply through diversification of fuel (oil, gas, hydro, coal)
Automatic Pricing Mechanism (APM) 1983	<ul style="list-style-type: none"> • Domestic petroleum products prices are set administratively to cushion oil shocks.
Five Fuel Policy (2001) (8 th Malaysian Plan)	<ul style="list-style-type: none"> • Encourage utilization of renewable resources (biomass, solar, mini hydro etc.) • Efficient utilization of energy
National Renewable Energy Policy and Action Plan 2009 (9 th Malaysian Plan)	<ul style="list-style-type: none"> • Enhancing the utilisation of indigenous renewable energy (RE) resources to contribute towards national electricity supply security and sustainable socioeconomic development.
New Energy Policy 2010 (10 th Malaysian Plan)	<ul style="list-style-type: none"> • Energy Pricing: remove market distortion of subsidies • Energy Supply • Energy Efficiency • Governance • Change Management
Pursing Green Growth for Sustainability and Resilience 2015 (11 th Malaysian Plan)	<ul style="list-style-type: none"> • Strengthening the enabling environment for green growth • Adopting the sustainable consumption and production concept • Conserving natural resources for present and future generations • Strengthening resilience against climate change and natural disasters

Source: Ministry Of Science Technology And Innovation (MOSTI), Economic Planning Unit (EPU), Sustainable Energy Development Authority Malaysia (SEDA), Ministry Of Domestic Trade Cooperative Consumerism (MDTCC)

Fuel Strategy was introduced in 1981 to ensure reliability and security of supply of energy while reducing Malaysia's over dependence on oil. Other sources of energy such as gas, hydropower and coal were promoted to replace oil in power generation. The strategy also emphasized on the use of local resources to enhance the security of supply. As a result, the proportion of the four fuels in electricity generation has shifted from being heavily reliant on oil as dominant fuel to natural gas. While the diversification program has reduced Malaysia's over dependence on oil, the electricity sector is now dependent mostly on natural gas. However, measures are being implemented to increase the utilization of coal for power generation. Although the coal option has both environmental and foreign exchange implications, it is preferred on the basis of cost and the cap imposed on gas production. Hydropower development and renewable energy are also being pursued for electricity generation. In 2012 though solar, biomass and biogas were introduced for power in small quantities, the share of input by fuel type for power generation was dominated by coal 48% followed by 40% natural gas, 7% hydropower, 3% diesel and 2% fuel oil. (National Energy Balance, 2014)

While natural gas continues to be the main fuel in key energy consuming sectors, the government recognized the need for a long term and flexible energy supply strategy for security of supply as well as to leverage on technological evolution, particularly in the development of new and renewable energy sources. In 1999, the government widened the band of the four-fuel options to include renewable energy as the fifth fuel in the supply mix. The Five-fuel Diversification Strategy was formally incorporated into the Eight Malaysia Plan 2001-2005 (Oh, Pang & Chua 2010). One of the main deliverables from this plan is to further enhance the sustainable development of Malaysia energy resources while continue providing sufficient and secure supply of energy. The main purpose of the utilization objective is to promote efficient utilization of energy and discourage wasteful and non-productive patterns of energy consumption. Initially, there were limited initiatives to pursue the utilization objective, relying mostly on the energy industry and consumers to exercise efficiency in energy production, transportation, conversion, utilization and consumption. Demand side management initiatives by the utilities, particularly through tariff incentives, have had some impact on efficient utilisation and consumption.

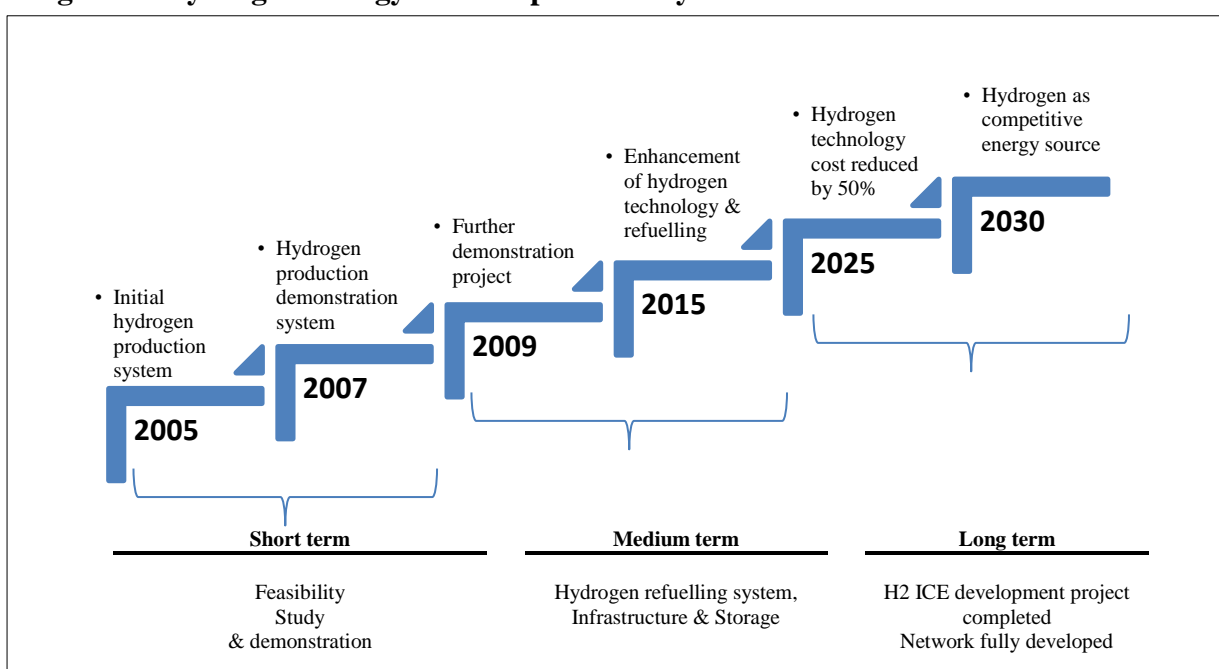
While electricity generation strategy was focused on diversification, the energy policy for retail fuel was geared towards price stabilization. Consequently, the transport sector in Malaysia has been and continues to be the least diversified in terms of fuel use and is still highly oil dependent. Policy-directed initiatives in the transportation sector continue to be constrained by lack of technology and high costs. The vision set in the 11th Malaysia Plan for green growth and sustainability is hoped to be more effective to decarbonise transportation sector.

3.3 Fuel Cell and hydrogen development in Malaysia

Hydrogen and fuel cells are identified as priority research by the Ministry of Science, Technology and Innovation (MOSTI) after solar, with RM7 million (US\$2 million) funded

on hydrogen production and storage technologies between 2002 and 2007 and RM34 million (US\$9.7 million) on the national fuel cell research and development from 1996 to 2007 as applications of fuel cells are viewed as one of the more important energy conversion devices in the future (Oh et al., 2010). This was done in joint collaboration between Universiti Kebangsaan Malaysia (UKM) and Universiti Teknologi Malaysia (UTM). The research programme has so far produced 50, 200 and 500 W air-cooled open cathode prototype, 1, 3 and 5 kW water-cooled prototype PEMFC stack and system, a titanium based metal foam bipolar plate, polymer composite bipolar plate, minimum load Pt-AC, manufacturing process for MEA in UKM; and new alternative polymer electrolyte membrane, conceptual design of fuel cell powered motorcycle, conceptual design of fuel cell powered automotive comfort system and carbon nanotube manufacturing process in UTM (Oh et al., 2010). Figure: 1 shows the hydrogen energy roadmap for Malaysia.

Figure 1: Hydrogen Energy Roadmap for Malaysia



Source: Compiled from literature

Malaysia's fuel diversification policy towards the use of renewable oils like biodiesel and has timeline for introduction of HFCV; but lacks action plan to drive the changes (Kari & Rasiah, 2008; Solangi et al., 2011). Europe, USA, Canada and Japan are leading fuel cell research and development and commercialization; it is not too late for Malaysia to master this technology and to apply it to niche markets in the future. While HFCV will continue to be used in the near term, the fuel cell will slowly be introduced first in hybrid power systems but ultimately in the long term in hydrogen energy systems (Sopian and Daud, 2006). The literature showed that the HFCV fuelled with solar electrolysis hydrogen have the greatest benefits in energy conservation and GHG emission reduction (Hwang, 2013). However, hydrogen can be produced from separate pathways, and create particular consequences on a nation's overall energy security (Ren et al., 2014).

The Malaysian National Automotive Policy (NAP) launched in 2014 acknowledges concerns to reduce CO₂ emission for climate change and need to increase energy security within the transportation sector. The long term potential of hydrogen technology to address hydrogen production, transportation and distribution within the automotive industry is outlined to be adopted from 2021 (MAA, 2014). There are initiatives to automotive remanufacture for adoption of environmentally friendly green technology in Malaysia but it is still in its early development (Yusop, Wahab, & Saibani, 2015). This is a cause for concern as considerable delay in demonstration and adoption of HFCV in Malaysia has serious implications for effective CO₂ emission reduction and sustained energy dependence.

The R&D financing in the absence of widely known, existing, successful energy efficiency projects, it is still more difficult to obtain financial support for energy efficiency projects than for traditional business ventures. The Chinese government on the other hand though lags behind in multinational automotive companies, intends to leapfrog past the conventional vehicle technology with HFCV technology; consequently pushing R&D towards HFCV (Zhang & Cooke, 2010; Zhao, & Melaina, 2006).

4. Backstop Technology, and Induced Technological Change (ITC)

The body of literature that discusses backstop technology and innovation are primarily based from modelling outcomes. The effects of cost increase in other models are eliminated with backstop technologies whereby costs fall as it matures while; depleting energy source becomes more expensive (Löschel, 2002).

High cost of a backstop technology relative to current technology due to R&D becomes a barrier. However because it backstop technology exists, it has a feasible solution (Nordhaus, 1973). Nevertheless, availability and cost assumptions have important bearing on outcomes (Manne and Richels, 1994).

It is a daunting task for countries when considering mitigation policies to address a multitude of energy related concerns such as reducing global warming while ensuring economic development. Developing countries especially lack instruments of economic analysis that are required to visualize, plan, apply and compare alternative methods (Nordhaus, 2008; Stern, 2007). Among the many factors necessary for sustainability of depleting natural resources, Growiec and Schumacher (2008) highlight substitutability and technical change being most important though a study by Cleveland and Ruth (1997) argue these factors are not sufficient. The literature on technological change is as uncertain and unpredictable exercise. However incorporating uncertainty into the model though challenging is useful in long term processes like climate change (Bosetti & Tavoni, 2009). Model-based scenario studies assist in assessment the role of hydrogen in future energy systems and shaping climate policy. For this purpose, global energy models have been extended to also cover hydrogen-based technologies (Van Ruijven, Van Vuuren, & De Vries, 2007).

In addition, (Edenhofer et al., 2006) show modelling comparison of innovation for ten global economy-energy-environment models and induced technological change (ITC). They find assumptions about long-term investment behaviour with foresight of actors and number of available investment options, exert a major influence. Therefore, whether and how options

for carbon-free energy are implemented (backstop and end-of-the-pipe technologies) strongly affects both the mitigation strategy and the abatement costs. Popp (2006) includes policy-induced energy R&D in a model with a backstop energy technology. The element of uncertainty need to be modelled as the role of which renewable energy may play is not clear. This implies that the consideration of hydrogen energy and HFCV as a viable renewable energy option in Malaysia though uncertain may influence uptake favourably.

(Van Ruijven, et al., 2007) found that even under optimistic assumptions hydrogen plays a minor role in the global energy system until the mid-21st century due to the system inertia but could become a dominant secondary energy carrier in the second half of the century. Hence, hydrogen-rich scenarios without climate policy increase CO₂ emissions up to 15% by 2100 compared to the baseline. However, if climate policy is assumed CO₂ from fossil feedstock-based hydrogen production is captured and sequestered, which indicates that an energy system that includes hydrogen is much more flexible in responding to climate policy. However, some of the limitations of these models are that most of these global studies will not be able to take into consideration regional and country specific and therefore simplifies policy impact drastically. The element of uncertainty of introducing HFCV as backstop technology needs to be explored further in modelling.

In terms of changes in composition of passenger cars of conventional technologies versus HFCV (Wang, 2011) find that slight negative impact to California economy and even in the aggressive scenario, FCVs will account for 58% of new sales can only account for a minor fraction through 2030 as conventional vehicles on-road stock dominate. (Kim & Moon, 2008) find for Korea, Btu taxation is effective for accelerating the changes in the vehicles' market share of hydrogen would reach 76% of the road transportation sector by 2044. Similarly (Nakata, 2003) finds that the share of conventional vehicles, hybrid vehicles and fuel cell vehicles in the year 2040 reach 44.2%, 45.7% and 10.1%, respectively.

5. Discussion and way forward

The development and integration of HFCV in the Malaysian transportation system has important implications for reduced emission while also meeting growing energy demand needs. Though the benefit of hydrogen and HFCV is highly anticipated, policy makers must assess the potential trade-offs with other renewable alternatives particularly in transportation. Sustainable development of renewable energy strategies and policies requires consideration of complex interaction of economy, environment as well as social needs of a nation (Mitchell, 2005). Developing countries face the daunting challenge to grow the economy while also reducing emission. If environmental damage is a structurally decided and accepted as an inevitable result of initial growth, then attempts to avoid climate damage in the early stages of development may be futile (Munasinghe, 1999). This has very important implications especially in the full participation of fast growing developing nation's climate change policy response and effectively reducing CO₂ emission levels to stabilize extreme weather conditions. The vulnerability of developing nations is expected to worsen in investing on backstop technologies.

This is why timing and investment in viable renewable energy options are both important considerations for energy policy for all nations. It is for this reason, among others, that Arrow et al., (1995) emphasize the importance of getting the institutions right in rich and poor countries. The role of government in both developed and developing in pursuing energy security through backstop technology can be further strategically coordinated. (Von Hippel et al, 2011) find that the approaches of different governments largely seem to prefer policy guidance and control if energy resource is viewed specifically as strategic technology. For developing countries climate being a less pressing concern, energy security policy is prone to be more focused on addressing energy supply and consumption to meet increasing demand of economic growth.

While countries need for energy depends on various factors, in the case of Malaysia, HFCV as a backstop technology is an important consideration given the level of fossil fuel dependence especially in the transportation sector. Interest in overcoming challenges and implementing hydrogen systems has started in transportation sector though still in its infancy. In successful adoption of new technology, adequate information is important both in reducing the gap between government technology targeting and market future response and acceptance (Kim and Nelson, 2000). The acceptance of HFCV also heavily relies upon successful cost reduction to enable developing countries to favourably adopt the backstop technology.

The introduction of future energy source HFCV despite its many benefits is nevertheless a difficult and uncertain venture. Malaysian climate change and energy policy needs to pay particular attention to critical new technology like hydrogen to root and the understanding of HFCV application within the transportation sector is needed to understand how to maximize potential benefit while minimizing risks will be worthwhile.

6. Conclusion

This article reviewed Malaysian energy policy in response to energy security concerns with particular focus on transportation sector. Fossil fuel subsidies as energy security strategy in the past had consequently affected the transport sector in Malaysia to be the least diversified in terms of fuel use and underdeveloped technologies. Though interest in hydrogen pathway had been initiated in the past, but uncertainty and fragmented renewable energy focus has stifled possible development. It is evident that Malaysia has the capacity and natural resources to contribute to the alleviation of the concerns of climate change and increase energy security by expanding policy initiatives towards sustainable energy policy like hydrogen that shows the most promise compared to other renewable energy options. Even in a second best option of producing hydrogen fuel though not much effective in the short run but effective and flexible for a transition towards in the long run toward and utilization and extraction process. This article has taken an initiative toward that end and intensified what needs to be done and what policy should be taken in the developing country like in Malaysia. Future studies should undertake modelling of backstop technology and R&D. The potential to participate in a more vibrant hydrogen economy particularly in the transportation HFCV must be backed up by inducing policy that will create interest in concentrated R&D in HFCV.

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