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Research paper

Decision hierarchy, competitive priorities and indicators in large-scale 'herbaceous biomass to energy' supply chains

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ABSTRACT

In this study we focus on herbaceous biomass, and particularly on the supply chains organised to deliver feedstock to biorefineries. We look at the supply chain as a whole and examine what organisational capabilities (competitive priorities) large-scale herbaceous biomass supply chains (LHBSC) should possess to achieve an appropriate level of sustainable competitive advantage. Supply chain of herbaceous biomass-based CHP is used as a model. In addition to these, we also present specific applicability issues to other herbaceous biomass supply chains. We identified three principal competitive priorities: cost efficiency, reliability of supply and sustainability. However, to be able to develop these competitive priorities, quality and flexibility, as well as information sharing, innovation and a strong proclivity to cooperate are also essential. In addition, we have pointed out the importance of competitive priorities in decision making by proposing appropriate indicators to measure them and by constructing a decision hierarchy relevant to biomass-to-energy supply chains.

1. Introduction

The ratio of biomass in the world's primary energy demand is estimated to be of 10%, approximately 50–60 EJ [1]. According to predictions published in the last 5 years, its relevance may increase by an order of magnitude by 2050 [2]. In this paper, we focus our attention on herbaceous biomass and, particularly, on its supply chain delivering feedstock to biorefineries. The literature focussing on design, planning and operating biomass-based energy systems is continuously growing, and a few review articles have also been published recently on biomass supply chain modelling, classifying the literature according to several criteria. In Refs. [3–9], The majority of the relevant papers offer decision-support models and analyses that mostly use cost-oriented criteria and objectives: aiming at minimising investment and operating cost of the supply chain and the logistics system. Few models deal with profit maximisation, environmental sustainability, risk mitigation or stability of supply, and only a limited number of papers offer models with multiple criteria. All of these suggest a potential and important research direction for the near future. However, no theoretical confirmation of these criteria and objectives has appeared yet. The same is true for the proposed business strategies and necessary organisational capabilities, and their relationship and interaction with these criteria.

In our paper we explore the types of organisational capabilities (competitive priorities) that are necessary in the upstream segment of large-scale herbaceous biomass supply chains (LHBSC), the nature of the links between these, and relevant indicators to quantify their levels. As a supplementary, but in our opinion, valuable, exercise we have constructed is a hierarchy of decision situations related to biomass supply chains, emphasising the importance of linking competitive priorities to decision-making models.

A serious discussion of the use of biomass for energy generation purposes must clearly involve the entire supply chain. This encompasses operational matters starting with the feedstock producers and moving on to pre-treatment units before reaching the final stage of the actual production of the energy. This covers the entire value creating process as represented in Fig. 1.

Since the term 'biomass' covers organic materials which differ physically, biologically and technologically, the supply chains handling and processing them may also differ. That is why a relatively detailed analysis calls for delimiting a particular

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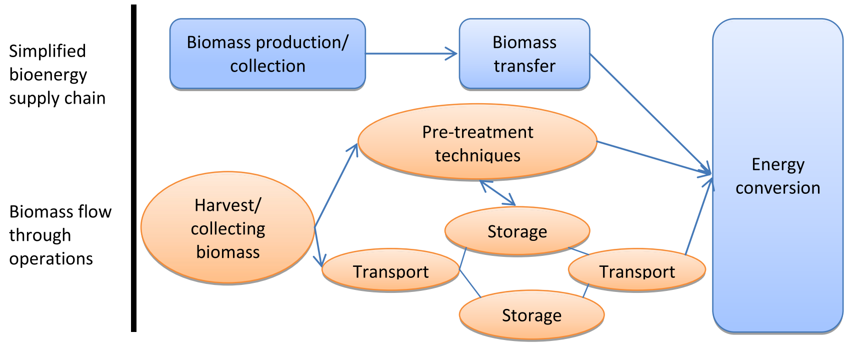

Fig. 1. General biomass supply chain proposed by Gold and Seuring [9].

configuration. To define the supply chain which we propose to examine as a model of LHBSC, we use the framework constructed by Voytenko and Peck [10]. Our study focuses on agro-biomass-based systems and their supply chains where a large (>6 MW) CHP plant is fuelled by agricultural residue transported in bales, over short-to-medium distances (<150 km), and end-products of the energy conversion are electricity and heat for district heating or industrial use. Effective use of by-products must be considered an important factor in terms of feasibility of biomass supply chains. Common characteristics of these systems are that they require high volume of feedstock and complex logistics operations, which substantially influence the key performance indicators of the supply chain [11].

The main participants of the supply chain are the feedstock producers themselves, the cross-docking facilities adjacent to the production fields (satellite storage locations), transport companies with high capacity vehicles, the power plants and, of course, the end-users (networks, retailers, consumers). We use the above described supply chain as a model for our qualitative analysis. Main findings of this analysis remain valid in the case of other biomass supply chains which we present in later sections of this study.

2. Business and functional strategies, competitive priorities

Earlier, companies chose and defined their own customer service and operational dimensions, which granted them competitive advantage. They made their own decisions in accordance with their own business strategy. However, in developed economies, supply chains compete with each other, even if we only consider local value-creating networks operating in a narrow geographic area. When analysing LHBCS, we follow this logic: we are not dealing with organisational boundaries in the chain from feedstock producers to energy producer; rather, we are looking at the supply chain as a whole. This is in line with our expectation that supply chain members ought to be strategically integrated as well as working towards common goals and strategic targets.

The general business strategy that a supply chain follows is based on an analysis of the business environment and the available organisational capabilities. Competitive priorities are the link between business strategy and functional strategies. In our paper, competitive priorities are defined as the expected organisational capabilities necessary to meet the customers' product and service expectations (e.g. low price, reliability, responsiveness). The overall business strategy directs functional strategies as to which competitive priorities are adopted and which functional strategies are to realise these through their own decisions on the strategic, tactical and operational levels (Fig. 2 [12]).

In the literature, Skinner [13] was the first to advocate linking operational strategy to the organisation's business strategy and to other functional strategies. In another article Skinner [14] defined short delivery cycles, superior quality and reliability, dependable deliveries, rapid new product development, flexibility in volume changes and low cost as the main performance criteria. Wheelwright [15] stressed efficiency, dependability, quality and flexibility as the most important performance indicators of operational units. The concept of competitive priority was introduced by Hayes and Wheelwright [16] who defined four major capabilities: cost, quality, dependability and flexibility. In later research many authors applied the same list of competitive priorities, but we also find many papers that suggest modifications in one way or another: Ward et al. [17] expanded the list by adding innovation; Diaz-Girrardo et al. [18] added service (e.g. after-sales service) and the environment (e.g. ability to generate positive environmental impacts).

Judgement of the relationship between competitive priorities has also changed since Skinner's [13] paper. Skinner strongly argued that there is a trade-off between different operational capabilities, i.e. one can be improved only by sacrificing others. The sand-cone model of Ferdow et al. [19] stated that, assuming there is a particular order, competitive priorities can support and reinforce one another. Hill [20] differentiated two groups of competitive priorities: the qualifying criteria are the minimum conditions that are necessary to enter a market, whereas order-winning criteria explain why consumers choose a given product.

Whilst these authors interpret competitive priorities at a corporate level, papers published after the millennium extended the competitive priority theory to the entire supply chain. Chan [21] described seven performance measurements, two of which are quantitative (cost and resource utilisation) and five are qualitative (quality, flexibility, visibility, trust and innovativeness). Saarijarvi et al. [22] aimed to assess the strategic fit of supply chain partners along cost efficiency, speed, reliability, innovativeness, flexibility and collaboration as competitive priorities.

3. Competitive priority structure of large-scale herbaceous biomass supply chains

One of the most frequently cited papers in the supply chain literature is Fisher's theory [23]. Fisher stated that a product's demand characteristics define the focus of the supply chain operations. When defining the competitive priority structure of LHBSC, we also rely on this theory. According to Fisher, a product is primarily functional or innovative. Functional products fulfil everyday needs, and demand for them is stable and predictable over a longer period of time. This type of product has a long life cycle but tends to allow low margins. Regarding innovative products, demand is