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An Investigation of Sustainable Power Generation from Oil Palm Biomass: A Case Study in Sarawak

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Abstract: Sarawak is the largest state in Malaysia, with 22% of the nation's oil palm plantation area, making it the second largest contributor to palm biomass production. Despite the enormous amount of palm biomass in the state, the use of biomass as fuel for power generation remains low. This study is designed to investigate the sustainability of power generation from palm biomass specifically in Sarawak by conducting a survey among the palm oil mill developers. To conduct this investigation, several key sustainability factors were identified: the security of the biomass supply, the efficiency of conversion technology, the existing network system, challenges and future prospects for power generation from palm biomass. These factors were assessed through a set of questionnaires. The returned questionnaires were then analysed using statistical tools. The results of this study demonstrate that Sarawak has biomass in abundance, and that it is ready to be exploited for large scale power generation. The key challenge to achieving the renewable energy target is the inadequate grid infrastructure that inhibits palm oil developers from benefiting from the Feed-in-Tariff payment scheme. One way forward, a strategic partnership between government and industrial players, offers a promising outcome, depending on an economic feasibility study. The decentralization of electricity generation to support rural electrification is another feasible alternative for renewable energy development in the state.

Keywords: renewable energy; sustainability; palm; oil; biomass; Sarawak

1. Introduction

Malaysia is the world's second largest palm oil producer with 38% of the global market, and is the largest palm oil exporter, consisting of about 88% of the market's palm oil in 2011 [1]. As one of the world's leading producers of palm oil, an average of 50 million tons of dry oil palm residues are produced every year and this is expected to reach 100 million tons by 2020 [2]. Oil palm biomass emerges as a potential major contributor to renewable energy as the government has now shifted from conventional energy sources such as coal, oil and gas to promoting renewable energy sources in order to increase energy security [3–6]. Indeed, the combustion of fossil fuels as a source of energy for heat, electricity and transportation is known to be the dominant factor in global warming [7]. The world's transition from conventional non-renewable energy sources to renewable energy sources, due to their renewability and environmentally-friendly nature, is critical for future generations, [8–13].

Sustainable development or sustainability is multidimensional [14] and its definition is vague, [15,16] which makes it remain a confused topic [16,17]. There is no general agreement on how the concept should be translated into real-life practice [18]. However, most of the interpretation of sustainable development revolves around the Bruntland formula and varies in relation to the focus on each of the three components of sustainability namely, economy, environment and society [19,20].

Jabareen [16], in one of his significant works, has come up with a new conceptual framework of sustainable development that blends seven concepts to create the theoretical framework for better understanding of sustainability (see Figure 1).

Jabareen [16] identified key areas of the concept as:

(a) Ethical paradox: This is the heart of the framework where ethics represents the paradox between sustainability and development [16].
(b) Equity: This concept depicts the social aspect of sustainability. It embodies very wide concepts such as environmental, social equity, quality of life, democracy, freedom, participation and empowerment. Basically, sustainability works by sharing the capacity for the well-being of the current generation without adversely affecting the next generations [16].
(c) Natural capital stock: This concept represents the environmental and natural resource assets of development and preservation which aims to keep the natural capital constant for the benefit of future generations [16].
(d) Integrative management: This concept emphasizes that the integration of the three components—environmental, economic and social—in planning and management for sustainable development is critical for sustainability [16].
(e) Utopia: This concept represents visions for human habitats in accordance with sustainability development where people live perfectly contentedly and flourish with nature [16].
(f) Global agenda: This concept represents a global political environmental discourse reconstituted around the ideas of sustainability. The concept reflects the difference in demand between the Northern and Southern countries [16].
(g) Eco-form: This concept derived from the ecologically-desired form of urban spaces and communities which focus on energy efficiency and sustain a long life [16].

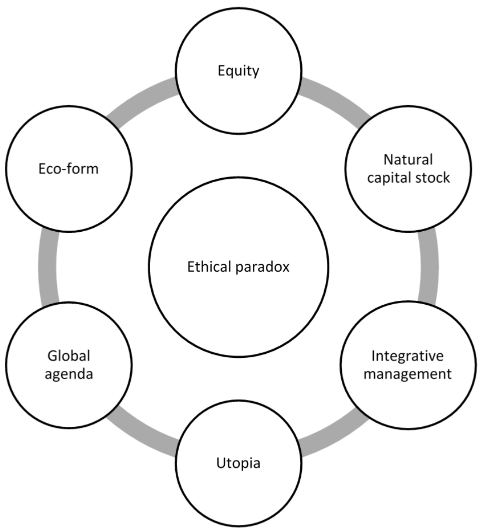

Figure 1. Jabareen's conceptual framework for sustainable development [16].

The Malaysian government has made several efforts to encourage the use of renewable energy to scale down dependency on fossil fuels and to meet the growing demand for energy [21–23]. As a result, the Fifth-Fuel Policy was introduced in 2001 to encourage new renewable energy sources such as oil palm, rice husk and wood waste, as complements to the conventional energy supply [24]. The adoption of this Fifth-Fuel Policy was supported by the implementation of the Small Renewable Energy Power (SREP) program under the Eighth Malaysia Plan. Due to the discouraging performance of SREP and lack of response, however, the National Renewable Energy Policy and Action Plan were introduced under the Tenth Malaysia Plan in 2010, to address the inadequacies in the previous system. Recently, the Feed-in-Tariff system, which came into effect in 2011, has served as the fundamental tool to boost the growth of renewable energy for the next 50 years [25].

Theoretically, Sarawak has the potential to generate a total of 425 MW of electricity from biomass sources, where 375 MW of the amount is contributed to by palm biomass [14]. Not all of this biomass potential can be practically brought to realization, however, due to constraints such as sustainability of the resource supply, conversion technology and the network system [26]. In this context, a strong policy and thorough plan is vital to support the growth of oil palm biomass renewable energy in Sarawak. Stakeholder opinions serve as the basis for formulating an effective and strong policy system, as their views reflect the market insights that will be useful in improving the current policy. On this understanding, a survey was specifically designed to study the current status of the sustainability of power generation from oil palm biomass in Sarawak so that any challenges can be identified and serve as the key factors for the government's consideration in filling the gaps in the existing policy system.

2. Renewable Energy Programmes

Renewable energy and green programmes were launched as complements to the renewable energy policies. The following sections will discuss the Small Renewable Energy Power (SREP) and the Feed-in-Tariff (FiT) programmes, which were implemented to support the Five Fuel Policy and the National Renewable Energy Policy and Action Plan 2010, respectively. Table 1 summarises a comparison between these two renewable energy programmes.

Table 1. Comparison between Small Renewable Energy Power (SREP) and Feed-in-Tariff (FiT).

Small Renewable Energy Power (SREP)	Feed-in-Tariff (FiT)
Introduced in Eight Malaysia Plan	Introduced in Tenth Malaysia Plan
Renewable energy program under Fifth Fuel Diversification Policy	Renewable energy program under The National Renewable Energy Policy and Action Plan 2010
Govern by Special Committee on Renewable Energy (SCORE)	Administered by Sustainable Energy Development Authority (SEDA)
Not legally contract	Legally contract under Renewable Energy Act 2011 and Sustainable Energy Development Authority Act 2011
Unattractive payment structure	Guaranteed and fixed payment structure
Focus on six renewable energy sources	Focus on only four renewable energy sources
Capacity target: 5% or 500MW of energy mix in 2005	Capacity target: 73% or 21.4GW of energy mix in 2050

2.1. Small Renewable Energy Power (SREP)

The SREP programme was used under the Five-Fuel Policy in the Eighth Malaysia Plan where it focused on encouraging the use of renewable energy among the project developers for generating electricity in order to increase the share of renewable energy in the country's total energy mix. SREP allows independent small renewable energy power plants such as biomass, solar, wind, mini-hydro, biogas and municipal solid waste plants, to sell generated electricity at a maximum of 10 MW power to the grid [27].

The SREP programme demonstrated an unimpressive performance, however, as less than 14 MW of renewable energy was achieved compared to the 350 MW of renewable energy stipulated in the Ninth Malaysia Plan [28]. Studies of SREP performance identified the low tariff, inconsistent biomass supply, low incentives, high capital expenditure and insufficient interconnecting infrastructures are among the factors that contributed to the shortfall in renewable energy development [29].

2.2. The Feed-in-Tariff (FiT)

Malaysia has previously introduced new legislative measures, the Renewable Energy Act 2011 and Sustainable Energy Development Authority Act 2011, to spur the growth of renewable energy and address the weakness of the previous system. The Feed-in-Tariff (FiT) system, introduced in 2011, is a tool that will help to support the growth of the renewable energy industry [30]. Figure 2 shows the target capacity outlined for the FiT programme. Under the FiT scheme, the utility is legally contracted to purchase electricity generated from any of four renewable sources: biomass, small hydro, biogas and solar power, at a fixed rate and period, as stated in the law. In this context, for every kilowatt hour (kWh) exported to the main grid, a guaranteed payment is made to the FiT energy developer. The Sustainable Energy Development Authority (SEDA) is the governing body responsible for managing the FiT system in Malaysia by monitoring and evaluating all the manual and internet submissions for new entry [3].

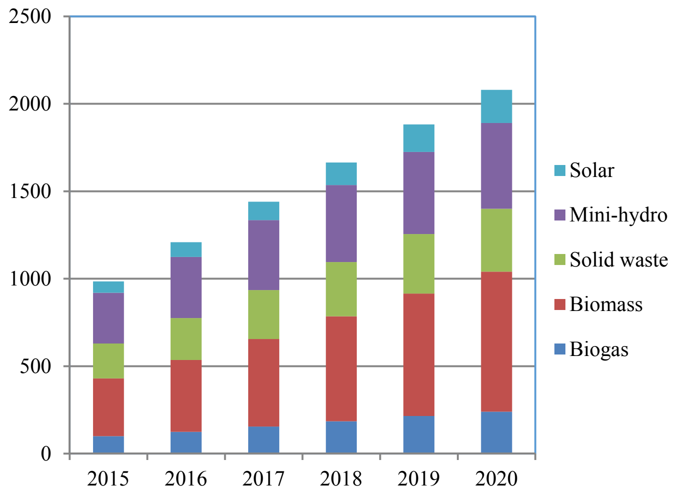

Figure 2. The Feed-in-Tariff capacity target for 2015–2020 (MW).

In 2016, the FiT implementation outcome presented by SEDA states that as of 31 December 2014, FiT only achieved 250 MW, which is very much far off from the 2015 target of 985MW. There is a dramatically different renewable energy mix from the plan set in FiT. Instead of 65 MW of solar power as the target in FiT, it is recorded to be approximately 200 MW in 2014 and exceeds 300 MW in 2015. The installation of solar power, which is easy to build compared to other renewable energy resources, has been given first priority, which results in a very positive growth. The original 2020 target of 2080 MW will fall short, and thus is reduced to 1464 MW if all are commissioned. The 2030 target of 4,000 MW is sure to be completely off, as solar power FiT will end in 2017, followed by small hydro FiT in 2020, and biogas and biomass will end in 2025. Although FiT and Renewable Energy Act implementation has seen a dramatic changes in renewable energy capacity, from 65 MW in 2011 to 300 MW in 2015, another mechanism apart from FiT should be introduced to achieve the Renewable Energy Plan target [31].

3. Methodology

This survey was conducted to investigate the current status of the sustainability of power generation from oil palm biomass in Sarawak so that any challenges can be identified and serve as the key factors for the government's consideration in filling the gaps in the existing policy system. Data was gathered for evaluating the sustainability of oil palm biomass renewable energy in the palm oil mills in Sarawak. The complete data gathering process for this study is summarised in Figure 3.

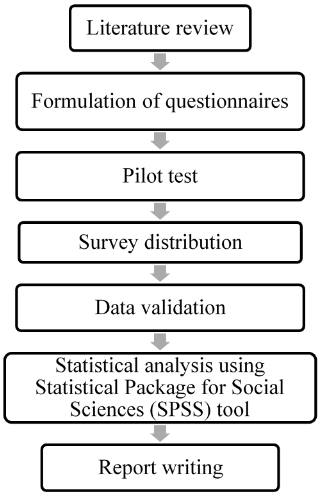

Figure 3. Data gathering process for study.

3.1. Formulation of Questionnaires

The survey questions were formulated based on the limitations and gaps identified from a comprehensive study of academic publications and government reports. An industry survey of the sustainable electricity generation from oil palm biomass in Malaysia by Umar *et al.* [3] served as the guidelines for narrowing the survey questionnaires to the following themes:

(1) Sustainability of biomass supply chain,
   (a) The questions are related to the capacity of the palm oil mill
   (b) Quantity of palm oil biomass produced in their mill
   (c) Quantity of biomass bought from outside supplier
   (d) Biomass utilization
   (e) Cost of the purchased biomass
(2) Sustainability of conversion technology,
   (a) Types of conversion technology used
   (b) Years of operation
   (c) Efficiency of biomass conversion technology
(3) Sustainability of grid network system,
   (a) Usage of electricity generated from mill
   (b) Distance of nearest grid point
(4) Key challenges and future prospect of power generation from palm biomass.
   (a) Key challenges of power generation from palm biomass
      i. Inconsistent supply of biomass
      ii. Cost

   iii. Unattractive tariff
   iv. Low expertise

(b) Willingness to collaborate for joint-venture with other developers for high-efficient biomass conversion technology

The finalised questionnaires consisted of 41 questions, a combination of dichotomous questions, closed-format questions, open-ended, and descriptive questions. Dichotomous questions require respondents to answer “Yes” or “No”. Respondents were also invited to share their industry knowledge by making relevant comments or giving opinions in the open-ended questions.

3.2. Pilot Test

Before final delivery to the target respondents, the questionnaires were submitted to experts with experience working in the oil palm industry in Malaysia to ensure the relevance and clarity of the questions. The questionnaires were corrected after taking into consideration the feedbacks from the pilot test.

3.3. Sample Size

As of September 2014 there are 67 palm oil mills registered in Sarawak, however, only 53 are currently operating and the rest are yet to operate. The sampling method used in this study was purposive sampling: non-random sampling where samples were selected using personal judgement because they meet special qualification or criteria of some sort. In this study, the criterion for sample selection was that the oil palm mills were located in the northern region of Sarawak that is in the Bintulu, Miri and Limbang areas. The northern region of Sarawak is defined as a high potential hub due to its many mills and the palm estate density in this region. There are 26 mills located in this region and all were invited to participate in the study. The sample size was 26 palm oil mills. Most of the palm oil mills are located in a remote area which is more than five hours from the nearest town and there is no contact information available, thus they did not participate in the survey. Details of the target respondents were obtained from their company websites and the market data used was the most recent at the time of the survey in October 2014.

3.4. Survey Distribution

Dual mode strategies, which include conventional postage mode and electronic mode, were used to recruit participants for this study. Since most of the palm mills did not have access to the internet, conventional postage mode was the only alternative for reaching them. The survey document was distributed in the first week of October and the last document returned was in the final week of November. Table 2 shows the distribution of survey documents and response rate by regions.

Table 2. Summary of survey documents distribution and response rate by regions.

Region	Method Sent		Total by Region (Sent)	Method Received	
	Email	Postal		Email	Postal
Miri	4	9	13	2	6
Bintulu	3	7	10	3	4
Limbang	-	3	3	-	2
Total Sent: 26				Total Received: 17	
				Response rate percentage: 65.4%	

Statistical analysis of the returned questionnaires was conducted using the Statistical Package for Social Sciences (SPSS) version 22. Descriptive analyses were carried out to present the findings in form of frequency counts and percentage for every dataset. Quantitative data analysis inferential statistics such as independent sample t-test, analysis of variance (ANOVA) and correlation tests were also carried out for greater detail about the study findings.

4. Results and Discussion

4.1. Sustainability of Biomass Supply Chain

The continuous supply of palm biomass is one of the fundamental elements of sustainable power generation from palm biomass. Inconsistent boiler fuel supplies, such as kernel shells, Empty Fruit Bunch (EFB), and mesocarp fibres will affect the business of small developers who rely upon a third party's supply. Uncertainties related to long-term biomass supply will expose the market to fluctuating prices, as the major plantation developers dominate the market with full control according to their business model [32]. Based on the demographic profiles from the returned questionnaires, it was found that 94% of oil palm mills in the Sarawak Northern region are associated with major developers. All of these palm mills affiliated with major developers have their own oil palm plantations, ranging from 1500 hectares to 200, 000 hectares.

The survey results showed that regardless of their palm plantation size, all the respondent relied on outside suppliers for Fresh Fruit Bunch (FFB). The average quantity of FFB processed yearly by these mills amounted to 300,000 tons in 2012 and 2013. It was also demonstrated that one million Malaysian ringgit was spent by these palm mills per year to purchase two million tons of FFB from outside suppliers. Eighty-three percent of the palm mills that purchase FFB from outside suppliers are in long-term contracts which guarantee them a continuous supply of FFB.

When asked about the projection volume of FFB for the next two years, 2014 and 2015, it was found that these palm mills estimated that they will receive a total of 11 million tons of FFB, an increase of 10% from the previous two years reported, 2012 and 2014. The increment in FFB volume is due to the increase in matured palm plantations. The total palm plantation area in Sarawak is expected to reach two million hectares by 2020, from 1.2 million hectares recorded in 2014.

To investigate the current use of palm biomass as a source of power generation, the respondents were asked about the quantity of biomass they produced monthly and how they use the waste from their own mills. The average amount of palm biomass produced monthly in each mill and the sustaining period is given in Table 3. The amount shown is consistent with the findings that identify Bintulu as the second highest potential hub of biomass due to the high density of biomass that can be mobilised in the National Biomass Strategy.

Table 3. Biomass production of each mill per month and their sustaining period.

Biomass	Average Quantity Produced Per Month (Metric Tons)	Average Sustaining Period (Days)
Empty Fruit Bunches (EFB)	6170	12
Palm Kernel Shell	1863	30
Mesocarp Fibre	4630	2

The average sustaining periods for EFB, palm kernel shell and mesocarp fibre are 12 days, one month and 2 days, respectively. All respondents were having problems handling their excess biomass feedstock, however, due to storage limitations. According to the open-text comments about the storage limitation issue, some of the respondents had opted to tender their excess palm kernel shells and mesocarp fibres to outside traders for quick revenue rather than keep their biomass as feedstock. Another alternative used by the mills to reduce their storage problem was by enforcing the estate plantation to evacuate EFB regularly for mulching purposes.

In response to the biomass use of each mill, it was found that only 23% of palm biomass generated is being used as boiler fuel for power generation, 21% for mulching purposes, 7% was used as bunch ash and 4% was tendered, as presented in Figure 4. According to this result, this is closely linked to oppression by the major developers, who are using their palm biomass according to their business models. All the plant operators used palm kernel shell and mesocarp fibre for power generation and were not currently using EFB as boiler fuel. The situation in Sarawak's mills is in contrast with practice in palm mills in Peninsular Malaysia where EFB is also used as boiler fuel, along with palm kernel shells and mesocarp fibres [32]. None of the respondents used EFB as boiler fuels mainly because of its bulkiness and high moisture content, which requires pre-treatment before being used as boiler fuel. This is consistent with the findings of previous studies, which outlined the same issues linked to EFB [9,33,34].

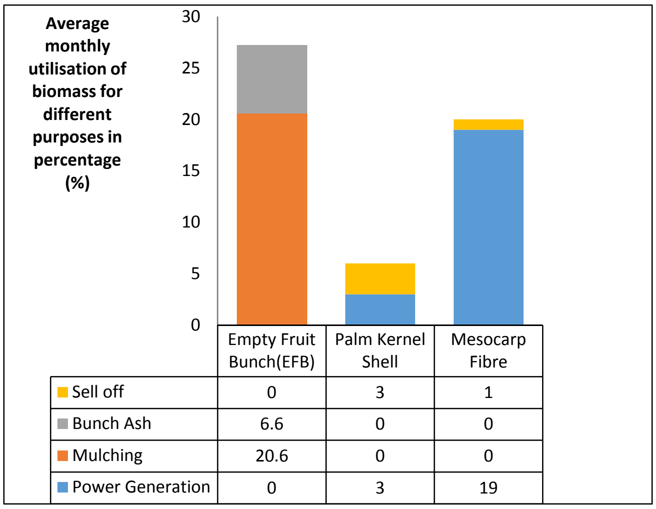

Figure 4. Utilization of biomass for different purposes.

Mulching was found to be a popular option for palm mill developers in Sarawak as all the respondents were using their biomass feedstock for mulching. Mulching with EFB supplemented with inorganic fertilizers is widely practiced in oil palm plantations, as this practice helps to improve soil nutrition and results in high yields of oil palm [35].

In response to a question investigating industry willingness to purchase biomass for power generation in their plant, three quarter (75%) of the respondents expressed their unwillingness to do so. This can be demonstrated as only 23% is utilised for generating electricity in the plants.

An independent sample t-test was performed to ascertain whether there is a significant difference between the willingness of palm oil mills to purchase biomass for power generation in relation to the total of FFB received by the mills. The independent sample t-test resulted in a p-value of $0.36 < 0.5$, which implies that there is a significant difference between the two groups (the palm mills that are willing to purchase biomass for power generation and the palm mills that are not willing to purchase biomass for power generation) in terms of the total FFB received. Given that there is a significant difference, the palm mill that was willing to purchase biomass FiT for power generation reported receiving a significantly higher amount of FFB. Palm oil mills with a higher capacity of processing more than 50 tons per hour require more power to cater for their production line, and thus, in order to meet the power requirements, they are not against the idea of purchasing biomass as boiler fuel for power generation in their plant.

According to the survey outcomes, Sarawak has sufficient palm biomass supply in the marketplace to cater for its own industry needs. The probability of a shortage of palm kernel shell and mesocarp fibre for power generation is relatively low, as these mills have a high quantity of biomass feedstock in their plants. In terms of using palm biomass in boilers to generate electricity, however, the percentage is still low as only mesocarp fibre and palm kernel shells are currently used for this purpose. The Malaysia Oil Palm Board (MPOB) has mandated that palm mills fully utilize their Palm oil mill effluent (POME) and EFB by 2020 to generate power in their mills that can be tapped into the main power grid as an additional power supply. In Sarawak's current situation, this requires more research to examine the suitability and economic viability of EFB as a power resource for large scale power production before it can come into realisation.

4.2. Sustainability of Conversion Technology

The survey data implies that 100% of the oil palm mill plants are operating with a combination of combustion and combined heat and power (CHP). This finding is consistent with a study by Trummer who found that the majority of the plants in Malaysia are run with combustion engines and combined heat and power (CHP) [36]. Figure 5 shows the current situation in palm oil mills in Sarawak based on the results of the survey. Power is generated from the combustion of shell and fibre, whereas palm oil mill waste and EFB are excluded from this process. Electricity generated from the combustion of shell and fibre is supplied to the palm oil mill and also used to sterilise FFB.

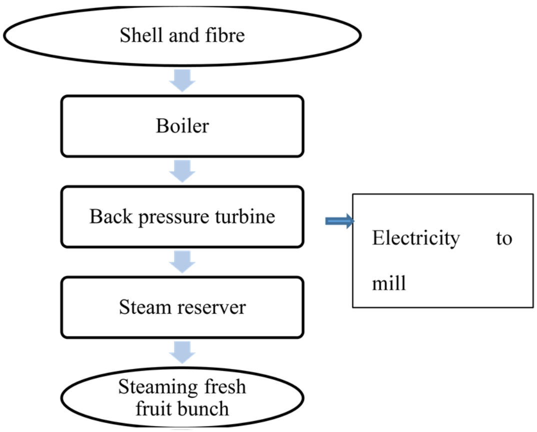

Figure 5. Current utilization of oil palm biomass in power generation in palm oil mills in Sarawak.

As shown in Figure 6, it was found that 44% of the respondents' mills were equipped with technology that has been operating between three–six years. Regardless of the age of their technology, about 70% of the respondents claimed that the conversion efficiency of their technology is satisfactory, at above 60% efficiency, and the remaining 30% of respondents' mills were equipped with technology that has a conversion efficiency of 30%–60%.

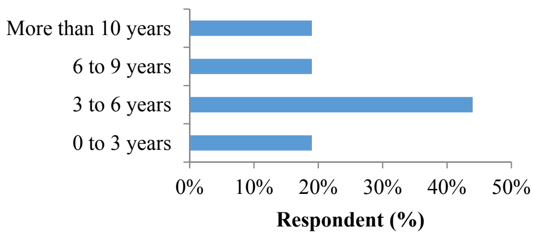

Figure 6. Age of conversion technology in Sarawak palm oil mills.

A one-way ANOVA was conducted to examine whether there are statistically significant differences between the technologies in different age groups, in relation to their technology conversion efficiency. The results revealed statistically significant differences among the technology age groups, $F(3, 12) = 5.023$, $p = .018$. Post-hoc Scheffe tests revealed statistically significant differences between technology over 10 years (M = 2, SD = 0.00), those 0–3 years (M = 3, SD = 0.0), 3–6 years (M = 2.86, SD = 0.387) and those 6–9 years (M = 2.67, SD = 0.577). Technology that had operated 0–3 years, 3–6 years and 6–9 years reported significantly higher conversion efficiency compared to technology over 10 years old. There were no other significant differences between the other groups.

When asked about whether they were willing to change to new conversion technology for better efficiency, 30% of the respondents are reluctant to do so, but 70% showed interest in changing to new conversion technology. The survey found several reasons to explain this. Firstly, some of the respondents have relatively new technology which has only operated between 0–3 years. Changing to new conversion technology requires high capital-intensive investments that expose them to business risk due to the long payback period. All the mills were using their electricity for self-consumption which means that excess electricity from new technology would not result in extra profit. Nevertheless, the survey found that 100% of the respondents were interested in embarking on palm biomass as a renewable energy business should the energy venture be shown to provide profits.

An independent sample t-test was conducted to determine whether there was a significant difference between the two groups (palm oil mills who were willing to change to new technology and palm oil mills who were not willing to change to new technology) in relation to the conversion efficiency of their existing boiler technology. The test revealed no statistically significant difference between the two groups ($t = 0.651$, df = 8.79, $p > 0.05$. Given that there was no significant difference found, willingness to change to new technology is not related to the performance or efficiency of existing boiler technology.

The issue of respondents only using palm kernel shells and mesocarp fibres as boiler fuels for power generation is closely related to the lack of development of biomass conversion technology in Malaysia. There is no local manufacturer for new conversion technology, which makes it very difficult to encourage technology change due to the high capital investment. Utilizing EFB as boiler fuel requires pre-treatment plants are not equipped with the latest technology, and thus they opted for the feasible and practical alternative which is to exclude EFB as boiler fuel in their plant.

Malaysia should use foreign knowledge and technologies and start to increase the number of local technology manufacturers and skilled workers. China serves as the best example of this, as they have successfully developed their small and medium-gasification system for biomass renewable energy by providing locally manufactured technologies that can be easily accessed and are readily available [37]. The cost of technology and maintenance is relatively low compared to the foreign technologies, and thus they are able to attract investors [38]. A shift in conversion technology in Sarawak's context involves much more investment in boilers that can use EFB as boiler fuels. As most of the mills in Sarawak are affiliated with major developers, state government can intervene by encouraging the major developers to invest in the latest and upgraded conversion technology. Since major developers normally have more than one palm oil mill, they can install new technology in one of their mills which then can be shared among the sibling mills in the same area.

4.3. Sustainability of the Grid Network System

The renewable energy target from oil palm biomass is not possible without the excess power being fed into the main grid. The survey revealed that all respondents use the power generated from their plant for self-consumption. Consistent with previous studies, it is reported that electricity generated from oil palm mills is used for their own operational needs [7]. The current condition in Sarawak is different from that in Peninsular Malaysia in terms of grid infrastructure developments, with legal implications as well as tariff considerations.

All of the respondents' mills were located in remote locations, which explains their inability to support the Feed-in-Tariff policy. Eighty-two point four percent expressed their unwillingness to invest in grid infrastructure to export their excess electricity and only 18% were interested in doing so.

Constructing transmission line infrastructure requires extremely high capital investment from the industry and government. Most of the mills are dispersed in remote locations, more than 10 km from grid connection points, thus making infrastructure construction a difficult, expensive and laborious task. Sarawak oil palm industry players are not interested in investing in a renewable energy business unless they are guaranteed a return on their investment. Nevertheless, all the respondents stated that they would enter the biomass renewable energy business if the transmission line infrastructure costs were borne by government.

Transmission gridlines in Sarawak are still very much lacking, including infrastructure for feed-in excess power generated from palm oil mills into the main power grid in the state. Infrastructure for a rural electrification scheme is still under development. The power generation for domestic and industrial use in Sarawak comes under the purview of Sarawak Energy Berhad (SEB). SEB oversees the power generation from hydropower projects, coal, diesel and gas to be supplied to the Sarawak state. These resources provide sufficient energy to power the state's growth beyond 2030 and also for international export [26]. As a result, the cost of power generation by SEB in Sarawak is significantly lower than the cost of production from palm oil mills. State government, therefore, has to intervene by negotiating for a mutually acceptable feed-in-tariff rate with SEB to support the palm biomass renewable energy business.

The survey findings indicate that the current network system in Sarawak is still inadequate, and achieving the targeted biomass renewable energy is still far in the future. In Sarawak's context, more factors needs to be taken into consideration, such as the demographic profiles and legal and tariff considerations, before the biomass renewable energy business can be developed on a larger scale, as discussed earlier. Instead of only targeting biomass renewable energy for feeding into the grid, one possible solution is to include a non-grid power generation infrastructure to supply surplus electricity from mills to rural communities at a comparable tariff charged by Sarawak Energy Berhad under the Rural Electrification Scheme. This alternative would not just help to avoid investing in grid extension, but would also offer a practical solution where potential power supply from palm oil mills is fully exploited [39]. The palm oil industry is a vital contributor to economic growth in Sarawak and expected to continue to grow in the future. It is therefore timely that the both the Sarawak state government and the federal government puts forward plans to utilize the potentially wasted power supply from palm mills by providing the necessary infrastructure.

4.4. Key Challenges in Implementing Biomass Renewable Energy in Sarawak

To investigate the challenges in implementing biomass renewable energy business in Sarawak, the respondents were asked about the main barrier to the issue. One hundred percent of the respondents agreed that the high investment cost is the main challenge restricting their participation in the renewable energy business. Under the National Key Economic Areas (NKEA), Entry Point Project (EPP) Five, the Malaysian Palm Oil Board mandated that palm oil mills be installed with biogas capture facilities so that the palm oil mill waste and EFB can be fully utilized by tapping the excess power from the mill into the grid connection. The cost of setting up a biogas plant can amount to RM10 million per mill, which will impose a heavy burden on the mill developers due to the long payback period and uncertainty of recouping their investment costs. This is thus a serious concern for palm oil developers, especially the Sarawak developers, as there is no grid connection that will allow them to enjoy the Feed-in-Tariff. According to Sarawak Oil Palm Plantation Owners Association (SOPPOA), they are trying to negotiate with the government to consider granting the industry in Sarawak an additional five years for the implementation of biogas capture in view of the current conditions.

Forty-one percent of the respondents agreed that the unattractive tariff means they are not interested in investing in the biomass renewable energy business, and 18% of respondents agreed that the inconsistency of the biomass supply chain was one of the challenges, as shown in Figure 7. On questions related to their awareness of the Feed-in-Tariff policy, the results revealed that only 47% of the respondents were aware of the new policy. When asked how they came to know about the Feed-in-Tariff policy, most of them had learnt about the issue from the internet. One hundred percent of the respondents stated that they understand the importance of utilizing palm biomass as renewable energy. When asked whether their business model focused on crude palm oil production as a single product, 76% of the respondents disagreed.

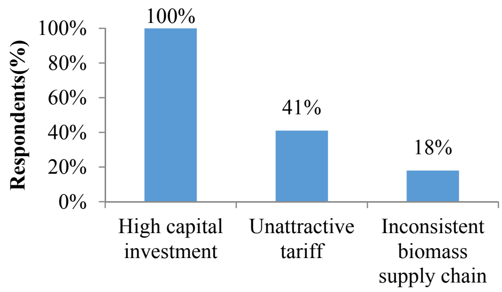

Figure 7. Key challenges in implementing biomass renewable energy business.

4.5. Future Prospects of the Biomass Renewable Energy Business in Sarawak

With regard to potential involvement in the renewable energy business, 94% of the respondents demonstrated interest in expanding their business into biomass renewable energy, and all expressed their readiness to form a strategic partnership with government and other developers to support the biomass renewable energy business in Sarawak. The high number of respondents supporting this proposal was due to the fact that they have a large quantity of unused biomass feedstock, as revealed through this survey. Another reason was due to storage constraints in handling their biomass feedstock. Due to the high moisture content of the palm biomass, it can easily rot and grow mould, which can result in further environmental concerns. The palm oil mill operators are thus open to renewable energy business ideas that could bring extra profit, as they will not have waste disposal costs and can reduce their biomass feedstock in storage.

4.5.1. Palm Biomass Power Plant Joint-Venture

The following sections will discuss in detail the important factors that must be considered in order for the biomass power plant joint venture between palm oil mill developers in Sarawak to be put forward.

Capacity of Power Plant

Further to the idea of strategic collaboration, a biomass CHP power plant with a capacity of 50 MW and connected to the state's power supply, where the biomass supply comes from the mills around Sarawak, is one of the ways to accelerate the biomass renewable energy business in Sarawak. The size of the power plant is driven by the availability of biomass in the region. It is important to select a suitable power plant scale, as this is one of the key factors in gaining optimal profits from this system.

As has been reported by Sarawak Energy Berhad, the total power output that could be generated from oil palm biomass in 2014 was 100 MW. A CHP plant with a capacity of 50 MW would be reasonable in this context. Centralised biomass collection and electricity generation helps to simplify connectivity to the state's power grid. Different strategic partnerships should be analysed to find the best option, where business risk can be shared among the partners. Operation of the biomass power plant should come under the purview of the state government or the energy utility, Sarawak Energy Berhad.

Sustainability of Biomass Supply Chain

Developing a large-scale centralized biomass power plant where the electricity from the plant will be tapped into the state's power supply is no simple task. There are many issues that need to be taken into consideration in the business plan regardless of the size of the plant. Foremost, it is critical to set a dependable supply chain to keep a constant and reliable feedstock (EFB, shell and fibre) for the energy conversion process. A well-planned biomass supply chain will limit risk to capital [34].

The cost of a large scale biomass energy facility can range from RM100 million to RM500 million and require a long payback period.

The feedstock for the proposed biomass power plant will include EFB along with shells and fibres. The projection volume of biomass production in Sarawak, as shown in Figure 8, is calculated to determine the sustainability of the supply chain for the proposed biomass power plant, should the project come to realization. According to an MPOB statistics report, Sarawak's FFB tons yielded per hectare in 2013 was 16.23 [1]. The FFB yield per hectare in this calculation is assumed to increase by one ton each year. On the other hand, the oil palm plantation area is assumed to increase by 10% every year. By the year 2020, it is estimated that the total palm plantation area in Sarawak will reach up to two million hectares, thus establishing a dependable biomass supply chain for the proposed biomass power plant.

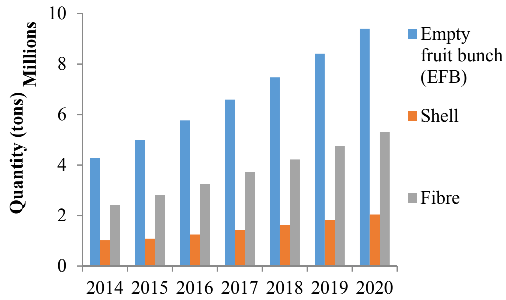

Figure 8. Projection volume of biomass production.

Environmental Issues

Environmental issues are also an important concern in a power plant project. Poor environmental planning can affect the environment and at the same time tarnish the reputation of biomass energy. Thus, it is important that thorough and comprehensive planning for the biomass supply chain takes place at an early stage of the project [40].

In the context of a biomass power plant, carbon dioxide emissions are an important aspect for assessment, because they can acquire carbon credit via the Clean Development Mechanism (CDM), which is an additional source of income [41]. Any CDM project that achieves a reduction in their greenhouse gas emissions will be quantified in standard units, known as "Certified Emission Reduction (CERs)". This involves trading in the emission reduction project (known as CERs after their emission reduction is certified) produced from specific projects to countries that can use these CERs to meet their targets. In return for the traded CERs, money will be transferred to the project that achieves the greenhouse gas emission reduction [42].

Traditionally, using EFB for the mulching process is well-accepted as environmental-friendly, as this method helps to retain the soil nutrients and provide a nutrient-balanced land for the FFB to grow. EFB mulch also serves as organic fertilizer and soil conditioner in oil palm plantations. Using EFB as fuel, however, can reduce carbon emissions to half those emitted from mulching [43].

Electricity Sales Revenue

In regards to the projection of electricity sales revenue that can be generated from the biomass power plant, Table 4 shows that up to 15 billion Malaysian ringgits could be created by 2020. Under the Feed-in-Tariff payment scheme, electricity from renewable energy industry is paid at RM0.21 cents for every electricity unit transmitted to the grid connection [3]. For the computation shown in Table 4, thermal efficiency is set at 50% and the tariff is assumed to be at minimum price offered by Sarawak Energy Berhad for a unit of electricity, RM0.21 cents/kWh. The operational and maintenance cost is assumed to be 30%. This figure does not take into account the benefits of biomass for other purposes, assuming all the biomass is used as fuel in the proposed biomass power plant.

Table 4. Projection of total power output and electricity sales revenue.

Year	Power Output (MWh)			Total Capacity (MWh)	Electricity Sales Revenue (MYR) (Billion)
	Empty Fruit Bunch (EFB) at 65% Moisture Content	Shell at 20% Moisture Content	Fibre at 50% Moisture Content		
2014	3911.9	2282.4	3196.0	9392.6	1.38
2015	4573.6	2425.0	3736.4	10,735.0	1.57
2016	5281.2	2801.2	4315.8	12,398.0	1.82
2017	3911.9	3203.2	4935.4	14,177.6	2.08
2018	4573.6	1815.6	5594.8	16,072.0	2.36
2019	5281.2	2042.5	6294.2	18,080.8	2.65
2020	3911.9	4564.8	7033.4	20,204.4	2.97

Location of the Proposed Biomass Power Plant

A carefully selected location of the proposed biomass power plant plays a key role in minimising the transportation cost of the biomass from mills to the power plant. A study in 2011 to evaluate the potential location of an independent combined heat and power (CHP) plant using the data from 19 mills in Sarawak, will be important guidance. Data about the palm oil mills and transportation distance were simulated using a geographical information system (GIS) to obtain a potential location for the proposed biomass power plant, as shown in Figure 9. The location is somewhere between Bintulu and Miri as these have the most active palm oil mills located within 20–30 km radius of the proposed power plant [43].

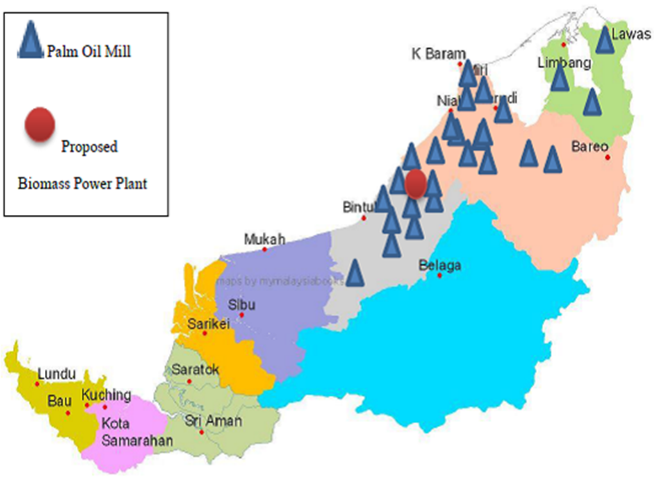

Figure 9. Potential location of proposed biomass power plant.

As discussed earlier, Sarawak is rich in energy resources such as hydropower from dams, coal-fired power plants, diesel and gas. With the abundance of resources and adequate energy to last beyond 2030, the cost of power production from these resources is low compared to power production from mills [26]. As a result, the electricity generated from mills will be at great disadvantage when competing in the market. One way to support the development of the renewable energy biomass business in Sarawak is revision of the existing tariff to become relevant to the local conditions and operational complexity.

Incentives

Incentives could be rewarded to the palm oil mills that supply their biomass to the overall project. One of the incentives could be in the form of providing electricity from the mega joint-venture project at a nominal price to the mills that participate as a way of rewarding their distribution. Incentives in terms of the transportation cost of the biomass from mills borne by the proposed plant operator should also be taken into future consideration.

4.5.2. Use of Palm Biomass as Fuel for Decentralized Power Generation for Rural Electrification

All-hours electricity is a critical component in improving the general quality of life for rural Malaysians. The state of economic development can be measured by the energy pattern and quality of energy consumption, as energy demand increases with economic growth.

The use of palm biomass as a fuel for the decentralization of electricity generation could be a future option for the rapid expansion of the biomass renewable energy business in Sarawak [44]. In this context, rather than using electricity generated from their plant for self-consumption, the excess electricity from palm oil mills will be supplied to the surrounding rural communities in Sarawak. Harnessing readily available resources such as palm biomass to generate off-grid power to supplement conventional energy sources has great potential. India's biomass gasification project provides a good example of how the decentralization of electricity generation using biomass as a fuel provides electricity to the rural community [45].

Under the similar business model to that practiced in India's biomass power plant project, the palm oil mill developers would own the entire system, from electricity generation to electricity sales revenue collection, with virtually no dependence on the energy utility or state government. Palm oil biomass from the mill, EFB, shell and fibre would be used as fuel for power generation. The bunch ash residue could be sold as a by-product to customers. Under this business model, the electricity revenue comes from the surrounding rural communities within a three kilometre radius who subscribe to the electricity from the palm oil mill plant. An electricity purchasing contract has to be agreed to by the involved parties to protect them from business risk.

The difference with the current practice is that EFB is added to the list of boiler fuels, and the excess power is supplied to the surrounding remote communities instead of being self-consumed. Figure 10 shows the proposed flow of electricity generation from palm oil mill plant to the surrounding rural communities. The distribution lines have to be set up by the palm oil mill and each line has to be fused to prevent loss of revenue due to power theft.

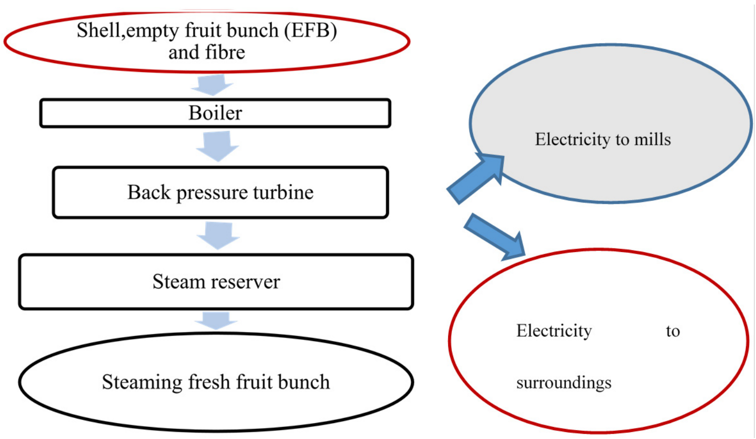

Figure 10. Decentralized electricity generation from palm oil mill plant to rural communities.

Electricity sales should be according to the standard affordable price set by Sarawak Energy Berhad, which is set at RM0.21 for a unit of electricity [18]. The advantage of the decentralization of electricity generation compared to centralized electricity generation is that the cost of grid expansion can be avoided and at the same time rural communities can benefit from this project. The palm oil mill developers also benefit from the project as they are not just using the electricity to cater for their own production needs but also making profit through electricity sales revenue. There is a need for the government to consider restructuring the existing electricity tariff to further facilitate the palm oil mill operators and at the same time provide basic electricity to the rural communities at an affordable price.

In the Rural Electrification Scheme projects in Sarawak under the Ministry of Public Utilities for rural communities which are isolated and located in remote areas with difficult accessibility, emphasis shall be placed on the development of renewable energy systems such as hydro, wind turbine and solar power. Including palm biomass in the list of renewable energy systems to support rural electrification would be a feasible and practical practice in Sarawak and at the same time help to transform the entire economic activity and lifestyle of the rural community. One of the important lessons learned from the success of decentralized power generation from biomass as practiced in India is that this project has to be highly localised in both its design and implementation. A detailed assessment of the rural community's energy requirements and resources has to be made in order for such a project to achieve its target.

The shift from conventional practice requires much more investment in infrastructure, equipment and research and development in the case of palm oil biomass renewable energy industry in Sarawak. This plan also requires strong commitment from the palm oil mill developers and also intervention by the state government to ensure that consumers, the rural communities and the palm oil mill developers benefit from this project.

5. Conclusions

The sustainability of power generation from palm biomass specifically in Sarawak was investigated in this study by conducting a survey among the palm oil mill developers. The current use of oil palm biomass as boiler fuel for power generation in Sarawak mills was evaluated. It was found that the northern region, comprising Bintulu, Miri and Limbang, has the highest density of palm oil mills and the largest oil palm plantation area, contributing to a vast amount of biomass production in Sarawak. Only 23% of the generated palm biomass, which consists of palm kernel shells and mesocarp fibres, is used as boiler fuel for power generation purposes, and is just sufficient for on-site operations.

To understand the market behaviour of oil palm biomass renewable energy in Sarawak, the palm oil mill developers were using their biomass according to their own business model. EFB is mainly transported back to palm plantations for mulching, which is a traditional practice to retain the soil nutrients that support the growth of FFB. Shell and fibre are also tendered for quick revenue.

The challenges in the development of palm biomass renewable energy in Sarawak were analysed and it was shown that the zero export of surplus electricity to the grid can be explained by the situation in Sarawak, where grid infrastructure is still very much lacking.

In this work, the future prospects of oil palm biomass renewable energy in Sarawak were studied. In addition, two strategies that could be taken into consideration in order to accelerate the growth of the renewable energy business in the state were identified. The first was by establishing a centralised mega biomass power plant as a collaboration between state government and the palm oil mill developers. Rural electrification as practiced in India is also a feasible alternative that will help to develop the growth of renewable energy in the state and at the same time contribute to the nation's economy. Although this effort pales in comparison to other countries such as the Netherlands, the United States and the United Kingdom which have become leaders in renewable energy development, Malaysia as a developing country will see economic, environmental and also political benefits.

In conclusion, the government should start looking into providing the necessary infrastructure and expertise for the use of potential power supply from oil mills in Sarawak, especially as it was revealed in this study that all the participating respondents welcomed the idea of a strategic partnership with the state government to further develop the biomass renewable energy industry.

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