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ABSTRACT

The choice of context-generic or -specific themes and subthemes (goals and objectives) for sustainability assessment implies a number of tradeoffs; for instance, benchmarking and resource efficiency vs. coverage and engagement. Analyses of the potentials and limitations of generic assessment themes and sub-themes within specific contexts may help to develop frameworks that minimise the tradeoffs between generic and specific assessment approaches. The aim of this study was to analyse the effectiveness of generic themes and sub-themes of existing frameworks for covering the key sustainability issues of a specific case study – the case of Danish maize for German biogas. The results indicate that generic frameworks can effectively cover context-specific issues related to the environmental dimension of sustainability. Conversely, generic frameworks can be unable to identify context-specific issues related to social and economic dimensions. This study suggests that the coverage gap of generic themes is mainly an issue of framework incompleteness that can be advanced with additional research. A one-size-fits-all specificity-level for sustainability assessment is not applicable, and the specificity-level should be tailored to the assessment purpose. A certain degree of stakeholder participation is recommended not only in the assessment process, but also during the framework design to support stakeholders' sustainability education and action.

1. Introduction

1.1. Globalisation and pluralism in sustainability assessment

Following the Brundtland Report (WCED, 1987), a diverse range of methods and tools have been developed for assessing and promoting sustainability (Pope et al., 2004; Pintér et al., 2012). Globalisation and the need to govern international externalities and global public goods (e.g. climate, biodiversity, financial stability, food safety) can be seen as a key driver in the development of various generic assessment frameworks. These frameworks seek standardisation, accreditation, performance benchmarking (comparisons) among enterprises, regions or nations, and applicability to a diversity of user groups and contexts (Mineur, 2007; Ness et al., 2007; van Zeijl-Rozema et al., 2011). For example, the CSD Indicators from the United Nations' Commission on Sustainable Development aim to monitor and benchmark sustainable development at the national level for different countries (UN, 2007).

Despite the need for global and generic assessment frameworks, the sustainability discourse implies a plurality of world views, knowledge and values across individuals and institutions, which depend on the context in which the process is embedded (Lélé and Norgaard, 1996). Sustainability assessments raise questions (either explicitly or implicitly) such as: what is to be sustained, in what form, at what scale and within which system boundaries? Over which period of time, and with what certainty level? Through which social process(es), involving whom, and with which tradeoffs against other objectives? (Lélé and Norgaard, 1996; Briassoulis, 1999). Some of these questions do not have a single answer. Therefore, sustainability assessment practise involves not only an empirical but also a normative perspective for defining processes and goals for sustainable development (Alrøe and Kristensen, 2002).

In contrast to generalising trends, this pluralism in conditions and world views has contributed to the development of a number of context-specific assessment frameworks (e.g. Reed et al., 2006; Binder et al., 2010; van Zeijl-Rozema and Martens, 2010). The design of these frameworks and their components (e.g. themes, indicators, and reference values) focuses on the specific context in which the sustainability assessment is embedded. Important context characteristics in sustainability assessment include:

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(i) issues and stakeholders affecting or affected by the assessed operation and the assessment process, (ii) capacities, priorities and values of the stakeholders, (iii) rules and procedures that govern the process, (iv) culture and history of the involved organisations and stakeholders, and (v) timing and resources of the assessment process (adapted from Pastille Consortium (2002)).

1.2. The dilemma between generic and specific approaches

Context-generic assessment approaches have been criticised for not allowing the inclusion of specific characteristics or discourses that are inherent to local contexts (Morse and Fraser, 2005; Lee, 2006). Context-generic approaches have also been criticised for relying on value judgements of external-experts in defining the concept of sustainability, and selecting an arbitrary array of objectives and a method of aggregating them (Lélé and Norgaard, 1996). Consequently, the use of these approaches has been associated with gaps and insufficiency in monitoring critical sustainability issues and the impairment of trust and adoption of improvement measures by the stakeholders (Parkins et al., 2001; van Zeijl-Rozema et al., 2011).

Context-specific assessment approaches have been criticised for reducing the possibilities of standardisation and benchmarking of sustainability performances among different systems (Binder et al., 2010; Mascarenhas et al., 2010). Consequently, the use of context-specific approaches can limit the identification of relative strengths and weaknesses, and the gathering of ideas and coordination of efforts among different systems or places (Pastille Consortium, 2002; Mascarenhas et al., 2010). Context-specific frameworks have also been criticised for isolating the monitoring results from more global sustainability issues and higher level sustainability processes (e.g. governmental regulations) (Mascarenhas et al., 2010). Moreover, context-specific frameworks can be more time- and resource-demanding due to the need for context analysis, and the design of specific sustainability goals and assessment framework components (Binder et al., 2010).

1.3. Themes in sustainability assessment

Indicator-based sustainability assessments are generally structured according to several hierarchical or aggregation levels. In the present study, the most general level comprises sustainability dimensions. These are general discipline-independent fields, which are normally differentiated into environmental, social and economic. At the intermediate level, each dimension comprises a number of themes and sub-themes. These are defined as the relatively independent elements associated implicitly or explicitly with specific sustainability goals and objectives (FAO, 2013). When themes are divided into sub-themes, general goals are connected to the themes and specific objectives to the sub-themes. Themes and sub-themes are also referred to as principles and criteria (van Cauwenbergh et al., 2007; RSB, 2011), impact categories and subcategories (UNEP/SETAC, 2010), or components (Bélanger et al., 2012). Each theme or sub-theme is linked to one or a number of indicators. Indicators are the most specific level. These are measureable and verifiable variables or factors that are independent of the aggregation method and allow performance communication (Lenz et al., 2000; FAO, 2013). As an example, the "environmental" dimension may have an "atmosphere" theme and associated goal, which includes a "greenhouse gases" sub-theme and associated objective and uses the "entity's annual net CO_2-equivalent emissions per ton of produce" as an indicator.

Generic assessment approaches make use of generic themes and sub-themes, which require a universal definition of sustainability goals and objectives. Context-relevant sustainability issues may not be captured if sustainability themes and sub-themes are very context-sensitive. Although some studies have to some extent explored the context-sensitivity of sustainability indicators (Mineur, 2007; Efroymson et al., 2013; Guerci et al., 2013), there is a research gap on the context-sensitivity of themes and sub-themes. The context-sensitivity of themes and sub-themes is relatively independent to the indicators one, because indicators selection may involve additional context-dependent factors such as assessment resources, data accessibility and availability, and expertise of the users of the indicators (Reed et al., 2006; Binder et al., 2010).

Analyses of the potentials and limitations, in terms of practicality and usefulness, of generic assessment themes and sub-themes within specific contexts may help to develop frameworks that minimise the tradeoffs between generic and specific assessment approaches. The aim of this study was to analyse the effectiveness of generic themes and sub-themes for covering the key sustainability issues of a specific case study. The selected case study consists of the value chains of Danish maize for German biogas.

2. Methods

2.1. Case study background

In 2000, the German Renewable Energy Act (Erneuerbare-Energien-Gesetz) came into practice to promote the production of renewable energy. This policy has driven Germany to become one of the largest biogas producers in the world (Gömann et al., 2009). Biogas, compared to other bioenergy technologies, has the advantage of having a relatively high energy and resource-use efficiency (Börjesson and Mattiasson, 2008; Samson et al., 2008; Herrmann, 2013). The process can convert a wide range of biomass sources, including organic wastes, into fuel (Börjesson and Mattiasson, 2008; Samson et al., 2008; Herrmann, 2013). The main feedstock of the German biogas industry is based on the co-digestion of animal manure and energy-crops (Herrmann, 2013). Whole-crop maize silage has become the dominant German biogas crop (Gömann et al., 2009) due to its high biomass yield, relatively undemanding agronomical conditions, easiness of storage, and high methane production rate (Thyø and Wenzel, 2007; Heydemann, 2011).

The German region of Schleswig-Holstein shares a border with Denmark, and has some of the densest distribution of biogas plants in Germany (Heydemann, 2011). The region's dramatic increase in energy-crops demand and importing opportunities have created a new transnational agricultural market. The Danish region sharing border with Germany (Southern Jutland or Sydjylland), has become an intensive maize supplier for the German biogas industry (Landbrugsavisen, 2011). The Danish area cultivated with maize for German biogas has expanded significantly since 2007 and it is now estimated to be 18,000 ha, distributed up to 100 km north of the German border (Dagbladet Information, 2012).

It is assumed that the expansion of biogas production has a number of environmental, social and economic benefits, such as reducing use of fossil fuels, securing energy supply, and enhancing rural development (FAO, 2007; Heydemann, 2011). However, the cultivation of maize for the German biogas industry is also a source of increasing concern about potential negative impacts to society and the environment (Heydemann, 2011; Dagbladet Information, 2012; Landbrugsavisen, 2012).

This case study was selected due to its distinctive context characteristics: (i) transnational value chain boundaries; (ii) diverse cultural and expertise backgrounds of the involved stakeholders; and (iii) multi-scale and multi-dimensional sustainability tradeoffs (Heydemann, 2011; Dagbladet Information, 2012; Landbrugsavisen, 2012).

2.2. Case study analysis

To identify the key sustainability issues from the selected case study, a qualitative in-depth analysis was used based on individual semi-structured interviews with stakeholders.

Purposive sampling was used. In this approach participants are selected because they are likely to possess relevant knowledge for the study. The first stakeholders interviewed were agricultural consultants working within the biogas-maize production region of Sydjylland district, Denmark. The consultants' expertise and network covered a range of agricultural areas. The remaining stakeholders were selected using the snow-ball sampling method in which initial participants identify other potential participants who have direct knowledge relevant to the case study (Bryman, 2001). Ten stakeholders were interviewed, including agricultural consultants, crop farmers, livestock farmers, a biogas producer, researchers, and a non-governmental organisation representative (Table 1). The number of interviews was not extended beyond ten because new sustainability issues and new relevant stakeholder-types (relevant in terms of involvement level and informative capacity) did not appear during the last two interviews.

The individual semi-structured interviews were conducted during summer 2012 in Denmark and Germany at a time and venue chosen by the participants. The individual interviews had a duration ranging from 50 to 90 min and were audio-recorded. The interviews were generally structured from more general to more specific questions, to allow the emergence of less biased new issues. First, participants were asked to describe their occupation and their personal and their community relationships and experiences with the Danish maize for German biogas industry. Subsequently, they were asked about their perceptions of environmental, social, and economic sustainability issues (one dimension at a time). These dimensions are generally recognised as the major dimensions of sustainability and are concepts generally understood by the public. Finally, the stakeholders were asked non-structured and more specific questions in relation to particular issues either mentioned by them, previous participants, or the media.

The interviews were transcribed verbatim and were coded by the use of Nvivo9 qualitative data analysis software (Nvivo9, QSR International). The coding enabled the data to be organised into common categories associated with sustainability issues.

The emerging issues and participants' perceptions were systematically organised and reported according to sustainability issues and dimensions. The emerging issues had a significant normative component. For example, there were a variety of responses amongst participants in valuing the importance of different case study issues. Therefore, some issues were reported using quotations to retain their qualitative character.

2.3. Coverage analysis of assessment frameworks

Existing generic sustainability assessment frameworks were selected to analyse the effectiveness of their themes and sub-themes in terms of covering the case study sustainability issues.

From an extensive (but not exhaustive) review of scientific and grey literature and expert consultation, 27 generic assessment frameworks were identified (OECD, 2003; methods reviewed in Althaus et al., 2007; UN, 2007; GSCP, 2010; UNEP/SETAC, 2010; GRI, 2011; RSB, 2011; BFH, 2012; CFI, 2012; Elferink et al., 2012; Sedex/Verité, 2012; COSA, 2013; FAO, 2013).

From these frameworks, only the ones having explicitly reported goals or objectives (instead of only keywords) for each theme or sub-theme were selected to facilitate a more practical and objective analysis of the coverage of themes and sub-themes. From the frameworks that were initially identified; three met the selection criterion (Table 2): (i) Roundtable on Sustainable Biofuels Impact Assessment (RSB, 2011); (ii) Sustainability Assessment of Food and Agriculture Systems (SAFA) (FAO, 2013); and (iii) Social Life Cycle Assessment (SLCA) (UNEP/SETAC, 2010) (SLCA only at the sub-themes level).

Table 1
Details of interviewed stakeholders.

Main occupation	Responsibilities	Working region
Crop consultant	Advise crop producers, landowners, and public bodies	Sydjylland district, Denmark
Livestock consultant	Advise livestock farmers	Sydjylland district, Denmark
Environmental consultant	Perform environmental assessments and advise farmers regarding environmental regulations	Sydjylland district, Denmark
Biogas consultant/researcher	Advise biogas producers in terms of investment and management, and part time academic research on biogas technologies	Jutland region, Denmark
Energy-crop producer[a]	Manage energy-crop farms for German biogas	Sydjylland district, Denmark
Environmental researcher	Research on agro-ecology and energy-crop production (academic and extension), and support to policy-makers	Denmark
Biogas producer[b,c]	Manage a biogas production plant in Germany	Schleswig-Flensburg district, Germany
Self-sufficient livestock farmer[d,e]	Manage a conventional livestock farm (dairy and pigs)	Sydjylland district, Denmark
Non self-sufficient livestock farmer[f,g]	Manage a conventional livestock farm (dairy)	Sydjylland district, Denmark
Wildlife conservation member	Direct scientifically-based projects involving the interaction between agriculture and bird life in a wildlife conservation non-governmental organization	Denmark

[a] Production size: 1300 ha (owned and rented) and 700 ha (buying and harvesting the crop) with whole-crop maize (80%), grass, and sugar-beet for the German biogas industry.
[b] Production size: 2 million m^3, 700 kWel.
[c] Biogas feedstock supply: 160 ha in Germany and about 100 ha in Denmark cultivated with whole-crop maize and grass (owned), and manure from 800 pigs (up to 200 kg) and 2500 pigs (up to 20 kg) (owned).
[d] Production size: 400 conventional dairy cows, and 9 thousand conventional pigs.
[e] Livestock feed supply: 750 ha (owned); grain-feed self-sufficient. Additional activities: surplus land normally used to produce whole-crop maize for the German biogas industry.
[f] Production size: 350 organic dairy cows and 220 organic calves.
[g] Livestock feed supply: 150 ha (owned) and 120 ha (rented) cultivated with whole-crop maize and grass, and 70 ha (owned) of permanent grass; non grain-feed self-sufficient.

Table 2
Selected assessment frameworks description.

	RSB	SAFA	SLCA
Name and reference	Roundtable on Sustainable Biofuels Impact Assessment (RSB, 2011)	Sustainability Assessment of Food and Agriculture Systems (FAO, 2013)	Social Life Cycle Assessment (UNEP/SETAC, 2010)
Developer	Roundtable on Sustainable Biomaterials	United Nations' Food and Agriculture Organisation (FAO)	United Nations Environmental Program agency (UNEP) and Society of Environmental Toxicology and Chemistry (SETAC)
Sector scope	Bioenergy and bio-based products industry (biomass and biogas for heat and electricity generation and liquid biofuels)	Food and Agricultural industry (cropping, livestock husbandry, forestry, fisheries and aquaculture)	Generic
Geographical scope	Generic	Generic	Generic
Object of assessment	Organisation	Organisation or site	Product or service
Level of assessment	Production and processing of biofuel feedstock and raw material, and production, transport and use of liquid biofuels	Entire supply chain or single supply chain component	Entire life cycle (from raw materials extraction to disposal)
Dimensions covered	Environmental, social, economic and governance	Environmental, social, economic and governance	Social, economic and governance[a]
Sustainability Societal	perspective[b]	Societal	Societal and organisational
Results audience	Market regulatory bodies, and supply chain stakeholders	Supply chain stakeholders; policy makers; non-governmental organisations; and sustainability standards and tools community	Supply chain stakeholders; product designers; consumers; policy makers; non-governmental organisations; and trade unions and workers representatives
Purpose	Certification and management	Self-assessment and management; managing or benchmarking suppliers; planning and legislation development; monitoring projects outcomes; and gap analysis with existing sustainability schemes	Self-assessment and management; product development; managing or benchmarking suppliers; reporting and labelling; planning and legislation development; and monitoring projects outcomes

[a] SLCA is complemented by the Environmental Life Cycle Assessment, which addresses the respective environmental dimension (Kloepffer, 2008).
[b] Organisational or societal, depending on whether the subject to be sustained is the organisation or the society, respectively.

The framework analysis was performed by assessing the extent (complete, partial, or nil) in which each sustainability issue associated with the case study was covered by the goals and objectives of the respective themes and sub-themes.

3. Results

3.1. Case study sustainability issues

Twenty-two sustainability issues classified according to the environmental, social, economic and governance dimensions were identified by the participants in the case study of Danish maize for German biogas (Table 3). The governance dimension of sustainability was not part of the interview structure; however, it was extensively discussed by one of the participants. Indirect stakeholders refer to those outside the organisations involved in the biogas-maize supply chain. In the following sections, identified issues are presented within the specific case study context and described in terms of trend, tradeoffs, extent and importance according to the different stakeholders.

Table 3
Sustainability issues of the case of Danish maize for German biogas.

Environmental	Social	Economic	Governance
Greenhouse gas emissions	Landscape aesthetics	Marketing resilience	Pre-decision making assessment quality
Soil carbon balance	Food security	Supply resilience	Public communication
Nitrate leaching	Fairness in trading	Investment capacity	Public participation
Pesticide use	Rural traffic intensity	Indirect stakeholders economic vulnerability	
Native wildlife diversity	Rural odour	Production process resilience	
	Nature cultural and metaphysical services	Regional employment opportunities	
		Inter-regional materials procurement	
		Inter-regional costs shifts	

3.1.1. Greenhouse gas balance

It is widely accepted that the production of renewable energies such as biogas presents an opportunity for reducing atmospheric greenhouse gas (GHG) emissions. Nevertheless, the environmental researcher described the production of maize-based biogas as "absurdly stupid" because the reduction of GHGs can be non-significant when taking into account the entire life cycle. This fact was also acknowledged by the biogas consultant/researcher. The environmental researcher further explained this issue:

If you use manure, you will have very large reductions of GHGs because you reduce the methane emissions coming from the manure storage. However, when you use maize or grass, you will have no base emissions reduced. In addition, you have losses of methane. Some is lost through the combustion engine, some from the degassed slurry, and maybe some during the distribution and use if it is feed into the gas grid. So, you may end up having no reduction of GHG gases.

One factor that may also have contributed to an increase in GHG emissions was the increase in transport distances compared to previous practices (self-sufficient livestock farmer; energy-crop producer).

The environmental researcher stated that when taking into account the additional carbon emissions from indirect land-use-changes in other parts of the world, maize-based biogas may lead to an overall increase in the GHG gases. The production of energy crops induce indirect-land use changes including increased

deforestation to meet the global food demand. Nevertheless, the biogas producer emphasised that the use of energy crops is necessary because the use of manure alone does not produce a sufficient amount of biogas.

3.1.2. Soil carbon balance, nitrate leaching and pesticide use

It was mentioned that the production of maize tends to deplete soil carbon (environmental consultant; environmental researcher), and can be an important vector of nitrate leaching to ground waters (environmental and crop consultants). Nevertheless, the environmental researcher insisted that these soil carbon and nitrate leaching effects are not important in relation to the impacts of previous land uses involving other annual crops such as barley or wheat in the Danish conditions. This highlighted that "the issue is not that it is getting worse, the issue is that we are not improving" and there is a need to fulfil environmental regulations and targets, such as the EU water framework directive. According to the environmental researcher, the production of maize tends to decrease the amount of pesticide use compared to the average level of the Danish agriculture. In contrast, the environmental consultant warned that the common approach of non-rotation in maize production" "maize after maize" can induce higher pesticide use than would otherwise occur.

3.1.3. Native wildlife diversity

The wildlife conservation member explained that the cultivation of maize is an important threat to local biodiversity, specifically to farmland birds:

When farmland birds like the lapwing, the skylark, the corn bunting, or the partridge are coming for breeding in March/April and they look around, they see a lot of fields with grown-up vegetation, because now we have mainly winter crops and no so much spring crops left. So they think: "we should not use those fields because we cannot see predators approaching; but we could use those other fields with bare soil or very small plants (the maize fields)". So they go to the maize fields and start breeding, and suddenly, within few weeks, very tall plants have grown due to the C4-photosynthesis type of maize. So they leave their nests and that generation is lost because it became too late within the season for getting another clutch anywhere else.

The wildlife conservation member stated that typical farmland bird populations are dramatically declining in recent years, both in southern Denmark and especially in Germany, partly due to the increased production of maize.

Some participants mentioned that maize fields can be a good shelter for deer (self-sufficient livestock farmer), as well as providing feeding opportunities for bird species such as geese, crane and pheasant (wildlife conservation member). The wildlife conservation member emphasised that it was important to differentiate between the impacts on native and non-native birds. For instance, the introduced pheasant was seen as a competitor placing pressure on the native partridge (wildlife conservation member).

Given the potential effects of maize production on native farmland birds, the wildlife conservation member commented on the importance of native bird populations for ecosystem resilience, noting that "all types of activities which threaten these birds are not acceptable".

3.1.4. Landscape aesthetics

The effects of maize crop production on landscape aesthetics was a common issue that was raised spontaneously during interviews (crop and environmental consultants; environmental researcher; non self-sufficient livestock farmer). The crop consultant explained that visibility in the countryside is reduced between August and September due to the considerably tall maize plants and the relatively flat landscape-profile of the region. Some participants used the expression "maize deserts", which has become a cliché in the public opinion and the media, referring to the large extent and lack of diversity associated with the production of maize (crop consultant; environmental researcher). The environmental consultant was more explicit about her negative opinion and mentioned that these types of landscape can "change one's mood".

The energy-crop producer – a large scale maize producer – was taking measures to avoid public complaints on landscape aesthetics:

I have not received any complaints, but I try to prevent them. We are sowing sunflowers at the edges of the maize fields because I want people, when for example have a bicycle trip, to enjoy them, maybe collect them, and go back home happy.

Other participants expressed a neutral opinion on the issue of landscape aesthetics change (energy-crop producer; self-sufficient livestock farmer; environmental researcher). The environmental researcher observed the need to make some tradeoffs between issues. He considered landscape aesthetics as a "kind of luxurious issue", and added that "if we want to save the world, it will have some costs". All the participants producing maize for biogas held neutral opinions on landscape consequences. The crop consultant observed that it was especially people who are not farmers who do not like large extensions of maize. The distinction between farmers and non-farmers may be a reflection of different interests in terms of the services provided by the agricultural landscape, for instance aesthetics or production services.

3.1.5. Food security

Food security was another issue spontaneously arising during a number of interviews (environmental consultant; non self-sufficient livestock farmer; wildlife conservation member). The environmental consultant highlighted issues of global food limitations and the need to find non food-competing alternatives for producing energy. The non self-sufficient livestock farmer mentioned that "it would be better to use wastes; we do not need to make bioenergy from things that cows or people can eat; nobody eats shit!" The environmental consultant explained that some communities within the region, especially in urban areas, do not support the use of land for bioenergy. However, the participants producing energy-crops did not mention the issue of food security. The exception was the biogas producer who expressed a neutral opinion on the use of food for bioenergy, explaining that globally "there is land enough, more than enough" for producing both food and energy-crops.

3.1.6. Fairness in trading

According to the self-sufficient livestock farmer, trust and fairness in trading practices can be impaired due to the non-local business relationships that this trade implies. Furthermore, the biogas producer disclosed that frauds have taken place on both the supply and the demand side (committed by both Danish and German producers).

3.1.7. Rural traffic intensity and rural odour

An increase in the traffic intensity of heavy machinery in the countryside due to the biogas-maize trade has raised some complaints in the respective local communities (self-sufficient livestock farmer; biogas producer). The self-sufficient livestock farmer mentioned that some local communities "are sick and tired" of the tractors transporting maize.

According to the biogas consultant/researcher, the issue of odour improves with the production of biogas, because the biogas digestate (digested manure and energy-crops) is less odorous than the non-digested manure, and farms neighbours "do not complain that much".

3.1.8. Nature cultural and metaphysical services

Seeing the potential effects of the production of maize on native farmland birds, the wildlife conservation member stressed the importance of protecting bird populations, in terms of cultural and metaphysical services:

Many times we have discussed the value of the song of the skylark. To Danes, at least to Danes of my age (about 50 years), the song of the skylark and the cry of the lapwing belong to the farmland. These are still in our heart, so it means a lot to have those birds. This is a gift which we are rather proud of and very interested in keeping.

3.1.9. Marketing resilience

The marketing resilience of the crop producers is strengthened by the trade of maize for biogas, because it increases demand and marketing possibilities (crop consultant; self-sufficient livestock farmer). The marketing preferences of the crop producers depend on the competition between global agricultural commodities prices and German bioenergy subsidies (crop and livestock consultants; energy-crop producer; self-sufficient livestock farmer; biogas producer). On the other hand, the marketing resilience of crop producers could be negatively affected by lower trust and the potential for fraud associated with non-local business relationships (self-sufficient livestock farmer; biogas producer).

The marketing resilience of biogas producers is relatively strong, due to the existence of long term contracts with the German government. The biogas producer explained that half of the price is set 20 years ahead, and the rest is set every 5 years taking into account current agricultural commodity prices.

3.1.10. Supply resilience

According to the biogas producer, the supply resilience of the biogas producers is relatively weak because they are vulnerable to the biomass availability and biomass price fluctuations. The biogas producer explained that "it is very hard to find whole-crop maize because there are too many biogas plants and the price of maize-grain for livestock is going up so farmers want to grow maize-grain instead". Some biogas producers have become bankrupt due to the biomass supply difficulties (energy-crop producer, biogas producer; livestock consultant), while others with more biomass self-sufficiency have "a great business", declared the energy-crop producer.

3.1.11. Investment capacity

Land prices in Denmark have decreased since around 2008–2009 (self-sufficient livestock farmer). However, most stakeholders mentioned that the trade of maize for German biogas has buffered the land price decline and increased the rent price in the southern regions of Denmark (crop and livestock consultants; self-sufficient and non self-sufficient livestock farmers; biogas producer). In Germany, the land price has been significantly rising partly due to the energy-crop demand (biogas producer). The land price in Germany has overtaken the land price in Denmark, leading to the purchase of Danish land by the German biogas industry, as in the case of the interviewed biogas producer.

Higher land prices can strengthen the economic resilience and increase access to bank loans for farmers and producers who own land, which in turn enhances their investment capacity (self-sufficient livestock farmer; crop and livestock consultants; energy-crop producer). The self-sufficient livestock farmer explained that bank loans are more accessibility in the southern regions of Denmark, compared to the rest of the country, due to buffered land-prices.

Conversely, the effects of the maize trade on land and rent prices can impair the economic resilience of biomass farmers who own less land and biogas producers with feedstock deficit, by limiting their land purchasing and renting capacity as well as their access to bank loans (biogas producer; self-sufficient livestock farmer; non self-sufficient livestock farmer). The non self-sufficient livestock farmer reflectively asked "why should always those who have land make the best business?".

3.1.12. Indirect stakeholders economic vulnerability

The feed supply possibilities of cattle farmers with non grain-feed ("roughage") self-sufficiency can be reduced in part due to an intensification of competition for renting land (non self-sufficient livestock farmer; energy-crop producer). The non self-sufficient livestock farmer described the intensity of this competition: "we were five persons participating in an auction for renting some land, including one German biogas guy; and at the end, the land end up being rented by almost double of the price that I wanted to offer".

Pig farmers are less vulnerable than cattle farmers to the feed and land competition, as they have more feed supply possibilities. For example, they can buy the feed from other regions or countries (self-sufficient and non self-sufficient livestock farmers). This feed supply flexibility provides an incentive to pig farmers with land to rent it to the biogas industry instead of cultivating it for their own feed supply, hence reducing production risks (non self-sufficient livestock farmer).

3.1.13. Production process resilience

The production process resilience of the whole-crop maize was seen by the crop consultant as relatively strong because it requires little farmer knowledge and expertise. On the other hand, it was seen by the energy-crop producer as relatively weak because the usability of the machinery for harvesting whole-crop maize depends more on soil moisture levels, in comparison with the machinery for harvesting only grain.

The production process resilience of maize-based biogas was seen by the biogas producer and consultant/researcher as relatively strong because it results in less technical problems compared with other biomasses.

3.1.14. Regional employment opportunities

The creation of additional employment opportunities in Denmark related to the production of maize for biogas is not significant, according to several of the interviewed stakeholders (crop and environmental consultants; self-sufficient and non self-sufficient livestock farmers; energy-crop producer). Part of the employment related to the production of maize is managed by German companies (self-sufficient and non self-sufficient livestock farmers), which do not create value through employment within the Danish region economy. Few additional employment opportunities may arise for transporting biomass to Germany (energy-crop producer). In contrast, the German biogas industry was seen by some of the interviewed consultants as a significant opportunity for employment creation and rural development within Germany (environmental and livestock consultants).

According to several participants, the trade of maize for biogas allows cattle farmers that are more vulnerable to commodity price fluctuations to shift to only biomass production (livestock consultant; biogas producer; energy-crop producer; self-sufficient and non self-sufficient livestock farmers). This in turn helps to keep part of the human capital in the rural and agricultural areas.

3.1.15. Inter-regional materials procurement and costs shifts

The Danish maize for German biogas supply chain involves international imports and exports of raw materials (e.g. exported maize and imported livestock feed), which could otherwise be traded within the region, enhancing regional value creation through tax payment, employment and investment (crop consultant; energy-crop producer; biogas producer). The energy-crop

producer observed that "it is a little bit stupid that we make so much maize for Germany, instead of using it for cows or biogas in Denmark". Moreover, international supply chains cause shifts of environmental and other economic costs within countries. For instance, the environmental costs of cultivating maize and the environmental benefits of having biogas, or the economic costs of providing biogas subsidies which will be partially invested in other countries (environmental consultant).

3.1.16. Pre-decision making assessment and public communication and participation

The main governance issue that arose was the potential lack of more holistic analyses before deciding on respective policies (environmental researcher). Specifically, analysis of the societal costs of abating carbon emissions with maize-based biogas, rather than analysis of only farmers- and industry-related costs (environmental researcher).

The environmental researcher highlighted the importance of having public opinion favour biogas development and hence the need for better communication of the reasons and arguments behind the use of maize until alternatives are developed. He also highlights the importance of involving the general public in the decision process:

If we can involve more the public in the decision, they will feel that it is also their project, a common project to save the globe, and not only for farmers looking for money. Then, I think, people can be more acceptant about, for instance, that you cannot see a pretty landscape in August.

3.2. Coverage analysis of assessment frameworks

The effectiveness of themes and sub-themes of sustainability assessment frameworks in covering the sustainability issues of the case study differed depending on the sustainability dimension and the respective frameworks (Tables 4 and 5).

The key environmental issues of the case study (i.e. GHG emissions, soil carbon balance, nitrate leaching, pesticide use, and native wildlife diversity) were completely covered by the themes and sub-themes of the analysed frameworks (Table 4). RSB themes and sub-themes emphasised more explicitly the assessment of GHG emissions within the entire life cycle and with the inclusion of land-use-change effects.

In contrast, the social issues of the case study were less effectively covered by the themes and sub-themes of the analysed frameworks (Table 4). Food security was explicitly covered only using the RSB themes and sub-themes, while SAFA and SLCA only covered it indirectly through broader themes and sub-themes, such as decent livelihood and public health. Fairness in trading was covered by a broad SLCA sub-theme, while the other frameworks' sub-themes only partially covered this by addressing human and labour rights aspects, or responsible demand aspects ignoring the supply side. Rural odour coverage effectiveness was high for the air pollution related RSB and SAFA themes and sub-themes. However, the odour-related SAFA theme goal was more focused on human health rather than a more cognitive wellbeing. The rest of the social issues (i.e. landscape aesthetics, rural traffic intensity and nature cultural and metaphysical services) were not covered by any of the frameworks themes and sub-themes, with the exception of nature cultural and metaphysical services that were partially covered by the SLCA cultural heritage sub-theme.

The economic issues were covered differently depending on the framework (Table 5). The SAFA themes covered all economic issues. Issues such as marketing, supply and production process resilience, as well as investment capacity issues were only covered by the SAFA themes and subthemes. The regional economic issues

Table 4
Analysis of the case study issues coverage by the frameworks themes and sub-themes (environmental and social dimensions).

		RSB		SAFA		SLCA
Dimension	Case Study Issue	Theme	Sub-theme[a]	Theme	Sub-theme	Sub-theme
Environ-mental	*GHG emissions*	Greenhouse gas emissions (P3)	Lifecycle GHG emissions (C3.b) & Emissions reduction significance (C3.c)	Atmosphere (E1)	Greenhouse gases (E1.1)	n.a.
	Soil carbon balance	Soil (P8) & Greenhouse gas emissions (P3)	Soil quality (C8.a) & Lifecycle GHG emissions (C3.b)	Land (E3) & Atmosphere (E1)	Soil quality (E3.1) & greenhouse gases (E1.1)	n.a.
	Nitrate leaching	Water (P9)	Water quality (C9.d)	Water (E2)	Water quality (E2.2)	n.a.
	Pesticide use	Soil (P8), Water (P9) & Conservation (P7)	Soil quality (C8.a), Water quality (C9.d) & Ecosystem maintenance (C7.b)	Land (E3), Water (E2) & Biodiversity (E4)	Soil quality (E3.1), water quality (E2.2) & Ecosystem diversity (E4.1)	n.a.
	Native wildlife diversity	Conservation (P7)	Ecosystem maintenance (C7.b)	Biodiversity (E4)	Ecosystem diversity (E4.1) & Species diversity (E4.2)	n.a.
– Social	*Landscape aesthetics*	**	**	**	**	**
	Food security	Food security (P6)	Food security management (C6.a)	Decent livelihood (S1)	*Public health (S5.2)	*Safe and healthy living conditions
	Fairness in trading	*Human and labour rights (P4)	*Law and agreement compliance (C4.e)	Fair trading practices (S2)	*Responsible buyers (S2.1)	Corruption
	Rural traffic intensity	**	**	**	**	**
	Rural odour	Air (P10)	Air pollution management (C10.a)	*Atmosphere (E1)	Air quality (E1.2)	**
	Nature cultural and metaphysical services	**	**	**	**	*Cultural heritage

Frameworks references: SAFA (FAO, 2013), RSB (2011) and SLCA (UNEP/SETAC, 2010). See the respective reference documents (open access) for a complete description of the goal/objective associated to each theme/sub-theme (not included due to spatial constrains). Codes between brackets: reference to each theme/sub-theme within the respective literature.

* Partial coverage.

** No coverage by any theme/sub-theme of the framework.

[a] The respective sub-theme names are not explicitly reported in the reference document, but are implicit within the sub-theme objective. n.a.: not applicable sub-theme because the respective dimension is not targeted by the framework.

Table 5
Analysis of the case study issues coverage by the frameworks themes and sub-themes (economic and governance dimensions).

		RSB		SAFA		SLCA
Dimension	Case Study Issue	Theme	Sub-theme[a]	Theme	Sub-theme	Sub-theme
Economic	Marketing resilience	**	**	Vulnerability (C2)	Stability of market (C2.3)	**
	Supply resilience	**	**	Vulnerability (C2)	Stability of supply (C2.2)	**
	Investment capacity	**	**	Vulnerability (C2)	Liquidity (C2.4)	**
	Indirect stakeholders economic vulnerability	*Rural and social development (P5)	**	Local economy (C4)	**	**
	Production process resilience	**	**	Vulnerability (C2)	Stability of production (C2.1)	**
	Regional employment opportunities	*Rural and social development (P5)	*Local socio-economy (C5.a)	Local economy (C4)	Value creation (C4.1)	Local employment
	Inter-regional materials procurement	*Rural and social development (P5)	*Local socio-economy (C5.a)	Local economy (C4)	Local procurement (C4.2)	Local employment
	Inter-regional costs shifts	*Rural and social development (P5)	**	Local economy (C4)	**	**
– Governance	Pre-decision making assessment quality	*Planning, monitoring and continuous improvement (P2)	*Impact assessment (C2.a)	*Corporate ethics (G1) & Holistic management (G5)	*Due diligence (G1.2)	**
	Public communication	*Planning, monitoring and continuous improvement (P2)	*Consent (C2.b)	*Accountability (G2)	*Transparency (G2.3) & *Stakeholder dialog (G3.1)	*Access to immaterial resources
	Public participation	*Planning, monitoring and continuous improvement (P2)	*Consent (C2.b)	*Participation (G3)	*Stakeholder dialog (G3.1)	*Community engagement

Frameworks references: SAFA (FAO, 2013), RSB (2011) and SLCA (UNEP/SETAC, 2010). See the respective reference documents (open access) for a complete description of the goal/objective associated to each theme/sub-theme (not included due to spatial constrains). Codes between brackets: reference to each theme/sub-theme within the respective literature.
* Partial coverage.
** No coverage by any theme/sub-theme of the framework.[a]The respective sub-theme names are not explicitly reported in the reference document, but are implicit within the sub-theme objective.

directly associated with the supply chain stakeholders, such as employees and suppliers (i.e. regional employment opportunities and inter-regional materials procurement), were completely covered by all analysed frameworks' themes and sub-themes, except for RSB, which only provided partial coverage due to its focus on regions of poverty. The regional economic issues indirectly associated with the supply chain (i.e. indirect stakeholders economic vulnerability and inter-regional costs shifts) were less effectively covered. These issues were covered by broad themes referring to the socioeconomic development and value creation for local communities. These issues were less effectively covered by the frameworks sub-themes.

Governance issues (i.e. pre-decision making assessment quality, public communication and public participation) were partially covered by the themes and sub-themes of the analysed frameworks (Table 5). However, an assessment level mismatch occurred because the governance themes and sub-themes of all analysed frameworks focus on the internal supply chain or life cycle level governance, while the selected case study governance issues focused on a more general sector and national policy-making level of governance. The SLCA sub-themes did not explicitly cover the pre-decision making assessment quality issue.

4. Discussion

4.1. Coverage effectiveness

The results of this study show that environmental context-specific issues may be effectively covered by generic themes and sub-themes and the economic context-specific issues by generic themes, as is the case with SAFA. This distinction is supported by the findings of other studies that have found environmental and economic issues are the dominant ones in the perception of sustainability and in the practice of sustainability assessment in fields such as agriculture (von Wirén-Lehr, 2001; Carof et al., 2013).

Wider coverage of the economic dimension in the SAFA framework probably occurs due to the different interpretation of the concept of sustainability (e.g. organisational or societal). While RSB and the SLCA have a more societal perspective, SAFA has both organisational and societal perspectives (Table 2). From an organisational perspective, the subject to be sustained is the organisation and the focus is, for example, the organisation resilience for using its natural, social and economic resources without depletion while coping with potential shocks. From a societal perspective the subject to be sustained is the society (Schader et al., 2012). These different perspectives could be a reflection of the different frameworks' purposes. For example, SAFA has a strong focus on self- and suppliers' management and planning, whereas RSB mainly aims to provide certification for regulations compliance (Table 2). Organisational perspective themes may better resonate with the investment decisions and management actions that are more commonly exercised by producers, and hence, help to enhance producers' assessment uptake and sustainability action. Therefore, the use of generic frameworks combining both societal and organisational perspectives may help to cover a wider range of stakeholders' needs and concerns. However, caution should be taken in the decision making process to avoid obscuring the societal perspective component and misinterpreting the assessment results. Accordingly, the sustainability-perspective definition should consider the assessment purpose and be clearly reported to the system decision-makers in order to contextualise the decision process.

A mismatch between the level of the assessment (e.g. enterprise, supply chain, region, nation) and the level of the sustainability-affecting processes (e.g. national policy-making) can also affect the coverage of relevant sustainability issues, as shown in the study's governance dimension (Section 3.2) and as discussed by van Passel and Meul (2012).

None of the analysed generic frameworks covered social issues such as landscape aesthetics and nature cultural and metaphysical services. However, other studies designing context-specific

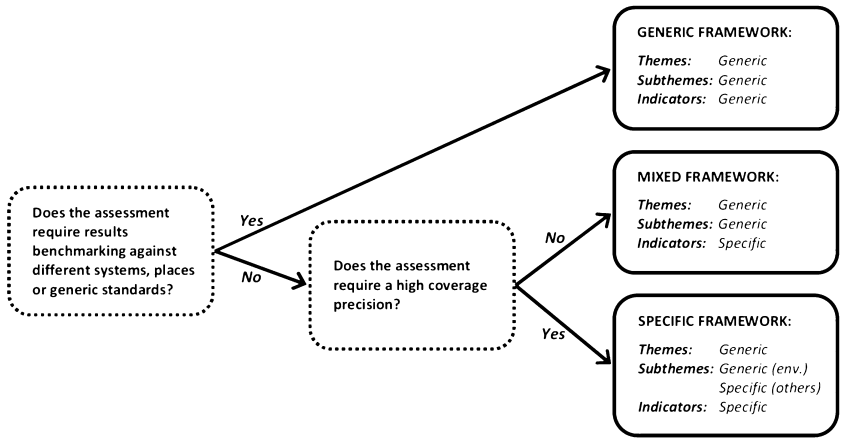

Figure 1. Frame for setting the specificity-level of sustainability assessment themes and sub-themes.

bottom-up frameworks based on participatory approaches have included issues associated with landscape aesthetics and nature cultural aspects (e.g. King et al., 2000; Louwagie et al., 2012). In this study, participants held differing views in relation to landscape aesthetics, probably due to differences in the frame of reference (values, norms, convictions, interests, and knowledge) as suggested by te Velde et al. (2002). A challenge arises in deciding which themes and sub-themes to include in the framework and establishing who gets to decide. Top-down decisions (Fraser et al., 2006) may help to regulate, for instance, the influence of stakeholders' business-as-usual aspirations. However, this approach places the decision power into a discourse of biased legitimacy. On the other hand, involving stakeholders with different aspirations and values in a dialogue requires more resources (Burgess and Chilvers, 2006), but may help to find common sustainability objectives as well as enhance stakeholders' education, assessment adoption and outcomes acceptance (Reed et al., 2006).

4.2. Advancing generic frameworks

The findings of this study suggest that the coverage gap of generic themes is potentially more of an issue of framework incompleteness that can be advanced through an iterative process of validation and reformulation, such as in the framework described by Reed et al., 2006. Therefore, generic themes have the potential for effectively covering context-specific issues in all analysed dimensions if the themes set is enhanced through expanding its coverage. On the other hand, sub-themes and the associated sustainability objectives are more dependent on the pluralistic needs and aspirations of the involved stakeholders. Therefore, the coverage gap of generic sub-themes may be an issue mainly caused by their less context-specific nature and may not be manageable only by expanding the generic sub-themes set. Cross-validation through analysing different contexts and frameworks is required to validate these results.

The expansion of generic framework themes and sub-themes could take place in terms of increasing the number of themes and sub-themes or in terms of increasing their individual scope. In terms of increasing the number of themes and sub-themes, the inclusion of additional social and economic themes and sub-themes for issues involving stakeholders more indirectly related to the respective value chain may significantly enhance the frameworks coverage. For example, the frameworks could also include themes related to protection of cultural heritage and human psychological and cognitive well-being, so case study issues such as landscape aesthetics, nature cultural and meta-physical services and rural traffic intensity would be better covered. However, the use of a large number of themes and sub-themes and the associated indicators can be a barrier to the framework applicability and adoption by the stakeholders and could complicate the interpretation of aggregated results. Increasing the scope of themes or sub-themes is another possibility for increasing coverage of sustainability issues. For example, RSB's local socio-economy sub-theme could better cover the identified regional economic issues directly associated with the supply chain (regional employment opportunities and inter-regional materials procurement) if the sub-theme objective is expanded beyond the regions of poverty scope. SAFA's atmosphere theme could increase the coverage of rural odour issues if the theme goal is expanded beyond the human health scope.

4.3. Balancing generality and specificity

Based on the previous results, this section proposes a rationale to set the specificity-level of sustainability assessment themes and subthemes (Fig. 1) for minimising the tradeoffs between generality and specificity (e.g. benchmarking and resource efficiency vs. coverage and engagement).

When the assessment requires results benchmarking against different systems, places or generic standards, the use of generic themes, sub-themes and indicators (generic framework type (Fig. 1)) should be considered, otherwise the benchmarking processes can be biased by the use of different goals, objectives or metrics. When results benchmarking is not a requirement, more specific frameworks can be used.

When results benchmarking is not required and a high coverage precision is not a possibility or a requirement due to resource limitations or a low assessment potential impact, the use of generic themes and sub-themes and specific indicators (mixed framework type (Fig. 1)) should be considered. In this case, the use of specific indicators is recommended due to their significant context dependency in terms of assessment resources availability, data accessibility and availability, and knowledge and capacities of the indicators users (Reed et al., 2006; Binder et al., 2010). SAFA is partly based on this framework approach because it allows some level of indicators customisation.

When results benchmarking is not required and a high coverage precision is a possibility or a requirement, a specific framework type is recommended (Fig. 1). In this case, generic themes (enhanced through expanding its coverage) can still be considered in all dimensions, as well as generic sub-themes in the environmental dimension. For example, this framework type would be appropriate in the case of designing governmental policies to improve the sustainability performance of biogas subsidies.

To involve stakeholders in the assessment specificity-level selection can help to minimise biases in the selection process. For example, affected stakeholders should be informed and consulted about the principal benefits and drawbacks of each option. These procedures may also help to enhance the stakeholders' assessment adoption and outcomes acceptance.

5. Conclusions

The study results indicate that generic sustainability assessment frameworks can effectively cover context-specific issues related with the environmental sustainability dimension. On the other hand, generic frameworks can be unable to identify context-specific issues related with the social and economic dimensions, especially at the sub- themes level and for issues involving stakeholders more indirectly related to value chains. This study suggests that at the themes level, the coverage gap of generic frameworks is mainly an issue of framework incompleteness that can be advanced with additional research. At the sub-themes level, the coverage gap of generic frameworks is probably more an issue caused by their less context-specific nature. The design or selection of a sustainability assessment framework should consider characteristics such as the sustainability perspective and the level of assessment, as these can influence the framework coverage effectiveness. Further research is needed to validate the findings of the study. For example, generic themes and sub-themes coverage should be analysed in different contexts and frameworks.

The choice of a specificity-level implies a number of tradeoffs that should be taken into account; for instance, benchmarking and resource efficiency vs. coverage and engagement. A one-size-fits-all specificity-level is not applicable, and this level should be tailored to the assessment purpose, specifically to the results benchmarking requirements and the coverage precision requirements or possibilities.

A certain degree of stakeholder participation, independent of the chosen specificity-level and despite the additional resource requirements, is recommended not only in the assessment process, but also during the framework design or selection process. Stakeholder dialogue should target issues such as reflection on benefits and drawbacks of each available framework design or selection process option, and reconciling common sustainability objectives. This may help to minimise biases in selecting the assessment characteristics, help stakeholders' sustainability education, and enhance assessment adoption, trust and sustainability action.

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