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Editor
Dr Leon Pretorius

Co-Editors
Dr Yasser Hosni
Dr George Alex Thopil

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THE MAIN CRITERIA OF BIOMASS SELECTION FOR ENERGY GENERATION IN BRAZIL

AMOLNUT KRAIPHANONT
Aston Business School, Aston University, Birmingham B4 7ET, UK
kraiphaa@aston.ac.uk

BRENO NUNES
Aston Business School, Aston University, Birmingham, B4 7ET, UK
b.nunes@aston.ac.uk

DAVID BENNETT
Chalmers University of Technology, 412 96 Gothenburg, Sweden
david.bennett@chalmers.se

ABSTRACT

The principal aim of this paper is to examine the criteria assisting in the selection of biomass for energy generation in Brazil. To reach the aim, this paper adopts case study and survey research methods to collect information from four biomass energy case companies and solicits opinions from experts. The data gathered are analysed in line with a wide range of related data, including selection criteria for biomass and its importance, energy policies in Brazil, availability of biomass feedstock in Brazil and its characteristics, as well as status quo of biomass-based energy in Brazil. The findings of the paper demonstrate that there are ten main criteria in biomass selection for energy generation in Brazil. They comprise geographical conditions, availability of biomass feedstock, demand satisfaction, feedstock costs and oil prices, energy content of biomass feedstock, business and economic growth, CO_2 emissions of biomass end-products, effects on soil, water and biodiversity, job creation and local community support, as well as conversion technologies. Furthermore, the research also found that these main criteria cannot be grouped on the basis of sustainability criteria, nor ranked by their importance as there is correlation between each criterion such as a cause and effect relationship, as well as some overlapping areas. Consequently, this means that when selecting biomass more comprehensive consideration is advisable.

Keywords: Biomass, Energy Generation, Brazil, Biomass selection

INTRODUCTION

CO_2 emissions from conventional energy sources consisting of oil, coal and natural gas are the principal factors causing climate change. Although new reserves of oil and gas are being found from shale rocks and consumption is depressed as the world economy slows down, the global population will increase up to 9 to 10 billion leading to higher energy demand (BP, 2015). With the increasing long-term energy consumption and the fact that mineral resources are finite, oil production is projected to peak before 2020 and eventually deplete. Against this background it can be seen that there is a pressing need to find alternatives to fossil fuels. The main alternatives are derived from natural resources, or renewable energy sources, namely: solar, hydro (including tidal and wave), wind, and biomass. These are considered key to face the World's energy supply challenges.

Biomass is primarily produced from natural "wastes". Therefore, its input is "free" or, at least, inexpensive, and in turn it helps reduce these natural wastes which would otherwise be disposed of at landfill sites. Other benefits can include flexibility to meet various requirements of energy demand, and storability (Sims, 2004). It can also lessen reliance on fossil fuels, especially from imported oil (Ericsson and Nilsson, 2006; Hoogwijk et al., 2003). However, certain issues regarding biomass applications, distribution and utilisation still hinder its enhancement. These factors imply that an initial and concise selection of appropriate biomass types in a specific area for a particular aim can help reduce risks particularly on investment (IRENA, 2015), to increase its demand, decrease reliance on fossil fuels, and finally mitigate climate change issue.

According to REN21 (2015), Brazil is one of the world's leading biomass power generators and biofuels producers. The country has placed a high emphasis on biomass since the 1970s (Hall and Overend, 1987). It has many of the most advanced implementation programmes in the world concerning the use of biomass (Lora and Andrade, 2009). It has also plentiful resources to produce biomass energy, including from energy crops such as sugarcane, soybean and corn, to residues from a wide range of agricultural yields. Brazil also possesses the world's second largest forest (FAO STAT, n.d.). Nevertheless, with the expected growing global population and energy demand, it is a challenge to Brazil to match this rapid pace. Certainly, effective energy management has a critical role to play in and studying the way the country has selected biomass energy as well as initiating a set of selection criteria could help it reach this target more quickly.

The above mentioned issues stimulated the authors' interest in biomass selection for energy generation in Brazil. As a result, the principal aim of this paper is "to examine the criteria enabling selection of biomass for energy generation in Brazil". Despite certain interlinkages with fields such as engineering, chemistry and biology, this paper focuses principally on business and technology management, and its analysis is from these perspectives.

LITERATURE REVIEW

The objective of this section is to critically review the existing literature associated with selection criteria for biomass and its importance. This will deal with the importance of establishing selection criteria and the criteria that researchers consider as significant.

Selection Criteria for Biomass and Its Importance

When selecting suitable biomass for specific areas, selection criteria are of importance. Wang et al. (2009) note in their review that to select the most appropriate energy options, evaluation criteria need to be developed to which priority should be given. They can also be helpful for decision makers who search for the integrated performances of other alternatives. Pohekar and Ramachandran

(2004) further emphasise the significance of selection criteria that in spite of the widespread promotion of renewable energy for different applications, the improved technologies for energy production, and the more intense competitiveness with other conventional energy, renewable energy contribution is considered modest. Consequently, it is preferable to formulate different concepts especially of energy planning so that decision makers can pinpoint and remove obstacles hindering the energy to become major sources in the future.

Scott et al. (2012), whose review systematically categorises existing literature to point out current issues and challenges within the renewable energy industry, reveal that main criteria academics usually view as significant for biomass selection is sustainability, with some other specific criteria also employed in considerable studies. With regard to sustainable development, consisting of economic, social and environmental aspects, they also argue that the criteria can attract substantial attention from academic circles as they are either presumably the universally acceptable indicators, or built upon the basis of viewpoints of local decision makers or planners. Wang et al. (2009) determine that evaluating sustainability of energy planning should come as a precondition of supporting sustainable development where evolving monitoring criteria can assist in exploration for economic, social and environmental impacts.

Wang et al. (2009) compile a list of sustainability criteria and suggest that economic criteria can take investment as well as operation and maintenance (O&M) costs into consideration. Investment cost refers to that associated with machinery, installations, construction and engineering services. Whereas operation cost is concerned with wages of employees, the energy itself, as well as products and services for operating energy systems. Maintenance cost is related to energy system life span coverage and prevention of errors tending to halt the operation, in agreement with Gerssen-Gondelach et al. (2014), who address the problems regarding investment and O&M costs between biomass and fossil generated heat. In terms of social aspects, Wang et al. (2009) conclude that social acceptability and job creation are two distinct keys. The former indicates opinions from local population or community on energy systems and projects. This is in accordance with abovementioned Pohekar and Ramachandran (2004). Having a meaning in itself, the latter highlights whether the new energy schemes would create jobs for the local and improve their quality of life. According to Wang et al (2009), CO_2 emissions and land use are also key indicators for environmental criteria. They note that the first issue is focused by considerable governments, researchers and academics, thus, needs to be considered as a criterion. For instance, McKendry (2002) regards biomass as more environmentally friendly energy owing to fewer or no CO_2 emissions when comparing with fossil fuels. Puppán (2002) argues for biomass as the emissions from the atmosphere is proven to be absorbed when biofuel crops grow. Price (1998) discovers that the majority of CO_2 could be offset by biomass-based power. The second subject Wang et al. (2009) pointing out implies not only land required for energy plant construction, but impacts of the plant on environment and landscape as well.

In practice, a significant number of researchers adopt sustainability criteria when carrying out energy selection or planning studies. Aiming to set targets for biomass energy planning and decision making for a South African biomass-electricity plant case, Beck et al. (2008) conclude that when the underlying trade-offs between the sustainability indicators can be pinpointed, it is easier to satisfy energy goal set by the local government. Cobuloglu and Büyüktahtakın (2014) who intend to provide criteria for policy makers and farmers summarise sub-criteria of each criterion owing to the lack of sufficient information from the studies prior to theirs. Under the economic consideration, due to the focus on biomass crop type selection of their research, investment, operation and maintenance costs to which Wang et al. (2009) give priority are excluded. Instead, they consider the costs correlating with land preparation, mechanical equipment, production, storage, and transport. They also involve CO_2 emissions as a sub-criterion in environmental aspects. Under these aspects, they and Escobar et al. (2009) believe soil and water quality as well as food security, which is taken as a sub-criterion under the social prospect by Cobuloglu and Büyüktahtakın (2014), should also be noted. They finally indicate that their future research will include interview with experts to specify weights of each criteria.

In line with the three sustainability pillars, certain authors take technological aspect into consideration as well. For instance, sketching the map for biomass-generated electricity technologies to assist policy makers in Greece, Doukas et al. (2006) consider the capability of technologies for conversing primary energy sources to electricity, stably remaining the quality of energy produced without the effects of natural factors such as sunlight, adapting themselves to the local conditions as well as the maturity rate of the technologies as sub-criteria. They point out that if the criteria were differently elected, the outcomes might be different, and argue that as a result of taking these four criteria into account, the evaluation has become more lucid.

Some academics omit the four criteria yet put emphasis on other specific factors. López et al. (2008) take technical aspect into account so as to prove that biomass-based power generation systems can become technically and economically possible. The study finds that by considering the technical constraints of the network, a satisfactory planning strategy can be devised. Assessing energy use of distributed biomass resources, Alfonso et al. (2009) regard logistics as a key factor and suggest that availability, seasonality, quantity and quality of biomass sources, the capacity, costs and obstacles of existing technologies for biomass-generated heat, power and fuels, emissions of CO_2, as well as end-customer quantification should also be analysed as minor indicators. Despite the divergent factors, some of them can be perceived as sub-criteria in certain studies. For example, attention to emissions of CO_2, one of the most controversial problems in the field of renewable energy, is particularly paid by McKendry (2002), Price (1998), and Puppán (2002) mentioned above. With these distinct considerations, Alfonso et al. (2009) conclude that the findings have become favourably variant.

METHODOLOGY

The main methods used in undertaking the empirical research for this paper are a Delphi survey and case studies. In this section the two methods are described and their application discussed.

The Delphi survey

Questionnaires are most suitable when researchers aim to study attitudes, beliefs, and opinions about particular topics (Phillips et al., 2013). Participation from experts to voice their opinions about the criteria is thus a key to fulfil the aim of this paper. The technique adopted was Delphi, a method designed to arrive at a consensus of opinion on a particular real-world subject from experts through a series of questionnaires. The fact that the questionnaires are conducted for several rounds, during which every respondent has an opportunity to review his/her own and other panellists' previous responses (feedback), and unnecessarily has to provide the same responses, depending on their interpretation of the feedback (Hsu and Sandford, 2007), allows researchers to eliminate minor opinions and reach consensus with more accuracy. Participants have to remain anonymous (Bell and Bryman, 2007).

The Delphi technique has advantages and disadvantages. The method can reduce anonymity of respondents in groups where there are dominant participants, but also it prevents biased opinions amongst participants (Dalkey, 1972). Moreover, confidentiality issue can also be minimised due to the difference in locations of respondents as well as the use of electronic tools such as e-mail to communicate and exchange the information. However, its most evident drawback is time consumed during the survey and evaluation processes (Hsu and Sandford, 2007), which can take up to two months (Delbecq et al., 1975). Another disadvantage is the possibility of low response rates as well as the consistency and the quality of the responses. It is probable that researchers will never receive the reply back whatsoever or some of the respondents may discontinue the participation. Therefore, researchers should be active in stimulating the respondents to avoid low response rates (Ludwig, 1994). Previous authors who adopted this technique can include Rikkonen and Tapio (2009) who conducted a two-round Delphi survey, asking experts to provide agro-based renewable energy scenarios in Finland, and Wu (2016) whose literature aims to seek patent keywords to identify technological trends and evolution via a panel of experts in biofuel field, to prevent bias from subjectivity.

In this paper, the Delphi survey was intended to be conducted in two rounds. However, after sending out the first round of questionnaire to seven experts, who previously agreed to take part in the survey, only two of them responded. The questionnaire also contained a question asking them to suggest other experts to participate in the survey, increasing to ten in total. Unfortunately, answers were never received from these suggested three experts. Consequently, the response rate was very low, merely 20%, resulting in the additional adoption of case study method. The use of the Delphi technique could have produced more accurate data, however, the invaluable opinions from the two experts still significantly contributed to the study.

Case study

A case study research method investigates “a particular contemporary phenomenon within its real-life context which relies on multiple sources of evidence” (Yin, 2003). It is often used to gain insights into and interpret characteristics of companies or individuals in their specific context. Unlike random sampling method, the studied cases are appropriately selected and usually compared with each other to search for a common theme (Mills et al., 2010). This research aims to answer the research questions by gathering information from four case biomass energy companies to find a common theme in factors for selecting their biomass end-products as well as the benefits of those companies view and the challenges they are facing.

General characteristics of case study can consist of flexibility and credibility. It is flexible in terms of the extent of the research topic, data collection method and procedure, as well as selection of the studied cases. Nonetheless, researchers have to be aware of prejudice when selecting the cases. (Hsieh, 2010). Moreover, credibility includes reliability, the extent of consistency of how the cases are agreed on by one person on different occasions or by many individuals (Hammersley, 1992), and validity, the extent of accuracy of how a case can represent social phenomena (Hammersley, 1990). Yin (2013) argues that credibility issues are caused by the lack of an adequately operational set of measures. Some examples of research employing case study methods can be the work of Malico et al. (2016) which assessed the positive impact of utilising residual biomass in a rural area of Portugal and gained insights into real-life decision making projects from case studies, as well as the study of Anttila et al. (2015) which evaluated the practical possibilities and barriers for a forestry biomass business made use of case study as concentrating on the smaller scale would make it more possible to find out some questions such as the availability of the feedstock rather than the whole country.

FINDINGS

This section will be concerned with the presentation of findings. The main points of information helping initiate a set of criteria for biomass energy selection in Brazil include 1) Comparison between four case biomass energy companies and 2) Opinions from experts. The comparison was made to examine the supply side. Opinions from experts who have a wealth of knowledge of and experience in biomass in Brazil will assist in supporting other information.

Comparison between four case biomass energy companies

In this part, a comparison of four case biomass energy companies was made to examine certain similarities and differences between biomass selection criteria. The selection of the case companies was justified by several factors. Firstly, each of the companies is one of the leading producers in the industry they exist. Neste, for example, is the world’s largest manufacturer of renewable fuels from waste and residues whilst being a major biofuel producer in the aviation industry (Neste, 2015). Secondly, they are all multi-national organisations. For instance, although Drax Power Station is located in the UK, the power generator also has an American subsidiary mainly supplying biomass used for electricity generation to the UK company (Drax Biomass, n.d.). The case of Archer Daniels Midland

Company (ADM) is also of interest. Even though it is the world's top agricultural processors, its biofuel profitability declined due to certain external factors which have impacts on biofuel production (Hackman, 2015; Nickel and Prentice, 2015; Polansek, 2015). Raízen was particularly selected as it is part of the joint venture of Royal Dutch Shell, one of the world's leading petroleum producers, and its operating location and feedstock origin are all situated in Brazil (Raízen, 2012; Shell, n.d.). Table 1 summarises comparison between four case biomass energy companies by criteria.

Table 1. Comparison between four case biomass energy companies by criteria

Criteria / Companies	ADM	Drax	Neste	Raízen
1) Operating locations: [a]				
• Inside of Brazil.	✓ (MN)			✓
• Outside of Brazil.	✓ (MJ)	✓	✓	
2) Feedstock origins:				
• Local.	✓ (MJ)	✓ (MN)		✓
• Imported.	✓ (MN)	✓ (MJ)	✓	
3) Biomass end-products:				
• Biodiesel.	✓ (MJ)		✓ (MJ)	
• Ethanol.	✓ (MJ)			✓ (MJ)
• Biomass-based power.		✓		✓ (MN)
• Biomass chemicals.			✓ (MN)	
4) Applications:				
• For residential purposes:		✓	✓	✓
• For industrial purposes:				
- For energy companies.	✓			✓
- For aviation units.			✓	✓
- For non-energy companies (excluding aviation units).		✓	✓	
5) Factors for selecting such biomass end-product(s):				
• To enter the new market.	✓			
• To increase market share.		✓	✓	✓
• To make use of available feedstock.	✓	✓	✓	✓
• To develop existing products.	✓	✓		
• To increase profits.	✓			
• To reduce cost.			✓	
• To meet customer demand.	✓	✓	✓	✓
• To raise shareholder value.		✓		
• To reduce GHG emissions.			✓	
6) Benefits and challenges: [b]				
• Economic:				
- Feedstock availability.		B		
- Strong currency (e.g. USD).	C			
- Cheap imported feedstock.	C	B	B	
- Impact of oil prices	C			
- Economic uncertainties.	C			
- Financial difficulties.		C		
- Increase in product sales.			C	
- High conversion costs.				C
• Environmental:				
- Less environmentally-harmful products.		B & C	B	B
- Less GHG emissions plants.	B			
- Increase in biomass feedstock proportion.			C	
- Effects on land use.				B & C
- Geographical conditions.	B			
• Political:				
- Product lobbying.	C			
• Social:				
- Local community support.		B		
- Displacements of the indigenous.		C		
- Human/Labour rights of employees and suppliers.			B & C	C
• Technological:				
- Patented production technology.	B		B	
- Advanced conversion process.	B			B

[a] MJ = The majority; MN = The minority. [b] B = Benefit; C = Challenge.

Opinions from Experts

Two respondents participated in the survey. The first is referred to as R1 and the other is R2. The participants were asked to state the main criteria for selection of biomass energy generation in Brazil in general, as well as from the viewpoint of supply and demand sides. The answers from each respondent can be found in Table 2.

Table 2. Answers from the respondents from the Delphi survey

Questions/Experts	R1	R2
In general	*Sugar cane is chosen to be raw material for ethanol and cane bagasse is selected for electricity as sugar cane production is "very competitive". In terms of biodiesel, supply chain of soybean, which produces 80% of the fuel, is "very well organised and competitive". "Very competitive" cattle raising allows beef tallow (bovine fat) to produce 15% of biodiesel. Castor bean, jatropha, sunflower, colza, and palm oils can produce only 5% of biodiesel as the production of these crops is "not well organised".*	*Utilisation of biomass residues (as energy sources) can avoid disposal in landfill or rivers which could be otherwise "aggressive to the environment". As biomass plants grow, they absorb CO_2, therefore biomass energy has "zero CO_2 emissions". In some distant areas, electricity grid is inaccessible and fuel transportation is expensive. "Biomass can be an alternative" in those areas. "High volume of residues" are generated from pulp and paper as well as agro-industries. They can be "used as energy sources" and "the surplus can be sold to the utilities". When "in shortage of hydroelectricity", biomass power plant can be activated.*
From the supply side	*Subsidies and tax reduction from PNPB (the National Programme for the Production and Use of Biodiesel) was initiated to stimulate biodiesel production from castor bean, jatropha, sunflower, colza, and palm oils. However, since the production of them is "not well organised", only a small quantity is used for biodiesel production.*	*Due to low density of biomass, "more energy for transportation" to the electricity plant may be required than the amount it can produce and this will "affect the final price of the energy". "Investment" in biomass power plant takes "a long time to be paid off". Certain "supply" of biomass "should be ensured" to cover the time. "Conversion process is hardly adaptable" and "designed for certain types of biomass and certain characteristics" such as bulk density, moisture and ash contents, as well as calorific value. "The price of biomass end-products" is also an important factor.*
From the demand side	*Demand of ethanol and biodiesel is "issued by law". There is 25% of ethanol containing in transport petrol and 7% of biodiesel (B7) mixed in transport diesel.*	*Two points from "In general" were repeated: disposal in landfill or river avoidance, as well as the use of residues as energy source and selling surplus energy.*

DISCUSSION

In this section, each argument starts with suggestions based on the literature, as appropriate. The criteria suggested by the relevant authors will then be linked to the information from the four case companies, the core data in this research, and other supporting information. Opinions from experts will be applied to the arguments only when they are mutually related. It should be noted that the criteria discussed in the section are neither ordered by importance nor alphabetically.

Geographical Conditions

Escobar et al (2009) mention that geographical conditions can affect biomass energy production. Considerable data show that they can create both positive and negative effects. Information regarding one of the case companies ADM (Polansek, 2015) implies that great geographical conditions can increase production volume and simultaneously decrease feedstock costs. Due to its high adaptability to Brazilian soil, water, and climatic conditions (Soccol et al., 2005), ethanol from sugar cane can be contributed to 42% of fuel consumption though the crop occupies only 1% of Brazilian land (Sugarcane, n.d.). Excellent geographical conditions also help expand eucalyptus plantations in Brazil to over 71% of total forestry area (Gibson, 2011), making it the major wood and potential feedstock for biofuels in the country. In addition, as corn planting in Brazil is often done after soybean harvesting (Freitas Jr, 2015), a bumper corn harvest can balance the decreased soybean production due to heavy rain (Newman and Lewis, 2015) for those farmers who grow both crops.

In contrast, poor topographical conditions such as droughts can have drastic impacts on the overall cultivation, for example, as occurred to soybean production during summer in

2015 in the country (Agrimoney, 2015). Yet, a more severe drought in 2001 could even cause shortage in hydroelectricity, forcing residents to cut down electricity uses (Rohter, 2001). Even though biomass feedstock was indirectly affected, the energy mix was diversified to other renewables including biopower, which is used when in shortage of hydropower (see Table 2). From this, "Geographical conditions" should become one of the main criteria for biomass selection.

Availability of Biomass Feedstock

Alfonso et al. (2009) consider availability of biomass raw materials to be a criterion for energy production. ADM and Drax also chose their biomass-end products on the basis of the considerable volumes of available biomass raw materials (see Table 1). ADM (n.d.) is the world's largest corn processor, thus, undoubtedly has sufficient corn for ethanol production. Drax can make use of the excessive forestry residues of 22 million tonnes per year in the US, where its subsidiary exports the feedstock from, whilst demand for forestry residues is only 15 million tonnes (Evans, 2015). Supporting data also demonstrate that biomass feedstock in Brazil has been chosen from its wide availability. Firstly, ethanol is mainly produced from sugar cane, of which bagasse can be further used for electricity production, and the majority of sugar cane globally was produced in the country in 2013 (Statista, n.d.a; n.d.b), thanks to its well organised supply chain (see Table 2). Secondly, soybean is a principal raw material for biodiesel production and the country was presumably the world's leader (Schober, 2015). Lastly, despite using corn as minor feedstock for ethanol production, Brazil was the third largest corn producer in the world (Statista, n.d.c.). From this, it is obvious that Brazil has efficiently made use of its abundant biomass feedstock as biofuels and bioelectricity are produced from the widely available feedstock in the country, and therefore, "Availability of biomass feedstock" should be taken into account as a criterion for biomass energy selection.

Demand Satisfaction

Table 1 reveals that every case company gives priority to meeting customer demand when selecting their biomass energy. ADM (2014) believes innovation in product development can satisfy evolving customer demand. Drax and Raízen aim to meet energy demand through high volumes and production of biomass raw materials (Evans, 2015; Shell, 2011). To fulfil various customer needs, Neste (n.d.) offers a range of biofuels. This point can also be reflected from Brazil's energy programmes. Even though the National Alcohol Programme (PROALCOOL) was launched owing to increasing oil prices (Soccol et al., 2005), when closely examined, the ultimate goal ethanol was selected as an oil alternative was to quickly satisfy domestic energy demand. The effect of severe droughts on electricity demand, later leading to the application of the Incentive Programme for Alternative Sources of Electric Energy (PROINFA), is more evident since residents were highly affected (Rohter, 2001). Consequently, demand satisfaction is imperative to both the supply side and policy makers (governments and related institutions).

Furthermore, Table 2 reveals that ethanol and biodiesel demand in Brazil is set by law. Since pure petrol is no longer available (Matsuoka et al., 2009), leaving a few options including 27.5% of ethanol (Rabello and Ewing, 2015) as well as 5% and 7% biodiesel blend (biodiesel B5 and B7 respectively) (Kotrba, 2014) for end-customers, demand of biofuels can be guaranteed. When biodiesel proportion was increased to 7%, both demand and production were expected to escalate (Ribeiro, 2014). It can be seen that when biofuel proportion is mandatory, the demand and production have a considerably close relation, and two possible variables affecting them are biomass feedstock costs and oil prices (due to a large proportion of petrol in the fuels) which will be discussed later. To conclude, this point should be considered as one of the criteria.

Feedstock costs and oil prices

Wang et al. (2009) point out that the costs of the energy itself is one of the indicators for energy selection and it can be interpreted as feedstock costs. From Table 1, three companies agree that cost-effectiveness of their products is a key to satisfy customers. Drax (n.d.) generates reliable biopower from imported low-value forestry residues. Neste (n.d.) imports inexpensive palm oil from Malaysia to produce high quality biofuels. Raízen supplies locally available feedstock (Shell, n.d.), presumably cost-effective due to the low transportation cost. Interestingly, Drax claims that its imported feedstock can be cost-efficient as it is shipped in bulk, even though across Atlantic (Drax Biomass, n.d.). Perhaps, derived from forestry waste, its majority of feedstock can lower its production cost, balancing the overall costs. Yet, Table 2 shows that as biomass has low density, transportation cost is unnecessarily low. In general, low feedstock costs can increase biofuel demand/production. Four years after PROALACOOL (Soccol et al., 2005), ethanol production experienced an explosive growth (Puppim de Oliveira, 2002). On the contrary, rising feedstock costs can affect the production, as occurred to Brazilian ethanol producers before the increased ethanol proportion (Rabello and Ewing, 2015).

In addition to feedstock costs, oil prices have played an enormous influence upon the Brazilian society. The turning point for a formerly heavy oil importer as Brazil was oil crisis in the early 1970s and the country transformed itself into an energy self-reliant country, becoming an ethanol society, thanks to the increased oil prices. When the government allowed the price increase in petrol and diesel, ethanol demand was expected to rise (Nogueira and Blount, 2015). Obviously, these two variables can possibly affect customer demand and production. As a result, “Feedstock costs and oil prices” should also be included as one of the selection criteria.

Energy content of biomass feedstock

According to Table 1, Neste and Raízen select the biomass raw materials based on their high energy content contained. Neste (n.d.) believes that palm oil is potential oil feedstock. Raízen holds an opinion that Brazilian sugar cane can produce more ethanol than corn in the US and wheat in Europe, considering the same size of land (Shell, 2011; Wesleyan University, 2012). It is possible that this benefit might be the reason Brazilian government chose sugar cane for ethanol production in the first place, in addition to other criteria. On the contrary, Table 2 shows that low density of biomass can impact the final price of the energy. Certainly, energy producers aim to produce as high volume as possible whilst investing as low as possible. Hence, properly choosing high energy density feedstock will provide them a competitive advantage and “Energy content of biomass feedstock” can be seen as a biomass selection criterion.

Business and economic growth

It was summarised in Table 1 that the goal of ADM is to increase profitability whereas the remaining companies share the same target, that is, to increase market share. ADM focuses more on profitability rather than sales (Hackman, 2015). Drax (n.d.) aims to commit to sustainability principles and become a leading sustainable electricity generator. Neste (n.d.) puts high emphasis on sustainability to increase business growth. Raízen tries to grasp the opportunity of its high production and sales to become a leader in Brazilian ethanol industry (Shell, 2011). Profitability is naturally of significance to many companies. It is, therefore, crucial to remain business growth, otherwise businesses cannot survive and are forced to close down. At a macro-scale, Brazil also pays high attention to economic growth. PROALCOOL was initiated, on one hand, to reduce reliance on oil import, on the other hand, to remain the economic growth (Rosillo-Calle and Cortez, 1998). Apparently, business and economic growth is also a significant factor that should be included in the criteria, meaning biomass raw materials should not be selected unless they can increase or maintain business and economic growth.

CO_2 emissions of biomass end-products

This point is likely to be one of the most controversial issues for the whole biomass energy industry. Frequently, the supply side claims that biomass end-products are less environmentally harmful than fossil fuels and can help reduce CO_2 emissions (Puppán, 2002).. Those who disagree argue that when taking other factors such as transportation and operations preparation into account, it is not less harmful and can generate even more CO_2 than fossil fuels (Haq, 2002). The argument also applies to the three case companies who consider their products can help reduce CO_2 emissions (see Table 1**.**). Neste (n.d.) claims that utilising its biofuels can improve air quality. Drax and Raízen agree that CO_2 emissions are captured as the plants grow (Drax Biomass, n.d.; Shell, 2011), which was supported by expert R2 (see Table 2**.**). However, Drax was criticised by some NGOs that its biomass feedstock, produced from wood pallets, is concerned with deforestation, and transatlantic feedstock shipping is considered unsustainable (Biofuelwatch, 2015a; 2015b). With this debate being taken place, CO_2 emissions of biomass end-products should definitely be a criterion for energy selection.

Effects on soil, water and biodiversity

Another disputable issue within biomass energy industry is effects on soil, water and biodiversity. They can create both positive and negative impacts, yet the latter is more controversial. According to Escobar et al. (2009) and Wang et al. (2009) negative effects on soil, water and biodiversity can include deforestation, water shortage, soil degradation, and land required. Table 1 shows that even Raízen, who is confident in its sound land control system developed to ensure that fertilisers and pesticides are used without offsetting the environment, still considers maintaining the quality of land and water challenging (Shell, 2011). However, eucalyptus in Brazil might not be the case as the plant can aid protecting soil erosion and offering a shelter to wildlife (Couto et al., 2011). Moreover, from Table 2, expert R2 also mentions the benefit of biomass utilisation to landfill. This can provide some implications for Brazil and, therefore, should also be part of the biomass selection criteria.

Job creation and local community support

Biomass energy production cannot be done without workers and employees. Pohekar and Ramachandran (2004) and Wang et al. (2009) suggest that job creation and quality of life of local community improvement should be included in a social criterion. According to Table 1, three companies place high emphasis on these two points. Drax (n.d.) provides various supports for local businesses and community. Neste (n.d.) encourages human equality in workplace and ensures the well-being of its palm oil suppliers. Raízen (2014) offers training programmes to its employees and promotes safe work environment. The Brazilian government also sees the significant role of humans who help grow the economy. The launch of PROINFA has created an estimate of 150,000 jobs (Prado et al., 2008). When manual cane cutting was prohibited, skill training programmes were provided for cane cutters who were made redundant (Solidaridad, 2014). Furthermore, the purpose of the National Programme for the Production and Use of Biodiesel (PNPB) is to support the family farmers in the impoverished regions in line with promoting biodiesel production (Pousa et al., 2007). It can be seen that these supports are crucial to encourage biomass energy production, both at the industry and the country levels. Thus, job creation and local community support is a key criterion for biomass energy selection.

Conversion technologies

Scott et al. (2012) point out that technology selection attracts considerable attention from academics. Table 1 reveals that three case companies also pay much attention to technology. ADM (n.d.) and Neste (n.d.) gain competitive advantage from their patented technologies. R&D of Raízen (2014) works closely with a world class research centre to ensure its ethanol production efficiency. Evidently, these companies use conversion technologies as tools to satisfy various customer needs and later increase their market share. Therefore, at least from the industry point of view, conversion technologies criterion should be taken into account.

Furthermore, ethanol and biodiesel conversion technologies are considered mature in Brazil. The ethanol conversion technology was developed before PROALCOOL in 1970s (Puppim de Oliveira, 2002). Flex Fuel technology of which engines were more flexible and in turn could satisfy a wider range of customer demand lead to massive sales in Flex Fuel Vehicles (FFV) only five years later (ANFAVEA, 2009). Since PNPB was introduced, the efficient biodiesel chain has also been structured and developed (Pousa et al., 2007). Nevertheless, the technology for biomass-based electricity generation is still in need for further development (Prado et al., 2008). According to Table 2, expert R2 points out that at least one barrier is the slightly adaptable conversion process. Sales are likely to increase if the generation technology can be improved, and this certainly comes with high cost, and one possibility to deal with it is ample biomass supply. Whereas the immature conversion technology will make the biopower prices less appealing and competitive than ethanol and biodiesel, guaranteed biomass supply from low-cost biomass feedstock can balance the overall prices. For these reasons, conversion technologies should be one of the key criteria when selecting biomass energy in Brazil.

CONCLUSION

In-depth analysis has been undertaken and a set of ten criteria for biomass selection for energy generation in Brazil was initiated. The reason these criteria were not categorised into groups such as sustainability was that some of them are closely related or overlapping. Virtually, “Geographical conditions” comes as an essential prerequisite to “Availability of biomass feedstock” and they are connected in a cause and effect manner. Furthermore, “Feedstock costs and oil prices” should also be considered along with “Demand satisfaction” as the former is a factor influencing the latter, as well as “Geographical conditions” since this criterion allows low-cost feedstock. In addition, “Job creation and local community support” can promote “Business and economic growth”. Finally, “Business and economic growth” as well as “Demand satisfaction” can be done by improved “Conversion technologies”, “Availability of biomass feedstock” and “Feedstock costs and oil prices” (see Figure 1).

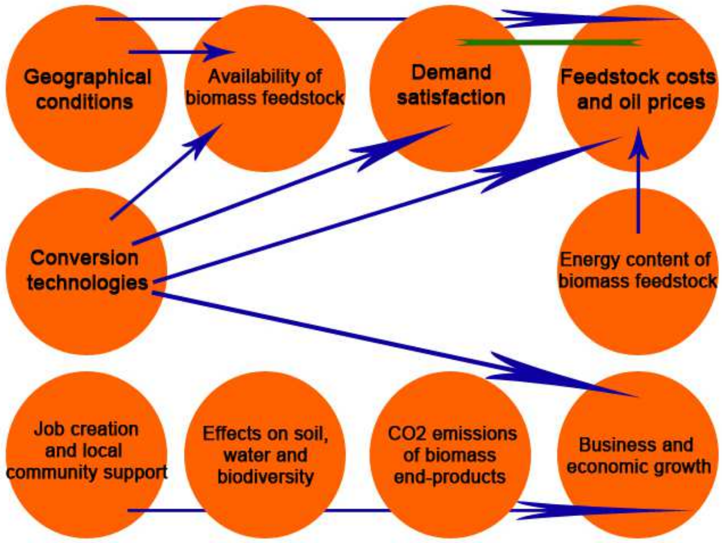

Figure 1. Summary of relationship between criteria

Note: Blue arrows = cause and effect relationship; where arrowheads mean effect. Green arrow = overlapping relationship.

From Figure 1, it should be noted that "Conversion technologies" unnecessarily means a cause of four other criteria and consequently should be considered as the most significant one. Likewise, although "CO_2 emissions of biomass end-products" and "Effects on soil, water and biodiversity" demonstrate no correlation with other criteria, they should not be considered as the least important criteria. Figure 1 simply reveals the relationship, not the rankings of importance. Therefore, when selecting biomass, comprehensive consideration is advisable.

In conclusion, Brazil still has a large potential to grow in the biomass energy industry. For example, it is the world's leading sugar cane producer (Statista, n.d.a; n.d.b) whilst the world's largest ethanol producer is the US (RFA, n.d.), the world's leader in eucalyptus production (Gibson, 2011), and the third largest forestry residue producer (FAO STAT, 2015). This set of criteria can be a useful guideline for all interested parties in Brazil, and in other countries for expanding biomass production capacity, increasing demand, and promoting economic growth. From Table 1., certain points could not be analysed previously either due to the lack of sufficient supporting information, or the situations were out of date, and, consequently, could not become main criteria for biomass selection for energy generation in Brazil. To these issues, as the time evolves and when adequate supporting data can be gathered, they may be able to draw much attention. In addition to this, the criteria and their relationship this study proposes have yet to be scientifically proven. Future research should take these into consideration.

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