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Full Length Research Paper

Assessing the scenario concerning environmental sustainability in Malaysia

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There is strong scientific evidence that energy consumption and production are often related to greenhouse emissions. It has been argued that the cost of taking smart, effective cooperative action towards reducing global warming should be manageable. Following an effective approach, our work investigates the scenario of environmental sustainability in Malaysia and reassesses energy policy and alternative energy sources such as the utilization of oil palm (that is as a source of renewable energy) to reduce the economic and environmental burden. Our efforts try to lessen the gap between greenhouse gas mitigation and sustainable development, focusing on changing conventional energy instruments. This paper may be useful in the formulation of policies on renewable energy in Malaysia and possibly elsewhere.

Key words: Energy, environmental impacts, renewable energy, palm oil bio-diesel, energy policy.

INTRODUCTION

Global climate change is regarded as an external shock to the economy, since trade does not take place in a vacuum. Instead, trading takes place against the backdrop of our environment, and it is this environment which is undergoing rapid global change. The scientific evidence, based on timescales, consequences and preparations, was recently published by the IPCC (2007) and cannot now be refuted. The global temperature is rising now and the main cause is the accumulation of CO_2 and other greenhouse gases (GHGs) in the atmosphere as a result of human activities (IPCC, 2007). According to UN Millennium Development Goal indicators (UN, 2009), one of the main contributors to CO_2 emission in Malaysia are the transport and energy sectors. In 2009, 28% of total CO_2 emissions came from the transport sector, another 28% came from the electricity and heat production industries, and Malaysia recorded 187 million tonnes of GHG (carbon) emissions in 2006 (UN, 2009). That puts it in third place in the South East Asian region behind Indonesia (333 million tonnes) and Thailand (273 million tonnes), with Vietnam (106 million tonnes) in fourth place. On a per capita basis, a different picture emerges; with 7.2 tonnes of CO_2 per capita, Malaysia is still the third highest emitter in Southeast Asia (UN, 2009). As Malaysia is rapidly growing, the demand for transport and energy is increasing, and so is its impact on the environment. According to the literature, this is now well evident (Hamid et al., 2008). Particularly, Hamid et al. (2008) investigate the Malaysian 2020 emission scenario from electricity generation. Their study results show that the 2020 fuel mix (the Malaysian 2020 energy vision) would result in significantly higher CO_2 emissions (GHG gases). The amount of emissions is even greater if calculated based on business-as-usual 2020 final demand. As such, even though the Fuel Diversification Strategy in Malaysia could provide the

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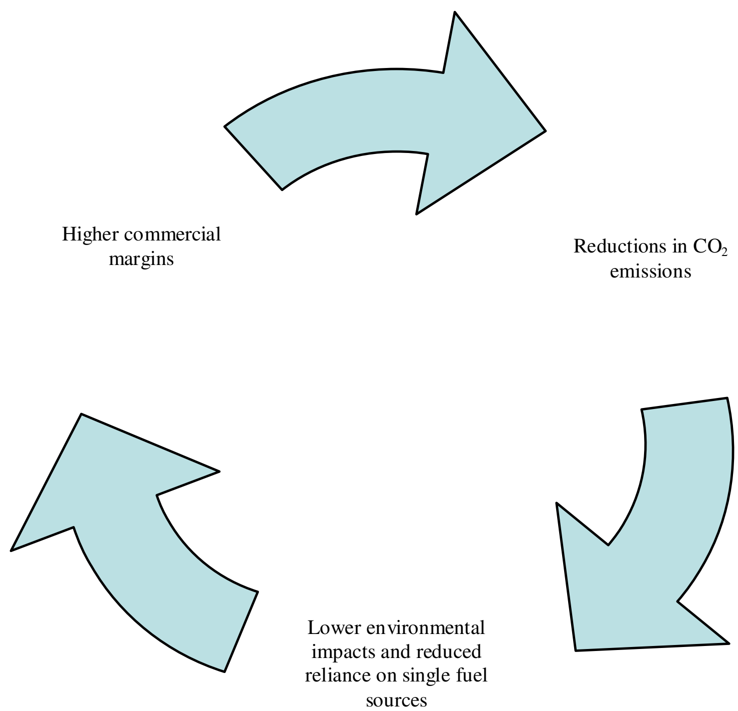

Figure 1. Some reasons for introducing fuel diversification strategies.
Source: Author.

needed security and cost effectiveness in future energy supply, it nonetheless does not meet the environmental objective of the Malaysian National Energy Policy. However, there are some reasons for introducing Fuel Diversification Strategies, as illustrated in Figure 1.

To ensure the security of the energy supply, the Four-fuel Diversification Strategy was introduced in 1981 as an extension of the 1979 National Energy Policy (EPU, 2006). Subsequently, the Five-fuel Diversification Strategy was introduced in 1999. This policy in the electricity sector aimed for a gradual change in conventional fuel use from 74.9% gas, 9.7% coal, 10.4% hydro, and 5% (The 5% uses of petroleum in the year 2000 apparently seems a smaller number, however in terms of volume that use is quite large quantity (that is, 21,673 thousand tones oils equivalent) compared to other regional economies (Hamid et al., 2008). petroleum in the year 2000 to 40% gas, 30% hydro, 29% coal, and only 1% petroleum by the year 2020 (Al-Amin et al., 2009). The motivation for this policy initiative was to reduce Malaysia's dependence on petroleum oil in overall energy consumption. Focusing on the coal reserve and requirement rate for next 285 years (2290), Malaysia is looking for coal energy for future energy sources; however, some research papers find many negative impacts of visioning 2020 coal-related fuel diversification policy (Al-Amin et al., 2009). Following quantitative methodology, Hamid et al. (2008) estimated that in Malaysia coal-related annual average efficiency has been moderately increasing by about 1.6% per annum from 1995 to 2000. Assuming that this continues until 2020, the conversion efficiency (that is the ratio between the useful output of an energy conversion machine and the input, in energy terms) would be approximately less than 48%. This change is still extremely poor in terms of international standards (70–80%).

With regard to the latest Malaysian energy policy and future visions, this study tried to find out some environmental impacts and drawbacks. The concern is striking a healthy balance between achieving sustainable economic growth and environmental quality. The failure of adopting an appropriate long-term climate policy regime would mean that (1) the balance of our delicate ecosystem, (2) our rich biodiversity and (3) the economic and trade potential of Malaysia would be at stake. It has been argued that the cost of taking smart, useful cooperative action towards reducing GHG emissions should be controllable. The consequences of ignoring a long-term climate policy regime would be much greater and more severe for the future. At the same time, our attempts to evaluate the alternative instruments focusing on changing conventional fossil energy (that is, introducing palm oil-based bio-diesel from a climate change/environmental perspective) that could improve Malaysia's long-term economic and environmental potential. Therefore, we investigate two scenarios, namely *Scenario a* and *Scenario b*. *Scenario a* quantifies the environmental impacts in 2020 of utilizing the

Table 1. Approximate heats of combustion and CO_2 emissions for common fuels.

Fuel	MJ/kg	Mcal*/kg	BTU/lb	CO_2/(kg/kWh)	CO_2/BTU**
Carbon	32.6	7.8	14021	-	119
Coal+	36	8.6	15445	1.18	97
Diesel	45	11	19300	0.85	73
Ethanol	30	7	12800	-	66
Gasoline	47	11	20400	0.83	69
Natural gas	54	13	23000	0.53	49

Sources: Hamid (2008), Casler and Wilbur (1984), Hawdon and Pearson (1995), David (2008), Miller and Blair (2009), Proops et al. (1996), Dietzenbacher and Kakali (2004). [M = one million; J = joules; 1 kg-cal = 3.96 BTU; 1 g-cal = 4.19 joules; 1 kg = 2.205 lb; 1 million joules = 0.278 kilowatt-hours, *gram calories; **grams CO_2/1000 BTU or kg CO_2/MBTU].

proposed fuel mix in power generation based on the Five-fuel Diversification Strategy. *Scenario b* quantifies the environmental impacts in 2020 of utilizing alternative instruments focusing on changing conventional fossil energy. Visualization of these scenarios would allow us to see the possible virtual impacts on the Malaysian economy with potential environmental improvements. This may find use in intensifying alternative sources of energy policy and the major factors behind the lack of focus in climate change issues in the country.

SUMMARY OF ENERGY SCENARIO AND OUTLOOK IN MALAYSIA

The dialogue on climate change, clean energy and sustainable development in Malaysia has been increasingly emphasized recently. However, the range of timescales, consequences, perspectives and methods of addressing the issues are still open to dispute; but researchers are scientifically agreed on focusing on changing conventional energy instruments for future energy: renewable energy. There is huge technical potential for renewable energy and it is accordingly given high priority. Expert views on long-term energy development are increasingly in demand and are relevant far beyond energy policy – and Malaysia is not an exception. However, the use of energy has increased immensely in recent years and the demand for it will further increase in an accelerated fashion (PTM, 2009). Essentially, fossil oil and coal are the raw materials for power generation or energy utilization and they create greenhouse gas emissions such as carbon dioxide (CO_2), Sulfur dioxide (SO_2) and nitrogen oxide (NO_x) (Table 1). The Malaysian government's intention for the Fuel Diversification Strategy focuses on the coal reserve and requirement rate for the next 285 years; the internal estimation of EPU (2006) has shown that greater contribution of coal would be about 40–45%, while natural gas would be less than 50%. Thus, the demand for coal for electricity generation is projected to increase drastically (6.03 million tonnes in 2000 to between 19 and 20 million tonnes per annum by 2010) (PTM, 2009; PTM, 2003; PTM, 2002). The direct consequences of diversification strategy on fuel would be that the contribution of oil in the energy mix would drop drastically from a high 87.9% in 1980 to 4.2% in 2000, as shown in Table 2, and projected to drop below 1% by 2010 (Tick et al., 2010).

As consequences of climate change impacts, the Malaysian Government is taking vital initiatives and focusing on alternatives. Under the government initiatives, recently 'Biomass Power Generation' focused on reducing the growth rate of GHG emissions from fossil fuels by utilizing excess palm oil biomass residues. One large project is run and jointly funded by the Malaysian Government, the United Nations Development Programme and various private sectors. According to PTM's latest report (PTM, 2009), 60 projects have been approved until 2005, using various types of renewable energies (Table 3). Among the renewable energy sources, biomass has recently emerged to be the most positive and promising source of renewable energy and the country has the capacity to produce up to 2,000 MW using only biogas and biomass (Tick et al., 2010).

In 2005, the Government of Malaysia introduced the use of bio-diesel for the transport sector as a step towards sustainable energy development through diversification of energy sources (Tick et al., 2010). Bio-diesel is mainly produced from the seeds or the pulp of oil-bearing crops. An alternative fuel such as bio-diesel is technically feasible, economically competitive (as Malaysia is considered the leading palm oil-producing country in the world), environmentally acceptable and widely available. This promising alternative to petroleum-based fuels, made using palm-oil seeds, can be used as a potential renewable resource for conventional fuel energy. It is termed bio-diesel and is chemically defined as a methylester and is prepared from triglycerides in palm oils by transesterification with methanol. This fuel is renewable, biodegradable, non-toxic, and has a lower emission profile compared to petroleum diesel (Tick et

Table 2. Energy mix in Malaysia (% rate).

Source	1980	1990	2000	2005	2010
Oil/diesel	87.9	71.9	4.2	2.2	0.2
Natural gas	7.5	15.7	77.0	70.2	55.9
Hydro	4.1	5.3	10.0	5.5	5.6
Coal	0.5	7.6	8.8	21.8	36.5
Biomass	-	-	-	0.3	1.8
Palm oil bio-diesel	-	-	-	-	-

Source: Tick et al. (2010).

Table 3. Status of SREP projects approved by SCORE as at 2005.

Type	Energy resource	Approved application	Generation capacity (MW)	Grid connected capacity (MW)
Biomass	Empty fruit bunches	25	220.5	174.8
	Wood residues	1	6.6	6.6
	Rice husk	2	12.0	12.0
	Municipal solid waste	1	5.0	5.0
	Mixed fuels	3	19.2	19.2
Landfill gas		5	10.2	10.0
Mini-hydro		26	101.9	97.4
Wind and solar		–	–	–
Total		63	375.4	325.0

Source: Tick et al. (2010).

al., 2010). As a substitute for conventional oil, palm oil-based bio-diesel has been established as a diesel substitute since 1996 in Malaysia and presently produces 500,000 tonnes of biofuel annually and as a palm oil-rich country, palm bio-diesel is here considered the most possible substitute for conventional diesel fuel (PTM, 2009; Tick et al., 2010).

MATERIALS AND METHODS

To achieve the above stated objective, the methodology employed in this article is based on Leontief's input-output (I-O) framework (Al-Amin et al., 2010; Miller and Blair, 2009; Proops et al., 1996; Dietzenbacher and Kakali, 2004). In matrix notation, Leontief's system of linear equations is expressed as:

$$x = Ax + f$$

which states that the gross output (x), is the sum of all intermediate demand (Ax) and final demand (f). In that equation, f is final demand vector, x is a vector. Matrix A is the direct input requirement matrix. The solution of the I-O model can be written as $x = (I - A)^{-1} f$, where $(I - A)^{-1}$, known as 'Leontief inverse' or technological matrix, A input coefficients, and I is an n×n identity matrix (detailed analytical forms can be found in Miller and Blair (2009).

THE EMISSION MODEL

An environmental extension of the input-output approach in this study is obtained by incorporating a matrix ***e*** which includes each sector's direct and indirect resource (fossil fuels) use in one unit of output (Miller and Blair, 2009). The multiplication of the environmental matrix ***e*** and the Leontief inverse sometime denoted (**L**) as $(I - A)^{-1}$ gives the multiplier matrix $\mathcal{E}$, which shows the resources intensity as:

$$\mathcal{E} = e(I - A)^{-1}$$

To test how much emission is generated by utilizing energy in the Malaysian economy, we multiply emission factors (shown below) with $\mathcal{E}$, using the guidelines of Intergovernmental Panel on Climate Change (IPCC). The detailed analytical forms can be found in Hamid et al. (2008). The conversion factors followed by IPCC are estimated as follows:

$$\begin{pmatrix} Emissions\ per \\ mtoe\ of\ fuel \end{pmatrix} = \begin{pmatrix} Fuel's\ emission \\ factor \end{pmatrix} \times \begin{pmatrix} Fraction\ of \\ pollution\ oxidized \end{pmatrix} \times \begin{pmatrix} Molecular\ weight \\ ratio\ of\ emission \end{pmatrix}$$

The final step shows the quantification of GHG emissions (CO_2+SO_2+NO_x) using energy demand ($\hat{\hat{f}}$) for Malaysia and can be express as:

$$\begin{bmatrix} c' \\ s' \\ n' \end{bmatrix} = \begin{bmatrix} c_1 & c_2 \\ s_1 & s_2 \\ n_1 & n_2 \end{bmatrix} \begin{bmatrix} (a_1' + b_1') \\ (a_2' + b_2') \end{bmatrix} \mathbf{L} \hat{\hat{f}} \equiv \begin{bmatrix} d' \\ f' \\ g' \end{bmatrix} \mathbf{L} \hat{\hat{f}}$$

Table 4. Modeling estimation procedure: a demonstration.

$\begin{bmatrix} c_1 & c_2 \\ s_1 & s_2 \\ n_1 & n_2 \end{bmatrix}$ =	$\begin{bmatrix} 0.004755 & 0.011245 \\ 0.000051 & 0.000034 \\ 0.000006 & 0.000330 \end{bmatrix}$	Conversion factors taken from A. Hamid el al. (2008)
$\begin{bmatrix} (a'_1 + b'_1) \\ (a'_2 + b'_2) \end{bmatrix}$ =	$\begin{bmatrix} 0 & 0.493 & 0 \\ 0 & 0.697 & 0 \end{bmatrix}$	Coefficient matrix of fossil fuels taken from PTM (2009)
$[L] = (I - A)^{-1}$ =	$\begin{bmatrix} 1.4173 & 0.2987 & 0.2986 \\ 0.0163 & 1.0373 & 0.373 \\ 0.0018 & 0.0041 & 1.0041 \end{bmatrix}$	Leontief inverse matrix taken from A. Hamid el al. (2008)
$\hat{\hat{f}}$ =	$\begin{bmatrix} xx \\ xx \\ xx \end{bmatrix}$	$[xx]$ is the final demand vector of energy for the year 2020
$\begin{bmatrix} c' \\ s' \\ n' \end{bmatrix}$ =	$\begin{bmatrix} 800,519 \\ 3,840 \\ 18,316 \end{bmatrix} = [822,675]$	Greenhouse gas (CO_2+SO_2+NO_x) emissions

where, c', s', n' express the row vectors of total emissions of GHGs (CO_2+SO_2+NO_x) at the sectoral level, respectively, and c_1.....n_2 are conversion factors and a'_1.....b'_2 are energy intensity *e* vector, while (a'_1 +b'_1) indicates the coefficients fossil fuels and (a'_2 +b'_2) indicates the coefficients of coals.

To fulfill our estimations, this study used the 2000 Malaysian I-O Table (DOS, 2005). The information of energy balance was obtained from the National energy balance data source published by the Malaysian Energy Centre (PTM 2002, 2003 and 2009). The other supplemented information for energy trend by the year 2020 and balances of energy statistics was taken from Hamid et al. (2008). To implement the modeling exercise for the Malaysian economy, I-O table of the year 2000 was aggregated 3 by 3 sectors. An example is included in Table 4 to show how formulas are experimented by the I-O modeling.

RESULTS

The scenario analysis for 2020 used here is based on macro-forecasted growth rate formula and the I-O approach mentioned in research methods. We forecasted final demand, Y_t for the Malaysian economy given the growth rate between 2000 and 2010 given in the Malaysian development plan (EPU, 2006). The estimation of Y_t for the year 2020 used year 2000 as a base as follows: $Y_t = Y_{2000} (1+ r_Y)^t$, where, t = 1,2,3,…,20, and r_Y is growth rate of final demand. The same macro-forecasted growth rate formula was used using EUP (2006) to estimate energy demand in Malaysia for the year 2020, ($Y_e = Y_{2000} (1+ r_e)^t$ where, t = 1,2,3,…,20). Here Y_e indicates energy demand for the year 2020 and r_e is used as growth rate of energy demand. The GHG emissions are estimated by utilizing energy in the Malaysian economy.

Here, we investigate the GHG emissions based on year 2000 pollution intensity, 2009 fuel mixed, business- as-usual 2020 fuel mix and finally the proposed 2020 Five-fuel Diversification Strategy. Based on 2000 pollution intensity with 2020 final demand, *Scenario a* indicates that GHG emissions would be 336.69 million tonnes (Mt) in the year 2020. Based on 2009 pollution intensity with 2020 final demand, GHG emissions would be maximum 356.72 million tonnes (Mt), or based on business-as-usual fuel mix in 2020 with 2020 final demand; this *Scenario* indicates that in the year 2020, GHG emissions would be less than 405 million tonnes (Mt). In contrast, following current technology and 2020 final demand, the proposed fuel mix (Five-fuel Diversification strategy) would result in higher GHG concentrations in the year 2020 (Table 5). In this scenario, the new fuel mix 2020 would result in 822.67 Mt of GHG emissions, which are very high compared to the present fuel mix 2009, as well as 'business-as-usual' fuel mix based on 2020 final demand. Simply comparing the results of the various fuel mixes indicates appealing outlines for the Malaysian 'Five-fuel Diversification Strategy' and visualizes alternative thinking of energy sources.

Table 5. GHG gas emissions (CO_2+SO_2 +NOx) of fuel-mix and palm oil based bio-diesel substitution impacts for 2020.

GHG gas emissions (CO_2+SO_2 +NOx) followed by conventional energy use				
Pollution emissions	**2000 pollution intensity (kt)**	**Present (2009) fuel mix (kt)**	**Business as usual fuel mix 2020 (kt)**	**Proposed fuel mix 2020 (kt)**
GHG emissions (*Scenario a*)	336,689	356,715	404,713	822,675
Palm oil bio-diesel substitution effect				
Bio-diesel potential	-	5%	8%	15%
GHG emissions (Scenario b)	-	338,879	328,178	303,208

DISCUSSION

The major reason for high GHG emissions in the year 2020 is the proposed high coal mix energy utilization (Table 2: Coal row). Although coal is projected to play a far more important role in the energy mix and future power generation up to 2290 in Malaysia (according to the Five-fuel Diversification Strategy), nevertheless, its utilization faces several major challenges that are obvious (comparison between business-as-usual fuel mix 2020 and proposed fuel-mix 2020) in our *Scenario a*. Thus, the environmental problems associated with coal must be closely considered to find new ways to overcome these problems, which is utilized in *Scenario b.* Based on our bio-diesel potentials, we estimate national impacts following substitution of coal energy by 5, 8 and 15% respectively compared to the present fuel mix, business-as-usual fuel mix and proposed fuel mix up to the year 2020 in national energy. The estimates indicate that the capacity to reduce GHG emissions using bio-diesel would be up to 303.28 Mt tonnes even through utilizing the Five-fuel Diversification Strategy. This shows a clear indication of huge promising outcomes from bio-diesel as a new source of renewable energy. Palm oil bio-diesel substitution outcomes reduce the environmental burden while fulfilling Malaysian motivation for the fuel-diversification policy initiative, which is clear in *Scenario b*.

Conclusion

This research paper aims to establish an assessment of the impacts by adopting a quantitative approach which investigates the probable impact of climate change as a direct consequence of Fuel Diversification Strategy and possible alternatives. This study examines *Scenario a* and *Scenario b* and quantifies the environmental impacts in 2020 of utilizing proposed fuel mix energy and alternative instruments focusing on alteration of conventional fossil energy. Although coal would play a far more important role in the energy mix in Malaysia for the next 285 years, its operation nevertheless faces several major challenges, as we observed in our results.

Thus, associated with the environmental problems, we look towards palm oil-based bio-diesel for alternative energy sources in terms of economic affluence and emission scenarios. To achieve environmental sustainability, improving the conversion efficiency of energy and clean-coal technology or solar technology would be expensive compared to palm oil-based bio-diesel in Malaysia (Sumathi et al., 2008). Specifically, clean-coal technology, which includes flue (chimney) gas desulphurization and electrostatic precipitators' technology for air pollutants emission control, must be expensive to meet the environmental standard. Therefore, our projections help to rethink environmental concerns in every step of economic development. Projections for Malaysian energy consumption and scenario impacts made by this study are analytically important for rethinking renewable energy alternatives which are readily available.

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