POTENTIAL AND CONSTRAINTS FOR INTEGRATING SOCIO-ECONOMIC ASPECTS IN LCA

Literature review and potential application to aquaculture in Asia

26 August 2010

Chen Oai Li and Froukje Kruijssen
The WorldFish Center
Penang

Summary

Life Cycle Assessment has become a popular tool to measure environmental impacts of products and services from 'cradle to grave', i.e. from inception to disposal after use. However, in the last decade, discussions on the integration of economic and social issues into Life Cycle Assessments to achieve a more complete assessment of the sustainability of products and services have also increased. The integration of economic issues into Life Cycle Assessment has been further developed in the form of Life Cycle Costing and is being applied more frequently. For Social Life Cycle Assessment guidelines have been developed by the UNEP/SETAC initiative; however, practical applications are presently limited. The development of measurable indicators and the weighting and scoring is therefore still underway. This paper gives an overview of the present status of the literature on Social Life Cycle Assessment. It also aims to assess the potential of doing so in the context of aquaculture products from four Asian countries that are exported into the EU and to contribute to the development of possible indicators.

Empirical case studies of Social Life Cycle Assessments are few and mostly exist in grey literature. This document gives an overview of some of these studies and examines the indicators used and the constraints in impact assessment. Few studies manage to develop a semi-quantitative analysis, mainly due to data limitations. If this method were to be applied in the assessment of social impacts of aquaculture products from the four participating countries in the SEAT project it is likely that similar data limitations will occur.

Methodologies for the integration of the three pillars of sustainability -environment, society and economy- through a life cycle approach are still under development. In this paper we show that the development of an integrated approach is well underway but that many obstacles still persist. While weighting and scoring of social issues remain a challenge, the three approaches (environmental life cycle assessment, life cycle costing, and social life cycle assessment) have a similar approach and unit of analysis, although the reach of the analysis may be narrower for both LCC and SLCA. The scope for integration especially exists in the identification of trade-offs between environmental, economic, and social issues in the comparison of two products. This will also enable the identification of major sustainability issues to be addressed in a particular product system. Further research and case study applications are necessary to expand the social life cycle assessment methodology. The SEAT project may provide an opportunity to contribute to this methodological development and to apply the guidelines in a developing country setting.

Acknowledgements

The authors gratefully acknowledge valuable inputs received from Jeroen Guinée, Richard Newton, Patrik Henriksson, Jimmy Young and Nireka Weeratunge.

List of acronyms

ELCA	- Environmental Life Cycle Assessment (normally referred to as LCA)
ISO	- International Standardization Organization
LCA	- Life Cycle Assessment (in this text referred to as ELCA)
LCC	- Life Cycle Costing
LCI	- Life Cycle Inventory
LCIA	- Life Cycle Impact Assessment
SLCA	- Social Life Cycle Assessment
UNEP	- United Nations Environmental Programme
SEAT	- Sustaining Ethical Aquaculture Trade
SETAC	- Society for Environmental Toxicology and Chemistry

Table of contents

List of tables

Table of figures

1 Introduction

"Life cycle thinking" commenced in the early nineties in the context of the UN program Agenda 21, in which governments, international organizations and the private sector were called to develop criteria and methodologies for the assessment of environmental impacts and resource requirements throughout the full life cycle of products and processes. A rise consumers' interest in the processes underlying the products they buy, further promoted the development of the idea. The basis of life cycle thinking is that everyone in the entire system of a product's life cycle, from cradle to grave, has a responsibility, taking into account all the relevant external effects (UNEP/SETAC, 2009).

This has lead to the further development of an existing product-related life cycle assessment by the Society for Environmental Toxicology and Chemistry (SETAC) called Life Cycle Assessment (LCA), later standardized by the International Standardization Organization (ISO 14040, 2006a; ISO 14044, 2006b). LCA aims to assess the environmental impacts of goods and services in the cycle from cradle to grave to inform production and consumption choices. Its basic principles enable comparison between two or more systems on the basis of a common benefit in a holistic way, distinguishing this method from other environmental assessment methods (Klöpffer, 2003). The LCA approach is by now well accepted and continues to be implemented. However, the application of LCA, and its integration into decision making processes of organizations, is far from being standard practice and is still, often limited to singular efforts and demonstration projects (Hunkeler & Rebitzer, 2005).

Sustainability however, not only includes environmental (ecological) aspects but also economic and social effects. These three pillars of sustainability are by now recognized, and a fourth, cultural aspects, is receiving increasing attention. From the beginning of this century, interest in including the other elements of sustainability increased, to complement the LCA assessments of effects that a product or process has on the environment. This lead to the creation of a platform for extension of the environmental life cycle view to include social and economic dimensions, and later on to identification of the challenges in its development and implementation (Klöpffer, 2003; Hunkeler & Rebitzer, 2005; Dreyer et al., 2006; Labuschagne & Brent, 2006; Jørgensen et al., 2008).

The economic dimension, relative to the social and cultural, is further along in its development, and there are several tools currently available that use a life cycle perspective to analyze economic aspects of a product and process, such as life cycle costing and total cost assessment (Norris (2001) as quoted in Kruse (2009)).

The focus of this document is on the potential and constraints for integrating socioeconomic aspects in environmental LCA (from now on referred to as ELCA). Before going into social LCA, section 2 gives a brief introduction to ELCA and Life Cycle Costing (LCC) approaches. Then in section 3 the early stages of the methodological development in social LCA are described, including some obstacles and questions raised in literature. One of the most recent developments has been the publishing of guidelines for social LCA (UNEP/SETAC guidelines, 2009). These will be discussed in section 4, including their effort in addressing the constraints raised. Subsequently, in section 5, a few recent case studies of SLCA implementation on a range of products are discussed. Lastly, a framework is developed for SLCA for fish produced and processed in Asia, and consumed in Europe in the context of the SEAT project.

2 Environmental life cycle assessment and life cycle costing

2.1 Environmental life cycle assessment

Environmental life cycle assessment was originally developed in the late 1960's and throughout the 1970's to address the desire of enterprises and policy makers to understand the relative environmental impacts of alternative packaging options. This took place at a time when awareness of the limits to growth and the vulnerability of the economic system was growing, among other reasons due to the first oil crisis (UNEP/SETAC, 2009).

The basic principles of ELCA distinguishing this method from other environmental assessment methods, are: (i) the analysis is conducted from cradle to grave, (ii) all mass and energy flows, resource and land-use, etc., and the potential impacts connected with these interventions, are set in relation to a functional unit as a quantitative measure of the benefit of the system(s), and (iii) ELCA is essentially a comparative method, where two systems are compared or improvements of one system are compared to the status quo (Klöpffer, 2003).

The ISO standards identify four phases for conducting an ELCA (UNEP/SETAC, 2009):

1. Goal and Scope Definition: where the reasons for carrying out the study and its intended use are described and where details are given on the approach taken to conduct the study. It is in this phase of the study that the functional unit is defined, and that modelling approaches are specified.
2. Life Cycle Inventory (LCI): where the product system(s) and its constituent unit processes are described, and exchanges between the product system and the environment are compiled and evaluated. These exchanges, called elementary flows, include inputs from nature (e.g. extracted raw materials, land used) and outputs to nature (e.g. emissions to air, water and soil). The amounts of elementary flows exchanged by the product system and the environment are in reference to one functional unit, as defined in the goal and scope phase.
3. Life Cycle Impact Assessment (LCIA): where the magnitude and significance of environmental impacts associated with the elementary flows are evaluated. This is done by associating the life cycle inventory results with environmental impact categories and category indicators. Life Cycle Inventory results, other than elementary flows (e.g. land use), are identified and their relationship to corresponding category indicators is determined. LCIA has a number of mandatory elements: selection of impact categories, category indicators, and characterization models as well as assignment of the Life Cycle Inventory results to the various impact categories (classification) and calculation of category indicator results (characterization). This can then be followed by optional elements such as normalization, grouping and weighting.
4. Life Cycle Interpretation, where the findings of the previous two phases are combined with the defined goal and scope in order to reach conclusions or recommendations.

Food production has only recently become the subject of ELCA studies (Ayer et al., 2007; Schau & Fet, 2008) as the approach was originally intended for industrial products. There is therefore still limited application of ELCA to fish farming, although some studies have been published in the last five years. The majority of those studies have focussed on production in Western and temperate countries (e.g. Papatryphon et al., 2004; Ellingsen & Aanondsen, 2006; Grönroos et al., 2006; Ayer et al., 2007;

Pelletier et al., 2007; Aubin et al., 2008). Few studies have appeared applying the LCA framework to aquaculture in Asia (Mungkung et al., 2006; Henriksson, 2009; Lebela et al., 2010). Application of ELCA in developing country contexts in general has been more difficult due to lack of data, and limitations in applying available databases from the western world (Ortiz et al., 2009).

2.2 Life cycle costing and environmental life cycle costing

Life Cycle Costing[1] (LCC) is "*an assessment of all costs associated with the life cycle of a product that are directly covered by any one or more of the actors in the product life cycle (e.g., supplier, manufacturer, user or consumer, or End of Life actor) with complementary inclusion of externalities*[2] *that are anticipated to be internalised in the decision-relevant future"* (Hunkeler et al., 2008, p. 173 as quoted in UNEP/SETAC, 2009). LCC can be used as a stand-alone method and can be integrated in ELCA. It is recognized as the tool for economic assessment, the second dimension of sustainability. Without this pillar, the traditional ELCA has limited influence and relevance for decision making, as it does not characterize the important relationship and trade-offs between the economic and environmental performance of alternative product life cycle scenarios. A number of industry guidelines and references have been developed for LCC but an ISO standard does not exist yet. Products can range from entire office buildings, trains or train carriages to one square meter of carpet (Norris, 2001; Steen, 2005; Hunkeler & Rebitzer, 2005; UNEP/SETAC, 2009).

The key issues in integrating LCC into ELCA include the use of the same system boundaries and functional units as in ELCA. LCC and ELCA have major methodological differences as ELCA evaluates the relative environmental performance of alternative product systems for providing the same function while LCC compares the cost effectiveness of alternative investments or business decisions from the perspective of an economic decision maker. It is important to note that in economic sciences, the term "life cycle" is often defined in another way, i.e. the sequence of product development, production, marketing/sales, and end of economic product live. The process scope of the LCC includes only those processes imposing direct costs (or benefits) upon the decision maker. Timing (present valuing or discounting) of the cost flows is critical for LCC. It may also include external costs, i.e. costs incurred by society, due to environmental damages connected with the products, although they may be difficult to quantify (Klöpffer, 2003). Recent literature has noted that there may be a rick of double-counting due to the inclusion of externalities into LCC, as it is already part of the ELCA (Guinée et al., 2009).

Despite these differences, it seems possible to link LCC and ELCA based on the broad consensus that one needs a clear distinction between the three pillars of sustainability (Norris, 2001; Steen, 2005). Norris (2001) describes two approaches that fully integrate ELCA and LCC, as opposed to half-way approaches that integrate a full ELCA with only a partial LCC, or vice versa. Both approaches have shown ability to take both economic and environmental performance, and their trade-off relationships, into account in product/process design decision making (Norris, 2001). A recent SETAC Working Group has developed a methodology for ELCA to address modelling issues (Hunkeler

[1] Life cycle costing was first developed and used by the U.S. military in the 1960's in order to assess the costs of long living goods such as tanks and tractors (Steen, 2005).

[2] Inclusion of externalities in the LCC (e.g. cost of environmental impacts caused by the product), follows a "polluter pays principle". Anyone who causes an impact on environment shall pay for its cost. In LCC, these costs could be made visible (Steen, 2005).

et al., 2008). Environmental Life Cycle Costing is meant to be applied in parallel to an ELCA. The number of applications of LCC on aquaculture found in literature was even fewer than of ELCA (one example of LCC in fisheries is Bouwer Utne (2009)).

3 Social life cycle assessment: early stages of methodological development

In the 1990s, research on social life cycle approaches and their interrelation with LCA took place. During that time, O'Brian et al. (1996) developed a Social and Environmental Life Cycle assessment (SELCA). SELCA consists of five phases: problem definition scoping, data analysis, process assessment, evaluation, and action. Data analysis is equivalent to inventory analysis, process assessment to impact assessment (O'Brian et al., 1996). However, this approach has not significantly advanced over the past decade until recently through the UNEP/SETAC Life Cycle Initiative and publications in this area (Hunkeler, 2006).

The development of the methodological basis for social assessments, however is far behind LCA and LCC, and probably much more difficult. By the end of 2003, the UNEP/SETAC life cycle initiative recognized a need for a task force on the integration of social criteria into LCA. The task force aims (a) to convert the current environmental tool LCA into a triple-bottom-line sustainable development tool; (b) to establish a framework for the inclusion of socio-economic benefits into LCA; (c) to determine the implications for Life Cycle Inventory analysis; (d) to determine the implication for Life Cycle Impact Assessment and (e) to provide an international forum for the sharing of experiences with the integration of social aspects into LCA. Five years later in 2009, the first guidelines – "Guidelines for social life cycle assessment of products"- were published by UNEP/SETAC Life Cycle Initiative (UNEP/SETAC, 2009).

Aside of the UNEP/SETAC Life Cycle Initiative effort there have been a series of ideas and concerns on integration of social and socioeconomic aspects into the LCA framework raised by Dreyer et al. (2006), Weidema (2006), Norris (2006), Labuschagne and Brent (2006), Hunkeler (2006), Klöpffer (2008), and Jørgensen et al. (2008), to name a few. In the domain of fisheries and aquaculture Kruse et al. (2009) developed socioeconomic indicators for the case of wild caught and farmed salmon. Some of the ideas presented in these papers are summarized in the following section. The subsequent discussion will follow the typical procedure used for an environmental LCA. The stages are: i) goal and scope definitions; ii) inventory analysis; iii) impact assessment; and iv) interpretation.

3.1 Goal and scope definition in Social LCA

In ELCA, the goal and scope definition is a clear statement of the purpose or goal of the assessment. The scope defines the function and the functional unit of the product and the depth of the study. Below we will describe some observations on SLCA with regard to the goal and scope definition such as the product system, the system boundaries, the allocation procedure, the inventory indicators and data types, and the so-called areas of protection.

3.1.1 General determinations

Product system definition in Social LCA

The product system covers all the processes involved in the different stages of a product's life cycle. In environmental LCA, the origins of environmental impacts are processes as there is a natural link between the physical input and output of a process and a change in the quality of the environment. Social LCA is about impacts on people and therefore the focus must be on those activities which affect people in a product's life cycle. Dreyer et al. (2006) argue that social impacts on people in the

life cycle of a product will depend on the conduct of the companies involved in the product chain and the way they organize and manage their business, rather than on the process itself, except for some direct occupational health impacts on workers. The authors therefore suggest that the conduct of a company towards stakeholders should be examined in the inventory analysis while the impact assessment phase addresses the impacts of this conduct on the stakeholders[3] . This means that the social life cycle profile for a product is an aggregation of a number of individual company assessments of the companies (or other actors) involved in the product life cycle of the product assessed from raw material suppliers to retailers and end-of-life actors (Dreyer et al., 2006).

System boundaries

For the analysis of a product system it is important to define which parts need to be assessed. Some authors point out that the choice depends on the goal of the study: if the focus is on product comparison, a full assessment is necessary; for supporting management decision it could be enough to include only those parts of the life cycle which can be directly influenced by the company (Zamagni et al., 2008). For example, the focus of Dreyer et al. (2006) is on the application of Social LCA in business decision-making and they narrow their focus to those parts of the life cycle that the companies involved in the life cycle of the product to be assessed, can influence directly. This however, cannot apply to the use phase of a product as the social impact from this stage will be derived from the use of the product itself, rather than from the company's conduct. In a comparison of two similar products produced in different ways the social impact of use of the product will not differ that much and it will therefore depend on the scope of the SLCA whether there is a need to include this phase in the assessment (Dreyer et al., 2006).

Allocation

The main question in an environmental LCA in the allocation phase would be: "How much of the impact should be allocated to each of the processes along the product system?". As for SLCA, as discussed in Dreyer et al. (2006), the origin of social impact is company conduct rather than the processes themselves. Therefore, the question will be: "How much of the total social impact of the entire life cycle of the product or service should be allocated to each company of chain actor along the value chain?".

To address this question Dreyer et al. (2006) propose a share factor to represent the weight that is given to a chain actor's social profile in the aggregation of social impacts along the product chain. The share in total number of working hour spent at a particular company (or by a particular group of actors), or alternatively the value creation along the product chain (monetary input and output) per functional unit of the product, could be used as the basis for determining the chain actor's share factor. A different approach is proposed by Jørgensen et al. (2008) who highlight a socio-labelling approach (as presented by Spillemaecker et al. (2004)). In this approach, each company included in the assessment of a product or service has to comply with the standard set by the label. If the standard is met, the label can be awarded. As it is then the entire company that is assessed instead of just the components that have contributed to the product or service, allocation does not need to be made (Jørgensen et al., 2008).

[3] People affected directly or indirectly by the company's business activities may be collectively termed as stakeholders of the company.

System expansion and allocation

In many processes more than one product is produced (joint production), in such cases it is necessary to divide the impacts from the process between the products. It is not straightforward to divide impacts between the product and the co-product, but with help from allocation or system expansion it can be done. The choice between the two methods can have large impacts on the result of the LCA. The ISO 14040 suggests using system expansion whenever possible and where it is not possible to use system expansion allocation can be used instead (Weidema, 1999).

The issue of by-products has always been an important ongoing debate, especially for food products, in the ELCA literature, but is equally relevant for SLCA (Ayer et al., 2007; Schau & Fet, 2008). It is often the case that the functional unit represents only a fraction of the total production from all the associated inputs and the remainder is used as by-products. For animal production for example, some of the inputs themselves, e.g. the feed, have been produced with many associated by-products. This poses problems not only in attributing the environmental burdens to the inputs in production, but also the impacts from final disposal within the production system, if some or all of these by-products enter into separate industries. Much of the argument centers on the proportion of environmental burdens to which the by-product contributes. In many cases economic allocation is used as there is no dedicated industry to produce by-products; however, this does not reflect the true impacts of production and in many cases the economic value of the by-product may change over time or according to its application (Ayer et al., 2007). Conversely if mass or gross nutritional energy allocation is used, the LCA may be short sighted in its boundary setting in that it does not consider the associated burdens of disposal of what would otherwise be considered a waste product when comparing the sourcing raw materials. This can be seen in the different approaches by Papatryphon et al. (2004) and Pelletier and Tyedmers (2007), who used economic and gross nutritional energy allocation respectively, when comparing the ELCAs of salmonid feeds using fishmeal from by-products or traditional reduction fisheries.

In some circumstances, by-product industries may result in higher environmental impact than the associated impacts from other (traditional) disposal methods, which may vary from composting to incineration but in others, the by-product may be used in industries which can alleviate burdens on natural resources in separate industries. For example, in Vietnamese production, on average, only 35% of the carcass from the striped catfish, *Pangasius hypophthalamus,* contributes to the fillet and much of the rest of the animal is most often directed to producing fishmeal for terrestrial livestock (Le Nguyen, 2007). Although the fishmeal production may result in higher environmental costs than composting, for example, the by-product resource is used efficiently and results in less trash fish or other resources being required to supply protein for terrestrial livestock production. Therefore, overall the environmental impacts may be far less than if only raw ingredients were used in the two production areas, fish and terrestrial livestock, and the by-products from each were disposed of. There have been few ELCA studies which investigate the synergies between different industries through the efficient use of by-products. However, Ardente et al. (2009) explored the use of plastic by-products within the car industry in Italy and reported substantially reduced emissions and production costs. Similarly there have been few SLCA studies performed on by-product industries which may result in positive or negative social-economic effects. Whereas extra employment and

income may be generated, through value addition, resulting in positive impacts for the livelihoods of local populations, there may also be impacts on health, welfare and other negative factors. Therefore, it is important to have strong arguments concerning where the boundaries of different production points are drawn and how the various impacts are allocated to each where overlaps occur, both for ELCA and SLCA. However it will clearly depend on the scope of the assessment.

3.1.2 Indicator selection

In ELCA, the Inventory Analysis will yield a long list of quantities of all the natural resources consumed and the emissions produced at various stages of the life cycle of a product or service. SLCA in contrast, will need another type of assessment, based on social indicators to assess the social impact of the product or service. Different types of indicators can be distinguished and an overview of definitions is given in Table 1.

Table 1. Overview of indicators for Social LCA

Indicator	Definition	Source
Mid-point*	Impact category indicators at an intermediate position of the impact pathways	Jolliet et al., 2004
End-point*	Indicators for the final impact or damage categories at the level of the ultimate societal concern	Jolliet et al., 2004
Top-down	Indicators for issues that have societal value	Dreyer et al., 2006
Bottom-up	Indicators for issues that are important in the context of the chain actor (e.g. manufacturer)	Dreyer et al., 2006
Additive	Indicators that relate to the functional unit and are measured quantitatively	Kruse et al., 2009
Descriptive	Indicators that cannot be related to the functional unit. They can be either quantitatively or qualitatively described and/or measured.	Kruse et al., 2009
Generic	Indicators that give a generic indication for a certain issue, measured at regional or national level	UNEP/ SETAC, 2010
Site-specific	Indicators that give information on issues, specific for a site (e.g. a factory).	UNEP/ SETAC, 2010

Source: authors' literature review. Note: indicators marked with *are also used in ELCA.

Mid-point and end-point indicators

The methodology of indicator selection depends on the Life Cycle Impact Assessment method chosen. Three methods can be distinguished - classical methods that determine impact category indicators at an intermediate position of the impact pathways (e.g. ozone depletion potentials), damage-oriented methods aiming at more easily interpretable results in the form of damage or impact indicators at the level of the ultimate societal concern, and an integrated approach that combine these families of methods (Jolliet et al., 2004). In the latter case, mid-point indicators may contribute to one or several end-point categories (UNEP/SETAC, 2005). Examples of end-point indicators for SLCA include mortality, non-lethal health impacts, autonomy infringements, safety, security and tranquillity, unequal opportunities, participation and influence (Weidema, 2006). A case study by Hunkeler (2006), in which a midpoint SLCA is developed for two detergents, notes that the advantage of midpoint over endpoint assessments is that the first does not require the level of

aggregation of the latter. Societal impacts may involve a high number of specific indicators and aggregation may therefore be difficult (Hunkeler, 2006).

Weidema (2006) states that in SLCA it is often difficult to distinguish between the different types of indicators. However, it is important to treat each social aspect according to its position on the impact pathways or in the different impact categories. Some aspects are inventory items (e.g. hours of child labour), others are midpoint indicators (e.g. the resulting lost education), some are impacts to instrumental values (e.g. lost income), and yet others are impacts to intrinsic values, either to human health and well-being (e.g. autonomy infringements) or to objects with heritage value (e.g. language). We can define indicators and units of measurement for each of these aspects, thus allowing quantification. A requirement for a good indicator is that it allows quantification of the extent (incidence or prevalence), the duration and the severity of the considered aspect. Resolving these questions is a necessary step in defining and validating social indicators (Weidema, 2006).

Bottom-up and top-down approaches

Indicator selection will further depend on the approach chosen with respect to the 'point of interest' of the assessment, i.e. bottom-up or top-down. In a bottom-up approach, the definition of assessment parameters will start with an identification of social issues in the business context of the product manufacturer[4]. The company cannot be held accountable for more than it possibly can influence and in this approach all impacts, which are relevant from the company's point of view, should be considered (Dreyer et al., 2006; Kruse et al., 2009) Alternatively, the bottom-up approach can also be used to adapt the assessment according to the data available (Kruse et al., 2009). In a top-down approach, the definition of assessment parameters starts with an identification of what is valuable to society. This ensures an inclusion of those impacts which are relevant from a societal point of view, but the relevance to the company's decision-making is not always straightforward, and sometimes it is completely absent (Dreyer et al., 2006). While the top-down approach ensures that selected indicators define and measure impacts that have a high societal value, it does not account for the potential lack of measurement methods and/or lack of access to data which could limit real world application of the indicator(s) (Kruse et al., 2009). Dreyer et al. (2006) and Kruse et al. (2009) use a combined top-down and bottom-up approach in generating indicators.

It is important to avoid an inconsistent indicator selection process based only on data availability and/or impacts for which industries are willing to be held accountable. Dreyer et al. (2006) therefore suggest two layers of impact categories, namely obligatory[5] and optional[6]. The two-layer framework is suggested in recognition of the observation that many important social impacts of companies and other chain actors will be dependent on the specific business context, in terms of who are affected by the business activities and how they are affected. Hence, for SLCA to be valuable as a decision

[4] In traditional LCA, the bottom-up or midpoint approach (sometimes referred to as 'environmental theme approach') is based on known and acknowledged environmental problems as categories of impact. The approach starts from the environmental exchanges between the product system and the surroundings, and these are taken as input to models of the environmental impact chain with underlying the environmental problem. Given the acceptance of such categories in decision-making, the results, expressed in terms of midpoint variables, can be regarded as relevant for decision-making (Dreyer et al., 2006).

[5] Consensus-driven, 'normative' assessment parameters expressing minimum requirements to business (Dreyer et al., 2006).

[6] Self-determined, context-specific assessment parameters to customize Social LCA (Dreyer et al., 2006)

support tool, the framework must enable inclusion of special concerns. On the other hand, there are some social impacts which are relevant to address for all companies and which must be considered by SLCA in order to ultimately serve the objective of reducing harmful impacts and promoting beneficial impacts on people (Dreyer et al., 2006).

Additive and descriptive types of indicators

Describing the causal relationship between a socioeconomic impact and the product in question, however, may neither be as straightforward, nor as easily quantifiable as for emissions in an ELCA. This becomes clear in application on a specific case study on salmon production, developed by Kruse et al. (2009). In that paper socioeconomic indicators are categorized into two groups, additive indicators and descriptive indicators. Table 2 gives an overview of these indicators as developed for the food production component of a salmon production system, both for capture fisheries and aquaculture.

Additive indicators must meet two criteria: (1) they can be measured quantitatively and (2) they relate to the functional unit (i.e., they are additive through the chain). While descriptive indicators (1) can be either quantitatively or qualitatively described and/or measured at each point in the chain and (2) cannot be related to the functional unit (i.e., are not additive through the chain). The category of descriptive indicators can be further broken down into two subcategories, general and specific, based primarily on the perspective or frame of reference being considered. Descriptive general indicators are meant to describe broad societal values and be widely applicable, and to a large extent reflect a top-down approach (i.e., internationally established standards). Descriptive specific indicators, on the other hand, are those indicators that may not be widely applicable but, rather, are focused on the relevant socioeconomic impacts of a specific process or product (Kruse et al., 2009).

It should be noted, that the indicators developed in the present case study by Kruse et al. (2009) show only the salmon food production system and are only divided by their methodological differences and not according to stakeholder, impact category, and other dimensions (an additional paper is forthcoming). As a result, indicators for other stages in the value chain (such as those that apply to transporters, wholesalers, exporters and retailers) are missing.

Spatial variation

In Dreyer et al. (2006), the Universal Declaration of Human Rights serves as normative basis for Social LCA, together with local or country norms based on socio-economic development goals of individual countries. The International Labour Organisation's Conventions and Recommendations, and the Tripartite Declaration of Principles concerning Multinational Enterprises and Social Policy, support development of the impact pathway top-down, starting from the normative basis.

Norris (2006) has a similar approach, noting that poverty is a highly local, context-specific, culturally and socially-dependent attribute. Thus, inaccuracies are likely to persist even with attempts to gather and report data on wage-based changes in national poverty rates, by process, by country. In line with this, Weidema (2006) acknowledges that site specific data in general will lead to more accurate assessments but argues that using generic data from statistical database (national, regional and global) can give a rough estimate on several social impacts. To overcome this, Hunkeler (2006)

proposes a geographically specific midpoint based-societal life cycle assessment methodology to tackle this issue.

Table 2. Indicator definitions for a salmon production system

Indicator	Indicator definition
Additive indicators	
Production costs	The cost to produce one functional unit (fu)
Labour costs	The labour cost to produce one fu
Gendered labour costs	Labour costs broken by male/female
Migrant labour costs	Labour costs broken by migrant/non-migrant
Value-added	The dollar value added per fu
Person hours of production	The total person hours required to produce one fu
Gendered person hours	Person hours broken by male/female
Migrant person hours	Person hours broken by migrant/non-migrant
Death/accidents	The loss of life/injury on the job per fu
Descriptive general indicators	
Fair wage	A wage adequate for a person to survive on
Employment benefits	The existence of and/or type of benefits
Hours worked per week	The number of hours worked per week by an average worker
Forces labour	The existence of compelled labour
Discrimination/gender	The breakdown employees by gender
Right to organize	A right to freedom of association and collective bargaining
Age distribution of workers	The breakdown of employees by age
Minimum age of workers	A proxy for child labour
Access to bathroom/potable water	A proxy for working condition
Industry concentration	The number of companies at each step in the value chain
Distance travelled	The distance between the different activities in the value chain
Descriptive specific indicator	
Contribution to income	Contribution of product/process to personal income
Fair price	Price paid to fishermen is fair
Access	Ability of a worker to enter the production process
Latent quota	Level of unused fishing permits
Owner-operator	Level of permit owners who also fish the permit
Adjacency	Worker adjacency to point of primary production
Compliance	Compliance with regulations by industry

Source: Kruse et al., 2009; p.14.

3.1.3 Areas of protection

The creation of indicators implies a notion of some underlying themes of importance or, in this case, something that needs to be protected, consequently denoted as Areas of Protection (AOP). In ELCA, there are four of these AOP, namely human health, natural environment, natural resources and man-made environment (Jørgensen et al., 2008). ELCA only considers damage to people which occurs as a consequence of impacts on the environment. Social LCA should however embrace a broader understanding of human life, encompassing the value of a good and decent life, to be able to truly consider social impacts and damage to people (Dreyer et al., 2006). Additional areas of protection are therefore suggested. At least three important prerequisites for a good and decent life can be identified, 'human health', to live a healthy and naturally long life; 'human dignity', to live a decent life and enjoy respect and social membership; 'basic needs fulfilment', to have access to food,

water, clothes, medical care, etc. These prerequisites are promoted by, and dependent on, fulfilment of basic needs. In keeping with this, a new area of protection is suggested to be used in SLCA, i.e. 'human dignity and well-being' (Dreyer et al., 2006).

3.2 Inventory analysis

The objective of the inventory is to collect relevant information, identified during the scope definition. One of the most challenging aspects regarding SLCA is data collection. Labuschagne and Brent (2006) found that a social footprint (i.e. measurement of the social impact of an activity or organization on people) is not available for all midpoint categories. It is regarded as an international problem that current available statistics are incapable of providing an integrated view of various dimensions of sustainable development. They therefore conclude that a quantitative social impact assessment method cannot be applied for project and technology life cycle management purposes in industry at present. It is emphasized that these conclusions were reached from a process LCA perspective, which is industry sector-wide. A similar assessment with a product LCA focus may lead to different outcomes (Labuschagne & Brent, 2006).

3.3 Life cycle impact assessment

The impact assessment consists of the selection of the impact categories and subcategories, and the characterization methods and models, relating the inventory data to these subcategories, and then calculating the results. An important challenge is to model the social impact pathways from the social inventory results to the impact indicators. As in ELCA, the modelling can be done both bottom-up (from inventory results to impact indicators) or top-down (starting from the impact categories). Modelling from the top-down is considered more efficient because it allows focus on only the most important or most impacted categories, thus avoiding spending disproportionate efforts on pathways of minor importance (Weidema, 2006; Labuschagne & Brent, 2006). Some impact pathways may be more complex than others. An example of a simple impact pathway can be given for the inventory indicator 'hours of child labour' and the area of protection 'human productivity'. Child labour will result in a lack of education, which leads to lower productivity of the affected individual. The benefit of the absence of child labour then can be measured as the resulting lifetime increases in income for the labourer relative to the average lifetime wage, and thus summed up as a human productivity impact. A complex pathway can be given for equal opportunities, where the challenge is to estimate the income foregone and model the impacts of the resulting distributional bias. With the current status of knowledge availability, complex impacts should, however, be not excluded just because of their complexity (Weidema, 2006).

The purpose of characterization in ELCA is to aggregate the inventory results within the same impact category. This involves conversion of inventory data to a common value (Jørgensen et al., 2008). For SLCA this may be more complicated if social impacts are not related to one process flows. Then there is a need for well-defined rules for allocating impacts to a specific product system (Swarr, 2009). Norris (2006) proposes a method which summarizes attributes of processes across a company's supply chain. Klöpffer (2003; 2008) however argues that all impacts must be quantitatively linked to a functional unit. Hunkeler (2006) decomposes unit processes of the life cycle inventory into regional labour hours, and then evaluates social impacts based on the ability to use the labour income to obtain basic needs, such as food and housing.

4 Social LCA: current methodological developments

4.1 Problems and unresolved questions

The discussion in the previous section shows that there are a multitude of different approaches to the different steps in the SLCA methodology, reflecting the immaturity of the field of SLCA. Many fundamental issues remain to be agreed upon and resolved. The critical issues for SLCA are found to be very similar to those identified in a recent review of unresolved problems in LCA methods, summarized in Table 3.

Table 3. LCA problems by phase

Phase	Problem
Goal and scope definition	Functional unit definition
	Boundary selection
	Social and economic impacts
	Alternative scenario consideration
Life cycle inventory	Allocation
	Cut-off criteria
	Local technical uniqueness
Life cycle impact assessment	Impact category and methodology selection
	Spatial variation
	Local environmental uniqueness
	Dynamics of environment
	Time horizon
Life cycle interpretation	Weighting and valuation
	Uncertainty in decision process
All	Data availability and quality

Source: Swarr (2009)

Some examples of unresolved questions are: Can the problem of defining a functional unit and delineating system boundaries be tackled? Which impact categories should be included in the assessment? Can the impact categories be related to the same process-based inventory data used for LCA and LCC? How should these impact categories be measured? The degree of complexity needed for measuring these social impacts is another fundamental issue, for example, some approaches advocate a detailed and site specific investigation whereas others claim that statistical sources suffice. Other associated questions will be related to the inherent disconnect between the global logic of product value chains and local-place-based sustainability assessment (Dreyer et al., 2006; Weidema, 2006; Norris, 2006; Labuschagne & Brent, 2006; Hunkeler, 2006; Klöpffer, 2008, Jørgensen et al., 2008; Kruse et al., 2009 and Swarr, 2009).

For this document the most relevant question will be: “Is the social life cycle assessment of a product different from the traditional environmental LCA and if yes, how so?”. The UNEP/SETAC Guidelines for Social Life Cycle Assessment of Products attempts to address these questions in detail. The remainder of section 4 is drawn from the UNEP/SETAC guidelines for social life cycle assessment of products (UNEP/SETAC, 2009; Benoit et al., 2010), unless otherwise stated.

4.2 Differences between environmental and social LCA

In the UNEP/SETAC guidelines, Social and Socio-economic Life Cycle Assessment (SLCA) is defined as a social impact (and potential impact) assessment technique that aims to assess the social and socio-economic aspects of products and their potential positive and negative impacts along their life cycle. SLCA complements ELCA with social and socio-economic aspects. It can either be applied on its own or in combination with ELCA. It can be assessed with generic and site specific data. Social and socioeconomic aspects assessed in SLCA are those that may directly affect stakeholders positively or negatively during the life cycle of a product which differs from other social impact assessment techniques. SLCA does not have the goal nor does it pretend to provide information on the question of whether a product should be produced or not. SLCA provides information on social and socio-economic aspects for decision making, instigating dialogue on the social and socio-economic aspects of production and consumption, in the prospect to improve performance of organizations and ultimately the well-being of stakeholders.

The guidelines acknowledge that ELCA and SLCA have much commonality. For example they both have a great need of data. SLCA complements ELCA by providing a more comprehensive picture of the product's life cycle impacts. The most obvious difference between ELCA and SLCA is the focus. Where ELCA focuses on the evaluation of environmental impacts, SLCA focuses on assessing social and socio-economic impacts. Furthermore, an ELCA collects information on (mostly) physical quantities related to the product and its production/use and disposal, while a SLCA collects additional information on organization related aspects along the chain. Table 4 gives a more detailed overview of the main differences between SLCA and ELCA.

Table 4. Differences between environmental and Social LCA

Phase	Characteristics
Goal and scope	The product utility should be described in functional terms, both in ELCA and SLCA. SLCA goes further by also requiring that practitioners consider the social impacts of the product use phase and function. Whereas ELCA encourages involvement of stakeholders (beyond the commissioners) in the peer review of the study, SLCA encourages that such "external" stakeholders be involved in providing input on impacts, within the assessment itself. In SLCA, justification needs to be presented when a subcategory is not included in the study. In ELCA this is not a requirement. The subcategories are classified both by stakeholder categories and by impact categories in SLCA. In ELCA they are classified only by impacts categories. Whereas both ELCA and SLCA impact assessment methods may be sensitive to location, no ELCA Life Cycle Impact Assessment methods are site-specific, and ELCA methods often define and use categories of location types that depend on physical factors such as geography type or population density. SLCA may require site-specific Life Cycle Impact Assessment in some cases, and may also need information about "political" attributes, such as the country and its laws.
Life cycle inventory	The activity variables data is collected and used more often in SLCA than in ELCA (e.g. number of working hours for estimating the share of each unit process in the product system). In ELCA, activity variables are used when data about impacts is not available. The subjective data is sometimes in SLCA the most appropriate information to use. Bypassing subjective data in favour of more "objective" data would introduce greater uncertainty in the results, not less. The balance between quantitative, qualitative and semi-quantitative data will generally be different. The data sources will differ (coming from stakeholders). The data collection steps and methods vary (e.g. the irrelevance of mass balances).
Life cycle impact	The characterization models are different. The use of performance reference points is specific to SLCA, e.g. thresholds. SLCA encounters both positive and negative impacts of the product life cycle, beneficial impacts in ELCA seldom occur.
Interpretation	The significant issues will differ. The addition of information on the level of engagement of stakeholders in SLCA.

Source: UNEP/SETAC, 2009 (p.39).

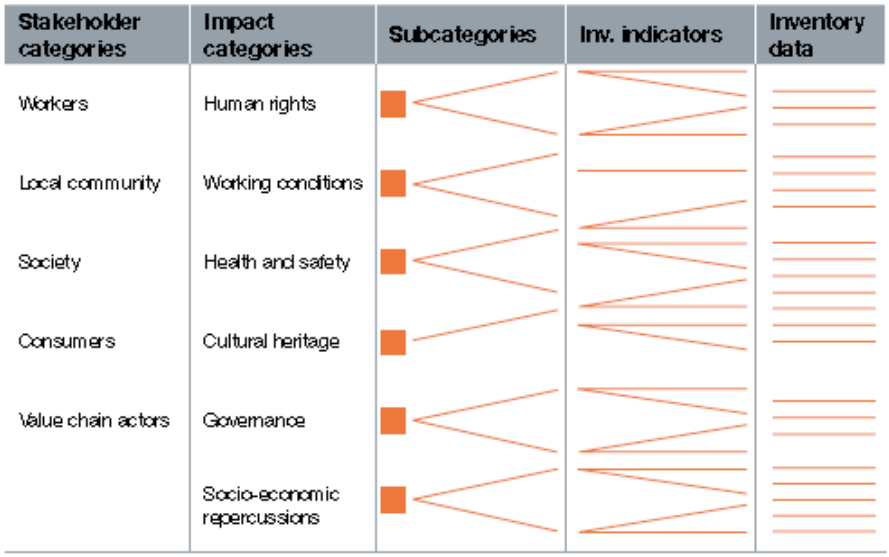
4.3 Technical framework for social life cycle assessment

4.3.1 Assessment framework

Figure 1 illustrates the assessment framework suggested for SLCA. The backbone of the SLCA is the information and data describing the product life cycle, the processes therein and the relations with different stakeholders in accordance with the goal and scope defined for the study. Subcategories are the basis of a SLCA assessment because they are the items on which justification of inclusion or

exclusion needs to be provided. The subcategories are socially significant themes or attributes which include: human rights, work conditions, cultural heritage, poverty, disease, political conflict, indigenous rights, etc.

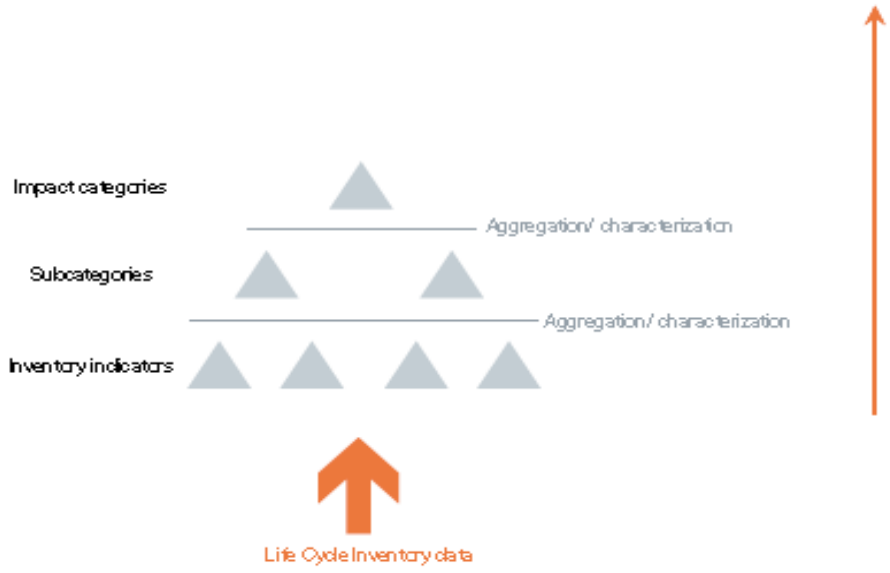
Figure 1. Assessment system from categories to unit of measurement.



Source: UNEP/ SETAC, 2009 (p45).

Subcategories are classified according to stakeholder and impact categories and are assessed by the use of inventory indicators (Figure 2). Several inventory indicators and units of measurement/reporting types may be used to assess each of the subcategories. Each inventory indicator specifically defines the data to collect; these data may be quantitative or qualitative.

Figure 2. Concept of sub-category



Source: UNEP/ SETAC, 2009 (p70).

Social/socio-economic subcategories may be first classified by stakeholder categories as this may assist the operationalization. It can also ensure the comprehensiveness of the framework. The purpose of the classification into impact categories (Figure 2) is to support the identification of stakeholders, to classify subcategory indicators within groups that have the same impacts, and to support further impact assessment and interpretation. There is currently no one set of impact categories[7] recommended. The stakeholder classification and the classification according to impact categories are complementary.

4.3.2 Stakeholder categories

A SLCA assesses the social and socio-economic impacts of all life-cycle stages from cradle to grave (e.g. from resource extraction, processing, manufacturing, assembly, marketing, sale, use, recycling, and disposal, looking at the complete life-cycle of a product). Each of these life cycle stages (and their unit processes) can be associated with geographic locations, where one or more of these processes are carried out (mines, factories, roads, rails, harbours, shops, offices, recycling-firms, disposal-sites). At each of these geographic locations, social and socio-economic impacts may be observed in five main stakeholder categories as listed in Figure 1 namely workers/employees, local community, society (national, global), consumer (covering end-consumers as well as the consumers who are part of each step of the supply chain) and value chain actors,

A stakeholder[8] category is a cluster of stakeholders that are expected to have shared interests due to their similar relationship to the investigated product systems. Additional categories of stakeholders (e.g. NGOs, public authorities/state, and future generations) or further differentiations or subgroups (e.g. management, shareholders, suppliers, transporters) can be added.

When conducting the goal and scope phase of a study, one may refer to a stakeholder classification and, according to this, classify the subcategories (comparable to GRI and other international schemes). The purpose of the classification of subcategories according to stakeholder groups is to make sure that the SLCA matches the goal and scope and is assessing the essence of the situation.

4.3.3 Subcategories of impact

The subcategories developed by the life cycle initiative project group are presented in Table 5. These impact subcategories have been defined based on international agreements (e.g. conventions, treaties) and best practices (international instruments, CSR initiatives, model legal framework, social impacts assessment literature) at the international level. The recommendation is that the list be used as a minimum of themes to include in a SLCA.

[7] The impact categories should preferably reflect internationally recognized categorizations/standards (like the UN declaration on economic, social and cultural rights - ECOSOC, standards for multinationals) and/or result from a multi-stakeholder process. The stakeholder classification and the classification according to impact categories are complementary.

[8] The proposed stakeholder categories are deemed to be the main group categories potentially impacted by the life cycle of a product.

Table 5. Overview of stakeholder categories and sub-categories proposed by UNEP/SETAC

Stakeholder categories	Subcategories
Local community	Access to material resources
	Access to immaterial resources
	Delocalization and Migration
	Cultural Heritage
	Safe & healthy living conditions
	Respect of indigenous rights
	Community engagement
	Local employment
	Secure living conditions
Worker	Freedom of Association and Collective Bargaining
	Child Labour
	Fair Salary
	Working Hours
	Forced Labour
	Equal opportunities/Discrimination
	Health and Safety
	Social Benefits/Social Security
Value chain actor	Fair competition
	Promoting social responsibility
	Supplier relationships
	Respect of intellectual property rights
Consumer	Health & Safety
	Feedback Mechanism
	Consumer Privacy
	Transparency
	End of life responsibility
Society	Public commitments to sustainability issues
	Contribution to economic development
	Prevention & mitigation of armed conflicts
	Technology development
	Corruption

Source: UNEP/ SETAC, 2009.

It was highlighted earlier that certain impact categories will be highly local, context-specific, and culturally and socially-dependent attributes (Norris, 2001). However, to go beyond personal and cultural subjectivity or political orientation, it is helpful to support the definition of categories, subcategories and inventory indicators with proper references to international instruments. The international conventions on Human Rights and Workers Rights are a good basis for a SLCA indicators framework. International conventions are valuable instruments that have been negotiated by countries. They are the best example of a universal set of social criteria. However, they often set a legal minimum, which means that going below these standards is a criminal offence. Then additional international instruments, initiatives, best practices, model legal framework, etc., are important to guide the development of additional categories and indicators that go beyond minimal compliance and assess additional and complementary social impacts.

Different contexts (across the supply chain) will represent different challenges and will need varying levels of assessment. For example, the legislation in developed countries may already cover many of Human Rights and Worker Rights indicators and the application of the law may be excellent. However, this might not be the case in a developing country. International standards also tend to define floors rather than ceilings. It will therefore sometimes be important to screen for minimum compliance when thresholds exist, and possibly also to assess performance beyond compliance thresholds.

When developing social and socio-economic mechanisms, it is important to keep in mind that there are two approaches for developing subcategories and the associated characterization models namely top down and bottom-up approaches. The top-down[9] approach consists of identifying broad social and socio-economic issues of interest. The bottom-up[10] approach attempts to provide summaries of inventory information, which is provided at the organization and process level, asking the appropriate stakeholders what would be relevant summary indicators and aggregation/summary methods according to their perspective. To achieve improvements in the sustainability of the product system, this could also be the entry point for negotiating specific and time-bound targets with stakeholders to progress towards compliance with global indicators.

4.3.4 Inventory indicators

The development of social indicators that can be integrated into LCA depends on the sector that is monitored and the national context. The UNEP/SETAC initiative is in the process of developing methodological sheets for 31 sub-categories of impact of which the draft version is presently available for consultation (UNEP/SETAC, 2010). These methodological sheets present a definition for each subcategory identified in the SLCA Guidelines and relate the subcategories' subjects to the relevant international instruments (see appendix 1). They also give possible data sources for both generic and site specific analysis. Indicators can be quantitative, semi-quantitative or qualitative depending on the indicator and the goal of the assessment. Further development of these sheets is expected while SLCA is increasingly applied to specific products.

4.3.5 Inventory analysis

The inventory is the phase of a SLCA where data are collected, the systems are modelled, and the life cycle inventory (LCI) results are obtained. The recommended steps for conducting life cycle inventory are as follow:

1. Data collection (for prioritizing and screening, using generic data, hotspots assessment)
2. Preparing for main data collection
3. Main data collection
4. Data needed for impact assessment (characterization)
5. Validation of data
6. Relating (main) data to functional unit and unit process (when applicable)

[9] This includes the inventory indicators needed to assess them and the development of characterization models that translate social and socio-economic inventory data into subcategory results and/or impact category results.

[10] The result is an assessment of local level issues of concern and their relative importance according to the appropriate stakeholders' understanding (workers, community etc.).

7. Refining the system boundary
8. Data aggregation (when applicable)

After the product system is modelled based on the reference flows, the next step is to identify the relative importance of the unit processes through unit process activity variables (e.g. worker hours or value added). Here, the share of worker hours (and/or where the value added is high) will be the first criteria in identifying the inventory data gathering efforts. However, this information remains indicative, as worker hours and values added are not the same as social impacts. To trace where potentially the most important social impacts are located within the product life cycle, hotspot assessment can be applied. Social hotspots are unit processes that are within a sector and region that has high risks of negative impact or high opportunities for positive impact. For the time being, there is no SLCA database available to help screening for hotspots.

4.3.6 Impact assessment

The Life Cycle Impact Assessment phase consists in a set of 3 steps identified in ISO 14044 (2006), as follows:

1. To select the impact categories and subcategories, and the characterization methods and models;
2. To relate the inventory data to particular Life Cycle Impact Assessment subcategories and impact categories (classification);
3. To determine and/or calculate the results for the subcategory indicators (characterization).

Impact Categories are logical groupings of SLCA results, related to social issues of interest to stakeholders and decision makers. The guidelines only present a general framework as impact assessment methodologies for SLCA are still under development. The framework is structured as a set of impact categories being aggregates of subcategories, which in turn are aggregates of inventory indicators (as presented in Figure 2). For the time being, stakeholder categories and subcategories are the basis on which to build. More experience needs to be gained, to determine one or several final sets of generally accepted impact categories. Two types of social and socio-economic impact categories can be identified. Type 1[11] impact categories aggregate the results for the subcategories within a theme of interest to a stakeholder, e.g. 'human rights'. Type 2[12] impact categories model

[11] Impact Categories type 1 used in SLCA will correspond to the goal and scope of the study and represent social issues of interest that will be expressed regarding the stakeholders affected and may cover health and safety, human rights, working conditions, socio-economic repercussions, cultural heritage and governance. The subcategory indicator results are aggregated into impact category results. All the aggregation formula (characterization) must be transparent. The information can be aggregated on one resulting end-category that may be Human Well-being or Fairness of relationships. It should be noted that, for the time being, there are no characterization models between subcategories and impact categories (type 1) that are generally accepted by SLCA practitioners.

[12] Impact categories type 2 correspond to a model of the social impact pathways to the endpoints 'human capital', 'cultural heritage' and 'human well-being', the latter with the midpoints health, autonomy, safety, security & tranquility, equal opportunities, participation & influence, resource (capital) productivity. To do so, one needs to model from subcategory results to impact categories on human well-being, with or without aggregating the information at the impact category (type 1) level. The information could also be modeled and/ or summarized (aggregated) with one result for Human Well-Being. For the time being, the causal models in social sciences are generally not well developed.

the results for the subcategories that have a causal relationship defined on the criteria, e.g. 'autonomy'.

Aggregation may take place through summarizing qualitative information or by adding up quantitative information or semi-quantitative information (for example, a yes/no form or a scale (scoring system). Another way of aggregating the inventory information is through life cycle attribute assessment, a method that defines the percentage of a supply chain that possesses (or lacks) an attribute of interest to be expressed (Norris, 2006), where we calculate the share of relevant activity across a life cycle which has attributes of interest. This generates results such as: 75% of the worker hours of the life cycle of the product are known to be child labour free.

4.4 Limitations of SLCA application and further research and development needs

The UNEP/SETAC-Guidelines for Social LCA is certainly a step towards an agreed procedure on how to implement social aspects. However, limitations in the SLCA methodology remain. For example, Feifel et al. (2010) point out that the questions of valuing and aggregating social indicator results remain unsolved. They argue that Social LCA is subject to regionalized impact assessment. Results from an SLCA will always, to some extent, be subjective, so if studies are carried out by different practitioners with different backgrounds and values, the results will not be objective enough to be comparable. The code could already be useful if the goal of the study is only to analyze social and socio-economic performance in the different stages in a product life cycle, especially if the study is performed at a company-specific level (Blom & Solmar, 2009).

The limitations observed by the UNEP/SETAC guidelines for Social LCA team are: (a) due to lack of techniques or tools, the use of SLCA may be limited and a large amount of resources will be needed to perform a comprehensive study; (b) caused by difficulty in accessing data as not many databases exist; (c) social effects are not always quantifiable; aggregating them by a common calculation rule may not be straightforward; aggregation of qualitative indicators requires expert judgment; for an aggregation of social effects along a life cycle, little experience exists so far; (d) ignorance of causal chains relations (for example when one effect or impact for one stakeholder, causes other social impacts, for the same or for another stakeholder or a causal chain to environmental or micro-economic impacts); (e) lack of skilful practitioners; (f) in the assessment of the use phase, s the emphasis in method development r was placed so far on production, distribution and end-of-life aspects; therefore, use stage aspects require further development; (g) in results communication due to the complex system approach of the studies.

The SLCA methodology is still in its early days, and the technique will be further refined in the coming years. General research needs in SLCA include the development of material for educational purposes that will effectively communicate the best practices in SLCA. It also includes conducting case studies that will support the practice of SLCA and build knowledge facilitating the further development of the methodology including the linkages with ELCA and LCC. To develop tools such as models, databases and software will enhance the development of SLCA and also promote its usage widely. There is a need to improve documentation and communication aspects for presenting the differences, similarities and complementarities between the enterprise-oriented methodologies, techniques, tools and product-oriented methodologies, techniques and tools, as they are developed.

The scope of the stakeholder approach and the role of SLCA regarding the acceptability of products or services are topics that can be further developed.

Impact assessment methodologies remain an open field for future research. More specifically, future research should: i) investigate the cause and effect relationships for social and socio-economic aspects; ii) look at possible trade-offs between the areas of protection as identified in ELCA, LCC and SLCA; iii) further elaborate the inventory indicators to assess a range of social issues; iv) define characterization models, as well as scoring and weighting systems, following more up to date knowledge from the social sciences and the relevant international agreements; and lastly v) development of a database with the necessary data for interpretation (e.g., minimum wage and living wage by country).

5 Case study applications of Social LCA methods

Some case studies of Social LCA methods exist in peer reviewed literature (e.g. Gauthier, 2005; Hunkeler, 2006), but further development of social indicators and full application of the UNEP/SETAC guidelines was only found in grey literature. Table 6 gives an overview of some of these studies, with more details in appendix 2.

The earliest detailed studies that were found apply PROSA, the Product Sustainability Assessment (Manhart, 2007; Manhart & Grießhammer, 2006) a method related to and harmonized with the UNEP/ SETAC guidelines, developed by the Öko-Institut (Grießhammer et al., 2007). PROSA is a sustainability assessment and therefore includes all elements of sustainability. Social LCA is therefore only one part of the assessment. Other components are environmental LCA, Benefit Analysis (based on consumer research) and the ProfitS (Products Fit to Sustainability) evaluation framework (Grießhammer et al., 2007). Beside these, it is worth noting the Life Cycle Sustainability Analysis (LCSA), a sustainability assessment, developed in the CALCAS projects[13] (Guinée et al., 2009). The LCSA as adopted in the CALCAS projects both broadens and deepens ISO-ELCA to also include economic and social aspects and goes beyond the boundaries of ISO-ELCA constraints. It is not a method by itself but comprises a variety of methods, models and tools (either on top of a basic ELCA or independently) that may have an independent meaning and may be applied jointly when addressing life cycle sustainability questions (Guinée et al., 2009).

The UNEP /SETAC guidelines were published early 2009 and a few case study applications have appeared in grey literature since then (e.g. Blom & Solmar, 2009; Franze & Ciroth, 2009; Dobón López et al., 2009). In the following an overview is given of the functional unit analysed, the system boundaries set, the inventory indicators used and the impact assessment methods applied in these five studies.

The functional units in the case studies are similar to functional units one would expect in environmental LCA (see table 6). The system boundaries however are more limited and in several studies do not include use and disposal after use; they also mostly include only limited (or no) input and services suppliers. The most common stakeholder categories assessed are employees, local community and society. Two studies include consumer and supply chain actors as stakeholders. One study includes secondary stakeholders (the institutional environment of the value chain) and another includes the company as a stakeholder.

The impact sub-categories mostly follow the UNEP / SETAC guidelines (see also appendix 2). Most documents do not contain detailed information on the specific indicators, except for the study by Dobón López et al. (2009). For example, for the stakeholder category 'workers' there are two inventory indicators for the subcategory 'diversity and equal opportunity', i.e. 1) composition of governance bodies and breakdown of employees per category according to gender, age group, minority group membership, and other indicators of diversity; and 2) ratio of basic salary of men to

[13] CALCAS is an EU 6th framework co-ordination action for innovation in life-cycle analysis for sustainable (Guinée, 2009).

women by employee category. These specific indicators are important as they determine the data collection needs and are the basis of the impact assessment when they are aggregated.

For the life cycle impact assessment (characterization), the PROSA guidelines suggest using a grading scale of 1 to 10 (with 1 representing the best social situation) for a maximum of ten indicators per stakeholder group. As an analytical tool they propose SocioGrade, an Excel-based tool that calculates a numerical overall evaluation (Grießhammer et al., 2007). However, this grading scale is not applied by Manhart and Grießhammer (2006) and Manhart (2007) who present descriptive analyses. The UNEP / SETAC guidelines simply state that characterization will depend on the type of data available and may consist of summarizing qualitative data and summing up quantitative data.

Table 6. Overview of applied case studies of Social LCA

Author(s)	Year	Product(s)	Type of document	Framework	Functional unit	System boundaries
Manhart & Grießhammer	2006	Notebooks	Report	PROSA (ILO standards, OECD guidelines etc.)	"ready-for-sale device"	Resource extraction, transport, supply of base materials, research and development, electronics production, software development, marketing, user, recycling and disposal
Manhart	2007	Electronics	Report	PROSA	(not specifically mentioned)	Component manufacturing, component assembly, final equipment assembly, collection for recycling, disassembly, material recovery. Supplier industries not grouped under electronics manufacturing are excluded.
Blom & Solmar	2009	Comparison of biofuels (ethanol, biodiesel, biogas)	Master thesis	UNEP/SETAC	Fuel used for driving a medium sized car 100 km	Feedstock production, processing, refining, storage, transport to pump. Excluded are use and inputs of infrastructure or services.
Franze & Ciroth	2009	Comparison of roses produced in Ecuador and Netherlands	Conference presentation	UNEP/SETAC	Packaged rose bouquet with 20 caulis	Production of roses, cutting and packing
Dobón López et al.	2009	Plastics	Project report	UNEP/SETAC & Global Reporting Initiative	1 ton of current plastic materials by means of average plastic resin processes	Extraction of raw materials, manufacturing of constituents and production of plastic resin in form of pellets. Distribution, polymer resin processing, use and final disposal have been excluded.
Kruse et al.	2009	Farmed and wild-caught salmon	Peer reviewed	UNEP/SETAC (implicit)	1 kg of consumption-ready salmon	Fishery / farm, processor, wholesale, retail, consumer. Feed production has been excluded.

Source: Authors' literature review.

Blom and Solmar (2009) also apply a scoring system where sub-categories are scored (1, 0, -1) and scores are then summed over the impact categories. Franze and Ciroth (2009) apply an alternative form of scoring system which scores indicators into five colour-coded categories (dark green – green – yellow- orange –red). Dobón López et al. (2009), who apply a combination of the UNEP/SETAC guidelines and the Global Reporting Initiative, conduct a qualitative (descriptive) analysis because of lack of quantitative data.

The case studies in Table 6, especially those applying the UNEP/ SETAC guidelines or PROSA, illustrate that implementation of Social LCA methods is feasible, but that many indictors are sensitive to interpretation. This raises difficulties for a quantitative analysis and many authors therefore do not attempt to 'grade' the results and limit the analysis to a descriptive appraisal. This clearly demonstrates the limitations, raised in section 4.

6 Application of social LCA on aquaculture products from Asia

In the following, we attempt to design a (hypothetical) social LCA for fish species production and consumption life cycle system in the four participating Asian countries in the SEAT project. This is a generic model and more discussion will be needed to further refine the formulation of the subcategories and indicators.

6.1 Goal and scope of the study

Goal of the study

The goal of this study is to perform a hotspot assessment of the social and socio-economic impacts of the production of fish species namely tilapia, Pangasius catfish, Peneid shrimp and Macrobrachium prawns in Bangladesh, China, Thailand and Vietnam, in order to identify the best socially sustainable options.

Scope of the study

1. For hotspot analysis generic data will be used (already partially available from the WP2 scoping study). More specific analysis will be conducted through a site-specific approach.
2. Social issues defined by UNEP/SETAC will be used as the basis for the selection of social issues addressed in SLCA.

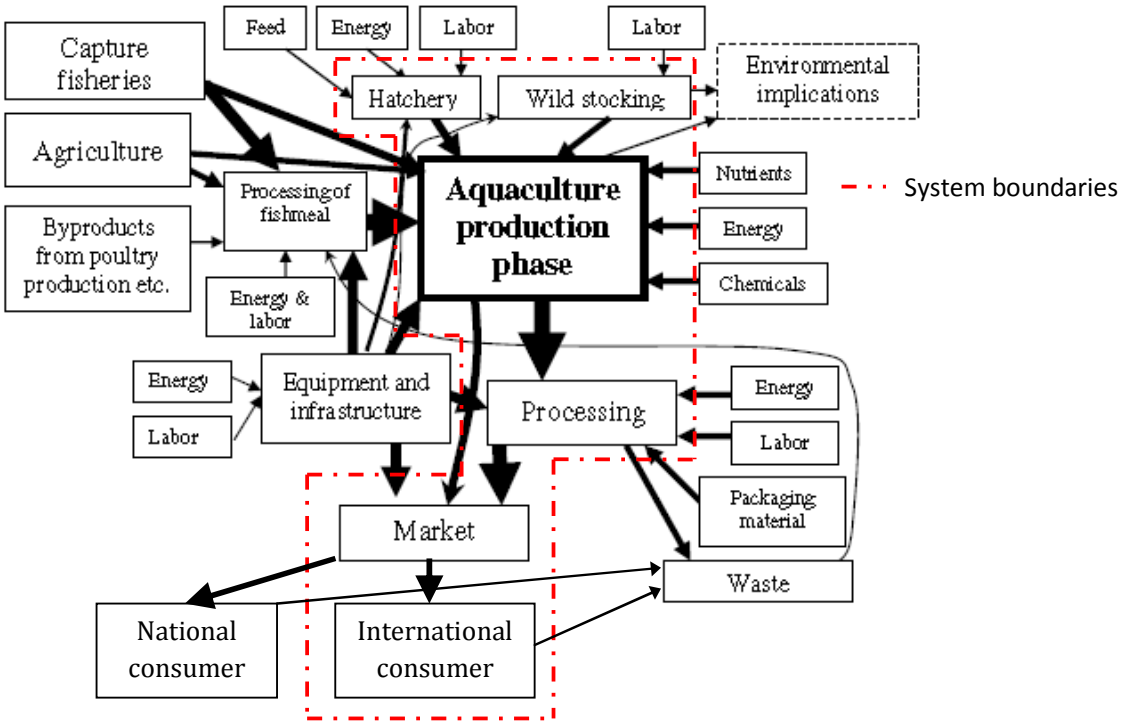
Functional unit

The purpose of fish in the context of the SEAT project in this study is to provide input into human diets (and incomes for those that participate in the production, processing, transporting and marketing the product). Therefore, the functional unit used for this study will be 1 kg of fish (tilapia, catfish, shrimp, and prawn) processed, packaged and ready for sale for human consumption (both national and global).

System boundaries

Figure 3 represents the generic life cycle framework of farmed fish covering the important stages. Ideally the SLCA would cover the entire cycle of fish production and consumption, including the production of fish feed and other inputs such as equipment, as far as it can be controlled in business-decision making by the companies to be assessed (following Dreyer et al. 2006). However, with the resources available, the analysis will be limited to production, processing and consumption stages. The figure shows a life cycle inventory of the production process in tropical aquaculture from an existing environmental LCA study by Henriksson (2009). The analysis will include hatchery and wild stocking, aquaculture production, processing (and packaging), transport, marketing, and consumption.

Figure 3. The life cycle system of cultured fish production and consumption



Source: adapted from Henriksson, 2009 (p16).

An analysis will be conducted to identify hotspots that face socio-economic issues/impacts. The first step will be a screening to identify the importance stages based on working-hour and value added (in each of the stages). Subsequently, a few stakeholder interviews are conducted to identify where the most pressing socio-economic issues are located. Therefore, the inclusion of stages for a site-specific survey will depend on the outcomes of the screening and stakeholder interviews.

6.2 Life cycle inventory

Sub-category and inventory indicator considerations

All stakeholder categories as suggested in the UNEP/SETAC guidelines will be included, i.e. workers/employees, local community, society (national, global), consumer (covering end-consumers as well as the consumers who are part of each step of the supply chain) and value chain actors (Table 7). Impact sub-categories as identified for each stakeholder group may not be relevant for all stages in the value chain and may be dropped from the analysis.

Social issues will largely follow from the UNEP/SETAC guidelines. However, the guidelines are flexible and during the screening phase of the SLCA some issues may be eliminated while others could arise that should be included. Based on this, a set of inventory indicators will be developed that serve as a generic list to be considered and applied for every stages of the life cycle within this study. The chosen inventory indicators are to reflect socio-economic issues that can be related to operations/stages in the analyzed aquaculture value chains. For example, the following table consists of inventory indicators that might be relevant for the “employee” group. From the scoping phase of the SEAT project, specific issues may already be identified. However, since social and socio-

economic impacts can be subjective and the themes can be broad, it will be a challenge to develop generic inventory categories (sub-indicators) to suit all different species in the SEAT project (shrimp, prawn, tilapia, catfish) and countries (Bangladesh, China, Thailand, Vietnam) that allow for comparison between the product systems.

Table 7. The sub-indicators for employee group

Sub-category	Inventory Indicator
Freedom of association and collective bargaining	Does legislation exist for freedom of association in the four countries?
	Do employees have the right to exercise freedom of association and collective bargaining?
Wages	Workers paid below-minimum wage
Working hours	Average no. of working hours in industry
Child labour	Existence of child labour in industry sector / region
	Reported incidents of child labour
	Is the operation identified as having significant risk for incidents of child labour?
Forced labour	Existence of forced labour in industry sector / region
	Is the operation identified as having significant risk for incidents of forced or compulsory labour?
Equal opportunities/discrimination	Ratio of employed men to women in industry sector/region
	Ratio of basic salary of men to women by employee category
Health and safety	Rates of injury in industry sector
	Risks of occupational diseases in industry sector
	Total number of work-related fatalities in industry sector
Social benefits/social security	Do the workers have the right to social benefits by legislation in country or region?

Source: UNEP/ SETAC, 2009.

Data collection

Data for this study will come from secondary sources such as literature, national statistics, company records (where available), and from information gathered from stakeholder interviews within the system boundaries.

6.3 Life cycle impact assessment

As described in section 4.2.6 and as observed from the empirical cases in section 5, the impact assessment methodology is currently still under development and implementation is facing difficulties, especially due to a lack of specific data and a high level of need for individual interpretation. The data in this study will be analysed using several methods. The first method is the aggregation of the qualitative data from the inventory categories into sub-categories and subsequently into impact category by a descriptive summary of the social issues of each fish species.

For a more visual interpretation of the data, a second assessment method will be used based on the work of Franze and Ciroth (2009). As explained above, their scoring system is based on the colour-coding of sub-categories with a traffic-light system. A scoring template for sub-category level is

presented in Table 8 based on the inventory categories listed in Table 7. An important consideration to note is that this system is based on a high level of individual interpretation.

Table 8. Example of scoring system: sub-category scores by value chain stage

Stakeholder Category	Sub-category	Fish production and consumption life cycle system						
		Hatchery	Grow-out	Processing	local markets	international markets	local consumers	international consumers
Employee	Freedom of association and collective bargaining							
	Wages							
	Working hours							
	Child labour							
	Forced labour							
	Equal opportunities/discrimination							
	Health and safety							
	Social benefits/social security							

Source: adapted from Franze and Ciroth (2009).
Note: Dark-green: positive effect; light-green: indifferent effect; yellow: more or less negative effect; orange: negative effect; red: very negative effect; empty cell: does not apply.

It is likely that some sub-category outcomes for certain stakeholder groups will differ across the value chain. For example, workers in hatcheries are unlikely to be facing the same conditions as those in European wholesale markets as they are governed by different rules and regulations. We therefore suggest using two scoring sheets, one that scores the sub-categories for the individual stages in the chain (Table 8), and a second that scores them for the chain as a whole but differentiates the impact categories as defined by UNEP/SETAC (human rights, working conditions, health and safety, cultural heritage, governance and socio-economic repercussion) (Table 9). The scoring sheets can be used to quickly identify social issues that need attention.

It will be challenging to arrive at an objective assessment of the magnitude of the social issues and their impacts as different stakeholders, communities or countries may perceive impact differently. Some issues may also only exist in certain parts of the sector, for example forced labour may exist in large-scale production, but not in small-scale. It is therefore difficult to generalize for an entire sector or value chain.

Table 9. Example of scoring system: sub-category scores by impact category

Stakeholder Category	Sub-category	Impact categories						Assessment
		human rights	working conditions	health and safety	cultural heritage	governance	socio-economic repercussion	
Employee	Freedom of association and collective bargaining	*	*	*	*	*	*	
	Wages	*	*	*	*	*	*	
	Working hours	*	*	*	*	*	*	
	Child labour	*	-	*	-	-	*	
	Forced labour							
	Equal opportunities/discrimination	*	*	*	-	-	-	
	Health and safety	*	*	*	-	-	*	
	Social benefits/social security	*	*	*	*	*	*	

Source: adapted from Franze and Ciroth (2009).

Note: '*' indicator influences impact (positive or negative), '-' indicator does not influence impact, '<empty cell>': indicator is not present. Dark-green: positive effect; light-green: indifferent effect; yellow: more or less negative effect; orange: negative effect; red: very negative effect; empty cell: does not apply.

7 Discussion on integration in the SEAT project

7.1 Environmental LCA and life cycle costing

There are two major components of the SEAT project that have a synergy with the analysis proposed in the previous section. First of all, this is obviously the conducting of an ELCA and LCC for the same species. The main aim of this document was to assess whether integrating of SLCA into the other life cycle approaches is feasible. In this paper we have shown that the development of an integrated approach is well underway but that many obstacles still persist. The main achievement in the methodological development is, however, that at least the assessment made is based on the same functional unit and the same product system (albeit probably a narrower slice of it).

Due to the nature of social and socio-economic issues, it remains a challenge to quantify or score these impacts. Aggregation of these issues over the impact categories is then also difficult. There is however, still scope for integration, especially to identify trade-offs between environmental, economic, and social issues in the comparison of two products. However, that also opens up a new area of discussion, which is how to weight the impacts of a product in the three different pillars of sustainability. Still, ELCA, LCC and SLCA together will be able to identify the hotspots of issues that are most urgent to be addressed to approach a more sustainable total product system.

Even though it is clear that a full integration of the three pillars of sustainability into a life cycle approach is still in its early stages there is a rising demand from stakeholders, along with increasing research and publications on the topic. This shows that there is both a need for, and interest in a methodology or framework that provides a comprehensive measure of process or product sustainability using a life cycle perspective. Further research and case study applications are necessary to expand the UNEP/SETAC guidelines and other approaches. The SEAT project may provide an opportunity to contribute to this methodological development and to apply the guidelines in a developing country setting.

7.2 Global value chain analysis

The second element in SEAT that has a clear synergy with SLCA is the global value chain analysis (GVCA). In SEAT this is applied to understand the vertical elements and links in the selected value chains of aquaculture products produced in Asia, consumed in Europe such as the composition of the chains, the institutional environment it operates in, the opportunities, threats and dynamics in the chain. We link this to the analysis of the horizontal components of the chain, i.e. the impacts of the value chain on livelihoods, vulnerability and equity of the actors along this chain.

It is evident that there is a great deal of overlap between SLCA and GVCA. The value chain can be defined as “the full range of activities that are required to bring a product from its conception to its end use. These include design, production, marketing, distribution, and support to get the product to the final user. The activities that comprise a value chain may be contained with a single firm or may embrace many firms. They can be limited to a single country or stretch across national boundaries” (Downing et al., 2006). While value chain analysis usually does not take into account the disposal after use phase, the reach of the product chain or system is otherwise similar to that in life cycle approaches. The value chain analysis however takes the same, more limited, system

boundaries as were discussed for SLCA, as it only considers those suppliers directly linked to the main chain actors. SLCA and GVCA may use similar indicators to assess such issues as equity (equal opportunity) in the value chain / product system. Furthermore, analytical tools will partially overlap. For example, value chain mapping (a common tool applied in GVCA) will provide the inputs needed for the boundary setting, as well as for the identification of stakeholder groups in SLCA. Similar to SLCA, key data for GVCA may also come from both primary and secondary sources such as key informant interviews, company records and national statistics, and, as indicators overlap, the data needs do so as well. Finally, similar to SLCA, GVCA has the ability to identify major hotspots of social (and economic) issues taking place in the value chain / product system.

The main difference between GVCA and SLCA lies in the point of entry and focus. While in GVCA the chain actors and chain environment of a certain commodity or product are studied, thereby often following the raw product up the chain, the SLCA starts from the end-product and traces it back down the chain. SLCA uses the concept of functional unit (e.g. 1 kg package of frozen shrimp for human consumption), while in GVCA a more general approach is taken (e.g. by assessing the value chain of 'shrimp in Thailand'). It thereby casts the net wider to include all possible products, and by-products, including all types of market channels (i.e. local, national, international) and all types of markets (e.g. retail, wholesale, exports). GVCA is therefore better able to place the value chain of a certain product in its local, national and/or global context. Furthermore, GVCA focuses much more on the dynamics, opportunities and threats in the existing value chain, rather than a snapshot of its present status. This makes the two approaches mostly complementary, while the similarities also provide for sufficient grounds for integration.

References

Ardente F, Cellura M, Lo Brano V, & Mistretta M (2009) Life Cycle Assessment-Driven Selection of Industrial Ecology Strategies, Integrated Environmental Assessment and Management 6(1): 52-60.

Aubin J, Papatryphon E, Van der Werf HMG, Petit J, Morvan YM (2008) Characterisation of the environmental impact of a turbot (Scophtalmus maximus) re-circulating production systems using Life Cycle Assessment, Aquaculture 261: 1259-1268.

Ayer NW, Tyedmers PH, Pelletier NL, Sonesson U, Scholz A (2007) Co-Product Allocation in Life Cycle Assessments of Seafood Production Systems: Review of Problems and Strategies, International Journal of Life Cycle Assessment 12(7): 480-487.

Benoit C, Norris GA, Valdivia S, Ciroth A, Moberg A, Bos U, Prakash S, Ugaya C, Beck T (2010) The guidelines for social life cycle assessment of products: just in time! International Journal of Life Cycle Assess 15: 156-163.

Blom M, Solmar C (2009) How to Socially Assess Biofuels: a Case Study of the UNEP/SETAC Code of Practice for social- economical LCA. Master thesis for the division of Quality and Environmental Management at Luleå University of Technology, commissioned by Enact Sustainable Strategies in Stockholm.

Bouwer Utne I (2009) Life cycle cost (LCC) as a tool for improving sustainability in the Norwegian fishing fleet, Journal of Cleaner Production 17: 335–344.

Dobón López A, Razza F, Slimani D, Hortal Ramos M, Cordero Gordillo P, Calero Pastor M (2009) Report on the current situation analysis: recyclability, social and economic requirements evaluation and how it can affect new developments. SustainComp, ITENE, Spain.

Downing J, Snodgrass D, Northrip Z, Woller G (2006) The new generation of private-sector development programming: the emerging path to economic growth with poverty reduction. USAID & Development Alternatives Inc.

Dreyer L, Hauschild M, Schierbeck J (2006) A framework for social life cycle impact assessment, International Journal of Life Cycle Assess 11(2):88–97.

Ellingsen H, Aanondsen SA (2006) Environmental Impacts of Wild Caught Cod and Farmed Salmon – A comparison with chicken, International Journal of Life Cycle Assessment 1: 60-65.

Feifel S, Walk W, Wursthorn S (2010) LCA, how are you doing today? A snapshot from the 5th German LCA workshop, International Journal of Life Cycle Assessment 15: 139-142.

Franze J, Ciroth A (2009) Social Life Cycle Assessment of Roses: a Comparison of Cut Roses from Ecuador and the Netherlands. Presentation at the IXth Life Cycle Assessment conference "Toward the global life cycle economy", Boston, September 29th - October 2nd, 2009.

Gauthier C (2005) Measuring Corporate Social and Environmental Performance: The Extended Life-Cycle Assessment, Journal of Business Ethics 59: 199-206.

Grießhammer R, Buchert M, Gensch CO, Hochfeld C, Manhart A, Reisch L, Rüdenauer I (2007) PROSA – Product Sustainability Assessment Guideline. Öko-Institut e.V., Freiburg.

Grönroos J, Seppälä J, Silvenius F, Mäkinen T (2006) Life cycle assessment of Finnish cultivated rainbow trout, Boreal environment research 11: 401-414.

Guinée JB, Huppes G, Heijungs R, Van der Voet E (2009) Research strategy, programmes and exemplary projects on life cycle sustainability analysis (LCSA), deliverable 22 of work package 7 of the CALCAS (Co-ordination action for innovation in Life-cycle analysis for sustainability) project.

Henriksson P (2009) Energy intensity in tropical aquaculture – cumulative energy demand of milkfish, pangasius and oyster production in SE Asia. Master thesis in Marine Biology. Stockholm University, Department of System Ecology.

Hunkeler D, Rebitzer G (2005) The future of life cycle assessment, International Journal of Life Cycle Assess 10(5):305–308.

Hunkeler D (2006) Societal LCA methodology and case study, International Journal of Life Cycle Assessment 11(6):371–382.

Hunkeler D, Rebitzer G, Lichtenvort K (Eds.) (2008). Environmental Life Cycle Costing. SETAC, CRC Press, Pensacola, FL.

ISO (2006a) Environmental management—Life cycle assessment—Principles and framework. ISO 14040:2006(E), International Organization for Standardization, Geneva.

ISO (2006b) Environmental management—Life cycle assessment—Requirements and guidelines. ISO 14044:2006(E). International Organization for Standardization, Geneva.

Jolliet O, Müller-Wenk R, Bare J, Brent A, Goedkoop M, Heijungs R, Itsubo N, Peña C, Pennington D, Potting J, Rebitzer G, Stewart M, Udo de Haes H, Weidema Bo (2004) The LCIA midpoint-damage framework of the UNEP/SETAC life cycle initiative, International Journal of Life Cycle Assessment 9(6): 394-404.

Jørgensen A, Le Bocq A, Nazarkina L, Hauschild M (2008) Methodologies for social life cycle assessment, International Journal of Life Cycle Assessment 13(2):96–103.

Klöpffer W (2003) Life-cycle based methods for sustainable product development, International Journal of Life Cycle Assess 8(3):157–159.

Klöpffer W (2008) Life cycle sustainability assessment of products (with comments by Helias A. Udo de Haas, p 95), International Journal of Life Cycle Assess 13(2):89–95.

Kruse AK, Flysjo A, Kasperczyk N (2009) Socioeconomic indicators as a complement to life cycle assessment – an application to salmon production systems, International Journal of Life Cycle Assess 14:8-18.

Labuschagne C, Brent AC (2006) Social indicators for sustainable project and technology life cycle management in the process industry, International Journal of Life Cycle Assessment 11(1): 3-15.

Lebela L, Mungkung R, Gheewalac SH, Lebela P (2010) Innovation cycles, niches and sustainability in the shrimp aquaculture industry in Thailand, Environmental Science & Policy 13(4): 291-302.

Le Nguyen DK (2007) Description of the Pangasius value chain in Vietnam, Centre for ASEAN Studies, CAS Discussion paper No 56.

Manhart A (2007) Key Social Impacts of Electronics Production and WEEE-Recycling in China, Öko-Institut e.V., Freiburg.

Manhart A, Grießhammer R (2006) Social Impacts of the Production of Notebook PCs, Contribution to the Development of a Product Sustainability Assessment (PROSA). Öko-Institut e.V., Freiburg.

Matos S, Hall J (2007) Integrating sustainable development in the supply chain: The case of life cycle assessment in oil and gas and agricultural biotechnology, Journal of Operations Management 25: 1083-1102.

Mungkung R, Udo de Haes H, Clift R (2006) Potentials and Limitations of Life Cycle Assessment in Setting Ecolabelling Criteria: A Case Study of Thai Shrimp Aquaculture Product, The International Journal of Life Cycle Assessment 11(1): 55-59.

Norris GA (2006) Social impacts in products life cycles towards life cycle attribute assessment, International Journal of Life Cycle Assessment 11(Spec Issue 1): 97–104.

Norris GA (2001) Integrating life cycle analysis and LCA, International Journal of Life Cycle Assessment 6(2): 118-120.

O'Brian M, Doig A, Clift R (1996) Social and environmental life cycle assessment (SELCA), International Journal of Life Cycle Assessment 1(4) 231-237.

Ortiz O, Castells F, Sonnemann G (2009) Sustainability in the construction industry: A review of recent developments based on LCA, Construction and Building Materials 23: 28–39.

Papatryphon E, Petit J, Kaushik SJ, Van der Werf HMG (2004) Environmental Impact Assessment of Salmonid Feeds Using Life Cycle Assessment (LCA), Ambio 33(6): 316-323.

Pelletier NL, Ayer NW, Tydmers PH, Kruse SA, Flysjo A, Robillard G, Ziegler F, Scholz AJ, & Sonesson U (2007) Impact Categories for Life Cycle Assessment Research of Seafood Production Systems: Review and Prospectus, International Journal of Life Cycle Assessment 12(6): 414-427.

Pelletier NL, Tyedmers P (2007) Feeding farmed salmon: Is Organic better?, Aquaculture, 272: 399-416.

Schau EM Fet AM (2008) LCA Studies of Food Products as Background for Environmental Product Declarations", International Journal of Life Cycle Assessment, 13(3): 255-264.

Spillemaeckers S, Vanhoutte G, Taverniers L, Lavrysen L, van Braeckel D, Mazijn B, Rivera JD (2004) Integrated Product Assessment – The Development of the Label 'Sustainable Development' for Products Ecological, Social and Economical Aspects of Integrated Product Policy. Belgian Science Policy, Belgium.

Swarr ET (2009) Societal life cycle assessment – could you repeat the question? International Journal of Life Cycle Assessment 14: 285-289.

Steen B (2005) Environmental costs and benefits in life cycle costing, Management of environment quality: an international journal 16(2): 107-118.

UNEP/SETAC (2010) Methodological Sheets for 31 Sub-Categories of Impact (for consultation), UNEP/SETAC Life Cycle Initiative, UNEP.

UNEP/SETAC (2009) Guidelines for social life cycle assessment of products, UNEP/SETAC Life Cycle Initiative, UNEP.

UNEP/SETAC (2005) Life cycle approaches: the road from analysis to practice, UNEP/SETAC Life Cycle Initiative, UNEP.

Weidema B (2006) The integration of economic and social aspects in life cycle impact assessment., International Journal of Life Cycle Assessment 11(Spec Issue 1): 89–96.

Weidema B (1999) System expansions to handle co-products of renewable materials, Presentation summaries of the 7th LCA Case Studies Symposium SETAC-Europe, 1999: 45-48.

Zamagni A, Buttol P, Porta PL, Buonamici R, Masoni P, Guinée J, Heijungs R, Ekvall T, Bersani R, Bieńkowska A, Pretato U (2009) Critical review of the current research needs and limitations related to ISO-LCA practice. Deliverable D7 of work package 5 of the CALCAS (co-ordination action for innovation in Life-cycle analysis for sustainability) project.

Appendices

Appendix 1: Stakeholder categories, sub-categories and indicators

Stakeholder categories	Subcategories	Generic inventory indicators	Specific analysis
Worker	Freedom of Association and Collective Bargaining	- Evidence of restriction to Freedom of association and Collective bargaining - Evidence of country/sector/ organization or factory non respect or support to Freedom of association and Collective bargaining - Operations identified in which the right to exercise freedom of association and collective bargaining may be at significant risk, and actions taken to support these rights	- Employment is not conditioned by any restrictions on the right to collective bargaining - Presence of unions within the organization is adequately supported (Availability of facilities to Union, Posting of Union notices, time to exercise the representation functions on paid work hours) - Copies of collective bargaining negotiations and agreements are kept on file - Workers are free to join unions of their choosing - Employee/union representatives are invited to contribute to planning of larger changes in the company, which will affect the working conditions - Minimum notice period(s) regarding significant operational changes, including whether it is specified in collective agreements - Workers have access to a neutral, binding, and independent dispute resolution procedure
	Child Labour	- Percentage of children working by country and sector - Operations identified as having significant risk for incidents of child labour, and measures taken to contribute to the elimination of child labour	- Absence of working children under the legal age or 15 years old (14 years old for developing economies) - Children are not performing work unauthorized by the ILO conventions C138 and C182 (hazardous work) - Records on all workers stating names and ages or dates of birth are kept on file - Working children younger than 15 and under the local compulsory age can attend school
	Fair Salary	- Living Wages in the country by state, county, community - Minimum wage by country - Non poverty wage by country	- Lowest paid worker, compared to the minimum wage - The lowest paid workers are considering their wages meets their needs - Presence of suspicious deductions on wages

Stakeholder categories	Subcategories	Generic inventory indicators	Specific analysis
			- Regular and documented payment of workers (weekly, bi-weekly)
	Working Hours	- Excessive Hours of work	- Respect of contractual agreements concerning overtime - Clear communication of working hours and overtime arrangements - The organization provides flexibility
	Forced Labour	- Commodity that are at high risk of having being produce using forced labour - Percentage (estimate) of forced labour by region - Operations identified as having significant risk for incidents of forced or compulsory labour, and measures taken to contribute to the elimination of forced or compulsory labour	- Workers voluntarily agree upon employment terms. Employment contracts stipulate wage, working time, holidays and terms of resignation. Employment contracts are comprehensible to the workers and are kept on file - Birth certificate, passport, identity card, work permit or other original documents belonging to the worker are not retained or kept for safety reasons by the organization neither upon hiring nor during employment - Workers are free to terminate their employment within the prevailing limits - Workers are bonded by debts exceeding legal limits to the employer
	Equal opportunities/Discrimination	- Women in the Labour force participation rate by country - Country gender index ranking	- Presence of formal policies on equal opportunities - Total numbers of incidents of discrimination and actions taken - Composition of governance bodies and breakdown of employees per category according to gender, age group, minority, group membership, and other indicators of diversity - Ratio of basic salary of men to women by employee category
	Health and Safety	- Occupational accident rate by country	- Number/ percentage of injuries or fatal accidents in the organization by occupation - Presence of a formal policy concerning health and safety - Adequate general occupational safety measures are taken. - Preventive measures and emergency protocols exist regarding accidents & injuries. - Preventive measures and emergency protocols exist regarding pesticide & chemical exposure - Appropriate protective gear is required in all applicable situations. - Number of (serious/non-serious) Occupational Safety and Health Administration (OSHA) violations reported within the past 3 years

Stakeholder categories	Subcategories	Generic inventory indicators	Specific analysis
			and status of violations - Education, training, counselling, prevention and risk control programs in place to assist workforce members, their families, or community members regarding serious diseases.
	Social Benefits/Social Security	- Social security expenditure by country and branches of social security (eg. Healthcare, sickness, maternity) - Benefits provided to full-time employees that are not provided to temporary or part-time employees, by major operations	- List and provide short description of social benefits provided to the workers (eg. Health insurance, pension fund, child care, education, accommodation etc.) - Evidence of violations of obligations to workers under labour or social security laws and employment regulations - Percentage of permanent workers receiving paid time-of
Consumer	Health & Safety	- Quality of or number of information/signs on product health and safety - Presence of consumer complaints (at national or sector level) - Total number of incidents of non-compliance with regulations and voluntary codes concerning health and safety impacts of products and services and type of outcomes	- Number of consumer complaints - Presence of Management measures to assess consumer health and safety - Quality of labels of health and safety requirements
	Feedback Mechanism	- Presence of feedback mechanisms (e.g. after sale services) (by organization or sector/country) - Number of consumer complaints at the sector level	- Presence of a mechanism for customers to provide feedback - Management measures to improve feedback mechanisms
	Consumer Privacy	- Country ranking related to regulations on data-sharing - Country ranking related to strength of laws protecting privacy against organizations and government	- Strength of internal management system to protect consumer privacy, in general - Number of consumer complaints related to breach of privacy or loss of data within the last year - Number of complaints by regulatory bodies related to breach of

Stakeholder categories	Subcategories	Generic inventory indicators	Specific analysis
		- Country ranking related to the strength of regulatory powers to investigate privacy-related complaints	consumer privacy or loss of data within the last year
	Transparency	- Presence of a law or norm regarding transparency (by country and/or sector) - Sector transparency rating: number of organizations by sector which published a sustainability report	- Non-compliance with regulations regarding transparency - Consumer complaints regarding transparency - Publication of a sustainability report
	End of life responsibility	- Strength of national legislation covering product disposal and recycling	- Level of management attention to end-of-life impacts - Do internal management systems ensure that clear information is provided to consumers on end-of-life options (if applicable)?
Local community	Access to material resources	- Changes in Land Ownership - Levels of Industrial Water Use - Extraction of Material Resources - Percent of Population (Urban, Rural, Total) with Access to Improved Sanitation Facilities	- Has the organization developed project-related infrastructure with mutual community access and benefit - Strength of organizational risk assessment with regard to potential for material resource conflict - Does the organization have a certified environmental management system
	Access to immaterial resources	- Patent Filings - Freedom of Expression in Country of Operation - Levels of Technology Transfer	- Annual arrests connected to protests of organization actions - Do policies related to intellectual property respect moral and economic rights of the community? - Presence/strength of community education initiatives
	Delocalization and Migration	- Forced Evictions stemming from Economic Development - Description of Causes for and Treatment of Internally Displaced Persons - International Migrants as a Percentage of Population	- Number of individuals who resettle (voluntarily and involuntarily) that can be attributed to organization - Strength of organizational policies related to resettlement (e.g. due diligence and procedural safeguards) - Strength of organizational procedures for integrating migrant workers into the community
	Cultural Heritage	- Cultural Heritage in Urgent Need of Safeguarding - Prevalence of Racial Discrimination	- Strength of Policies in Place to Protect Cultural Heritage - Presence/Strength of Organizational Program to include Cultural Heritage Expression in Product Design/Production - Is Relevant Organizational Information Available to Community

Stakeholder categories	Subcategories	Generic inventory indicators	Specific analysis
			Members in their Spoken Language(s)?
	Safe & healthy living conditions	- Burden of Disease by Country - Pollution Levels by Country - Presence/Strength of Laws on Construction Safety Regulations by Country	- Management oversight of structural integrity - Organization efforts to strengthen community health (e.g. through shared community access to organization health resources) - Management effort to minimize use of hazardous substances
	Respect of indigenous rights	- Human Rights Issues Faced by Indigenous Peoples - Prevalence of Racial Discrimination - Indigenous Land Rights Conflicts/Land Claims	- Organization Operates in a Region where there is Land Rights Conflict with Indigenous Groups - Strength of Policies in Place to Protect the Rights of Indigenous Community Members - Annual Meetings Held with Indigenous Community Members - Response to Charges of Discrimination against Indigenous Community Members
	Community engagement	- Freedom of Peaceful Assembly and Association - Transparency of Government Policymaking - Public Trust of Politicians	- Strength of written policies on community engagement at organization level - Diversity of community stakeholder groups that engage with the organization - Number and quality of meetings with community stakeholders - Organizational support (volunteer-hours or financial) for community initiatives
	Local employment	- Unemployment Statistics by Country - Poverty and Working Poverty by Country - Presence of Local Supply Networks	- Percentage of workforce hired locally - Strength of policies on local hiring preferences - Percentage of spending on locally-based suppliers
	Secure living conditions	- State of Security and Human Rights in Country of Operation - Strength of Public Security in Country of Operation	- Management policies related to private security personnel - Number of legal complaints per year against the organization with regard to security concerns - Number of casualties and injuries per year ascribed to the organization
Society	Public commitments to sustainability	- Existence of (legal) obligation on public sustainability reporting - Engagement of the sector regarding	- Presence of publicly available documents as promises or agreements on sustainability issues - Complaints issued related to the non fulfillment of promises or

Stakeholder categories	Subcategories	Generic inventory indicators	Specific analysis
	issues	sustainability	agreements by the organization by the local community or other stakeholders at OECD contact points or Global Reporting Initiative. - Presence of mechanisms to follow-up the realisation of promises - The organization has pledged to comply with the Global Compact principles and has engaged itself to present yearly Communication On Progress - Implementation/signing of Principles or other codes of conduct (Sullivan Principles, Caux Round Table, UN principles, etc.)
	Contribution to economic development	- Economic situation of the country/region (GDP, economic growth, unemployment, wage level, etc.) - Relevance of the considered sector for the (local) economy (share of GDP, number of employees in relation to size of working population, wage level, etc.)	- Contribution of the product/service/organization to economic progress (revenue, gain, paid wages, R+D costs in relation to revenue, etc.)
	Prevention & mitigation of armed conflicts	- Is the organization doing business in a region with ongoing conflicts? - Is the organization doing business in a sector that features linkages to conflicts, e.g. where the depletion of resources allows significant profits (e.g. extractive industries, forestry, fishery)? - Is the organization doing business in a sector otherwise linked to the escalation or de-escalation of conflicts (e.g. conflict escalation by massive pollution, de-escalation by trade beyond conflict boundaries)?	- Organization's role in the development of armed conflicts - Disputed products
	Technology development	- Sector efforts in technology development - Research and development costs for the sector	- Involvement in technology transfer program or projects - Partnerships in research and development - investments in technology development/ technology transfer

Stakeholder categories	Subcategories	Generic inventory indicators	Specific analysis
	Corruption	- Risk of corruption in the country and/or sub-region - Risk of corruption in the sector	- Formalised commitment of the organization to prevent corruption, referring to recognised standards. - The organization carries out an anti-corruption program - The organization installs or co-operates with internal and external controls to prevent corruption - Written documents on active involvement of the organization in corruption and bribery; convictions related to corruption and bribery - Financial damages
Value chain actors (not including consumers)	Fair competition	- National law and regulation - Sectoral regulation - Sectoral agreement - Sector is present in consumer unions	- Legal actions pending or completed during the reporting period regarding anti-competitive behavior and violations of anti-trust and monopoly legislation in which the reporting organization has been identified as a participant - Membership in alliances that behave in an anti-competitive way - Documented statement or procedures (policy, strategy etc.) to prevent engaging in or being complicit in anti-competitive behavior - Employee awareness of the importance of compliance with competition legislation and fair competition.
	Promoting social responsibility	- Industry code of conduct in the sector	- Presence of explicit code of conduct that protect human rights of workers among suppliers - Percentage of suppliers the enterprise has audited with regard to social responsibility in the last year - Membership in an initiative that promotes social responsibility along the supply chain
	Supplier relationships	- None	- Absence of coercive communication with suppliers - Sufficient lead time - Reasonable volume fluctuations - Payments on time to suppliers
	Respect of intellectual property rights	- General Intellectual Property Rights and related issues associated with the economic sector	- Organization's policy and practice - Use of local intellectual property

Source: UNEP/SETAC, 2010.

Appendix 2: Overview of some Social LCA case studies

Author(s)	Year	Product(s)	Type of document	Stakeholder categories	Subcategories / indicators
Gauthier	2005	"La Souris Verte", a manual charger for mobile phone batteries	Peer reviewed	Employees, contractual stakeholders, other stakeholders	Internal: consideration of employees, quality health and safety at work. External: relations with contractual stakeholders, relations with various other stakeholders
Hunkeler	2006	Comparison of two detergents	Peer reviewed	Employees	Employment hours (person-hours of labour per LC inventory element), number of work hours a person requires to access various societal midpoint needs: nr of employment hours to afford housing, health care, education and other necessities
Manhart & Grießhammer	2006	Notebooks	Report	Employees, local community, society	Employees: Safe & healthy working conditions, freedom of association, right to collective bargaining & workers' participation, equality of opportunity and treatment & fair interaction, forced labour, child labour, remuneration, working hours, employment security, social security, professional development, job satisfaction. Local Community: Safe & healthy living conditions, human rights, indigenous rights, community engagement, maintaining & improving social and economic opportunities. Society: Public commitments to sustainability issues, prevention of unjustifiable risks, employment creation, vocational training, anti-corruption efforts, social & environmental minimum standards for suppliers and co-operation partners, non-interference in sensitive political issues, contribution to the national economic development, impacts on armed conflicts, transparent business information, intellectual property right
Manhart	2007	Electronics	Report	Employees,	Employees: Safe & healthy working conditions, freedom of

Author(s)	Year	Product(s)	Type of document	Stakeholder categories	Subcategories / indicators
				local community, society	association, right to collective bargaining, equality of opportunity and treatment & fair interaction, forced labour, child labour, remuneration, working hours, employment security, social security, professional development, job satisfaction. Local Community: Safe & healthy living conditions, human rights, indigenous rights, social and economic opportunities. Society: Unjustifiable risks, employment creation, vocational training, corruption, contribution to the national economy, contribution to the national budget, impacts on conflicts, transparent business information, intellectual property right
Matos & Hall	2007	Oil and gas; agricultural biotechnology	Peer reviewed	Employees, local communities, secondary stakeholders	Jobs created, Knowledge enhanced/ transferred to local communities, health and safety of employees, health and safety of local communities, equal opportunities and diversity (for woman, aboriginals, persons with disabilities), Potential negative side effect on or from secondary stakeholders, Stakeholders engagement satisfaction
Blom & Solmar	2009	Comparison of biofuels (ethanol, biodiesel, biogas)	Master thesis	Employees, local communities, society, company	Employee: freedom of association and collective bargaining, wages, working hours, child labour, forced labour, equal opportunities/discrimination, health and safety, social benefits/Social security. Local community: secure, safe and healthy living conditions, land acquisition, delocalisation and migration, respect of indigenous rights, access to resources, cultural heritage and traditional knowledge. Society: Public commitments to sustainability issues, employment creation, contribution to the national economy and stable economic development, prevention and mitigation of armed conflicts,

Author(s)	Year	Product(s)	Type of document	Stakeholder categories	Subcategories / indicators
					technology development. Company: corruption, fair competition.
Franze & Ciroth	2009	Comparison of roses produced in Ecuador and Netherlands	Conference presentation	Workers, supply chain actors, local communities, society, consumer	Workers: Freedom of association, discrimination, child labour, fair salary, working hours, forced labour, health and safety, social benefits Supply chain actors: Fair competition, promoting CSR Local communities: Respect of indigenous rights, net migration rate, safe and healthy living conditions, local employment. Society: Contribution to economic development, corruption, technology development, prevention of armed conflicts Consumer: Health and safety, transparency
Dobón López et al.	2009	Plastics	Project report	Workers, value chain actors, local community, society, consumer	Workers: employment, labour / management relations, occupational health and safety, training and education, diversity and equal opportunity, non-discrimination, freedom of association and collective bargaining, child labour, forced labour, security practices Value chain actors: anti-competitive behaviour, compliance Local community: indigenous rights, community governance Society: investment and procurement practices, corruption, public policy Consumer: consumer health and safety, product and service labelling, marketing communications, costumer privacy, compliance
Kruse et al.	2009	Farmed and wild-caught salmon	Peer reviewed	Not explicit: fishermen, workers	Workers: fair wage, employment benefits, hours worked per week, forced labour, discrimination/gender, right to organize, age distribution of workers, minimum age of workers Other: industry concentration, distance product travelled

Source: authors' literature review.