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Application of theory-based evaluation for the critical analysis of national biofuel policy: A case study in Malaysia

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ABSTRACT

Theory-based evaluation (TBE) is an effectiveness assessment technique that critically analyses the theory underlying an intervention. Whilst its use has been widely reported in the area of social programmes, it is less applied in the field of energy and climate change policy evaluations. This paper reports a recent study that has evaluated the effectiveness of the national biofuel policy (NBP) for the transport sector in Malaysia by adapting a TBE approach. Three evaluation criteria were derived from the official goals of the NBP, those are (i) improve sustainability and environmental friendliness, (ii) reduce fossil fuel dependency, and (iii) enhance stakeholders' welfare. The policy theory underlying the NBP has been reconstructed through critical examination of the policy and regulatory documents followed by a rigorous appraisal of the causal link within the policy theory through the application of scientific knowledge. This study has identified several weaknesses in the policy framework that may engender the policy to be ineffective. Experiences with the use of a TBE approach for policy evaluations are also shared in this report.

1. Introduction

Theory-based evaluation (TBE) has been used for over 40 years for evaluating programmes and projects (Suchman, 1987; Weiss, 1995), however it was only in the recent past that it gained popularity within the wider community of practitioners and for applications in other areas, such as for policy evaluations (European Commission, 2013). TBE essentially is an approach in which attention is paid to theories of policy makers that are logically linked together to produce the desired outcomes. The effectiveness of a policy will critically depend on the mechanisms that make the intervention work. A TBE therefore explores the mechanisms that policy makers believe make the policy effective and compare these against evidences gained through researches (White, 2009). Over the years, numerous publications have been produced in literature to develop TBE into a detailed methodological framework, some of which are: (Chen, 2005; Donaldson, 2007; Weiss, 2000; White, 2009).

The application of TBE is not limited to the evaluations of programmes only, instead it has also been used in other areas requiring evaluations, including for evaluating the effectiveness of policies. Whilst the applications of TBE for policy evaluations is not uncommon, the reality however is that it has not been widely applied within the energy and climate change sector (Harmelink, Joosen, & Blok, 2005). Arguably, this is one of the policy sectors that would need effectiveness evaluation the most given that climate change mitigation is an area that is in urgent need of efficacious government interventions, especially since whatever climate policies that are implemented will take time to show effect, whether positive or negative (IPCC, 2013). Given the time limitations, there is a narrow opportunity for experimenting with policy options. Therefore, evaluation of policy effectiveness becomes a critical aspect of climate change policy making.

It is believed that a TBE is a very fitting evaluation technique for assessing the efficacy of climate change policies. One of the key strengths of a TBE is the use of credible research reviews for the critical analysis of the underlying theory of the policy. This reduces the possibility that the informations and empirical contents of the policy theory are being negotiated (European Commission, 2013; Leeuw, 2003). What this means is that, ideologies or even political-correctness has less of an influence on the overall evaluation process, instead the evaluations are mostly based on substantiated and credible research evidences. This is absolutely critical given that it is widely a recognized fact that policies are typically poorly designed, being most often built on consensus based on

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stakeholder's perceptions and belief and very little to do with sound science and knowledge (Brouselle & Champagne, 2011; Fitzpatrick, 2002; Weiss, 1997).

A survey of literature has shown that there are not many practical examples for the use of TBE in evaluating climate change policies. The one relevant publication that was found was by Harmelink et al. (2005), that had conducted an ex post evaluation of 2 climate change policies in the built environment in the Netherlands. Specifically, the Dutch researchers had adopted the TBE approach to evaluate the effects and effectiveness of the Energy Premium Regulation (EPR) scheme and the Long Term Voluntary agreements in reducing the emissions of CO_2 from the built environment in the Netherlands. Given the limited practical examples in literature, and the importance of the subject matter, it felt very appropriate that more case studies are conducted and published widely as means of sharing experiences in the practical use of TBE for evaluating climate change mitigation policies. And so here we demonstrate the use of TBE for evaluating the effects and effectiveness of the national biofuel policy in Malaysia.

2. Problem statements

The population in Malaysia is about 28.6 million in 2010, and according to the Department of Statistics Malaysia (DOSM), this number is expected to rise by 35% to 38.6 million by 2040 (DOSM, 2013), meanwhile the World Bank reports that the country's gross domestic production (GDP) growth in the last 10 years has averaged at about 5% (World Bank, 2015). Studies have shown that rising incomes strongly correlates with higher levels of car ownerships and usages (Webster, Bly, Johnson, & Dasgupta, 1986a; Webster, Bly, Johnson, & Dasgupta, 1986b), as well as with greater trip rates and distances (Schafer, 2000).

Correspondingly, car ownership in Malaysia has seen a dramatic increase from 4.5 million vehicles in 1990 to 18 million vehicles by 2008 (Ong, Mahlia, & Masjuki, 2012); an increase of a substantial 300% in less than 20 years. This corresponds to a vehicle ownership rate of 260 and 660 vehicles per 1000 person in the year 1990 and 2008 respectively. As a result, the transport sector in Malaysia is responsible for a significant 36% of the total energy consumed in 2008, whereby road transport is the leading transportation mode, accounting for about 94% and 96% of total passengers and freights transportation respectively (Ong et al., 2012).

A recent research conducted by the World Bank has in fact shown that the transportation energy intensity in Malaysia has consistently been the highest amongst 11 Asian countries, and worse still, whilst some of these other countries are showing signs of improvement, Malaysia on the other hand, has shown a worsening trend over the years in which the gaps with these other Asian countries have been widening especially in the last 10 years (Fig. 1) (Timilsina & Shrestha, 2009). Moreover, there exists very limited fuel choices for the road transport sector in Malaysia, where currently petroleum-based diesel and gasoline fuels dominate more than 70% of the total energy consumed by the transport sector (Fig. 2) (Ong et al., 2012). The nation's heavy dependence on carbon intensive fossil-based fuels for mobility therefore results in significant GHG emissions contribution from the transport sector.

Furthermore, outcomes of the World Bank's statistical analyses on the Asian transport sector's growth in energy consumption and GHG emissions have revealed that economic activity, population growth and transportation energy intensity are the leading factors driving GHG emissions from this sector in Malaysia (Timilsina & Shrestha, 2009). However, it is unrealistic to expect developing Asian countries to slow down economic growth in order to control GHG emissions, especially since poverty eradication is also a pressing issue for many of these countries. Therefore a critical strategy for limiting emissions from the transport sector in Malaysia in the future must, inevitably, result in the eventual decoupling of GHG emissions growth from economic growth. This can be done in several ways, amongst which will involve the switch to cleaner fuels and the modal shift to public transportation.

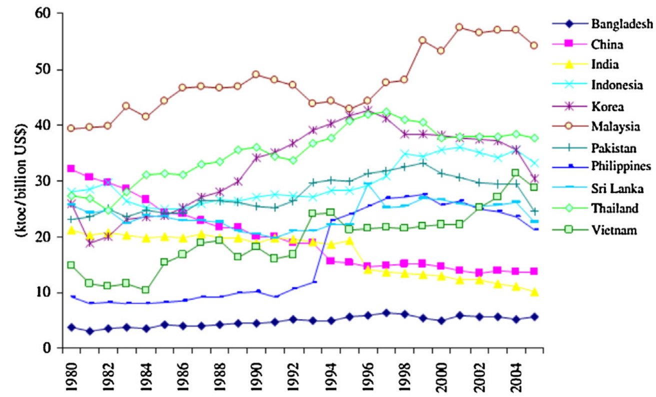

Fig. 1. Transportation energy intensity in several Asian countries from 1980 to 2005 (Timilsina & Shrestha, 2009).

The NBP is Malaysia's first foray into a bio-based energy economy as a strategic government intervention to drive development and implementation of palm biodiesel as substitute to regular fossil-based diesel. The policy is a first major step that Malaysia has undertaken to introduce alternative forms of energy to complement and partially substitute petroleum for transport application (Abdul-Manan, Baharuddin, & Chang, 2015). This is especially relevant in the context of Malaysia's growing dependence on oil by the transport sector; a sector that is already consuming the most and a sector that is expected to continue to consume even more. The NBP could potentially be the game changer that Malaysia needs in order to induce transition to sustainable mobility. However, the formulations of a biofuel policy based on imprecise assumptions are very risky. The absence of careful policy analysis and logical impact evaluation could lead to policy failures. Failure of the NBP may engender objections to future renewable/clean energy projects in parliament and by the public (Goh & Lee, 2010), and therefore impede the nation's journey towards sustainable development.

3. Malaysia national biofuel policy

Malaysia's first national biofuel policy (NBP) was formulated on the 21st of March 2006, in which in the initial stages the policy was largely championed by the Ministry of Plantation Industries and

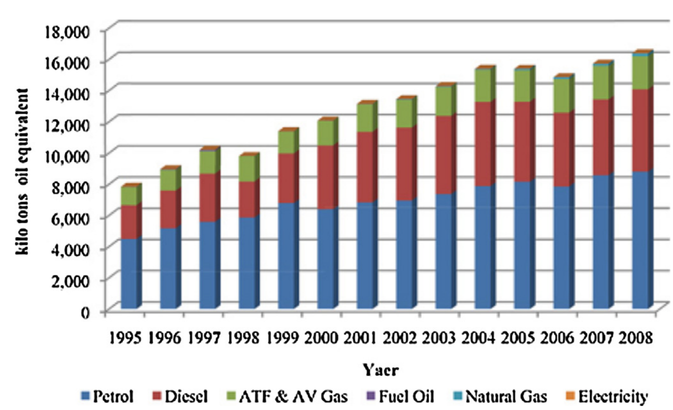

Fig. 2. Transport energy consumption from 1995 to 2008 broken down by energy types (Ong et al., 2012).

Commodities Malaysia (MPIC). Although the policy was developed following stakeholder consultations and on the basis of earlier research findings by the Malaysian Palm Oil Board (MPOB) (Chin, 2011), the MPIC itself was entrusted with the main responsibility to develop and implement the policy, with key decisions lying with government bodies like the MPIC and MPOB (Chin, 2011). Although the Malaysian Biodiesel Association (MBA) has actively lobbied for the interest of the biodiesel investors, the fact of the matter is that the MBA has limited influence over government policies pertaining to biofuels (Chin, 2011).

At the time the policy was being formulated, the motivations were quite simply to stabilize the prices of crude palm oil (CPO) whilst at the same time exploit a new and emerging market opportunity especially with the rapid increase in biofuel mandates and demand globally (Abdul-Manan, Baharuddin, & Chang, 2014; Chin, 2011). Given the fact that palm oil is the leading edible oil traded in the world market in which Malaysia alone accounts for about 48% of the total production and 58% of total world trade (Simeh, 2009) and coupled with the fact that the Malaysian Palm Oil Board (MPOB) has successfully pioneered the research, development and implementation of palm-based biofuel in diesel engines since 1982, the policy is primarily aimed towards the use of palm products as feedstock for the manufacturing of biofuel (MPIC, 2006).

The formal objectives of the NBP are twofold, those are:

1) Use of environmentally friendly, sustainable and viable sources of energy to reduce the dependency on depleting fossil fuels;
2) Enhanced prosperity and well-being of all the stakeholders in the agriculture and commodity based industries through stable and remunerative prices.

The policy has taken a fairly holistic approach in its objectives in trying to balance between environmental quality, social equity and economic prosperity, consistent with the concept of sustainable development. It is believed, therefore, that the goals of the NBP are satisfactorily sound and appropriate.

The policy is basically underpinned by five key strategic thrusts as summarized below:

i. Thrust 1: Biofuel for transport

   As this sector is the main consumer of subsidized diesel, it will be given a higher priority in this policy. Diesel for land and sea transport will be a blend of 5% process palm oil and 95% petroleum diesel which will be made available country wide in stages.

ii. Thrust 2: Biofuel for industry

   The use of biofuel/diesel blends in industrial sectors.

iii. Thrust 3: Biofuel technologies

   Increased funding and to promote research, development and commercialization of biofuel technologies.

iv. Thrust 4: Biofuel for export

   To encourage the production of palm based biofuel for global export market.

v. Thrust 5: Biofuel for cleaner environment

   To encourage the use of biofuel to improve the quality of environment.

Following the development of the biofuel policy, the Malaysian parliament in 2007 ratified the Malaysian Biofuel Industry Act of 2007 (Act 666) in order to regulate and provide a guiding framework for the implementation of this policy. According to this Act, biofuel is defined as any fuel, whether solid, liquid or gaseous, that is derived from biomass. In principle, the Act does not specify the types of biomass that can be used as well as the sector that is applicable, whether for marine, aviation, automotive or industrial, which therefore provides more room for future innovation. However the Act empowers the Minister charged with the responsibility for biofuel to prescribe the exact chemistry of biofuel and the volume percentage to be blended into any fuel. At present only palm derived fatty-acid methyl esters (FAMEs) are endorsed for use as blending components into regular diesel as transport fuel, where at the moment the mandate limits it to a maximum of 5% by volume, or also referred to as B5 (USDA, 2009). After several delays due to issues concerning logistics, infrastructure cost and blending facilities (USDA, 2009) the B5 mandate was finally rolled-out in November 2011 in the Klang Valley central region only. However, there are now serious considerations for further increasing the blend concentration from 5% to a maximum of 10%, and for a nation-wide implementation in 2015. The evaluation of the effectiveness of the NBP in Malaysia reported herein is therefore a timely input for consideration by policy makers before a much wider scale implementation are executed.

4. TBE methodology

A theory-based evaluation (TBE) works by modelling the micro-steps or linkages in the causal path from a programme or intervention to the ultimate outcomes and basing this on the detailed assumptions of how the intervention is supposed to work (Mickwitz, 2002). An evaluator then evaluates the logic behind every individual steps leading to the final outcomes. A TBE is an extremely useful tool as it is sufficiently flexible for evaluators to identify and prioritize evaluation criteria and therefore tailor the evaluation methodology to answer the specific evaluation questions (Donaldson & Gooler, 2003). The approach is method neutral as it argues that quantitative, qualitative or mixed method designs are neither superior nor applicable in every evaluation situation (Donaldson, 2005), but instead it is a case of horses-for-courses.

In principle there are 2 prime aspects to a TBE of policies, those are the conceptual and empirical aspects (Coryn, Noakes, Westine, & Schroter, 2011; Harmelink et al., 2005; White, 2009). Conceptually, a TBE articulates a policy or programme theory to explicate the underlying mechanisms on how the policy is meant to work. A policy or programme theory is constructed to reflect all the assumptions on the way the policy is expected to lead to the targeted effects. Sometimes the causal chain is well described within official policy documents, and well known by the policy makers, and in cases such as these the policy-theory is said to be explicit. However, in many cases the policy-theory is poorly described, also known as implicit policy-theory, and in this case the analyst has to construct a policy-theory by drawing information from formal policy documents, official speech texts, news reports, and through direct comparison with experiences elsewhere.

Empirically, TBE seeks to investigate and verify the mechanism of actions using evidence-based research. This involves critical analysis of every step within the cause–effect chain in order to evaluate the validity of the overall policy-theory. Evaluators should also identify possible side-effects (positive and negative), breakdowns, and variations in outcomes. Gaps in policy-theory are to be identified as learning, or where possible, should be recorded as feedback for further improvement on the policy designs.

4.1. Evaluation criteria

The NBP will be evaluated across 3 criteria, those are:

1. Effects on sustainability and environmental friendliness.
2. Fossil fuel independency
3. Stakeholders welfare

The choices of evaluation criteria are not arbitrary. These criteria relate to the official goals of the NBP (MPIC, 2006), those are:

1) Use of environmentally friendly, sustainable and viable sources of energy to reduce the dependency on depleting fossil fuels;
   - This objective has two distinct elements. On the one hand it is about reducing the country's reliance on fossil fuels (Criterion No. 2: "Fossil Fuel Independency"), while on the other hand it is also about the use of cleaner fuels (Criterion No. 1: "Sustainability & Environmental Friendliness").
2) Enhanced prosperity and well-being of all the stakeholders in the agriculture and commodity based industries through stable and remunerative prices.
   - This policy goal relates to the improvement in well-being of all stakeholders within the palm biodiesel value chain through stable and rewarding palm oil prices (Criterion No. 3: Stakeholders Welfare).

4.2. Construction of a policy theory for the national biofuel policy

The policy theory for the Malaysian NBP is not explicitly described by the policy makers on how it is thought that the policy instruments will lead to the desired outcomes. As a matter of fact, this is a fairly typical characteristic of policies and programmes that have been widely observed (Harmelink, Nilsson, & Harmsen, 2008). In cases of implicit policy-theory, the evaluators have to try to reconstruct the cause–impact chain of action based on the most likely logic (Harmelink et al., 2008).

According to Pawson and Sridharan (2010), one way of spotting the policy theory is through critical scrutiny of policy documentation, guidance, regulations, etc., which would help the evaluator to construct a logic model for how the policy goals would be achieved (Pawson & Sridharan, 2010). In 2003, Leeuw published a paper that had reviewed available methods for reconstructing programme theory (Leeuw, 2003), in which one of the approaches is to survey formal and informal documents, including interview transcripts and press statements, in order to elicit statements that indicate why it is believed necessary to solve the policy problem and what the goals of the policy are. These statements would point to the underlying mechanisms that are believed to make the policies effective.

On the other hand, Patton (2008) argues that deductive, inductive and user-oriented approaches are all valid approaches for constructing policy theory (Patton, 2008). According to White (2009), it is equally important that academic papers are also widely surveyed to discover similar evaluation exercises elsewhere in order to ascertain possible parallels in policy theories that can likely be adapted to the policy that is being evaluated (White, 2009). In addition to that, critical analysis of academic/scientific publications would similarly allow for the discovery of trends in mindset, worldview and prevalent thinking within a particular region which may shed light onto the logic underpinning a policy theory.

Based on all the above, the policy theory underpinning the logic behind the NBP can be re-constructed as per Fig. 3. A flowchart diagram provides a better visual of the conceptual cause–effect chain of actions. The theory behind Criterion 1 is based on a very widespread line of thinking about bio-based fuel, that is, because it is bio-derived, it is necessarily carbon neutral given that the carbons released during biofuel combustion are those that were absorbed from the atmosphere during plant growth. This can be seen very explicitly in the following extract:

> "The use of biodiesel can mitigate the emission of CO_2 because all biodiesel are derived from living plants that requires CO_2 for its growth. With the addition of water and energy from the sunlight, plant organisms will synthesized the absorbed CO_2 to carbon-based sugar molecules which is required for plant growth through photosynthesis. Therefore, although CO_2 is emitted when biofuel is used as a source of energy, **the net CO_2 emission is still considered zero.**"
>
> From (Lam, Tan, Lee, & Mohamed, 2009), page 1461, with author's emphasis.

This line of thinking is not unique to Lam et al. only. The literature survey conducted had revealed that the line of argument as presented by Lam et al. above is very commonly used in the literature, as also implicit in (Abdullah, Salamatinia, Mootabadi, & Bhatia, 2009; Basiron, 2007; Chua & Oh, 2011; Lau, Tan, Lee, & Mohamed, 2009) and many others. This is believed to be an important cause–effect logic underlying the policy theory, and relates to Criterion No. 1 on issues of sustainability and environmental friendliness.

4.3. Critical analysis of the policy-theory

The next step is for the evaluator to assess the logic of the cause–effect chain in the policy theory of the NBP. Logic analysis allows us to critically test the plausibility of a policy's theory using

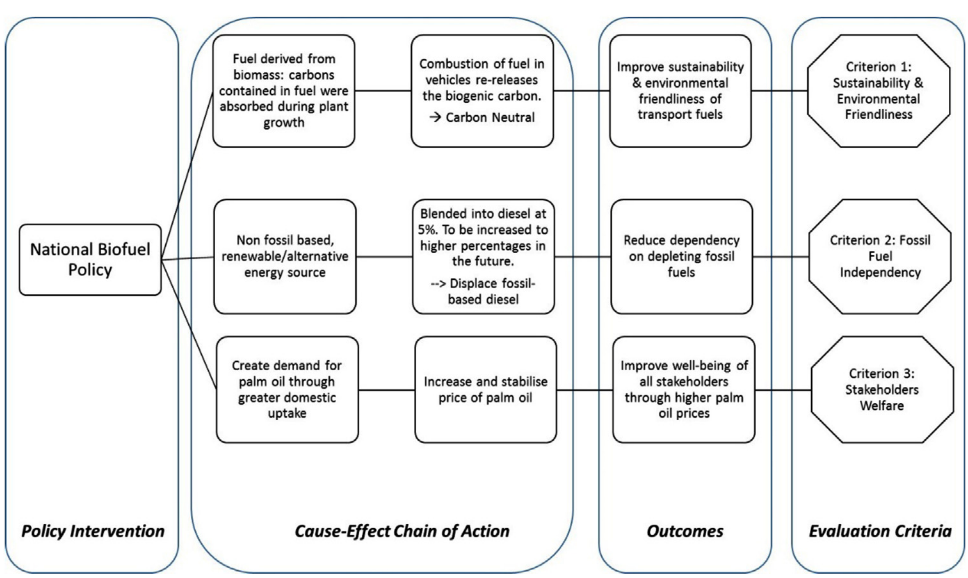

Fig. 3. Policy-theory flowchart depicting the cause–effect mechanisms underlying the logic behind the introduction of the NBP.

scientific knowledge-either scientific evidences or expert knowledge (Brouselle & Champagne, 2011; Rossi, Lipsey, & Freeman, 2004). It is important to note that logic analysis is not the same as logic modelling (Brouselle & Champagne, 2011). Logic analysis is an evaluation technique for analyzing whether the intervention is designed in such a way that is logically able to produce the desired outcomes. This enables us to understand the subtleties of the causal path and validate the intervention's theoretical construction with added advantage of applying sound scientific knowledge (Brouselle & Champagne, 2011).

There are two types of logic analysis, those are direct and reverse logic analysis. Direct logic analysis judges the intervention's design and adequacy towards meeting the desired outcomes, whereas reverse logic analysis approaches from the opposite direction in order to identify the most optimal and effective measures towards achieving the desired outcomes (Brouselle & Champagne, 2011). The direction of the analysis (direct or reverse) will depend primarily on the perspective of the analysis, and therefore determine the information required. A more detailed explanation on the application of logic analysis in TBE are provided by (Brouselle & Champagne, 2011).

This study has referred extensively to official policy documents, legal texts, scientific publications from a variety of disciplines, books and documents from official government and non-governmental websites in Malaysia and globally. Critical reviews of scientific publications across multiple disciplines ranging from soil sciences, climate change, environmental economics, all the way to several engineering fields and sustainability sciences have also been conducted, and relevant literatures have been cited throughout this paper to support the arguments presented herein. The careful and detailed appraisal of numerous references, from multiple disciplines, and varied with respect to time, locations and researchers would therefore increase the confidence and accuracy of this study by minimizing the risk of biases through cross-checking of information and identification of regularities in research data. Furthermore, approaching this study from several theoretical standpoints, such as from the perspectives of sustainability sciences, technological innovation systems and energy economics, aids the process of mapping out, or explain more fully, the richness and complexity of the issues being dealt with.

5. Evaluation findings

5.1. Criterion 1: Sustainability and environmental-friendliness

The national biofuel policy envisions the use of environmentally friendly and sustainable sources of energy to reduce dependency on fossil fuels. Despite this, the legislated Malaysian Biofuel Industry Act 2007 (Act 666) does not have a provision specifying the minimum sustainability criteria that a biofuel has to meet in order to ensure that it is sustainable. Although the Act allows for the Ministry responsible for biofuels to specify the types of biomass feedstock, no guidelines have been adopted to date to provide for the definition of environmental-friendliness and sustainability. This is vital to ensure that the policy goals can be met, otherwise governments risk encouraging the substitution of fossil fuels with alternatives that may have inferior sustainability performances.

Act 666 was formulated to advance the goals of the NBP in Malaysia, and therefore must be fit-for-purpose, or else risk being inadequate to ensure that the policy objectives are met. The policy envisions the use of environmentally friendly and sustainable sources of energy, but the absence of sustainability criteria within the biofuel mandate can imply one of two things:

I. All biofuels have the same sustainability performances, and environmental friendliness, regardless of the biomass source and processing, and/or
II. All Malaysian palm oils are environmentally friendly and sustainable regardless of the agricultural, milling and processing practices.

These, however, contradict what many scientific studies have concluded. Sustainability in general is a broad area, and so to elaborate more on this point, the global warming impact of biofuels, and specifically palm oil, will be presented as a case study, which has also become extremely topical in nature in recent times, particularly for biofuels and the transport sector. Similar arguments are available for other aspects of sustainability and environmental protection, but will not be discussed here as it will be too lengthy.

The GHG emissions from biofuel production and processing have been well-studied using the contemporary lifecycle analysis (LCA) approach, where biofuels can typically have a GHG saving of between 20% and 90% relative to fossil fuels (Thow & Warhurst, 2007). However, these estimates do not include the GHG emissions associated with land conversions which may be substantial depending on the agricultural practices as well as the land that is being converted (Navindranath et al., 2009). Numerous studies have shown that the GHG emissions from land use change can substantially influence the climate benefit of substituting fossil fuel with biofuels, see Leemans et al. (1996), Schlamadinger et al. (2001), Searchinger et al. (2008) and Fargione et al. (2008). In fact recent studies have revealed that conversion of native forestland uses to biofuel crops may lead to significant GHG emissions such that biofuel has a negative carbon balance, or carbon debt, for decades to centuries, making it even less attractive as fossil fuel replacement for climate change mitigation (Fargione et al., 2008).

The nature of the establishment of oil palm plantations will be an important criterion for determining the GHG impacts of palm-based biofuels. Deforestation and development on peat soils can lead to substantial increase in GHG emissions. In a different study, Crutzen, Mosier, Smith, and Winiwarter (2007) reported that the use of nitrogen fertilizers during plantation could lead to increased nitrous oxide (N_2O) emission, which according to the IPCC is 298 times worse than carbon dioxide (CO_2) in causing global warming (Jansen et al., 2007) and therefore different agricultural and fertilization management practices would result in biofuel with different GHG performances.

It is clear, therefore, that substituting fossil fuel with biofuels, if not carefully managed, can lead to higher GHG emissions from the transport sector. Or in other words, if the uses of biofuels are not properly regulated, there is a possibility that in reality fossil fuels are being replaced by an inferior alternative which may worsen the environmental impacts of the transport sector and therefore compromise on the policy goals. The NBP has a vision of using environmentally friendly and sustainable sources of energy. It is very important for Act 666 to differentiate between sustainable and non-sustainable palm-based biofuels as ways to incentivize the adoption of better management practices at the plantation sector whilst at the same time prevent future environmental degradation associated with the development of new oil palm plantings. At present this is still a gap to be addressed.

Looking at the palm oil mills specifically, the mill effluents generated (i.e. wastewater) are heavily polluted with biodegradable organic materials. The common treatment methods include a pond or lagoon system, however, the natural oxygen content of the treatment system is insufficient for all of the pollutants to decompose aerobically (Brinkmann, 2009). As such the decomposition process invariably evolves into an oxygen-starved regime (anaerobic decomposition) therefore resulting in large quantities of methane being emitted, where according to the IPCC, methane gas is 25 times worse than carbon dioxide in causing global warming (Jansen et al., 2007). Some mills have adopted, often costly, strategies to mitigate the emissions of methane from the effluent ponds, such as the use of methane capture technology, whereas others have not been equipped to do so. For this improved mill technology to be widely adopted, the policy has to make a distinction between the two and provide an inducement for mill operators to upgrade. The NBP in existing format, however, treats all palm biodiesel as the same and hence loses out on the opportunity to encourage continuous improvement, which is the essence of sustainable development.

Whilst the preceding paragraphs are discussions on segments of the palm-biodiesel supply chain, the discussion here will now shift to an overall lifecycle perspective. The Environmental Protection Agency (EPA) of the US has recently issued a report for public comments summarizing the outcome of a lifecycle analysis that they have conducted to determine the GHG emissions reductions potential of palm biodiesels globally as part of the Renewable Fuels Standard 2 (RFS2) (EPA, 2011). This study has taken into consideration of the various oil palm plantation management practices and mill systems that are widespread in the oil palm producing countries, predominantly Malaysia and Indonesia, and projecting it into the future. The scenarios built have taken into account of the various land conversion scenarios (i.e. deforestation and plantation on peat land). There are many other LCA studies on palm biodiesel available in literature, however this study has been chosen in particular because it builds a model to simulate the range of GHG saving potentials for palm biodiesel, which is unique as it presents the average and probability distribution for the range of GHG savings potential.

The outcome of the study depicts the GHG emissions reduction potential of palm biodiesel relative to fossil fuels (Fig. 4), where it can be seen here that although the average lifecycle GHG savings of palm biodiesel is about 17%, in reality it can range between a reduction of more than 40% to an increase in GHG emissions by more than 10%. This is a very large range and the discomforting fact is that some palm biodiesels actually emit more GHGs than fossil fuels. This situation, however, is not unique to palm biodiesel. Other sources of biodiesels are also in a similar conundrum, hence why many advanced biofuel regulations worldwide (such as the Low Carbon Fuels Standard in California, the EU's Renewable Energy Directives and the US Renewable Fuels Standard-2) have imposed strict sustainability requirements to ensure that fossil fuel is only replaced by alternatives with superior sustainability performances. Likewise, it is very important that for the NBP to be successful, a framework is also put in place to define the minimum GHG emissions savings that the palm biodiesel must achieve before it can be accepted for use as fossil fuel replacement. It is highly undesirable if the palm biodiesel that has replaced fossil fuel actually has higher GHG emissions.

In summary, it is clear from the preceding paragraphs that:

i. not all biofuels are the same (CONCAWE et al., 2007; Pimentel & Patzek, 2005);

where in fact

ii. two palm-based biodiesels from different plantations and mills can have significantly different environmental performances (Cherubini et al., 2009; Wicke, Dornburg, Junginger, & Faaji, 2008);

and in some cases

iii. the GHG emissions intensity of biofuel may even be worse than fossil fuel (Lange, 2010).

Hence, the absence of a sustainability element within the Malaysian Biofuel Industry Act 2007, especially when one of the five strategic thrusts of the NBP is to improve the quality of the environment, can be seen as incomplete. This is a gap which, if left unaddressed, may compromise the ability of the policy to meet the goals of ensuring the use of environmentally friendly and sustainable sources of energy. Moreover, a likely unintended adverse effect is the worsening of the environmental performances of the transport sector, particularly from a global warming perspective, due to the mandatory substitution of transport fossil fuels by an inferior alternative.

5.2. Criterion 2: Fossil fuel independency

Malaysia, like most other countries globally, are heavily dependent on fossil as a key energy source. The realizations that fossil fuels are depleting and contribute substantially to global warming have led many countries to find ways of replacing it with other alternatives. The price volatility of fossil fuels is a further incentive for finding a replacement. Many countries have

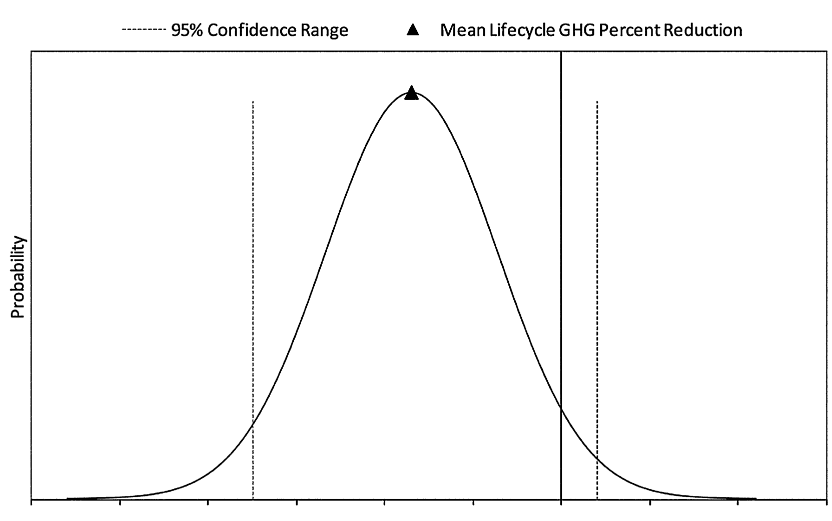

Fig. 4. Percent change in lifecycle GHG emissions compared to fossil fuel. Positive values denote that palm biodiesel has higher GHG emissions than fossil fuels, whereas negative values show a reduction in GHG emissions compared to fossil fuels (EPA, 2011).

introduced policies to promote the use of renewables as fossil substitute and gradually to wean the country from being overly dependent on petroleum resources. Similarly, the NBP in Malaysia was formulated with the goal of reducing the country's reliance on fossil fuels.

The NBP in Malaysia has mandated the blend of a maximum of 5% palm-based biodiesel into conventional fossil diesel as means to wean the transport sector's dependency on fossil fuels. Whilst there is no doubt that palm biodiesel is a renewable energy source, the reality is that from a lifecycle perspective, the production of biofuels would also require the use of fossil fuel, for instance, in the forms of diesel to power the operations of agricultural machines, the use of petroleum as feedstock for the manufacturing of chemicals and fertilizers, the use of fossil fuels in trucks to transport products from one point to another, and many more. And so, effectively, all biofuels will have a different degree of renewability; that is not all biofuels are equally capable of reducing the country's reliance on fossil fuels to the same degree. In other words, the degree of biofuels "renewability" can differ from one to another, depending to a large extent on how much fossil fuels are consumed throughout the entire biofuels production value chain. The lower the amount of fossil energy used in the entire lifecycle, the higher degree of renewability the biofuel has and therefore the more capable it is in reducing reliance on fossil fuels.

A popular way for measuring biofuels renewability is the contemporary lifecycle energy balance approach (Pradhan et al., 2009; Shapouri, Duffield, & Wang, 2002), which takes into account of all energy inputs, from cradle to grave, that are associated with the production of the biofuels. In this study, data for the lifecycle energy balance for biofuels were extracted from the GHG emissions savings calculations under the EU's Renewable Energy Directive (RED) (EC, 2009).

Fig. 5 depicts the total fossil energy consumed for the production of 1 MJ of fuel for a range of biodiesels and conventional fuels from the perspective of a LCA. For the production of 1 MJ of palm biodiesel, about 0.36 MJ of fossil fuel is consumed. This is much lower than the amount of fossil energy required for producing 1 MJ of gasoline and diesel. This is also slightly lower than the amount required for producing biodiesels from rapeseed and soybean oils. This strengthens the argument earlier that not all biofuels have the same degree of renewability.

Furthermore, it also highlights the very important point that a palm biodiesel mandate alone will not be able to completely

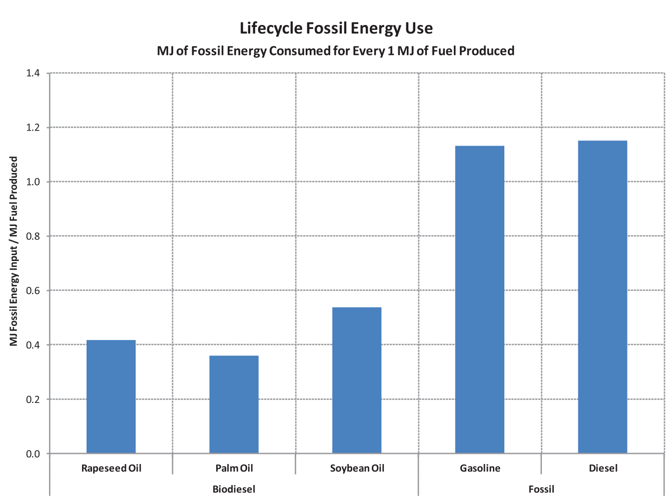

Fig. 5. Lifecycle fossil energy consumption for a range of biodiesels and fossil fuels. 0.36 MJ of fossil fuel are consumed for every 1 MJ of palm biodiesel produced. The results here were derived by the author by extracting data from (EC, 2009).

wean the sector off fossil fuels even if all the petroleum-based transport fuels are replaced with biodiesel. Nevertheless, it will indeed help reduce, but not completely stop, our dependency on petroleum. However, the significance of this fossil dependency reduction will depend critically on how much of the existing transport fossil fuels are substituted. Whilst obvious that the more the better, there are inherent limitations to this.

Currently the use of biodiesel is limited to the transport sector. However, the consumption of diesel fuel by the transport sector in Malaysia is significantly lesser then the consumption of motor gasoline (i.e. petrol). In 2009 more than 8249 kilo tonnes of gasoline were consumed by the transport segment, whereas in contrast only 4988 kilo tonnes of diesel were consumed during the same year (IEA, 2012). Hence, it is apparent that the implementation of B5 in the current market scenario would not substantially reduce the country's dependency on fossil fuel as for a large consumer segment lies in the gasoline sector, whereas the B5 mandate would only substitute about 5% of the total diesel fuel consumption. Based on the IEA's 2009 figures, the NBP, with its current palm-derived biodiesel mandate, will only be able to reduce the transport sector's dependence on fossil fuel by a mere 2%, an amount that is immaterial especially when taking into account of projected growth in fossil demand by the transport sector in years to come. However, if we were to include the fact mentioned earlier that 0.36 MJ of fossil fuel is consumed in the production of 1 MJ of palm biodiesel, the 2% reduction in fossil dependency will further decrease to an insignificant 1%.

To bolster the reduction in fossil fuel dependency by the transport sector, the mandate must be amended to increase the concentration of palm-biodiesel in regular diesel (currently limited to 5%). However, the mandate in its current form specifies that only fatty acid methyl ester (FAME) is the approved biofuel chemistry that can be used, which is self-limiting. FAME is a specific molecular chemistry which differs slightly from the typical molecular structures of petroleum diesel. The latter are typically composed of non-oxygenated paraffinic molecules whilst conversely FAMEs are oxygenated (Owen & Coley, 1995). The fourth edition of the Worldwide Fuel Charter (WWFC), which is a technical positioning report representing the views of automobile and engine manufacturers around the world, recommend that the use of FAMEs in diesel fuel are to be restricted to a maximum of 5% due to several potential incompatibility concerns (ACEA, Alliance, EMA and JAMA, 2006), and in fact some manufacturers even insist that the use of higher blends would void the manufacturer's warranty (Ecotraffic & Atrax, 2008). It is, therefore, clear that there is limited possibility of increasing the concentration of FAMEs blended in diesel fuel for use in existing diesel vehicles beyond 5%.

In summary, the following can be said:

- Act 666 mandates the use of palm biodiesel as 5% blends into regular diesel as means to reduce dependency on fossil fuels.
- However, the consumption of diesel fuel by the transport sector is small relative to the consumption of gasoline (i.e. petrol). Therefore, a B5 mandate would only reduce the transport sector's dependency on fossil fuel by a small 2%.
- The production of palm biodiesel, however, requires the use of fossil fuel throughout its production value chain, where it has been estimated that about 0.36 MJ of fossil fuel is consumed for every 1 MJ of palm biodiesel produced. And so, in reality the B5 mandate will only reduce the transport sector dependency on fossil fuel by a mere 1%.
- On top of that, the mandate presently only approves the use of a specific biodiesel chemistry (FAME), which, studies have shown,

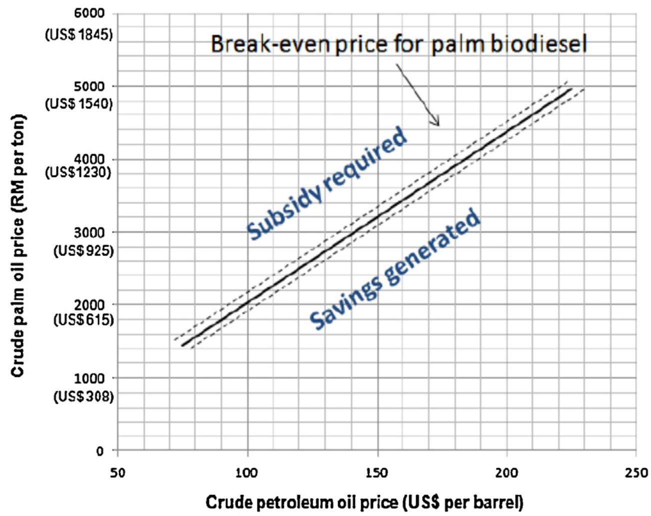

Fig. 6. Break-even price for palm biodiesel as a function of CPO and Crude Petroleum prices (Lopez & Laan, 2008).

can only be used in existing diesel vehicles to a maximum of 5%, above which incompatibility issues start to crop up. Hence, the mandate has self-imposed a limit on increasing the blend concentration to higher levels.

5.3. Criterion 3: Stakeholders welfare

In 2008 the Malaysian Institute of Economic Research (MIER) and the Global Subsidies Initiative (GSI) conducted a joint study for the International Institute for Sustainable Development (IISD) on government's support for biodiesel in Malaysia (Lopez & Laan, 2008). The report was part of a series to address subsidies for biofuels in several selected developing countries. The study comprised of a comprehensive assessment and review of existing literature on the cost structure of biodiesel production in Malaysia which was then contrasted against the cost of producing fossil diesel in order to estimate the profitability of replacing fossil diesel with palm biodiesel at various CPO and crude oil prices. The estimated break-even prices for biodiesel at varying CPO and crude oil prices are provided in Fig. 6. At CPO price of RM 2000 per tonne, palm biodiesel will only be competitive against petroleum diesel if the price of crude oil is above 100 USD per barrel. If on the other hand the price of crude oil is below 100 USD per barrel, then the consumers will have to bear the higher price of unsubsidized B5 in the market. Alternatively, if the B5 price were to remain the same as regular diesel, then that would need to attract larger subsidy from the government.

In order to put the variability in CPO and crude oil prices into perspective, it is important to review the historical prices of CPO and crude oil, but it is by no means a projection of future values. From Fig. 7, the prices of CPO in the last 2 years are highly variable typically ranging between RM2000 and RM 3000 per tonne of CPO (MPOB, 2015). At current level of about RM 2400 per tonne, the use of biodiesel as fossil substitute is only cost effective if the price of crude oil is above 120 USD per barrel. Tracking the historical price volatility of two different types of crude oil price indexes obtained from the U.S. Energy Information Administration (EIA) for the last 29 years (Fig. 8), it can be seen that the prices of crude oils seldom surpass the 120 USD per barrel mark (EIA, 2015). In fact, the prices of crude oils in the last few weeks (January 2015) have dropped significantly to below 50 USD per barrels, and so for palm biodiesel to be cost competitive, the price of CPO has to be below RM 1000 per tonne. But looking at the trends in CPO price for the last 2 years, it has never fallen below RM 1500 per tonne.

One can argue that it makes good economic sense to use palm biofuel if the feedstock price is adequately low and petroleum prices are sufficiently high. However, recent trends in CPO prices appear to have been following similar trajectory as the price fluctuations of crude petroleum oil (Fig. 9). It would therefore be logical to suggest that a significant price differential between CPO and petroleum oil will be highly unlikely if this sort of relationship were to persist into the future.

The introduction of mandatory blending requirements of palm biodiesel into regular mineral diesel is definitely a boon to the domestic palm and biodiesel industry as it guarantees a fixed level of domestic demand for biodiesel regardless of the price of CPO. However, it is also likely to impose substantial financial burden on taxpayers or consumers given its cost un-competitiveness. Assuming an equal subsidy structure as petroleum diesel is applied, it would also mean that the direct subsidy of B5 would also result in the government to lose potential revenue stream in the form of foregone taxes. It would not be unreasonable to suggest that the policy is therefore effectively causing a transfer of wealth from taxpayers (if subsidy is incurred) or motorists (if cost is passed down to consumers) to biodiesel producers, who would appear to have the enviable advantage of guaranteed sales regardless of the price of their product.

This contravenes directly with the second goal of the NBP which aims to enhance prosperity and well-being of all stakeholders in the agriculture and commodity based industry. The objective of the policy must not be misconstrued as a goal to improve the economic statuses of only the oil palm planters and biofuel processors. Actors in the palm-to-biofuel industry include a diverse range of stakeholders (Teoh, 2002) with various different interests which can be mapped out as below (Fig. 10). It is imperative that any institutional systems that are in place as measures to support the policy goals are not biased towards one group of stakeholders at the expense of another, otherwise potentially resulting in unintended inequitable policy outcomes.

There is no doubt that for a new renewable energy-based system to work there needs to be some form of support, especially

Fig. 7. Trends in CPO prices for 2 years (2013–2014) (MPOB, 2015).

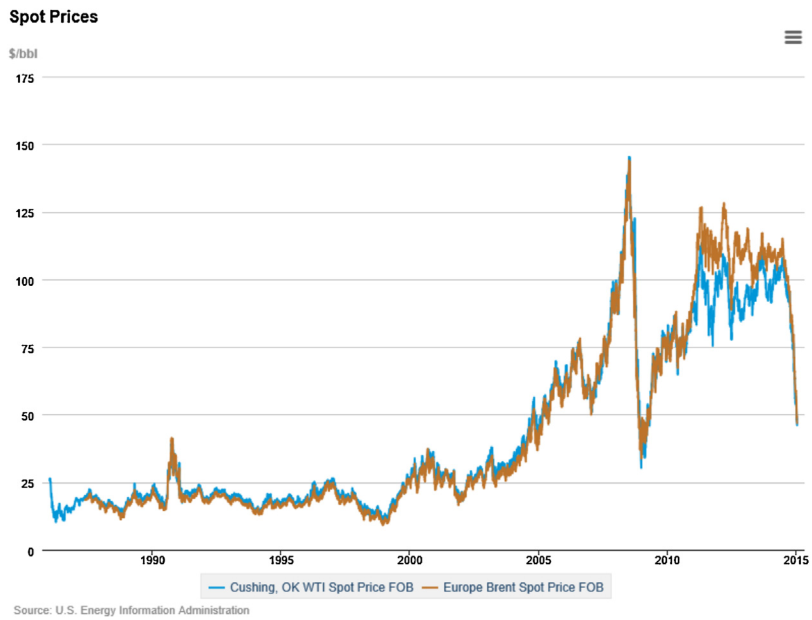

Fig. 8. Historical price fluctuations of two different types of crude oils for the last 29 years (1986–2015) (EIA, 2015).

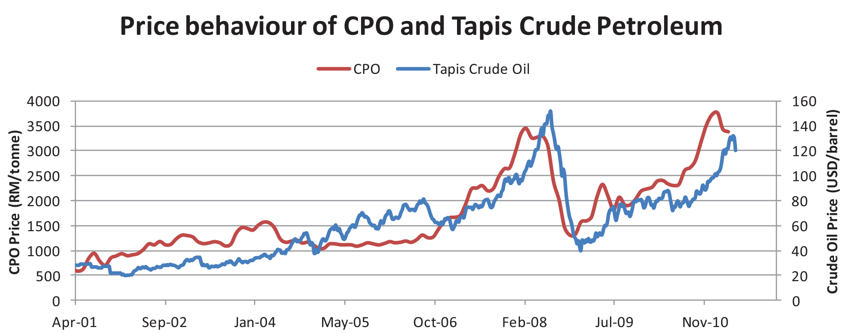

Fig. 9. The relationship between the prices of CPO and Tapis crude petroleum.

Fig. 10. The myriad of stakeholders involved in the palm-to-biofuel industry.

financially, since they are typically less competitive economically. However, government support must only be a temporary assistance during the initial stages of technology development and commercialization as means to incentivize a transition towards a new technology solution. Appropriate subsidy allocation is therefore critical otherwise there is a risk of sending the wrong market signals and incentivizing undesirable change and attitude. The classic example is the fossil fuels subsidy prevalent in many oil producing countries, including Malaysia. The industry is currently enjoying government support in the form of price subsidy and foregone taxes in order to successfully role out palm biodiesel. There needs to be a concrete plan in place for the gradual phasing-out of the subsidy. The policy and supporting legislations have failed to define a time-bound action plan when palm biodiesel has to compete on a level playing field. A prolonged subsidy will only create a non-competitive culture amongst Malaysian firms and eventually the subsidized palm biodiesel will be so entrenched into the marketplace that it becomes another subsidy issue that has to be dealt with in the future.

6. Conclusions and recommendations

Critical evaluation of the NBP has revealed several gaps in the policy framework that could possibly lead to unintended adverse effects or even resulting in the failure of the policy to meet its intended objectives. These gaps are (1) lack of sustainability assurances, (2) inability of the policy to wean the transport sector off fossil fuels, and (3) compromised multi-stakeholder welfare. Through careful consideration of other renewable energy mandates globally, and from various scientific publications, it is therefore recommended that the national biofuels policy in Malaysia are amended as per the following suggestions in order to improve the likelihood of policy effectiveness.

- Incorporate a minimum irreducible definition for sustainable biofuels. This would ensure that only biofuels that meet the regulatory definitions for sustainable biofuels are used in the transport sector. The benchmark here can be a sustainability standard such as the framework that was developed by the Roundtable for Sustainable Palm Oil (RSPO) via a multi-stakeholder consensus approach or, if preferred, a new and more germane standard can be developed through a consensus building process. It is important however, that whatever standard is adopted, it is being reviewed on a regular basis and updated when necessary to ensure that the standard is dynamic enough to continue to be relevant through time.
- Appoint an independent renewable energy authority to take ownership of the Biofuel policy. It is believed that giving authority to a party with strong interest in a particular outcome can breed unfairness or, at the very least, for others to perceive that the process is being unfairly driven even if the authority is perfectly non-biased. After careful consideration, it is recommended that the biofuel policy is placed directly under the administration of the Sustainable Energy Development Authority (SEDA), which is a statutory body that was only recently formed under the Sustainable Energy Development Authority Act of 2011 with key responsibility over matters relating to renewable energy. Centralizing all renewable energy activities in the country under a single authority also allows for a more streamlined approach towards a more sustainable national energy development agenda.
- Liberalize the biofuel policy to foster competitiveness for a greater good. The prescriptiveness of the policy denies competing firms the opportunity to outdo each other by developing alternative solutions with superior benefits. Therefore it is the recommendation of this study that the policy is being made more liberal by allowing:
    - the use of domestic feedstock other than just palm oil.
    - the use of other biofuels chemistry that can be shown to be compatible with existing vehicle systems.
    - biofuels not just as diesel substitute, but also as gasoline replacement.

Such liberalized policy design could incentivize development of advanced generation biofuels, using non-food based biomass as feedstock to allow for much greater benefits to be realized, such as larger GHG reduction potential, the use of waste products as feedstock to prevent competition with the food supply-chain and to allow greater reduction in fossil fuels dependency.

7. Lessons learnt

This study further add to the already many observations in literature that have reported that the logics underlying policy introductions are often not made explicit. It is then the evaluator's role to identify the logic chain within the policy theory. Here we managed to do so through critical analyses of newspaper reports, official and unofficial policy documents, scientific publications by universities and institutions that have links to the regulatory body, conference presentations by these institutions, and many more.

The use of the TBE approach has allowed for the identification of (i) logical flaws in the policy theory, (ii) gaps in policy framework that would lead to the policy to be ineffective, and (iii) solutions that can improve the chances of the policy to be effective. By relying on credible scientific publications, the assessments of public policy are made more robust and less influenced by stakeholders' interests. More importantly, the use of comparative policy evaluation technique allows for robust policy designs elsewhere to be emulated in order to further improve the existing policy framework.

However, a key challenge with this kind of evaluation approach is the need for the evaluator to critically review the various scientific domains that are relevant to the evaluation criterion and this can be time consuming. Moreover, the TBE approach is less used within the academic circle, or at least this is the case in Malaysia, and so, it has attracted criticism that the approach is less scholarly for policy evaluation. We believe that the soundness of the TBE approach is highly dependent on the robustness of the data sources that have been used for analyzing the policy theory. A key aspect of this involves the ability of the evaluator to critically examine information presented and to distill the implication of the various scientific findings. It is felt that the methodology should be further popularized within the academic and policy making circles as a practical approach towards the evaluation of policy effectiveness, especially in the field of renewable energy and climate change mitigation.

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