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Vehicle electrification in a developing country: Status and issue, from a well-to-wheel perspective

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ABSTRACT

The increase of public attention, scientific research and political interest in environmental problems associated with transportation has provided the motivation for re-invention of electric vehicles. However the usage of grid-dependent EVs with a high-carbon electricity grid might produce more damage to the environment. This study aims to provide an environmental impact comparison of ICEVs, HEVs and EVs during their usage cycle, by modeling their energy consumption (electricity or fuel) and the supply chains of the supplied energy, (well-to-wheel) based on a life cycle assessment. The results show that running EVs with the existing mixed sources of electrical energy produce larger impacts on the environment 60% of the time; when compared to HEVs. When compared to ICEVs, EVs produce a larger environmental impact on 7 out of 15 environmental impact categories. Overall the environmental impacts of EVs are substantial based on the well-to-wheel analysis. It will continue to be so if no change is made to the methods of electricity generation in the near future. Given that the environmental profile of EVs is linked with the existing national electricity generation mix, the national electricity supply must be made cleaner before the electrification of the urban transport system.

1. Introduction

Civilization through industrialization, agriculture, energy generation and transportation has released enormous amounts of anthropogenic greenhouse gases (GHG) into the atmosphere which are contributing to global warming and climate change concerns (Beniston, 2002). Demand for transport has led to the blossoming of energy harvesting activities around the world, as the transportation sector used almost one quarter of the world's energy (Ma et al., 2012). Based on the National Energy Balance report, in 2010 a total of 41,477 kilotons of oil-equivalent energy was used in Malaysia. The transport sector used up 40.6% of the entire amount and followed by the industrial sector at 31.1% (Energy Commission, 2010). It could be a formidable task ahead for Malaysia to reduce energy usage in the transportation sector, as almost 98% of the energy came from fuel consumption (Mustapa et al., 2011). An endless increase in fossil fuel consumption makes the transportation sector the second highest contributor in carbon dioxide emissions and emitted 26% of the global carbon emission after the energy sector (Chapman, 2007; International Transport Forum, 2010). Unless mitigating measures are implemented soon, carbon emissions from the transport sector will continue to rise (International Transport Forum, 2010). Fuel usage alone contributed 76% of the total carbon emissions from an average vehicle life cycle, 15% are from losses in the fuel supply system and a further 9% was from the manufacturing of the vehicle (Potter, 2003).

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Public attention, scientific research and political interest in problems associated with transportation and the environment have provided motivation for the re-invention of electric vehicles. The reemergence of electric vehicles is believed to be the catalyst that will reduce fossil fuel dependency in the transportation sector. The performance of automotive fuel has been improved since the introduction of petrol-electric hybrid vehicles, however the reintroduction of electric cars leads the industry to a whole new level with zero tailpipe emissions (Faria et al., 2013; Miller et al., 1999). Recent research by national automotive manufacturer -Proton indicated that the conventional internal combustion engine vehicles (ICEVs) that travelled on a 1.5 l engine would emit around 180 g of CO_2 emission per kilometer. A hybrid petrol-electric vehicles (HEVs) with the same engine capacity would emit 80 g of CO2/km. Because electric vehicles (EVs) have zero tailpipe emissions (Board of engineers Malaysia, 2012), there is a perception that EVs are an environmentally kind technology (Delang and Cheng, 2012) as they do not run on fossil fuels. At the micro level, EVs would benefit the local environment because they have no tailpipe emissions and have low noise levels. However at the macro level, since use electricity, the impact on the global environment may be worsened by the ways the electricity is generated (Klöckner et al., 2013). To determine their contribution to the environment, a comprehensive overview of the vehicle's fuel usage cycle would be required (Hawkins et al., 2012, 2013). Most studies (California Air Resources Board, 2009; Campbell et al., 2009; Ma et al., 2012; Nanaki and Koroneos, 2013; Wang et al., 1990) have shown that EVs can significantly produce lesser environmental impact compared to ICEVs provided that they use a relatively low carbon electricity grid to charge the batteries. However, based on Malaysia's national electricity mix, grid-dependent EVs might produce more harm than ICEVs or HEVs. The electricity generation is done with the combination of 52.2% of natural gas, 39.5% of coal, 5.1% of hydro power, 1.2% diesel oil, 1% biomass, 0.8% of fuel oil and 0.2% others (Table 1) (Energy Commission, 2010, 2012). The emissions from fuel usage by ICEVs are more or less alike over the same engine capacity, unlike the EVs. With EVs, emissions from electricity usages could vary substantially from country to country, determined by the share and type of the energy sources (Table 1) (Department of Energy and Climate Change, 2014; Energy Information Administration, 2012). Thus, EVs of the same specification running in Japan or the UK could generate different emission levels when they are run on Malaysian roads.

2. Problem statement

Green transportation is a topic of much debate in Malaysia, especially when the transportation sector is closely linked to the fuel subsidy. Malaysia was once Southeast Asia's top passenger car market, but lost out to Thailand years ago, partly due to policies to protect home grown car brands. Import taxes have dropped under the region's free trade treaty, but Malaysia imposes excise duties of up to 105 percent that kept prices of foreign cars high. The tax revenue from the automotive industry, collected 9.83 billion ringgit in 2013, with excise duties contributing 75 percent of the total. The National Automotive Policy (NAP) was introduced to transform Malaysia's automotive industry to be one of the important components of our economy, contributing 30 billion ringgit (3.4%) to the national gross domestic product in 2013 (Harman, 2014; Ng, 2014). Ever since 2011, in line with the National Automotive Policy (NAP), the government is promoting the establishment of local electric vehicle manufacturing capacity, with a plan to penetrate the regional and international market with locally manufactured electric cars. However, the government is aware of the need to develop a domestic market for electric cars that will help to broaden the base for foreign investment to set up operation in Malaysia (Cicerello, 2012). EVs have been selected as an avenue to "greenifying" the transportation sector, with a roadmap that has a target of 3500 EVs on the road by 2020 (Green Technology: Accelerating a sustainable transportation system, 2012). Nevertheless, some view these actions as a plan to seize the potentially lucrative export trade resulting from the production of EVs (Cicerello, 2012) rather than being environmentally motivated, since the impact from EV's usage is unknown without an environmental assessment. It is vital to perform an environmental assessment of the usage of EVs, ICEVs and HEVs to understand their environmental impacts when driven on Malaysian roads. Nevertheless, the consistent comparisons between each option (ICEVs, HEVs and EVs) are necessary to support effective policy making, research development and investment decision (Hawkins et al., 2013).

3. Goal and scope definition

The definitions set for this LCA study are as follows:

Table 1
National electricity composition, 2010.

	Japan	Malaysia	United Kingdom
Coal	26%	40%	28%
Natural gas	27%	52%	46%
Nuclear power	27%		16%
Crude oil (Diesel + Fuel)	10%	2%	1%
Hydro power	7%	5%	1%
Renewable/biomass	3%	1%	7%
Others		<1%	2%