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Sustainability criteria and indicators of bioenergy systems from steering, research and Finnish bioenergy business operators' perspectives

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A B S T R A C T

This paper addresses the interface of steering, research, and business operators' perspectives to bioenergy sustainability. Although bioenergy business operators are essential for sustainable development of bioenergy systems through implementation of sustainability criteria, their perspective to sustainability is rarely studied. We systematically studied the relevant sustainability criteria and indicators from the three perspectives in different stages of a general bioenergy life cycle and in different sustainability dimensions, and evaluated bioenergy operators' sustainability principles, criteria and indicators simultaneously with respect to the steering and research data and a business sustainability maturity framework. We collected data from literature and a workshop for Finnish bioenergy experts. The results show a similar division of steering and operators' sustainability criteria and indicators to life cycle stages and sustainability dimensions with a slight emphasis on business economic sustainability from operators' perspective. The acceptability principle could provide bioenergy operators a meaningful way of identifying the role of sustainability criteria and indicators from steering and research sources in advancing their business sustainability maturity.

1. Introduction

In 2010, 10% of the global primary energy demand was met by bioenergy production. One third of bioenergy was consumed by the industry, energy, or transportation sector (IEA, 2012). According to a scenario by the IEA (2012), the global primary energy demand for bioenergy, excluding traditional uses, could more than double by 2035. Currently, the markets of energy biomass are increasing and internationalizing rapidly (Vakkilainen et al., 2013).

Greenhouse gas emission reduction and renewable energy promotion targets, such as the EU 20-20-20 policy (2009/28/EC) and resulting political mandates and subsidies (FAO, 2008; ICTSD, 2009) for biomass-based solutions as part of the energy infrastructure affect the production of bioenergy. Renewable energy production, including bioenergy, is generally recognized as a promising solution to replace fossil fuels in an attempt to cover the rapidly growing energy demand, triggered by drastic population and economic growth, especially in the developing areas of the world.

The bioenergy growth should be managed so that the bioenergy systems develop sustainably. The sustainability of human operations presumes that the planetary boundaries or local environmental ceiling are not exceeded and the quality of life is maintained by respecting the social foundation of human wellbeing (Griggs et al., 2013; Heijungs et al., 2014; Raworth, 2012; Rockström et al., 2009).

Scientists stress the importance of a holistic vision and integrated approach to bioenergy system sustainability assessing the environmental, social, and economic impacts together (Buchholz et al., 2007; Dale et al., 2013; Purba et al., 2009; Sheehan, 2009). Several authors have found interactions and interdependencies between the sustainability dimensions (Brose et al., 2010; Dale et al., 2013; ISO 13065 draft; Pülzl et al., 2012) resulting in both synergies and conflicts between the environmental and socioeconomic impacts (Diaz-Chavez in Rutz and Janssen, 2014). For example, Rettenmeier and Hienz (in Rutz and Janssen, 2014) found links between the environmental and socioeconomic indicators, for instance the land use impacts on food security, ecosystem services, biodiversity, water, and soil.

However, bioenergy sustainability studies have tended to concentrate on the environmental sustainability and especially on two issues: greenhouse gas and energy balance (Buchholz et al., 2009;

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Cherubini and Strømman, 2011), which are necessary but not sufficient sustainability indicators because they fail to include a variety of other relevant environmental aspects. (Liao et al., 2011; Maes and Van Passel, 2014). Furthermore, Diaz-Chavez (in Rutz and Janssen, 2014) states that in the context of sustainability emphasis has been put on economic and environmental dimensions, whereas social dimensions have been less vigorously addressed, until recently. The same trend is visible in the currently applicable sustainability criteria for biofuels and bioliquids in the legislation (EU Directive, 2009/28/EC (RED)) on the promotion of the use of energy from renewable sources) and standard series EN 16214 (1, 3 and 4), the criteria of which are in accordance with the RED criteria. Rettenmeier and Hienz (in Rutz and Janssen, 2014) state that the RED mandatory criteria currently concentrate exclusively on greenhouse gas and biodiversity effects, whereas criteria (on e.g. soil, water, and air protection) strongly linked to the ecosystem services would cover the social impacts better. However, new standards (such as ISO 13065) and certification schemes for bioenergy sustainability are under development creating a new potential for covering the sustainability more holistically from the steering perspective.

Bioenergy systems can be described as adaptive systems (Buchholz et al., 2007) where the bioenergy life cycle processes and their practical implementers, that is, bioenergy operators, constantly interact with different levels of their operational environment: business, micro-, and macro-environment (Ketola, 2005). A prerequisite for the sustainable development of bioenergy systems is that the bioenergy operators are aware of the sustainability aspects in the bioenergy life cycle stages adopting sustainability thinking and criteria in practice (Borghesi and Vercelli, 2008). In the research literature, the interface of bioenergy operators', steering, and research perspectives on the sustainability criteria and indicators of bioenergy life cycles has yet received little attention.

This paper aims to build a view of the bioenergy operators' perspective of the sustainability criteria and indicators in bioenergy systems and compare them with the current bioenergy sustainability criteria and indicators in the bioenergy legislation in the EU, international and European standards, and research literature. The operators' perspective is studied in a workshop for Finnish bioenergy experts and steering and research perspectives from the literature. Sustainability is considered holistically from the environmental, social, and economic perspectives, and the criteria and indicators are systematically categorized utilizing life cycle thinking. Workshop sustainability aspects, including criteria and indicators, are evaluated with respect to a business sustainability maturity framework. The results provide information on the extent to which bioenergy operators, steering and research currently consider different sustainability criteria and indicators with regard to life cycle stages and sustainability dimensions, on the current maturity of bioenergy sustainability thinking in Finnish bioenergy companies, and on possibilities to develop bioenergy systems towards a better state of sustainability through interactions between steering, research and bioenergy operators in the development of sustainability principles, criteria and indicators.

2. Theory

2.1. Systematic and holistic approach to sustainability

Fig. 1 shows how we structured our systematic approach to sustainability. Bautista et al. (2016) have previously applied a similar multidimensional sustainability framework with different sustainability principles, criteria and indicators and sustainability dimensions to biodiesel supply chain.

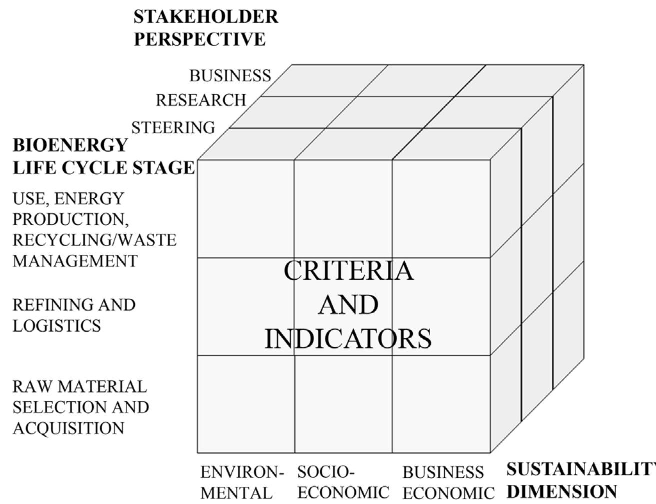

Fig. 1. Systematic approach: the perspectives to sustainability, life cycle stages and sustainability dimensions in which sustainability criteria and indicators were divided (the cube).

2.1.1. The sustainability dimensions

Sustainability is considered to comprise four dimensions: environmental, social, economic, and institutional (Herva et al., 2011). As stated in the introduction, this paper focuses on the environmental, social, and economic dimension of sustainability. Pülzl et al. (2012) have concluded that although artificial and suggestive at best, the categorization of sustainability aspects according to sustainability dimensions can be a useful attempt to manage the complexity of sustainability. To enhance the systematic structuring of our data, we utilized the sustainability dimension approach in our analysis. The socioeconomic dimension was considered to include aspects related to macroeconomy and microeconomy (i.e., the economy of the external operational environment of a company), human well-being, culture, and work. Although business economic sustainability aspects (i.e., company internal economy) have traditionally not been separately discussed and may be integrated into the socioeconomic sustainability dimension, we distinguished the business economic dimension to highlight the bioenergy operators' perspective and to compare its emphasis in the workshop versus literature.

2.1.2. The bioenergy life cycle stages

Life cycle approach was selected as the basis for the research because LCA is a generally accepted method for the environmental impact assessment of products (Cherubini and Strømman, 2011; ISO 14040, 2006), social impacts can be related either directly to the life cycle processes or to the supply chain and the conduct of companies performing the processes (Dale et al., 2013; Jørgensen et al., 2008), and the costs can be related to the life cycle (e.g. Klöppfer and Ciroth, 2011). Thus, this paper relates to the life cycle-based sustainability thinking as suggested by Klöppfer (2008), Guinée et al. (2011) and Klöppfer and Grahl (2014).

2.1.3. The stakeholder perspective

The three different stakeholders (steering, research and business) of bioenergy systems, have fundamentally different sustainability-related objectives. Steering aims to protect human health and the environment and ensure fair and equal treatment and well-being of humans, whereas research aims to produce new knowledge about bioenergy sustainability. The difference in the time span of the steering and research is remarkable: where research produces new knowledge, steering incorporates this knowledge into, for example, legislative acts after