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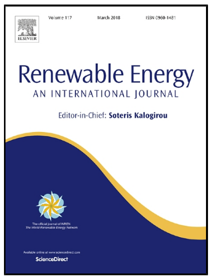

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A Policy Framework and Industry Roadmap Model for Sustainable Oil Palm Biomass Electricity Generation in Malaysia

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The current global trends demonstrate the significant role of renewable energy in meeting the growing energy demand across all sectors to support national economic growth. In Malaysia, palm oil is one of the major agricultural export commodities with a total production of 17.7 million tonnes or 41% of the total world palm oil production in 2008. This research evaluates the sustainability of the grid-connected oil palm biomass renewable energy industry in Malaysia and proposes a policy framework and industry roadmap. The factors investigated include resource supply, the efficiency of waste to energy conversion technology used in the existing plants, and the attractiveness of the electricity interconnection scheme in encouraging exports of excess power from the participating mills to the main grid. A literature review and field survey were conducted to understand the barriers and possible enhancements to the current FiT system. The study concluded that harmonisation between upstream and downstream palm oil agricultural activities is essential for achieving the goal of making the oil palm biomass waste to energy industry sustainable. The policy framework and industrial roadmap models provide a distinctive enhancement to the FiT system besides indicating the way towards a sustainable biomass to the energy industry.

Keywords: Oil palm biomass; Feed-in Tariff; sustainability; policy framework; and industry roadmap model

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1. Introduction

The current global trends demonstrate the significant role of renewable energy and electricity generated from conventional fuels in meeting the growing energy demand across all sectors to support economic growth [1]. There are huge potentials and opportunities for developing and expanding small scale energy generation from agricultural wastes, and one of the most prominent agricultural crops available is oil palm crops. For the past few decades, the two leading palm oil producers and exporters in the world have been Indonesia and Malaysia. Both countries produce 17.7 million tonnes of palm oil annually and each held a 41.3% share of the total world palm oil production in 2008 [2] [3]. The domination of these palm oil powerhouses on the global scene in the year 2008 is shown in Figure 1.

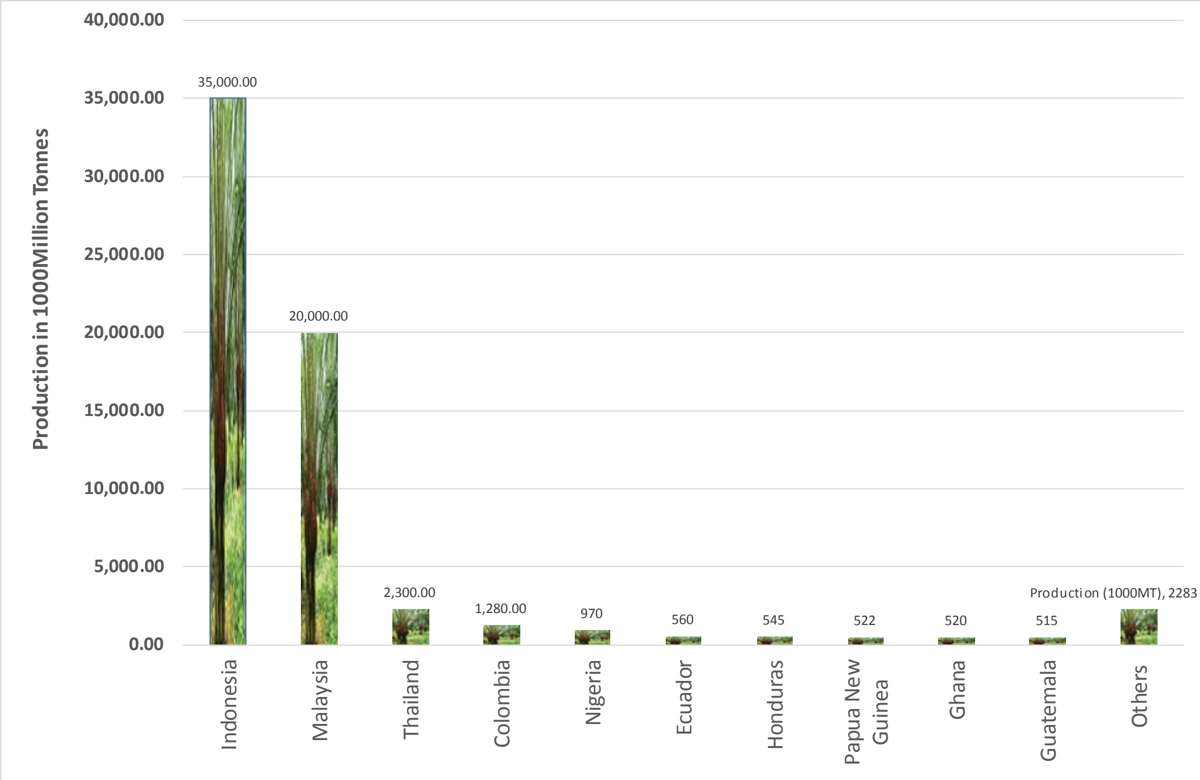

Figure 1: World Major Producers of Palm Oil

Data source: [4]

For Malaysia, palm oil is one of its major agricultural export commodities with a total production of 17.7 million tonnes or 41% of the total world palm oil production in 2008 [5]. It is projected to reach 21.5 million tonnes by 2015 and 25.6 million tonnes of crude palm oil per year (CPO/year) by 2050 in response to the upward trend of global vegetable oil demand as well as the maturity of the crops in the field [6]. The biomass wastes from the palm oil industry are one of the country's major sustainable energy resources, accounting for 85.5% of the total biomass volume available in the country [7]. A study indicates that solid waste feedstock in 2010 stands at 80 million tonnes and it is expected to reach 100 million dry tonnes of biomass by the year 2020 [8]. These data show the potential for making oil palm biomass an attractive crop for large scale power production [9]. Notwithstanding, the advantage of having such vast resources, it is meaningless without an appropriate policy driver from the Government. This has now been provided through the FiT scheme that was introduced in 2011. Now there are areas that require immediate attention, even after the industry has undergone significant market reform through the introduction of the FiT scheme. One of the example is the sustainability of the renewable energy market [10].

This paper is based on the research that evaluates the sustainability of the grid-connected oil palm biomass renewable energy industry in Malaysia. The motive behind this study is to develop a policy framework and an industry roadmap that identifies potential enablers and defines a pathway towards a sustainable industry under the present FiT settings. The factors investigated include resource supply, the efficiency of waste to energy conversion technology used in the existing plants, and the attractiveness of the electricity interconnection scheme in encouraging exports of excess power from the participating mills to the main grid. All of these downstream variables are the barriers that were identified from the former SREP program [11, 12]. Based on the findings and observations of this work, this paper categorises the suggested solutions into an implementation schedule including short-term, medium-term and long-term measures.

2. An Overview of the Feed-in Tariff (FiT) Mechanism in Malaysia

The FiT system in Malaysia was designed in response to recommendations put forward in the National Renewable Energy Policy and Action Plan 2010 that suggested the requirement for legislative solutions to elevate the country's renewable share in its energy mix [13, 14]. As a consequence, two legislative measures were mandated including the Renewable Energy Act 2011 and the Sustainable Energy Development Authority Act 2011. The FiT system was officially commenced on 1 December 2011 and it is deemed to be the main instrument for future renewable energy expansion. The FiT system was introduced in the Tenth Malaysia Plan (2011-2015) in the wake of the dissatisfaction with the former Small Renewable Energy Power (SREP) programme.

This new policy instrument, which was mandated by the Renewable Energy Act 2011, is a comprehensive structural reform designed to secure long-term renewable energy investment in the country through a guaranteed purchase agreement. The new scheme demonstrates the Government's commitment to accelerating the development of the renewable energy industry by boosting market growth [15]. More importantly, the FiT scheme offers the opportunity to attract entries from small budget power producers as the law will provide business risk protection for every new renewable energy investor. The FiT scheme sets an exponential trajectory for RE capacity development from 985 MW or close to 6% of the total energy mix in the year 2020 to 21.4 GW or 73% of the total installed capacity by 2050 [13, 14]. Table 1 shows the RE capacities (in MW) granted with Feed-in Approvals under the FiT mechanism.

Table 1: Renewable Energy Installed Capacity in Malaysia

	Installed Capacity of Plants in Progress (MW)					
Year	Biogas (Landfill / Agri Waste)	Biomass	Biomass (Solid Waste)	Small Hydro	Solar PV	Total
2012	0	0	0	0	0	0
2013	0	0	0	0	0.03	0.03
2014	0	0	0	0	0.53	0.53
2015	0	0	0	13.94	3.72	17.66
2016	12.39	9.95	0	0	29.39	51.73
2017	58.17	23.94	21	19.75	48.9	171.76
2018	24.45	35	2.5	98.15	0	160.1
2019	7.91	10	4	84	0	105.91
Cumulative	102.91	78.89	27.5	215.84	82.56	507.71

Source: [16]

There are four resources included in the FiT scheme: biogas, biomass and biomass (solid waste), small hydropower and solar photovoltaic power (Table 1). Across all the resources, small hydro technology dominates the overall renewable capacity share in the early years, with 13.94 MW in 2015 and 215 MW of total installed capacity by the years 2019 . Biomass energy is predicted to grow from 9.95MW in 2016 to 79.89MW of installed capacity by 2019. This capacity target is far ahead of the 40 MW in the original national renewable energy inventory [13]. This ambitious target explains the need for a reliable downstream mechanism that is capable of lifting and sustaining the oil palm biomass contribution to the total renewable energy share. In responding to this scenario, three (3) major downstream components were selected for investigation, comprised of resource supply, effective conversion technology, and grid extension [10]. Sustainability of these core components is important as any shortcomings could contribute to market distortion, and this could hinder the country's effort to increase the biomass contribution to Malaysia's energy capacity in the coming years.

On the 12 September 2016, the Sustainable Energy Development Authority, Malaysia (SEDA) set a quota on the amount of biomass systems that can be installed annually. Table 2 shows the update FiT rates for biomass. These rates are valid up to 16 years from the FiT commencement date [17].

Table 2: Feed-in Tariff Rates proposed on 2016 for Biomass

Description of Qualifying Renewable Energy Installation	FiT Rates (US$ per kWh)
(a) Basic FiT rates having installed capacity of :	
(i) up to and including 10MW	0.071
(ii) above 10MW and up to and including 20MW	0.067
(iii) above 20MW and up to and including 30MW	0.062
(b) Bonus FiT rates having the following criteria (one or more) :	
(i) use of gasification technology	0.005
(ii) use of steam-based electricity generating systems with overall efficiency of above 20%	0.002
(iii) use of locally manufactured or assembled boiler or gasifier	0.012

Source:[17]

3. Downstream Barriers to the Oil Palm Biomass Renewable Energy Industry

Umar et al)[18] in their study on Sustainable Electricity Generation from Oil Palm Biomass Wastes in Malaysia, identified three main downstream barriers, namely, irregular biomass supply, unattractive electricity tariffs and high capital outlay [19]. Above all, resource availability within the industry is regarded as the main hindrance that could slow down the take up of on-going and future biomass projects [12]. A literature review of Government reports and industry publications reveals that there are sufficient biomass supplies for meeting the large-scale biomass energy targets. Ahmad et al report that two-thirds of biomass resources in the country come from the palm oil industry wastes [7]. Nevertheless, the results of the oil palm industry survey contradict this report when 61% of the market players consider that security of supply and fuel price inflation are major barriers that inhibit their interest in participating in the biomass to energy business [19]. The data suggest possible difficulties that impede the potential non-estate small producers especially in securing long-term supply contracts. This can be explained by their dependence on third party supply, which may trade at a fluctuating market price. Without an effective policy mechanism, 90% of market respondents indicate their unwillingness to acquire biomass wastes from any third party for the purpose of generating electricity. In contrast, the major energy providers, who are managing large plantations and hold full access to their feedstock, have more flexibility about whether to enter the renewable energy business or to utilise their wastes for other purposes. This is consistent with the survey findings that 67% of respondents are generating wastes from their own estates, most of which (68%) they choose to sell on the open market, rather than participating in the renewable energy business.

A foreseeable hindrance that could impede the development of the oil palm biomass electricity generation industry in Malaysia is the strong influence of the large oil palm companies in determining the business model for the palm oil industry. On this account, the market analysis shows that 80% of mill operators transported up to 40% of their untreated wastes back to the plantation site for multiple uses, notably animal feeding, mulching, composting and soil conditioning purposes . The leading enterprises' common practice of utilising the majority of their wastes for non-electricity generation purposes affects the availability and thus creates uncertainty of feedstock supply in the market [19].

The industry is vulnerable to resource-supply risk and these activities could be an impediment to its growth [10, 19-21].

The survey results by Umar M.S. *et al* [22] show that about 25% of the total oil palm wastes are used in the mill's compound [8, 19]. These plants have been depending on the traditional empty fruit bunch (EFB), fibre and palm kernel shell as their common boiler fuels for electricity generation [8]. The remaining 75% of the solid wastes, consisting of palm frond and palm trunk, are being left on site for natural decomposition and soil conditioning without any added value to economic activities including the energy production industry [8]. Thus, there is an opportunity to capitalise on the abundance of these wastes as an addition to the existing fuels, but further study is needed to explore their commercial potential and economic viability.

Despite its success in eliminating most of the economic barriers, the FiT system does not provide permanent strategies to resolve fuel supply issues for small oil palm developers. Analysis of its provisions reveals that the system requires the plantation owners, enterprises and feed-in approval holders to find their own fuel supply solution, should they venture into the business [23]. The Government has chosen not to intervene in the market mechanism in the belief that the market players are able to overcome their supply problems. The Government's stance on this problem contradicts our survey results, in which 84% of respondents believe that the regulator's intervention is needed to stabilise the biomass supply. The cause of supply shortage resembles international experience that links inefficient biomass waste management by the stakeholders to unstable resource supply for electricity production purposes [10, 19, 24].

The other important downstream barrier that plagues the sustainable energy industry lies in the efficiency of the conversion equipment being deployed for turning oil palm solid wastes into electricity. Evaluation of this component is necessary to understand the reliability of the present conversion technology used in the existing mills. The efficiency of the technology used in the palm oil plants affects their capacity for electricity generation and export from the participating mills to the main grid. The widely used conversion technologies include direct combustion, gasification, anaerobic digestion, pyrolysis and modular systems [36]. The survey results show that over three-quarters of the palm oil enterprises in Malaysia are equipped with combustion, combined heat and power (CHP) or a combination of both systems. Only small fractions (5%) of plants are equipped with a gasification system. As shown in Figure 2, it has been observed that more than two-thirds of the mills are fitted with old technology (>10 years), which implies a low-pressure boiler [12, 19]. This is why most of the mills are achieving <40% overall cogeneration efficiency for their operations [21, 25].

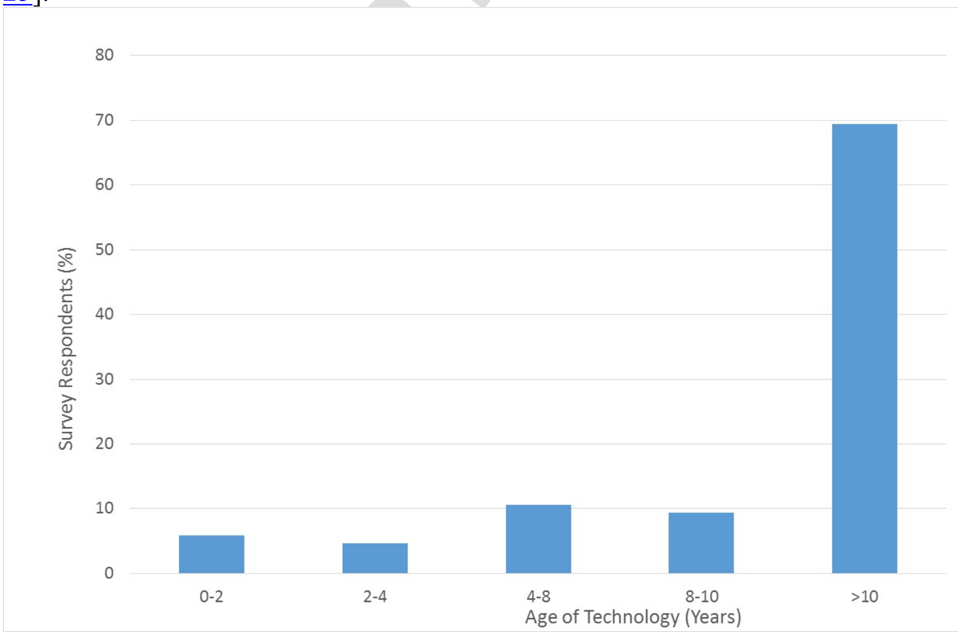

Figure 2: Age of technology installed at the existing oil palm mills
Source: Adapted from [12, 19]

The challenge now is to encourage massive technology change amongst the market players. It must be remembered that close to 60% of respondents regarded the renewable energy business as incidental and related to their environmental obligation to dispose of industrial residues from the mill compound. In other words, edible oil production remains their core business and energy generation offers an extra benefit to increase their profit margin in some cases [4].

Market investigation shows that the majority of respondents are not ready to convert their old boilers to modern conversion technology. This is supported by the survey findings, which indicate that more than half of the respondents chose not to venture into a project that is deemed to be outside their capacity and capability [19, 26, 27]. There are two reasons to explain this situation. First, the mill operators do not require a high-pressure boiler system because the electricity generated from the burning of biomass wastes is to cater for their daily operations, and not meant for exporting to the grid [25, 28]. Hence, a majority believe that the existing installation is reliable and sufficient to electrify their mills. Secondly, technology change demands high capital investment, which is beyond the capability of the small scale developers. This statement was agreed to by 53% of the market players and 75% of them are asking for financial assistance and technological support from the Government [19]. Moreover, massive spending on technology poses a major business risk and a long payback period which deters investors [29]. This explains why more than half of the respondents continue to use their current equipment, even though their energy conversion systems are outdated and inefficient. All of the stakeholders, therefore must find innovative approaches to reducing the impact of these externalities, which may help to remove the technological barriers [30]. Sustainable options have to be designed especially for lowering the technology cost and reducing the reliance on imported technologies.

The third obstacle inevitably comes from the network infrastructure barriers. Geographically, Malaysia is a country that is formed by Peninsular Malaysia in the west and separated from two States nestled on Borneo Island to the east, Sabah and Sarawak. Hence, inter-boundary connection difficulty limits the Government efforts to electrify all homes nationwide. Augmenting rural electrification in the local area is one way of providing for inhabitants in remote locations. Except for the Peninsular, which is almost 100% electrified in 2015, the other two States in East Malaysia, namely Sabah and Sarawak have only 95.1% and 94% electricity coverage respectively (Figure 3) [31]. In this regard, expanding deployment of the biomass renewable technology via off-grid generation is the most promising way to increase electricity coverage in these two States, especially by exploiting their leading position in terms of acreage of cultivated areas and active mills in operation. This is in tandem with the Government aspirations of improving the sustainability, efficiency, affordability and reliability of electricity supply by capitalising alternative sources that are available throughout the country in the period of the 11th Malaysia Plan (MP). At present, almost half of the planted areas are concentrated in these two States while more than one-quarter (159 mills) of the total plants in the industry are operating in Sabah and Sarawak [32]. The main question now is how to sustainably connect surplus power that is available from these mills to the grid or rural homes.

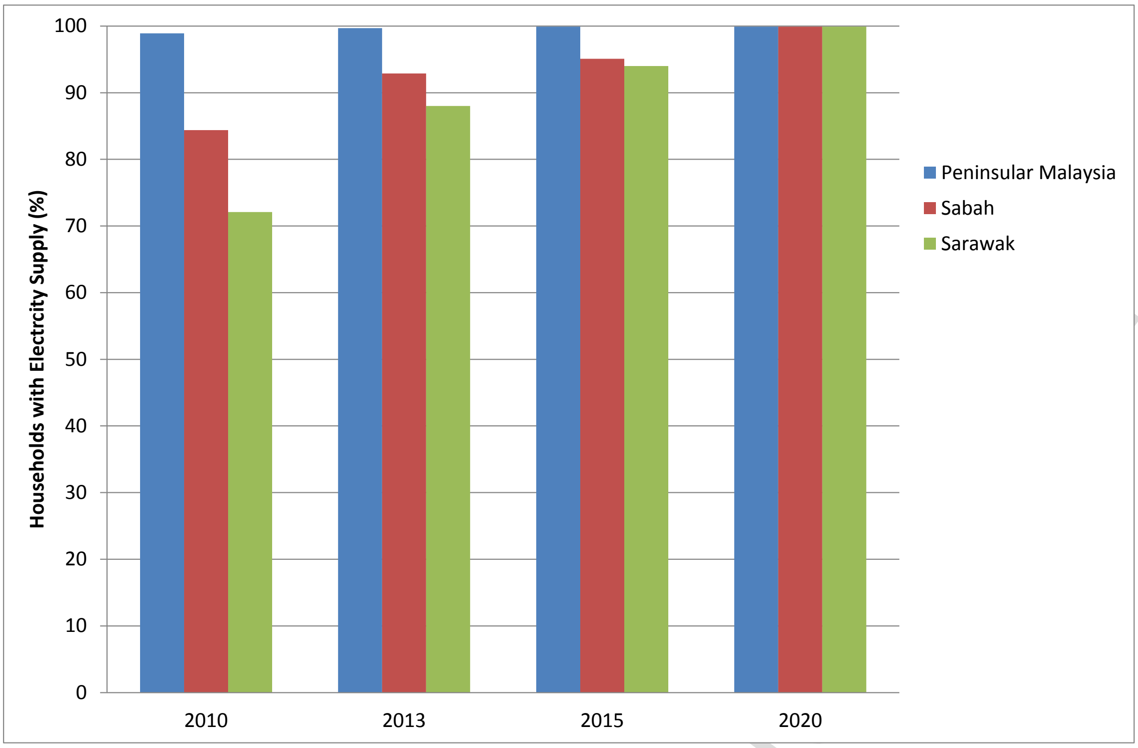

Figure 3: Percentage of Rural Electricity Coverage in Malaysia in the 10th MP (2010-2015) and 11th MP (2016-2020)[12, 31, 33]

The industry response shows that 86% of plants utilise their excess biomass energy for self-consumption [19]. This means that little energy is supplied to the grid, hence reducing the overall biomass renewable energy share in the country's total energy mix. The low grid-connected power supply from biomass could be explained by the fact that most mills are operating in remote locations. As statistical data suggest, about 36.9% of the existing biomass premises are operating beyond 10 km from the nearest grid connection point (Figure 4), which technically is not economically viable for grid extension [19]. The construction of transmission lines to connect remote plants to the main grid would require a huge infrastructure investment, which in turn would increase the biomass energy generation cost. This factor indirectly inhibits the entry of new energy investors into the market as the return on investment would take a longer period, thus limiting the interest of small energy providers from venturing into the business. Without attractive financing options, the expansion of small-scale biomass to energy projects remains questionable [34]. More than half of the industry respondents were interested in participating in the energy business provided the cost of building the transmission infrastructure is borne by other parties, either the Government or utilities [19].

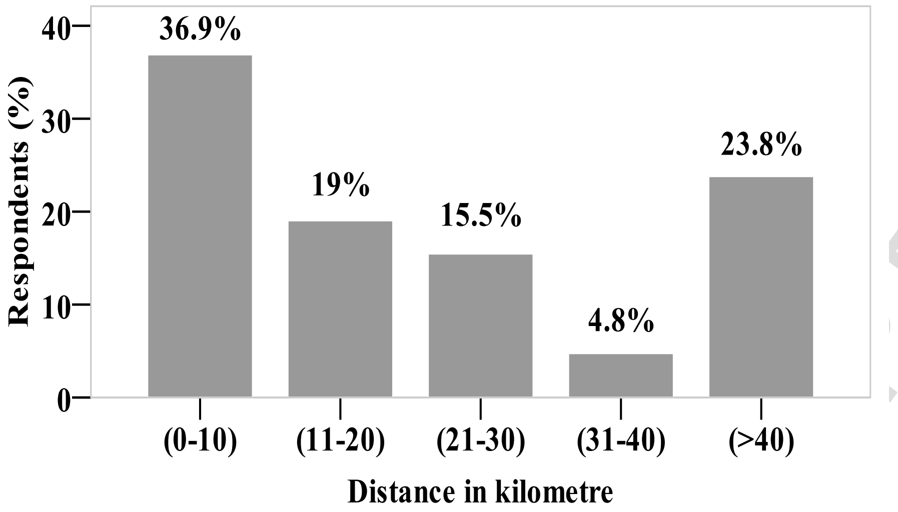

Figure 4: Distance of mill from the nearest grid point [12, 19]

Like the resource supply component, it has been observed that the present renewable energy policy system does not provide sustainable solutions to encourage and facilitate connection of excess power from mills to the grid. As such, the law requires the license holders to bear all connection costs (including the power systems studies) from their facilities to the main grid [23]. The detailed analysis found that the present system is visibly benefitting the plants operating in the utility service areas, while the off-utility boundary facilities are denied the opportunity to share in the scheme's incentives. The absence of an innovative interconnection scheme would restrain new entries because most of the players are not ready or able to invest in transmission infrastructure. Moreover, grid line investment is not a viable option for the small scale energy entrepreneurs as it exposes them to significant business risk, which therefore limits their involvement in the grid-connected biomass energy industry. A feasible alternative for overcoming the infrastructure barrier is to adopt a decentralised system of electricity generation [34, 35]. Interestingly, this idea was mooted by one of the key stakeholders in the energy sector. If an off-grid generation is further promoted, then the renewable inventory can be increased and modern services can be expanded to rural homes in outlying areas. The main stumbling block now lies in the controversial provisions in the Electricity Supply Act 1990 that prohibit trading of electricity between energy generators and a third party, other than the utility [12, 19].

4. Policy Implications

Government intervention is vital to drive the industry forward in a sustainable manner. The policy framework for this study is drawn from the results of the survey, interviews and focus group discussions. It contains strategies that could help to increase the sustainability of the downstream system. In order to enhance the credibility of the suggested measures, this study incorporates suitable international best practices from the biomass technology front runners for possible replication. The framework in Figure 5 includes policy drivers and market influences affecting the sustainability of the investigated components.

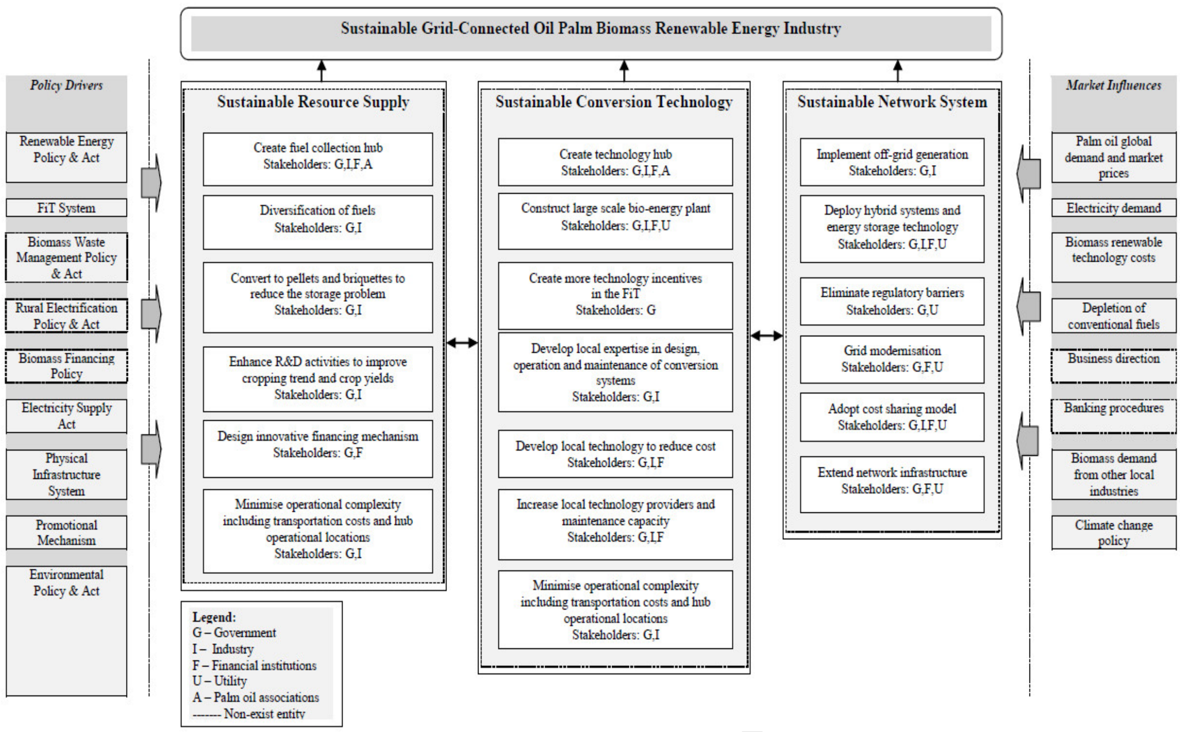

Figure 5

: Policy Framework Model for a Sustainable Grid-Connected Oil Palm Biomass Renewable Energy Industry in Malaysia

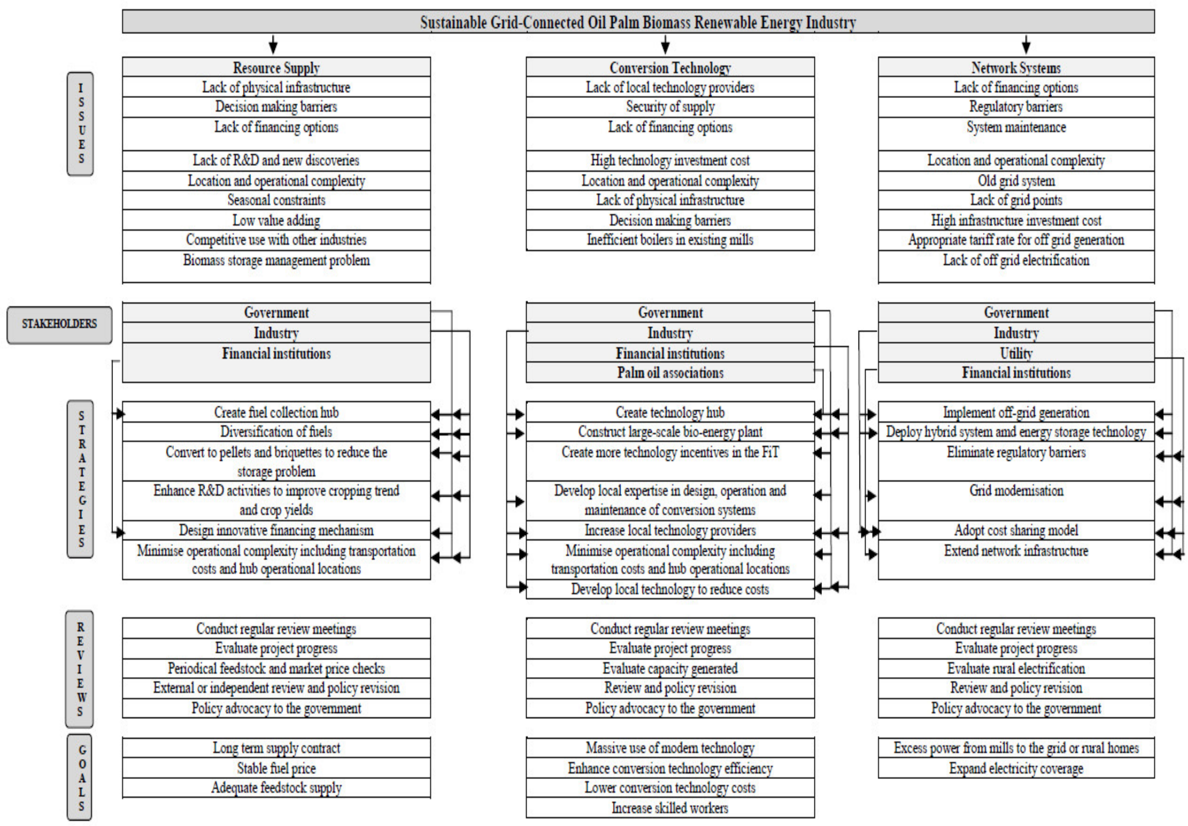

Figure 6: Industrial Roadmap Model for a Sustainable Grid-Connected Oil Palm Biomass Renewable Energy Industry in Malaysia

On the other hand, the industrial roadmap in Figure 6 contains a complete plan for maneuvering the industry towards achieving its goals. It details the real issues, linkages between stakeholders and strategies, review actions to be taken post-implementation, and the ultimate aims for every downstream component.

4.1 Policy Framework and Industry Roadmap Models

The major stakeholders for the oil palm biomass renewable energy industry are the Government and the market community. The stakeholders includes, the palm oil producers and other important stakeholders such as the utility, financial institutions and palm oil associations. The Government is responsible for ensuring the sustainable expansion of biomass processing by creating a favourable environment for the business to grow. This includes providing better financial options, ranging from attractive credit facilities and incentives, tax exemption and other innovative strategies. The industry must also accept its pivotal role as the engine of growth.

The framework positions both the main stakeholders at the same level, which reflects their equal shares of responsibilities, inputs and influences in the industry. A total of nine policy drivers have been identified. These are:

(i) Renewable Energy Policy and Act
(ii) FiT System
(iii) Biomass Waste Management Policy and Act
(iv) Rural Electrification Policy and Act
(v) Environmental Policy and Act
(vi) Biomass Financing Policy
(vii) Electricity Supply Act
(viii) Physical Infrastructure System
(ix) Awareness Campaign

Altogether, there are six enforced policy drivers in the present Government system, excluding the proposed Biomass Waste Management Policy and Act, Rural Electrification Policy and Act and the Biomass Financing Policy. In the waste management sector, there is a federal Act on Solid Waste and Public Cleansing Management, but it is mainly focussed on municipal wastes rather than biomass waste. Thus, it is necessary to formulate a regulation specifically for biomass wastes to ensure sustainable management of this resource, particularly for power generation purposes. Alternatively, the current Renewable Energy Act could be improved by including relevant provisions to address this issue. It is also a wise move to incorporate a more comprehensive biomass financing mechanism in the same policy and Act. Measures to regulate off-grid electrification should be considered as another priority of the Government, so that the abundance of resources in remote mills can be fully utilised. Improving physical infrastructure, particularly that connecting estates to the mills, and enhancing the awareness campaign, are the other vital Government roles, and should be given due attention.

Across the market influences, eight potential externalities have been identified, and these are:

(i) Palm oil global demand and market prices,
(ii) Electricity demand,
(iii) Biomass conversion technology costs,
(iv) Depletion of conventional fuels,
(v) Business directions of the major producers,
(vi) Banking procedures,

(vii) Biomass demand from other local industries, and
(viii) Climate change policy.

The evaluation of the current industry scenario identified three potential global market influences including trends in crop demand, volatility of the fossil fuels market prices and the international approach to climate change issues.

Basically, three policy pillars, representing the investigated downstream components are centred in the middle of the framework, carrying all the solutions that have been derived from the market investigation during the study. Overall, there are nineteen recommended measures across the board including three redundant strategies between pillars. There are two overlapping or common solutions that complied with all components and these include the need for innovative financing options and a strategy to overcome logistic problems. In this case, the Government is central to creating more fiscal incentives coupled with a business-centred environment that lowers financial pressure, particularly for small budget energy producers. The banking institutions, for instance, may offer attractive credit or mortgage facilities that allow more cash flow in the market besides assisting small entrepreneurs to enter the high investment energy business. In light of reducing mobilisation costs, it is the Government's responsibility to improve the unreliable physical infrastructure such as road access connecting the plantation sites to the plant gate.

On the other hand, the industrial roadmap is an implementation strategy for the policy framework. It sets out an action plan and follow-up actions that are required for every measure in the framework strategy. This is part of a review stage to identify any discrepancies or constraints that occur during the implementation process. The relevant stakeholders then need to take any necessary remedial action or improvements in order to achieve the final targets. The associations would be able to voice their thoughts and opinions about the system or industry problems through the policy advocacy forum.

4.1.1 Strategies for Sustainable Resource Supply

By excluding two common strategies mentioned above, this study has determined four additional solutions that could increase the security of supply in the market. The ultimate strategy is to develop a fuel collection hub operating at a location accessible to participating mills. This is the main strategy to ensure consistent supply and prevents market manipulation affecting non-estate enterprises [12]. On-site generation, akin to that implemented in China and Denmark, can be complemented with the hub initiative, especially in eliminating logistic complexity and unnecessary waste handling complications. A similar generation concept, as practiced in the Netherlands, could serve as another good example for the industry [36].

Diversification of fuels is a sensible solution to avoid over-reliance on the existing boiler fuels such as the EFB, palm kernel and shell [12]. The industry must be encouraged to explore the potential use of underutilised and discarded wastes including the less sought after large fibre, palm frond and chipped trunk. The maximum use of the on-site leftovers that make up two-thirds of the available wastes, offer fuel variation to energy producers and subsequently reduce supply constraints within the industry [8]. As the international best practice suggests, the areas where Malaysia could improve to ensure a consistent resource supply comprise enhancement to crop cultivation practice, adopting integrated harvesting systems, and exercising biomass cascading that includes energy generation [37, 38].

Converting untreated bulky wastes into pellet and briquette form will add economic value while minimising the storage problem. There is a great potential benefit to the country from these materials. At the international level, there is a significant trend of exporting condensed wastes to the central Europe and Asian markets in response to high demand and attractive prices [38, 39]. On the domestic scene, there are obvious synergies between the proposed large scale production of pellets and briquettes and the expanding biomass renewable energy business [8]. Sustainable fuel supply requires Government intervention by providing a larger research budget to aid in the discovery of new ways of improving the palm oil cropping trend. Major developers, with strong financial backup, could enhance their in-house research activities in order to increase their palm oil yield and provide more biomass supply to the market.

4.1.2 Strategies for Sustainable Conversion Technology

Except for one redundant measure, the framework model provides six distinct strategies towards enhancing the sustainability of the conversion technology component. Centralising technology facilities is an option for rapid technological change without investing in every single biomass plant [12]. The approach conforms with international action in which Denmark and China have adopted this method in their attempt to ease the operational complexity of biomass conversion [38]. This approach would benefit small budget energy investors and catalyse biomass energy development in less-served areas.

The major developers may introduce a cluster concept, in which a low carbon technology can be installed at one of their accessible biomass premises and this could be shared amongst their associated plants in the same vicinity. On the Government side, efforts can be made to facilitate the creation of a technology centre that can be shared by independent energy producers in remote areas.

Setting up a large-scale biomass to energy plant via strategic collaboration is a practical way of accelerating technology improvement by acquiring top notch equipment [12]. A cost sharing strategy leads to lower business risks while increasing economies of scale of the businesses. To initiate such a move, the Government can play an important role by designing a suitable business partnership model, whether it is a public-private collaboration, utility-major developer consortium, foreign investor-local developer joint venture strategy or a build, operate and transfer (BOT) model [12]. Another interesting proposition obtained from the market investigation was the establishment of a Special Purpose Vehicle (SPV) to initiate the project and create critical mass before it is sold to a capable party to run the business. There are also opportunities for major developers to merge small capacity and uneconomic plants, and turn them into large-scale facilities. Ultimately, the Government must act as a facilitator to avoid massive public capital expenditure, and at the same time encourage private business.

The Government can improve the FiT payment structure by offering more attractive and innovative incentives, in addition to technology bonuses, in the current system. On the other hand, extra benefits from the installation of modern technology should be expanded to other systems beyond the gasification technology favoured by the existing policy. The law could also be modified by rewarding the FiT participants who upgrade their low-pressure boiler to a higher one, as in the Brazilian model [40]. A better alternative is to impose different tariff levels based on the location and local conditions of the mills and their operational difficulties [10].

Enhancing human capacity building by developing local expertise in design, operation and maintenance of modern conversion systems is an ideal way to reduce dependence on foreign technology. Without having to invest in building new training schools, the Government instead should capitalise on the existing training and vocational institutions nationwide by emphasising more palm oil renewable energy industry-related training courses in order to produce more skilled and knowledgeable professionals for the local market.

The industry remains over-dependent on imported machinery to convert their wastes into energy. Foreign technology demands a huge financial investment, thus limiting the interest of small producers in technological change. The conversion system expenditure can be reduced through long-term planning that draws on a strategy to develop the local technology. The Chinese model, whereby locally-manufactured small scale gasification systems ranging from 2kW to 2MW capacity are widely deployed within the industry, is worthy of replication, given its capability to produce high electricity conversion at lower costs compared with the imported cogeneration equipment [41, 42].

Increasing the numbers of local technology providers and the maintenance capacity is synergistic effect derived from the moves discussed in items 4, 5 and 6 .

4.1.3 Strategies for Sustainable Network Systems

This study provides six measures that can be considered to improve the network systems connecting the participating mills to the main grid. Decentralised generation is a promising initiative for preventing excessive investment in grid extension and enhances electricity penetration capability in remote areas [12]. This study recommends two types of off-grid models either a mini grid distribution system or turning the plants into small-scale independent power producers (IPP). Massive deployment of off-grid solutions is expected to particularly benefit Sabah and Sarawak, which have the lowest electricity coverage in Malaysia and include the majority of active mills in the country. A decentralised generation with hybrid systems and energy storage technology is a solution to make the off-grid system more effective and capable of servicing a stable base load. The country's strategic equatorial geographical position offers advantages for oil palm biomass and solar hybrid generation besides exploring other rural renewable resources like hydro.

All of the suggested solutions in the model are meaningless without a strong Government policy commitment and legislative support. In this respect, the Government is recommended to eliminate regulatory barriers contained in the Electricity Supply Act 1990 that restrict electricity trading between small-scale energy producers and a third party. Allowing excess production to be sold to nearby demand centres would increase energy investors' profit margin and thus motivate these small players to venture into the business. The utility, on the other hand, must be ready to allow an electricity tariff that is comparable to conventional rates [12]. Grid modernisation is a pertinent strategy to make the industry efficient. Apart from installing automation technologies such as smart grid and other relevant devices, there are many initiatives the country could tap into from international counterparts including the United States, Japan, China, Spain, Germany and South Korea. Amongst the most important ones are: the creation of a national-level grid modernisation roadmap; enacting relevant legislative measures; and drawing up a project funding mechanism [43, 44]. Nevertheless, further consultation with the utility is needed to encourage investment in modern technology. As a start, the country could consider installing smart metering devices nationwide in response to the current cost reduction trend and technology maturity [37, 38, 45].

Exploring a cost-sharing option in building transmission lines from mills to the grid point may encourage infrastructure investment by the energy investors [12]. The Government must be at the forefront to facilitate negotiation and mutual understanding between the utility and the plant operators in determining the quantum of investment, the connection distance, and the system maintenance costs. The Government may also offer soft loans with attractive rates to eliminate upfront costs for mill operators to wire excess power from the generation point to the main grid system. There is substantial demand from the industry for the utility to upgrade their aging delivery system and extend the current transmission infrastructure to a wider end-user area. The move is intended to benefit rural mills which participate in the renewable energy scheme and simultaneously offers better access to modern services for remote communities.

4.2 Short-term, Medium-term and Long-term Strategic Planning

There are many factors that need to be taken into account before executing the strategies presented in these models. Amongst the important ones are business investment, administrative and operational complexity, business decisions, financial matters, planning, consultation processes, legal procedures, policy advocacy, policy revision, public acceptance and market readiness. In order to make better project planning and other pre-implementation preparation, this study categorises all the recommended solutions into short-term, medium-term and long-term strategies. This study anticipates completion of the least complex strategies by the year 2018 while capital-intensive, and strategies with massive engagement processes may take a longer period that lasts to the year 2050, the final life band of the existing FiT system. The strategies are systematically grouped below.

Short-term implementation period (years 2017-2018):

(i) create more incentives for biomass to energy conversion and design innovative financing options;
(ii) diversification of fuels through exploration of the use of less sought after large fibre, palm frond and chipped trunk;
(iii) enhance human capacity development;
(iv) adopt a decentralised generation policy;
(v) begin to deploy a combination of hybrid system and energy storage technology; and
(vi) eliminate regulatory barriers such as the ban on independent suppliers selling excess electricity to third parties.

Medium-term period ranging from the years 2019 to 2020:

(i) create a fuel collection and conversion systems hub;
(ii) improve the physical infrastructure of the industry;
(iii) enhance R&D activities in the palm oil industry;
(iv) investigate conversion of oil palm wastes to pellet and briquette form;
(v) increase local technology providers;
(vi) develop local technology for conversion of oil palm biomass to electricity;
(vii) develop cost-sharing arrangements for building infrastructure; and grid modernisation.

Long-term planning (years 2020-2050):
(i) extending grid lines and upgrading ageing infrastructure to remote sites; and
(ii) constructing a large-scale biomass to energy facility.

The dynamism of the energy business, together with accommodating the changing needs of the industry, imply that the Government has a responsibility to constantly review and update the policy over time, especially by correcting any defects that are discovered during the implementation period. In addressing this situation, policy adjustment is essential before a major evaluation of the effectiveness of the overall policy strategies is undertaken every five years or in any appropriate timeframe.

This study indicates that harmonisation between upstream and downstream palm oil agricultural activities is essential for achieving the goal of making the oil palm biomass waste to energy industry sustainable. This work, however, is only focussed on a small biomass market niche that forms the downstream electricity generation option. In the broader bio-energy spectrum, it is time for the country to address sustainability issues in a holistic manner through a long-term biomass to energy strategic plan, covering good cultivation practices, technology innovation prospects, grid modernisation strategies, funding mechanisms and other related areas. The country could learn from successful renewable energy partners like China, the United States and the European economies which have already drawn up their own biomass to energy master plans in order to boost their biomass renewable energy industries (REN21 2013). Nevertheless, formulation of such a comprehensive blueprint for Malaysia must involve full consultation with all key stakeholders of the industry in order to collate collective inputs and prevent missing some important comments.

5. Conclusions

The policy framework and industrial roadmap models derived from this study provide a distinctive enhancement to the FiT system besides paving the way towards achieving a sustainable biomass to the energy industry. Due to the enormous capital investment, as well as a lengthy planning and execution period, it is recommended to the Government and industry to concentrate on short-term measures before undertaking the next level of actions. Above all, Government intervention is necessary to attract the serious involvement of leading enterprises in the business. With the massive participation of major developers, who control the majority of the active mills, the country could expect a dramatic change in the industry landscape. The most crucial challenge now is to translate excellent strategies on paper into actual activities on the ground.

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