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Assessment of renewable bioenergy application: a case in the food supply chain industry

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ABSTRACT

The purpose of this paper is to assess the financial impact as well as greenhouse gas emissions of bioenergy application in a food-processing company. The assessment of bioenergy comprises collection and handling of organic waste and conversion of these biomasses through anaerobic digestion into biogas. In order to validate the proposed options of bioenergy application, we considered a food processing company in Denmark as a case company in a single in-depth case study. In the case studied, the produced biogas is to be utilized in one of two options at a bakery site: To substitute natural gas in combined heat and power (CHP) production (option 1) or substitute natural gas for production processes (ovens) and boilers (heat in form of water and steam production). The financial and environmental assessment is undertaken using the proposed bioenergy application, and indicates that it is possible to realize financial benefits in terms of additional profits and cost savings, but that challenging conditions can be problematic from a company perspective and provide challenges for the promotion of bioenergy investments. Specifically, substituting natural gas for processes and boilers is identified as the scenario providing the best financial result. The results also indicate that bioenergy application results in reduced greenhouse gas emissions in both options compared with the base scenario, however with no significant differences between the two options.

1. Introduction

The importance of developing more sustainable food supply chains has been recognized in recent decades given the relatively high environmental impact from production and consumption of food products (Tukker et al., 2006; Seuring and Müller, 2008; Notarnicola et al., 2012). In this context, one option that has been highlighted is to increase the application of renewable energy technology, especially at the food processing stage where high energy usage combined with rising energy costs and availability of fossil fuel resources suggests the need for investigating sustainable energy supplies (Hall and Howe, 2012). Specifically, bioenergy as a renewable energy option has been highlighted as a promising option well suited to the food supply chain given the biological nature of its products. For instance, Hall and Howe (2012) point towards the gap between the high energy consumption in the food processing industry combined with low energy generation in the industry and suggests that bioenergy from waste can provide, to some extent, a solution for closing this gap. Parfitt et al. (2010) also mention the possibility of utilizing unavoidable food waste for energy production using the appropriate technology as means for realizing more sustainable food production and consumption. In food supply chains, however, bioenergy has primarily gained momentum as an option for greening the agricultural stage by producing energy based on animal manure from livestock production (Wallgren and Höjer, 2009; El-Mashad and Zhang, 2010; Gold and Seuring, 2011; Yazan et al., 2011). Besides animal manure, energy crops, industrial residues and municipal organic wastes have been analysed in relation to their potential for use in bioenergy production (Cavinato et al., 2010). However, such analysis is often carried out as a means of improving the profitability of bioenergy applications at the agricultural stage by co-digesting the manure with more degradable wastes given that the low biogas and energy yield of manure not always justify the capital cost for farm-scale facilities (Cavinato et al., 2010; El-Mashad and Zhang, 2010; Karellas et al., 2010). Here, the industrial residues and municipal wastes only play a subordinate role for bioenergy applications (Gold and Seuring, 2011). Accordingly, Iakovou et al. (2010) find that the vast majority of research in the field of bioenergy production has examined the application from a purely technological or ecological perspective and thus not as means of developing more

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sustainable food supply chains taking a business perspective. Consequently, exploring bioenergy application at the food processing of the food supply chain taking a business perspective seems rather unexplored. Based on this, the aim of this paper is to assess the financial impact as well as greenhouse gas emissions associated with bioenergy application at the food processing company. Specifically, the research question of the paper is: "(*How*) *can bioenergy applications at the food processing stage affect the financial and environmental performance in terms of greenhouse gas emissions*?"

The structure of the paper is as follows. Section 2 is dedicated to reviewing the literature used as the frame of reference. Section 3 provides details of the methodology of the paper. In Section 4, the case is presented and the analysis is performed. Section 5 summarizes and presents the final result based on the analysis. Section 6 interprets the results of the case studied and discusses them in relation to the extant literature. Finally, concluding remarks are provided in Section 7 together with the limitations of this paper and proposals for future research.

2. Theoretical frame of reference

The theoretical foundation for this paper is organized according to two sub-sections. The first subsection outlines literature on the environmental impact originating from consumption and production of food products. The aim of the section is to clarify the environmental importance and challenge of reducing environmental impacts from consumption and production of food products. In continuation, the second subsection will outline literature on bioenergy application. The aim of the section is to provide a brief outline of extant literature on bioenergy application in food supply chains and to point towards the gaps in the literature as well as develop an analytical framework for bioenergy application in food supply chains that will be used to organise and analyse the selected case.

2.1. Food supply chains and the environment

In the past decade, numerous studies have been undertaken with the goal of illuminating the environmental impact associated with consumption of products. One major study is the 'Environmental Impact of Products' (EIPRO) performed by the European Science and Technology Observatory (ESTO) (Tukker et al., 2006; Styles et al., 2012). The study analyses the environmental impact of final household consumption in the EU-25 countries based on a model developed in the study and compare the results with seven previous studies from the years 2002–2005 on the environmental impact of products. One of the key findings is that food and beverage products account for approximately 22%–34% of the total environmental impact of consumption, depending upon the environmental impact category (excluding restaurants and hotels). The only exception is 'eutrophication,' where food and beverage products account for 60% (Tukker et al., 2006). With 31% of the greenhouse gas emissions, and an additional 9% points including restaurants and hotels, food and beverage products were identified as the single most contributing category (Tukker et al., 2006; Foster et al., 2006; Garnett, 2011). Overall, the result provided by Tukker et al. (2006) is consistent with previous studies, with the exception of those studies not comprehensively incorporating a category for food products. As a result, food and beverage products are consistently placed among the top three categories with the largest environmental impact (Dall et al., 2002; Nijdam and Wilting, 2003).

Food supply chains are generally dominated by the environmental impact originating from the agricultural stage (Garnett, 2011). According to Foley et al. (2011) agricultural production is today identified as a major contributor to environmental problems such as biodiversity loss, degradation of land and water resources, but also climate changes where the sector alone is responsible for approximately 30%–35% of global greenhouse gas emissions. Accordingly, Mena et al. (2013) explain that the further upstream a company is located in the food supply chain, the more likely it is to have a higher environmental impact. At the agricultural stage, emissions of nitrous oxide (N_2O), a strong greenhouse gas, is dominant in the cultivation of crops, methane (CH_4) from livestock production and carbon dioxide (CO_2) from land-use change (Garnett, 2011; Pathak et al., 2010). However, it is generally known that environmental impact evidences itself through all the stages along the food supply chains (Seuring, 2004; Pathak et al., 2010; Garnett, 2011). As noted by Zanoni and Zavanella (2012) energy consumption also plays a significant role along the food supply chain. Particularly, processing of food products as well as food preparation in homes has generally been found to be energy intensive and thus dominated by emissions of CO_2 directly through the combustion of fossil fuels, or indirectly by consumption of electricity from the grid, but losses of refrigerant gasses in industry also play a supporting role (Grönroos et al., 2006; Garnett, 2011; Hall and Howe, 2012).

2.2. Bioenergy application

Bioenergy is, in accordance with Gold and Seuring (2011), defined in this paper as: "*providing energy in terms of electricity, heat and mobility from materials from biological sources referred to as biomass*". In this context, biomass for bioenergy can be any organic material that has stored energy from sunlight in form of chemical energy and comprise wood, agricultural and forest residue, energy crops, human and animal excrements as well as industrial and municipal biodegradable waste (Gold and Seuring, 2011). From a sustainability perspective, bioenergy has attracted many hopes as an option that can result in economic benefits by generating income through investments, environmental benefits by reducing greenhouse gas emissions and preserve natural resources as well as societal benefits by creating jobs, enhance energy security and promote regional development (Gold, 2011; Gold and Seuring, 2011; Hall and Howe, 2012). In continuation, authors have argued that bioenergy can gain a decisive position among renewable energy technologies in future decades if it is properly designed and applied under favourable conditions (Schievano et al., 2009; Gold and Seuring, 2011). In accordance, Yazan et al. (2011) state that bioenergy, if not properly designed and evaluated, can lead to further degradation of land and ecosystems. Therefore, in order for bioenergy production to become sustainable it is necessary to optimize the structure and functioning of the supply chain and to adapt the implementation of bioenergy to the specific conditions of the respective production system (Gold and Seuring, 2011). Specifically, in the context of food supply chains, conditions that act as both drivers and barriers include (Hall and Howe, 2012):

Financial/accounting issues

1. High initial capital costs
2. Available arrangements to buying and selling energy to a national grid
3. Fluctuations in fuel prices

Political, macroeconomic and social factors

1. Renewable energy certificates
2. Feed-in-tariffs
3. Landfill taxes