OPTIMISING RESOURCES AND ENERGY EFFICIENCY IN GRASSROOTS ECO-INDUSTRIAL PARK BY SELECTING THE OPTIMAL TENANT COMPANIES

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ABSTRACT

The generation of oil palm biomass in Malaysia is estimated to reach 100 million tonnes annually. It has vast potential to be monetised to various valuable products such as bioenergy, bio-agriculture, bioproducts and biochemicals. However, the biomass industry has not been able to create value along the industry's value chain. The industry is also susceptible to several risks including regulatory, financing, technology, feedstock and supply chain, business, and environmental and social risks. Therefore, the selection and control of tenants' access have a vital effect on an Eco-Industrial Park's (EIP) stability and overall process efficiency. The establishment of the Oil Palm Biomass-based-EIP (OPB-EIP) model might be an effective approach toward optimizing oil palm biomass resources and energy efficiency, promoting sustainable growth and mitigating some risks. Planning a sustainable grassroots OPB-EIP can be complicated due to the competition among participating tenant companies. This study provides a systematic approach for selecting tenants. The entry indicator system consists of three primary and ten secondary indicators proposed from the perspective of the park developer. The criteria and sub-criteria are selected according to the industrial symbiosis principles and the three dimensions of sustainability (environment, economic and social dimensions). The technique renders the Analytic Hierarchy Process (AHP) model to prioritise the tenants. The optimal selection of tenants depends on the trade-offs between ten different indicators. The method is easy to use and improves the accuracy of decision-making. But there are two challenges in using this method. The first challenge is the unavailability and unreliability of data. It is difficult to get accurate values for some data and is also subject to manipulation. The second challenge is that an indicator's value assignment is often influenced by subjective factors such as personal preference and professional knowledge. A case study on 100 acres of proposed OPB-EIP in Pahang is adopted for this research. The results indicated that the proposed indicators and AHP method could select tenants with specified criteria. Conclusively, the systematic methodology presented can help park developers formulate guidelines to control tenants' access to a sustainable OPB-EIP.

ABSTRAK

Industri sawit dianggarkan menjana sisa biojisim sebanyak 100 juta tan setahun. Biojisim ini berpotensi untuk memberi pulangan ekonomi yang menarik melalui penghasilan pelbagai produk yang mesra alam seperti biobahanapi, biobaja, biogas dan lain-lain lagi. Walaubagaimanapun, buat masa ini industri biojisim tidak berkembang maju seperti yang diharapkan kerana terdedah kepada pelbagai cabaran dan risiko. Antaranya adalah membabitkan kekangan kewangan, peraturan-peraturan, teknologi, bekalan fidstok, risiko perniagaan, pencemaran alam sekitar dan juga isu-isu sosial. Model perniagaan yang baru iaitu menempatkan pemain-pemain industri biojisim dikawasan perindustrian yang khas dan mepraktikan *industrial symbiosis* atau dikenali juga sebagai Taman Perindustrian Eko mungkin dapat memaksimakan manfaat biojisim dan mengurangkan sebahagian daripada risiko. Oleh yang demikian, memilih dan mengawal kemasukkan syarikat yang akan beroperasi di Taman Perindustrian Eko adalah amat kritikal kerana peyertaan mereka akan memberi kesan kepada simbiosis dan kemampanan. Perancangan bagi membangunkan Taman Perindustrian Eko berasaskan biojisim adalah rumit kerana wujud saingan dikalangan syarikat yang akan beroperasi dan akan menjejaskan simbiosis. Kajian ini bertujuan menyediakan kaedah yang sistematik bagi pemaju untuk memilih syarikat yang dapat memberi pulangan yang maksima. Terdapat tiga penunjuk utama dan sepuluh penunjuk sekunder untuk digunapakai oleh pemaju. Kriteria dan sub-kriteria penunjuk dipilih berdasarkan prinsip simbiosis industri dan juga dirangka melibatkan tiga dimensi kemampanan, iaitu ekonomi, alam sekitar dan sosial. Bakal-bakal peserta dipilih melalui kaedah AHP. Pemilihan syarikat yang optimum adalah bergantung kepada kompromi (*trade-off*) di antara sepuluh penunjuk. Kaedah ini mudah untuk digunakan dan juga dapat membantu untuk memperolehi keputusan yang lebih tepat. Walaubagaimanapun, terdapat dua cabaran dalam mengaplikasikan kaedah ini. Cabaran pertama ialah sukar untuk memperolehi data yang jitu. Adalah sukar untuk mendapatkan nilai yang tepat untuk sesetengah data dan juga data tersebut tertakluk kepada manipulasi. Cabaran kedua ialah nilai penunjuk yang dipilih mudah dipengaruhi oleh faktor yang subjektif seperti pendapat peribadi dan juga bergantung kepada pengetahuan teknikal. Kajian kes terhadap kaedah AHP ini diaplikasikan pada Taman Perindustrian Eko yang berasaskan biojisim di kawasan seluas 100 ekar di Mukim Keratong, Pahang. Hasil kajian membuktikan penunjuk dan kaedah AHP berupaya memilih syarikat menepati kriteria seperti yang dicadangkan. Kesimpulannya, kaedah pemilihan syarikat yang sistematik ini dapat membantu pemaju untuk menyediakan garis panduan bagi memilih dan mengawal kemasukkan syarikat yang dapat memaksimakan penggunaan biojisim dan beroperasi dengan lebih mampan di dalam Taman Perindustrian Eko.

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LIST OF ABBREVIATIONS

AHP	-	Analytic Hierarchy Process
ANP	-	Analytic Network Process
BSPP	-	Biomass Steam Power Plant
CI	-	Consistency Index
CHP	-	Combined Heat Power
EIP	-	Eco-industrial Park
EFB	-	Empty Fruit Bunches
GHG	-	Green House Gases
MILP	-	Mixed -Integer Linear Programming
MADM	-	Multi-Attribute Decision Making
MCDM	-	Multi Criteria Decision Making
OPB-EIP		Oil Palm Biomass-EIP
OPT	-	Oil Palm Trunk
OPF	-	Oil Palm Frond
PP	-	Pellet plant
RM	-	Malaysia Ringgit
RSPO	-	Roundtable on Sustainable Palm Oil (RSPO)
TOPSIS	-	Technique for Order Preference by Similarity to Ideal Solution
MOO	-	Multi-Objective Optimization
UNIDO	-	United Nations Industrial Development Organization

LIST OF SYMBOLS

λmax	-	Mean consistencies
n	-	No of sample

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CHAPTER 1

INTRODUCTION

1.1 Background of the Research

Biomass helps reduce the amount of carbon emissions that give an adverse impact to global warming and climate change. Recognising the potential of biomass as a green feedstock source, the Malaysian government has introduced the National Biomass Strategy 2020 (NBS 2020, 2014) blueprint, which charts the development of the biomass industry. As highlighted in the NBS 2020 (2014), Malaysia is projected to produce up to 100 million tonnes of biomass annually in 2020, with the majority from the palm oil sector. However, despite institutional arrangements, policy frameworks, funding mechanisms and incentives to support the growth of the biomass industry, the industry has not been able to create value along the industry's value chain. According to Yatim (2017), a lack of understanding of risks associated with the biomass industry is often cited as one of the reasons for the industry's slow growth. The industry is susceptible to several risks including regulatory, financing, technology, feedstock and supply chain, business, and environmental and social risks. For the biomass industry to grow, de-risking mechanisms that address and seek to remove inherent barriers that cause these risks are needed.

Currently, there are several small and medium enterprises (SMEs) that are converting oil palm biomass to useful bioproducts such as pellet, biofertileser, fiber, pulp and paper etc., and export their product to the international market. Almost all are small in scale and scattered throughout the country. These practices are less efficient in terms of resource sharing and supply chain management. Additionally, according to the MBIC 2019/2020 (2020), sustainability and chain of custody requirements, as well as the Roundtable on Sustainable Palm Oil certification, are some of the requirements explored by importing countries., authorities in some countries such as the European Union, Japan and South Korea have raised concerns on sustainability and chain of custody (CoC) requirements such as Roundtable Sustainable Palm Oil (RSPO) and Renewable Energy Certificate. In view of these, a new strategy is needed to support the biomass industries.

One approach to spur growth and de-risk investment is to bring together all industries with a common goal to utilize biomass in the same location and aims for enhanced environmental, economic, and social performance through collaboration in managing environmental and resource issues. The symbiosis concept in the industry can be achieved through the development of Eco-Industrial Park (EIP). This is defined as a cluster of the entity and other facilities together with supporting infrastructure which creates the circular economy and promotes sustainable development. Such a park will apply conditions for participation and will select members who in total achieve the desired objective. This EIP will be profit and environment-driven and the tenants selected in such a way that economic performance increases as the level of integration and, therefore, efficiency increases. Participation will provide clear economic and other advantages over the current stand-alone processing model. In short, the EIP concept is about creating more resource-efficient and cost-effective industrial parks which are more competitive, attractive for investment, and risk resilient (UNIDO, 2017). On top of that, besides improving the carbon footprint of products, EIP also can support the government agenda in ensuring that the oil palm biomass is sourced from *Roundtable on Sustainable Palm Oil* (RSPO) or Malaysia Sustainable Palm Oil (MSPO)-certified plantations and palm oil mills.

1.2 Problem Statement

An EIP has great stability and systematic efficiency when each member tenant is suitable and compatible (Zhu *et al*., 2010). Therefore, the selection of suitable member tenant plays an important role in the early planning and design of an EIP. There is limited knowledge for EIP's developers in decision-making about how the tenants influence the industrial symbiosis within the park. Thus, there is a need to design an assessment model that maximizes EIP's profit gain and minimizes environmental impacts. The EIP concept might be an effective approach towards the efficient utilization of oil palm biomass, promote sustainable growth and mitigate some risks. But, clustering economic activity in one area for converting oil palm biomass to bioproducts may also risk concentrating adverse environmental and social impacts, such as pollution, greenhouse gas emissions, and poor health and safety standards. A typical EIP consists of previously established anchor tenants and support tenants to follow (Ubando et al., 2016). The anchor tenants represent the key industry of the EIP, which serves to attract other entities to join the EIP. These new entities are known as candidate tenants act as either suppliers or customers of these anchor tenants, whose entry creates new opportunities for integration. The main issue is how to integrate mass (both solid and liquid waste) and energy flows economically among processing units and even companies. For example, the biogas plant could utilize waste to generate heat and power. One company owns the facility while another serves as host for a portion of the output. The challenge within an EIP is to promote such integration. Therefore, the selection of a suitable candidate tenant plays a significant role in the early planning and design of an EIP.

There are many previous studies that have developed methods and tools involving the design and development of EIP that could improve sustainability. Mostly are focused on optimization, total site heat integration, water-energy nexus, etc. Lawal et al (2021) has suggested that the process integration (PI) and mathematical optimization tools related to industrial symbiosis, as well as other relevant models provide a better understanding of the industrial symbiosis concepts to assist practitioners in the design and establishment of EIPs. However, the literature review shows that the potential integration of candidate tenants in EIPs is still lacking in research, particularly in biomass-based EIP. Additionally, there is limited information available about the potential economic and environmental benefits of oil palm-based EIPs, the technologies needed to support them, the decision-making process for successful EIP development, or the important regulatory issues surrounding EIPs.

1.3 Research Objectives

The main objective of this research is to design a systematic tool for decision-making in selecting the suitable technology/process to be located within oil palm-based biomass EIP that meets both financial and environmental criteria as well as to minimize feedstock consumption. The sub-objectives are as follows:

(a) To analyze and propose suitable tenants to be in EIP

(b) To identify potential resources which are suitable to be recovered and reused in EIP.

(c) To provide a mathematical tool for evaluating the suitability of an entity to be integrated into an EIP to enhance its stability and efficiency.

1.4 Scope of the Research Goal

The details of the scope according to the objectives of the research are as follows:

(a) Conducting a literature survey on the utilization of oil palm biomass and the concept of EIP in contributing to benefits in terms of the environment, economy and society.

(b) Developing superstructure network to determine the possible tenant's integration for maximizing the profit and reduction of carbon emissions.

(c) Developing a MCDM, in particular the AHP procedure, is employed to develop a tool for optimizing tenants' selection for improving the efficiency and stability of OPB-EIP. In this stage, a mathematical model is formulated that accounts for the consideration of the minimum EIP requirement. Finally, the optimal anchor tenants are selected by a mathematical model using an excel spreadsheet.

1.5 Research Contributions

The significant of this study is the suggestion of several approaches for the development of greenfield oil palm biomass-bases EIP. Currently, there is no guide or tool for biomass-based EIP developers on how to systematically identify tenants to maximise resource recovery simultaneously in an integrated manner. This work will contribute towards the development of a tool for decision-making, which is generic, can aid any EIP developer to select potential entities to be in the oil palm biomass-based EIP site. The outcome of the research will benefit all the stakeholders within EIP including the park's manager, government, and industries in economics, environmental and social.

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