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Biomass Demand-Resources Value Targeting

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A B S T R A C T

With the global awareness towards sustainability, biomass industry becomes one of the main focuses in the search of alternative renewable resources for energy and downstream product. However, the efficiency of the biomass management, especially in supply chain is still questionable. Even though many researches and integrations of supply chain network have been conducted, less has considered underutilised biomass. This leads to the ignorance of potential value in particular biomass species. A new Demand-Resources Value Targeting (DRVT) approach is introduced in this study to investigate the value of each biomass available in order to fully utilise the biomass in respective applications. With systematic biomass value classification, integration of supply chain based on biomass value from biomass resources-to-downstream product can be developed. DRVT model allows better understanding of biomass and their potential downstream application. A simple demonstration of DRVT approach is conducted based on biomass resources in Malaysia.

1. Introduction and overview of biomass supply chain system

1.1. Introduction

Sustainability has been the main focus for most of the researchers in order to reduce environmental pollution. In Malaysia, energy demand increased about 66.5% from 1999 to 2009 [1]. Many attempts have been done by Malaysia government since the Eight Malaysia Plan in 2001 [2] to promote and encourage the development in sustainability, such as 5th Fuel Diversification Policy in 1999 [3] and Biomass Power Generation & Cogeneration Project (BioGen) in October 2002 [4]. Nevertheless, none of above managed to revolutionize the tradition system. Many works have been conducted such as process integration and synthesis on renewable resources, especially in energy industry to ensure the system is self sustainable [5]. Duić et al. proposed a RenewIslands methodology to create network mapping to provide energy supply to islands via renewable resource [6]. More works have been conducted to produce energy from renewable resources via various technologies which are well discussed by Orhan et al. [7]. However, along the development in renewable resources, ethical issue on converting food crops into energy or chemical product has arises [8]. Thus, currently, more researches are concentrating on non-food crops, especially biomass. According to Mohammed et al. [9], only about 10% of the whole palm oil tree consists of palm oil while remaining is palm biomass; while about 20% of pineapple is canned for nutrition usage and the rest are produced as biomass [10]. Although numerous studies had been conducted, implementation of biomass technology is still questionable.

1.2. Overview of biomass supply chain system

Current biomass supply chain systems are studied. Below summarized highlights from literatures that closely related to biomass supply chain system and model. Discussions are focusing on the methodologies or approaches proposed by respective researchers to optimise biomass supply chain system.

In 2001, Nilsson and Hansson [11] proposed that cereal straw and spring-harvested reed canary grass have similar material characteristics. Therefore, a supply chain modelling is conducted by introducing reed canary grass into straw-fired district heating plants as alternative fuel to reduce cost and increase supply reliability. Similarly, in 2012, Zhang et al. [12] investigated the biofuel production supply chain by introducing pulpwood as new feedstock. The effects of biomass co-firing on gasification based hydrogen production supply chain with various feedstocks are assessed [13]. The different types of feedstocks consist of coal only, or mixture of coal with sawdust or wheat straw. Each of the papers evaluates the effect of the biomass industry supply chain by introducing new species of biomass into the system. However, number

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Nomenclature

Set

I	resources
J	technology
K	demand
M	material (biomass and product)
E	element properties

Variables

RtoT (*i*, *m*, *j*)	mass of each material transported from resources ***i*** to technology ***j***
TtoD (*j*, *m*, *k*)	mass of each material transported from technology ***j*** to demand ***k***

Parameters

Resource(*i*, *m*)	material *m* availability at each resources ***i***
Element(*m*, *e*)	element properties ***e*** for each material ***m***
E_upper(*e*, *j*)	upper bound of element properties ***e*** at each technology ***j***
E_lower(*e*, *j*)	lower bound of element properties ***e*** at each technology ***j***
Demand(*m*, *k*)	demand of material ***m*** at each local demand ***k***
Distance_RtoT(*i*, *j*)	distance from resources ***i*** to technology ***j***
Distance_TtoD(*j*, *k*)	distance from technology ***j*** to demand ***k***
Transcost	transportation cost of material per tonne per km
TTranscost	total transportation cost (RM)
Value (m)	selling value of respective material ***m***

Equations

MatRecT(*m*, *j*)	material m received at each technology ***j***
TMatRecT(*j*)	total material *m* received at each technology ***j***
MatGenT(*m*, *j*)	material *m* generated/produced at each technology ***j***
EleRecT(*m*, *e*, *j*)	element properties of each material (***m***, ***e***) received at each technology ***j***
Cost_TtoJ(*i*, *j*)	transportation cost from resources ***i*** to technology ***j***
Cost_JtoK(*j*, *k*)	transportation cost from technology ***j*** to demand ***k***
Profit	gross profit without consideration of transportation cost (RM)
Net_Profit	net profit of the system (RM)

of new biomass species to be introduced is always limited by the knowledge and understanding of respective biomass, as well as the technology. Therefore, the efficiency of implementing underutilised biomass is limited.

On the other hand, other researchers have conducted biomass supply chain optimisation based on logistic issue. An overview of integrated supply chain including location, inventory, and transportation issue of biomass-to-biorefinery industry was conducted [7]. In biomass industry, transportation of biomass in logistic is always one of the highest cost [14,15]. Researchers performed cotton-stalk biomass supply chain modelling in Thessaly with collection–transportation model that considers different logistic methods, and warehousing model [16]. This study concludes that optimum logistic methodology requires farmers to engage in the logistic network. Problem in biomass storage in logistic network of biomass industry is tackled by Rentizelas et al. [17], by introducing a multiple biomass supply chain model. Study shows that multiple biomass supply chain enables reduction of storage space and hence reduces logistic cost in biomass storage. In 2013, an analysis of correlation between transportation cost and industrial coexistence is carried out [18]. In biomass logistic, profit-cost ratio is subject to the amount of biomass purchased by a processing plant or industry. The study suggested that, if an industry requires a large amount of biomass resources that equal or more that than biomass resources available in the system in order to achieve an acceptable profit-cost ratio range, this will cause limitation of industry in the system as resources in not sufficient for industrial demand.

Besides introducing new species of biomass into the system or optimisation in logistic network, researchers combined multi-biomass supply chain model with Tri-generation with district heating and cooling technology for system optimisation based on the demand [19]. This type of modelling approach allows an evaluation of efficiency of the supply chain model with multiple advance features. On the other hand, Lam et al. performed an optimisation model in biomass supply chain by minimising carbon footprint [20]. This model is very practical as an environment protection tool. Ng et al. has demonstrated the feasibility of Waste-to-Energy of municipal solid waste in varies size of area with the consideration of system economics and carbon footprint [21]. The study shows that a medium low size (neighbourhood) of the system results optimum profit [21].

Many integration techniques have been applied in biomass supply chain, however, maximum value of the biomass are not been fully utilised due to poor understanding of it is varies applications. For example, Empty Fruit Bunch (EFB) is mostly used as mulching in many palm oil mills for soil nutrient recovery [22,23] with fact that EFB can be converted into high value product, such as fertiliser, sugar, ethanol and power. These options should be considered in supply chain model for optimum system. On the other hand, biomass with high availability but less utilisation such as forestry residues, wet waste from daily activities, tree branches and energy crops should be in the consideration of biomass supply chain development. These classified as underutilised biomass.

From overview above, the means of optimisations are mainly conducted via several aspects: (i) introducing new biomass species, (ii) solving logistic problem, and (iii) minimising environmental pollution. None of the literatures have considered limitation of supply chain model in biomass selection to include underutilised biomass into the system. Similarly, Cucchiella and D'Adamo have conducted analysis on various supply chain modelling approach, and none of the literatures have looked into the potential value of each biomasses [24]. Therefore, this study is essential to fill the gaps, especially for underutilised biomass.

In order to fully understand the applications of each biomasses and optimised their potential value, a new Demand-Resources Value Targeting (DRVT) approach is introduced. The main advantage of this integration approach is it allows proper study and analysis of each biomass species and fully utilise their value through a systematic selection via biomass supply chain model. A conceptual case study is presented in this paper to demonstrate the advantage of DRVT approach. As the case study is based on the biomass industry in Malaysia, selection of biomasses focus on oil palm industry due to the highest resources availability with more than 3.88 million hectares of palm oil plantation [22] and Malaysia be one of the world's largest in palm oil production with total world palm oil production at about 41% in 2008 [25], 39% in 2009 [10], and 47%