Bioenergy Production's Supply Chain and Logistical Problems

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ABSTRACT: When intelligently developed and implemented under favorable circumstances, bio-energy may play a significant role in the coming decades as part of a symphony of renewable energy technologies. One important element in this regard is efficient and effective supply chain and logistics management. This study provides a survey of papers published in English-language peer-reviewed journals between 2000 and 2009 that address the intersection of bio-energy generation with logistics and supply chain management problems. First, descriptive criteria such as journal, year of publication, and study methodology used are applied to the papers. The issues and challenges of designing and operating biomass chains that ensure a stable and competitively priced feedstock supply for bio-energy plants were then divided into two categories: (1) harvesting and collection techniques, storage, transportation, and pre-treatment techniques, and (2) overall supply system design. Despite the fact that biomass supply chains for energy usage vary in size, design, and operation, the most important problems relating to supply chain management and logistics for bio-energy generation have been recognized. The results are addressed in light of bioenergy's potential as a long-term renewable energy source.

KEYWORDS: Biomass, Biodiesel, Bio-Energy, Logistics, Supply Chain Management

1. INTRODUCTION

A lot of hopes Bio-energy is primarily thought to decrease CO_2-emissions, conserve non-renewable resources, improve energy security, and promote regional development and rural diversification by providing employment and income in undeveloped rural regions. Critical voices, on the other hand, have become stronger in recent years on the academic and public arena, pointing to the negative sustainability balance of some types of bio-energy from a full lifecycle viewpoint. One example of a controversial bio-energy form is bioethanol manufacturing [1]. If agricultural climatic conditions are good, the environmental life-cycle balance of bio-diesel and ethanol is considerably more favorable than that of fossil fuels. A study of research comparing bio-ethanol systems to conventional fuels on a life-cycle basis, on the other hand, came to the conclusion that the balance of environmental effects of existing biomass-based liquid fuels is unclear. Apart from the undeniable benefit of reducing resource use, biofuels' effects on acidification, human and ecological toxicity, and eutrophication have been assessed more negatively than positively. Furthermore, the energy efficiency of biofuels varies significantly depending on plant species, environment, and manufacturing method: Bio-ethanol made from Brazilian sugar cane produces 8 units of bio-energy for every unit of fossil fuel used in the manufacturing process [2].

The efficiency of biodiesel made from rapeseed in the EU is 1:2.5, whereas bioethanol made from maize in the United States [3] .Apart from the environmental and efficiency concerns stated above, there are many more issues associated with bio-energy, of which only a few may be discussed within the scope of this paper: Competing land uses for biomass production for food, materials, and energy create challenges [4]. The most severe consequences of this rivalry are seen mainly in poorer nations. Because the produced energy crops are commodities to be sold to the industrialized world, food shortages and fuel poverty may be exacerbated in these areas. Furthermore, the production of energy crops has the potential to exacerbate water scarcity in vulnerable areas. Furthermore, converting former grasslands or woods into agricultural areas for the cultivation of energy crops or forest monocultures may result in significant greenhouse gas emissions. In this regard, one extreme example is the conversion of tropical and subtropical rain forests into oil palm monocultures in South Asia, which also damages the delicate soil permanently and may eventually lead to desertification [5].

When assessing bio-energy production, consider the components biomass resources, supply systems, conversion technologies, and energy services from a system viewpoint. In reality, there are many unique combinations of these components, making direct comparisons across various bioenergy systems problematic.

Nonetheless, it is self-evident that providing economically, environmentally, and socially sustainable bio-energy necessitates optimizing the structure and operation of the supply chain/network, which must be tailored to the specific conditions of each production system (climate and topology, feedstock, technologies, and final application). Harvesting, processing, and transporting biomass are important tasks that must be assisted by supply chain and operations management, as well as the use of the most appropriate technology [6].

These considerations reaffirm the importance of supply chain and logistical problems in the deployment of bioenergy production systems, making this a good topic for a study literature review. The current article examines and evaluates all publications on this topic that were published in English-language peer-reviewed journals between 2000 and 2009. The purpose of this article is to organize supply chain management (SCM) and logistical problems in the bioenergy industry [7]. The following is the paper's structure: The approach for the literature review is described once fundamental terminology is defined. Following a descriptive analysis of the paper sample's key characteristics, a systematic review evaluates the problems and challenges of building and managing biomass supply networks for energy consumption. Following that, the results are briefly addressed in the context of bio-energy as a long-term renewable energy source. The Brundtland Commission helped to create one of the most well-known definitions of sustainability, emphasizing that current and future generations have an equal right to fulfill their own needs [8].

The integration of the economically, ecologically, and socially intertwined elements of sustainability into a "triple bottom line." Also, emphasize the three aspects of corporate sustainability, which include the business case (economic), the natural case (environmental), and the societal argument (social). Wood, agricultural and forestry leftovers, energy crops, human and animal feces, as well as industrial and municipal bio-degradable waste, are all examples of biomass for bio-energy [9]. Biofuels are biomass-based solid, liquid, and gaseous fuels. Bio-energy is described as energy derived from bio-fuels (heat, electricity, and movement. Logistics management is defined by the Council of Supply Chain Management Professionals (CSCMP) as "the part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements [10].

2. DISCUSSION

Supply chain and SCM definitions that are widely used and accepted. The supply chain is defined as "a group of three or more entities (organizations or people) actively engaged in the upstream and downstream flows of goods, services, money, and/or information from a source to a customer" by them. SCM is defined as "the systemic, strategic coordination of traditional business functions and tactics across these business functions within a company and across businesses within the supply chain, with the goal of improving the long-term performance of the individual companies and the supply chain as a whole". The current article performs a literature analysis with the primary goal of examining SCM and logistics problems related to bio-energy production systems, with the goal of developing them in an economically, environmentally, and socially sustainable manner.

The main goal of biomass supply chains in terms of energy usage is twofold: (1) Feedstock prices must remain competitive. (2) A constant supply of feedstock must be maintained. In this regard, issues may emerge as a result of the growth cycles of most biomass kinds, unpredictable environmental circumstances like as droughts, and a lack of supply chain players' dependability, willingness, and coordination. Furthermore, the large volumes of biomass required in bio-energy plants make biomass sourcing such a critical and, at the same time, vulnerable activity. Biomass passes through various main operations along the supply chain in order to ensure a consistent and competitively priced feedstock supply for energy conversion plants. Harvesting and collecting, storage, transportation, and pre-treatment methods are the main activities. The entire supply system's architecture helps to coordinate these activities.

SCM and logistical problems in bioenergy production were systematized using categories. Within the examined paper sample, it is clear that the overall system design of bio-energy production chains and biomass transport are the most important problems, followed by biomass harvesting and collection. Although they appear in more than a third of all publications, pre-treatment methods and storage are less commonly discussed topics. The following subchapters present challenges and issues of supply chain and logistics management for bio-energy production, as addressed in the paper sample under review, along the main categories of (1) biomass harvesting and collection, (2) storage throughout the bio-energy chain, (3) transport in the bio-energy chain, (4) pre-treatment techniques, and (5) bio-energy chain design. Harvest and collection of biomass for energy usage are divided into two categories: (1) major choices for harvesting/collecting and then processing biomass, and (2) biomass characteristics that affect harvest, collection, and handling.

Pre commercial thinning, a bio-refinery technique, is of special importance since it removes wood that is of little value for forest product businesses; nevertheless, it involves additional harvest and shipping expenses. Following biomass collection, the most important processing choices are drying, baling, and chipping. After falling, it is standard practice to leave chopped trees at the harvesting site for a few months to reduce their water content. Baling and chipping may usually be done on-site at the harvesting site or at a central collecting location. Baling is an important technique for forest wastes and energy crops like miscanthus because it improves biomass density and makes it simpler to handle during logistical operations, while also lowering the danger of biomass degradation. Chipped biomass is typically immediately transformed to energy, either thermally or chemically, or processed into pellets for transport over longer distances. Advances in forestry harvest and collection technologies should be sought mainly in the important field of selective harvesting, that is, choosing biomass to be harvested while taking into account both ecological and long-term sustainability requirements.

Wet soil, like the availability of harvesting equipment or manpower, has an effect on the possible supply volume of wood. Wood product residues, on the other hand, may be collected directly at the facilities of the wood product sector; similarly, agricultural leftovers can be collected using existing road infrastructure. Another feature of biomass is its short harvest time, which is caused by the seasonality of most biomass forms. Over the yearly cycle, a single annual harvest results in substantial under-utilization of capital-intensive apparatus and equipment, raising operating expenses. Furthermore, yearly harvesting requires more effort overall than perennial harvesting. A shorter harvest time also means bigger stocks, which means higher storage costs and dry matter losses. Aside from these factors, the frequency with which various crops are harvested may have a significant effect on how different crops are accepted by farmers in underdeveloped nations like Tanzania. Multi-year crops, such as Jatropha, which produce seeds only one to two years after planting, pose significant financial difficulties for impoverished farmers.

The following three categories may be used to categorize the storage issues addressed in the examined paper sample: (1) Storage reasons throughout the biomass chain, (2) storage costs and hazards, and (3) storage alternatives. The main purpose for biomass storage along the biomass chain is to ensure that biomass supply and bio-energy plant demand are properly matched. The short harvesting time of most biomass types, as well as the widely dispersed geographical distribution of biomass throughout the country, need storage to guarantee a constant supply of feedstock for bio-energy plants or bio-refineries. In general, the greater the number of storage units required as buffer capacity, the shorter the harvest season. If the plants themselves do not have adequate storage capacity, storage terminals may be utilized to feed several plants. Closed-type warehouses near the bio-energy plant may be utilized to dry the stored biomass at the same time, for example utilizing the facility's exhaust heat. The cost of storage is mostly determined by the store's location and kind.

Furthermore, the amount of biomass to be kept and the length of time it will be held are important cost considerations. The main hazards of storage that may be reduced by selecting the right storage method are (1) deterioration of biomass quality and (2) dry matter losses in stored biomass. Biological shrinkage degrades biomass quality, resulting in bulk without yield. The number of storage stages and the storage length affect solid biomass dry matter losses, pointing to the advantages of (wood) pellets in this regard; wood pellets may be kept for long periods of time without substantial dry matter losses. In-field storage of canthus to decrease transportation emissions; however, this necessarily results in greater losses during storage. A bioenergy supply system's fundamental preconditions of operation are the general legal and infrastructure environment in which it functions. The significance of transportation legislation in this regard. Infrastructure, particularly road characteristics, is mentioned by several writers.

Poor infrastructure, particularly in developing nations like Tanzania, may provide a significant barrier to attracting international investment in bioenergy systems. Other legal and infrastructure characteristics, on the other hand, are regarded important in the industrialized world; in Austria, for example, road pricing has an effect on transportation expenses. Other important transit factors include biomass bulk and volume, as well as carrier capacity. Maximizing truck cycle capacity by increasing biomass bulk density while maximizing vehicle payload usage reduces transportation costs, associated environmental pollutants, and societal burdens. Additional important factors include truck driver labor expenses, which are mainly determined by trip duration, as well as vehicle and diesel fuel prices. Because the sites of biomass harvesting and collection, as well as the locations of plants that convert biomass into energy, are seldom the same, transportation efforts are needed, which have both environmental and social consequences.

Transport emissions are closely related to transport distances, i.e. the degree of proximity between the biomass site and the conversion facility, from an environmental standpoint. However, it is important to remember that the method of transportation has a significant impact on emissions. Long-distance shipping, for example, emits much less CO_2 per unit of length than vehicle transport, demonstrating that biomass carried from Scandinavia to conversion facilities in Holland is nevertheless environmentally friendly. The research finds that bio-energy may be exchanged across large distances if contemporary transportation modes are used, since the extra emissions from long-distance shipping are negligible. According to the study, lorry transit contributes very little to nitrogen oxide and particle emissions in compared to field harvesting and tractor activities. From a social standpoint, regular truck transfers that cause traffic congestion may readily elicit opposition from the towns and people impacted.

Rail transportation lowers the number of loads required and therefore improves the situation, while pipeline transportation would lessen the community's negative effects from biomass transportation. However, since the carrier fluid substantially lowers the biomass's heating value, carrying biomass via pipeline is not compatible with burning for energy conversion. Drying lowers, the moisture content, increasing the efficiency of combustion and gasification processes. Furthermore, drying makes biomass more resistant to decomposition and fire risks, while also passing a cost benefit down the supply chain since drying-induced weight reductions make handling and shipping easier. Ambient drying, or drying biomass in the open air without the use of electricity, is a cost-effective method; however, its efficiency is highly dependent on the climatic zone and season.

Given the wide range of different bio-energy system designs and the relatively high flexibility with which they can be operated, a sustainability assessment must look at the specific conditions of the individual bio-energy system under consideration, taking the entire system into account, including biomass resources, supply systems, conversion technologies, and systems. In addition, there are assessments of sustainability. The tight interconnectedness of actors in bio-energy chains necessitates supply-chain-wide co-ordination, relational governance, and collaboration in the same way that well-designed logistics planning, scheduling, and managing are undisputed key capabilities of competitive bio-energy systems, as evidenced by our literature sample. Inter-organizational resources and capabilities arising from supply-chain-spanning collaboration to ensure simultaneous economic, environmental, and social performance on a total life-cycle basis for bio-energy, such as acquired learning capabilities, are likely to become sources of sustained inter-organizational competitive advantage.

Due to their characteristics of being socially complex, causally ambiguous, and historically grown, these resources are particularly difficult to imitate by competitors. They must consider the "triple-bottom line," which includes and integrates economic, ecological, and social/human aspects of sustainability. Pillarization lowers biomass moisture content while increasing bulk density. As a result, wood pellets, for example, have a rather high heating value. In contrast to untreated biomass, they may be directly substituted and have a greater combustion efficiency. Simultaneously, handling and transport appropriateness are improved; this has special implications for longer transport routes; and associated costs are lowered. Longer storage periods may be achieved without significant dry matter losses. The disadvantage of is the high expenses in contrast to purely mechanical processes such as baling. Torre faction and pyrolysis are two very easy processes such as ensiling or drying. These technologies are still in the early stages of development, with unknown economic and technical performance characteristics. Torre faction in conjunction with palletization and palletization are obviously more efficient in terms of energy efficiency than the production of pyrolysis oil through pyrolysis is economically appealing on a small scale; therefore, pyrolysis represents a technology that is suitable for local deployment.

The overall design and operation of bio-energy systems are critical supply chain concerns. For properly evaluating bio-energy production systems, the majority of studies emphasize that the whole supply chain, with its interactions and feedback connections, rather than isolated components, must be taken into consideration.

System design issues are split into two categories: (1) supply chain architecture and (2) tools for improving supply chain performance. The need to optimize the entire supply chain architecture is generally recognized across the papers under review. The optimum locations of various operating sites, such as for chipping or storage, as well as the modularity of the various phases within the supply chain, play a significant influence in this. New technologies like as modular generators or tiny expulsion units guarantee that effective contemporary biomass energy generation may be used on a localized basis, thus supporting local populations. Bio-energy production systems are complex, involving a variety of market segments and supply chain actors, as well as a variety of biomass resources (wood, agricultural and energy crops, by-products, and wastes), a variety of conversion approaches and end-use applications, various harvesting methods, transportation requirements, and operation and handling needs, such as chipping, slicing, and shredding. Identify the most significant bio-energy players as energy businesses and biomass suppliers.

3. CONCLUSION AND IMPLICATION

This literature study identifies and expounds the most important problems of SCM and logistics for bio-energy generation using a mostly inductively derived systematization. The operations harvesting/collection, storage, transport, and pre-treatment methods are the major review categories conceptualized throughout the bio-energy chain. Another category is the supply-chain-spanning job of planning and managing the entire production system, which includes actors, activities, and timetables. These main themes are then (inductively) organized into sub-categories that emerge frequently from the subject under study. As a result, this article provides a review of academic research in the area of biomass SCM and logistics for energy consumption, as well as a general pattern for analysis and main characteristics.

Follow-up study may focus on specific aspects of the existing broad overview, giving them a more in-depth look via empirical studies or appropriate modeling and simulation techniques. Furthermore, academic research on relationship-focused management elements of operating bio-energy chains, which has been mostly ignored to date, should be bolstered. Empirical analyses can be used to distill the challenges and critical success factors of existing bio-energy systems, taking into account all three aspects of sustainability while addressing a wide range of supply chain actors as well as other relevant stakeholders such as government agencies, non-governmental organizations, citizens, and communities. As a result, implications and tools for enhancing the triple bottom line performance of bio-energy production systems may be created and developed, guaranteeing their profitability while preserving their environmental license to operate by maximizing their ecological and social balance.

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