SENSE tool: Easy-to-use web-based tool to calculate food product environmental impact

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ABSTRACT

SENSE project aims to deliver a harmonized evaluation system for the environmental impact assessment of food & drink products. The project evaluates existing relevant environmental impact assessment methodologies, and considers socio-economical, quality and safety aspects, to deliver a new integral system for the environmental and social assessment of agrifood and aquaculture products. The system integrates: (a) (regionalized) data gathering system; (b) matrix of key environmental performance indicators and a (c) methodology for simplified environmental impact assessment. The web-based SENSE tool has been validated in the juice, meat & dairy and aquaculture chains; however, the methodology and its associated software will be modular allowing its implementation in any food product.

The tool is based on the sustainability information collected along the production cycle of any food or drink products. The obtained results are reflected into an Environmental Identification Document (EID). Main results of SENSE will be: (i) Standard key environmental performance indicators (KEPI); (ii) harmonized methodology for environmental impact assessment; (iii) SENSE-tool for environmental data collection; (iv) EID; (v) Certification Scheme Concept (CSC) for sustainability; (vi) Roadmap for policy and governance implementation. SENSE consortium is formed by a multidisciplinary team involving 23 partners from 13 countries made up by a combination of complementary profiles: research organizations, food and drink SMEs, environmental and LCA experts, SMEs for dissemination and communication and European food Associations.

Keywords: Food SME, Online LCA tool, Impact communication, Benchmarking, SENSE Project

1. Introduction

Food production and consumption cause significant strain on the environment as it is estimated that 29% of global emissions of greenhouse gases (GHG) are from agriculture and food production. In the EU, food consumption accounts for 20–30% of various environmental impacts and, in the case of eutrophication, more than 50% (Tukker et al., 2005). In the UK, the food and drink sector is responsible for 14% of industrial energy consumption and 7 Mt of carbon emissions per year; it also uses 10% of all industrial water supplies and produces 10% of the industrial and commercial waste stream (DEFRA, 2006).

The food and drink industry in Europe, of which 99% are small and medium enterprises, is highly fragmented, and food chains are very complex. Hence, to assess the environmental sustainability of a product there is a need for applying integrated, harmonized and scientifically robust methodologies, together with appropriate communication strategies for making environmental sustainability understandable to the market. However, there are difficulties in developing a commonly agreed methodology for environmental impact assessment that still need to be overcome. Challenges are the complexity of food chains, the large number of agents involved, different suitable environmental indicators depending on the business sector, regional differences related to biodiversity among other challenges, including climate change and complexity of the current sustainability assessment tools - high data intensity, costs and expertise required.

Nowadays the calculation of the potential environmental impact of products can lead to great benefits to the industries which, in most cases, can lead to brand differentiation. However, most of the industries in the food sector, especially SMEs, neither have a strong background nor the capability to assess the sustainability of their products.

The European research project SENSE aims to deliver a harmonized system for the environmental impact assessment of food and drink products. The research evaluates existing relevant environmental impact assessment methodologies, and considers socio-economical, quality and safety aspects, to deliver a new integral system that can be linked to monitoring and traceability data. The system will integrate:

(a) (regionalized) data gathering system;
(b) matrix of key environmental performance indicators;
(c) methodology for environmental impact assessment; and
(d) a certification scheme

The methodology will be transferred to food & drink sectors and stakeholders by means of specific communication strategies.

The sustainability information collected along the supply chain of any food stuff and reflected into an Environmental Identification Document (EID) will be accessible by the EID-Communication Platform. This should contribute to making the environmental sustainability part of the usual purchasing behavior of consumers and provide a competitive advantage to those products (and companies) which choose to use the EID. Through a comprehensive environmental communication between the industry and consumers the latter are empowered to choose food products which are environmentally friendly.

2. Methods

2.1. Harmonised methodology for the environmental assessment of food and drink products

A set of consistent environmental impact assessment methods and impact indicators for three food chains (dairy/beef, orange juice and salmon aquaculture) and their supply chains has been selected based on literature reviews. The methodology is based on the key environmental challenges identified for each sector and the related impact categories. For the selection existing methodologies has been reviewed as well as current developments. The ILCD handbook (JRC, 2010) recommends LCIA methods for many impact categories and this has been a starting point for the review. The LCIA methods have also been reviewed on their suitability for the food sector and their practicability to use.

The life cycle assessment methodologies chosen for each impact category are listed in Table 1 along with the corresponding indicators and references. These are the same methods as later recommended by the European Commission on the Product Environmental Footprint (EC, 2013) and in the ENVIFOOD protocol except for water depletion where a revised approach to water footprinting is recommended in the ENVIFOOD protocol (ENVIFOOD, 2012).

Table 1. Life cycle impact assessment methodologies to be used in the SENSE-tool

Impact category	Unit	Selected LCIA method	Reference
Climate change	kg CO2-eq	Bern Model – IPCC	Solomon, 2007
Eutrophication, Terrestrial	molc N-eq	Accumulated Exceedance	Posch et al., 2008
Eutrophication, Freshwater	kg P-eq	EUTREND Model	Goedkoop et al., 2009
Eutrophication, Marine	kg N-eq	EUTREND Model	Goedkoop et al., 2009
Acidification	molc H+-eq	Accumulated Exceedance	Posch et al., 2008
Human toxicity	CTUh	USEtox Model	Rosenbaum et al., 2008
Ecotoxicity	CTUe	USEtox Model	Rosenbaum et al., 2008
Land use	kg C/m^2/a	Soil organic matter model	Milà i Canals 2007
Abiotic resource depletion	kg Sb eq	CML 2002	Guinée et al., 2002
Water depletion	m^3 H_2O eq	Ecological scarcity model	Frischknecht et al., 2009

2.2. Key Environmental Performance indicators for food and drink chain

The key environmental performance indicators were proposed as simple parameters to be used in the SENSE tool to calculate the environmental impacts. For the selection of those parameters three LCAs have been done in the beef and dairy, orange juice and aquaculture sectors. The LCA results confirmed the validity of the selected KEPIs taking into account their relevance for the environmental impact, the data availability and the easiness of measurement.

The KEPIs selected for the production of all the food supply chains are shown in Table 2. The selected KEPIs covered 95%, on average, of the environmental impacts of the respective food supply chains (Doubet et al., 2014)

Table 2. Selected key environmental performance indicators for the European food and drink sector.

INPUT	**UNIT**		**DS**
Land use	Ha*year	Land occupation for agricultural uses: permanent crops, arable land or grazing.	EcoInvent
Fertilizers	Kg N, P or K/year	Inorganic fertilizer consisting of nitrous compounds such as ammonium nitrate or ammonium sulphate and phosphorous or potassium compounds.	EcoInvent ESU
Organic fertilizer	Kg/year	Fertilizers derived from animal or vegetable matter (e.g. compost, manure	EcoInvent
Pesticides	Kg AI/year	Pesticides are plant protection products. The term "pesticides" covers insecticides, acaricides, herbicides, fungicides, plant growth regulators, rodenticides or biocides. The user has to provide the commercial name for the pesticide (i.e. RoundUp ®) in the free-text box and introduce the amount per hectare used. Once it is defined, an addition table will appear where they have to specify the percentage of active ingredient (AI) (i.e. glyphosate). If the AI is not in the list, generic pesticides could be used, such as, “fungicides” or “herbicides” or “pesticides”. When those AI are used, please introduce the 100% of the content.	EcoInvent
Energy	energy unit kwh, L of diesel, m^3 of natural gas / year	Energy consumption in agriculture systems are mainly related to fuel used during land labors (tractor), energy required for buildings maintenance and greenhouses maintenance, in the fisheries systems to the use of fossil fuel for the fishing vessels and in aquaculture, livestock and food processing systems the energy use is mainly related to the machinery requirements and building general consumption.	ESU
Freshwater use	L or m^3/year	For water requirements the user has to introduce the total water requirements for 1 year. Rain water is not taken into account, only tap-water	EcoInvent
Feeds	Kg/year	Data on feed can be obtained directly from the feed supplier as guest user and should then be added as an incoming product or Data on feed can be selected from a drop down menu, offering different kind of feed ingredients (crop and marine). In the questionnaire, the user should specify the different feed ingredients and add the relative amount by weight.	EcoInvent
Packaging	Kg/year	For the packaging the user should specify the type of final packaging (glass, plastic bottle or so) and the amount used per year. In some cases, intermediate packaging will be relevant too.	EcoInvent
Livestock	nº animals /year	For the livestock, the specific animal has to be selected. Specify the amount produced in one year and the share of the product in turnover (%).	IPCC
OUTPUT			
Wastewater	L or m^3/year	For inland aquaculture systems the user need to specify the amount (l or m3) of wastewater discharges per year. For marine aquaculture systems an average N direct emissions to the marine environmental due to faeces and uneaten feed per kg of fish has been taken into account (Solbakken, et al. 2008).	EcoInvent
Wastes	Kg/year	The user should first choose the waste material (organic waste, plastics, cardboard, glass or other type) and the disposal way (incineration, recycling landfill)	EcoInvent

2.3. Scientific validation of the SENSE tool

The validation of the integrated SENSE tool is based on performing simplified environmental impact assessment oriented to key indicators in the food supply chains representing three food chains (fruit juice, meat and aquaculture fish) in different European regions.

3. Results

Taking into account the methodology selected and the selected KEPIs, a web based tool, the SENSE tool, has been designed and developed with a common server and database allowing an active interaction between users. The developed tool aims to be used by industrial actors without a strong LCA background and to provide easy to be interpreted environmental information.

The tool compiles the information available at different levels in the food chain. The collected data are characterized and evaluated in order to obtain the key indicators associated to the evaluated product. This tool provides a common framework in which users from different stages of the supply chain introduce a simplified set of environmental data and compare respective environmental impacts. As far as the aim of the tool is to provide a tool for the SME's it has been designed as user friendly and very intuitive.

The tool is accessible via internet; therefore it is not necessary to install the program, making its use even simpler. This computer application has been developed using Visual Basic .Net, on Visual Studio 2010. The used database engine is SQL Server 2008 R2, where all the application's information is stored. As far as the application imaging, both design and used pictures, have been done using Photoshop CS 6 y Gimp 2.8.

For the allocation, economic allocation has been selected; however, the tool offers the possibility for system expansion option or to introduce manually the percentage of the economic allocation of different incoming materials, such as packaging or main ingredients.

Moreover, in order to facilitate the data gathering, the tool offers the possibility to send the questionnaires to the main suppliers of the chain. This data is confidential and it will be visible to the user just if the suppliers give the authorization for that.

For the impact characterization, the program sums up the environmental impact of each process involved in the food chain (**Error! Reference source not found.**).

$$T_{x,y} = \sum_{i=x}^{i=z} EI_{i,y} \qquad \text{Eq. 1}$$

Where for any of selected environmental impact, such as climate change or water depletion (Table 1):

- $T_{x,y}$ is the summation of the environmental impact of all inputs *j* of the product *y* from the process *x* to the last process *z* (where final product are generated)
- $EI_{i,y}$ is the environmental impact of the process *i* in the product *y*

For the impact assessment of each process, the proportional impact of each input into the final product has been added according to equation 2 (**Error! Reference source not found.**).

$$EI_{x,y} = \sum_{\forall j} I_{j,x,y} \qquad \text{Eq. 2}$$

Where:

- $EI_{x,y}$ is the environmental impact of the process *x* in the product *y*
- $I_{j,x,y}$ is the partial environmental impact of the input *j* of the process *x* in the product *y*

Finally, to calculate the proportional environmental impact of each input in the final product, the conversion factor of each input to each environmental impact has been multiplied for the amount of the input used in each process. Then a factor is applied to calculate the weighting of this input into the target product. This factor is calculated taking into account the share of product turnover of the processes involved and the ratio of the product of each process used in the next process (Eq. 3).

$$I_{j,x,y} = CF_j \times M_{j,x} \times \prod_{i=x}^{i=z} \left(S_{y,i} \times R_{y,i}\right) \qquad \text{Eq. 3}$$

Where:

- CF_j is the environmental characterization factor for the selected impact category of the input *j*
- $M_{j,x}$ is the quantity of the input *j* in the process *x*
- $S_{y,i}$ is the share of product turnover in the process *i* for the product *y*
- $R_{y,i}$ is the ratio of the product flow between the process *i* and *i+1* for the product *y*

For example, for the dairy chain described in
Figure 1, in order to calculate the impact of the farm process on the final product (i.e. sour cream) accordingly to the formulas described above, the procedure will be the following:

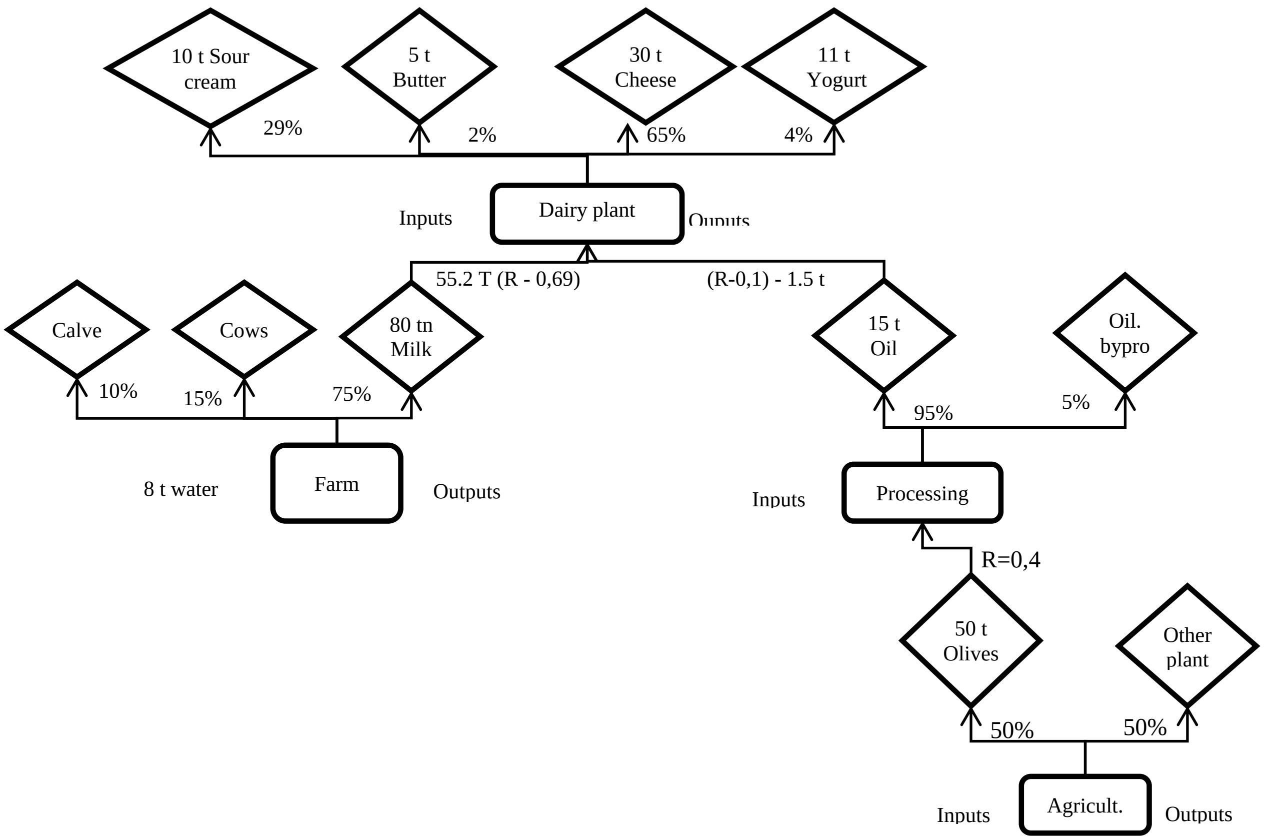

Figure 1. A hypothetical dairy plant which produces sour cream, butter, cheese and yogurt. Main ingredients are raw milk from a farm and oil. Percentages in the lines represent the share of product turnover and the Ratios (R) represent the ratio of product taken from the previous stage.

Taking into account that 8 tn of water enters the farm and that the characterization factor for the climate change of water is 0,0003 kg CO2 eq/kg water, the proportional climate change potential of the water consumption regarding the sour cream yearly production will be the following:

$$I_{j,x,y} = 0{,}0003 \times (8 \times 1000) \times 75\% \; x \; 0{,}69 \; x \; 29\% = 0{,}36 \; kg \; CO2 \; eq$$

Hence, adding all the proportional climate change impact of all the inputs to the farm stages, the user could differentiate the impact of that specific process. Thus, adding the processes involved in the whole chain, the complete impact will be obtained.

The SENSE tool application calculates the environmental impacts that are related to the previously described impact categories. The impact characterization can be shown for the production of one year, or for one unit e.g. kg product as defined in the user profile.

The results are presented in the following ways:

- Environmental impact per process and year. Those results are shown in a bar chart and show the impact generated for the selected environmental indicator and process. A table with the impact value is also shown under the graphic. (Figure 2)

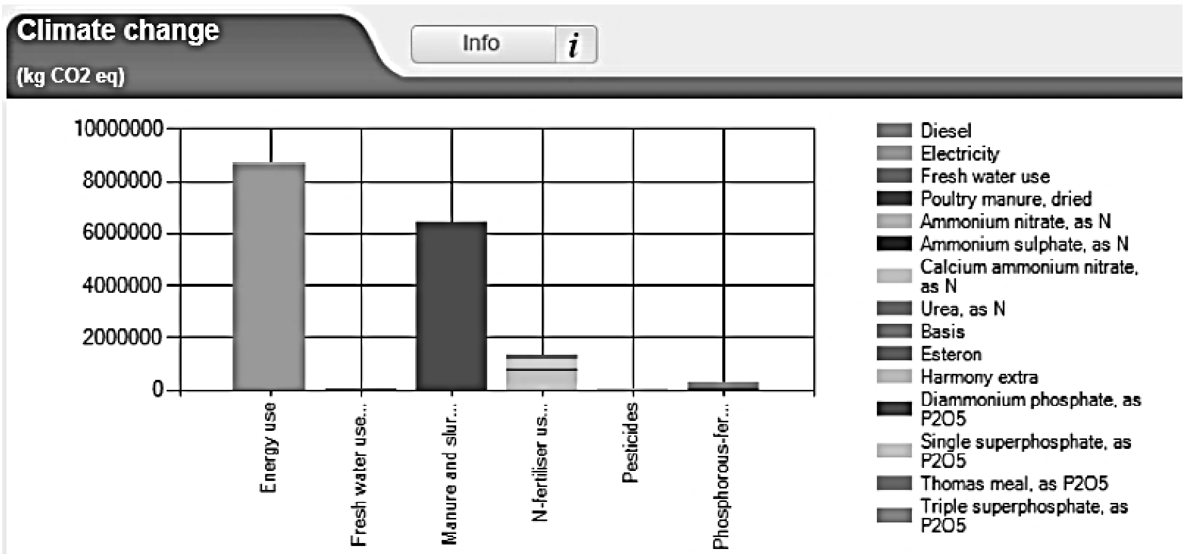

Figure 2. Captured figure of the sense-tool results for the climate change potential characterization results for the farm stage of the dairy production chain.

- Complete impact analysis: For each impact category a pie graph is shown with the contribution of each process to the total impact. An histogram is also shown with the summary of all the impact and processes (Figure 3)

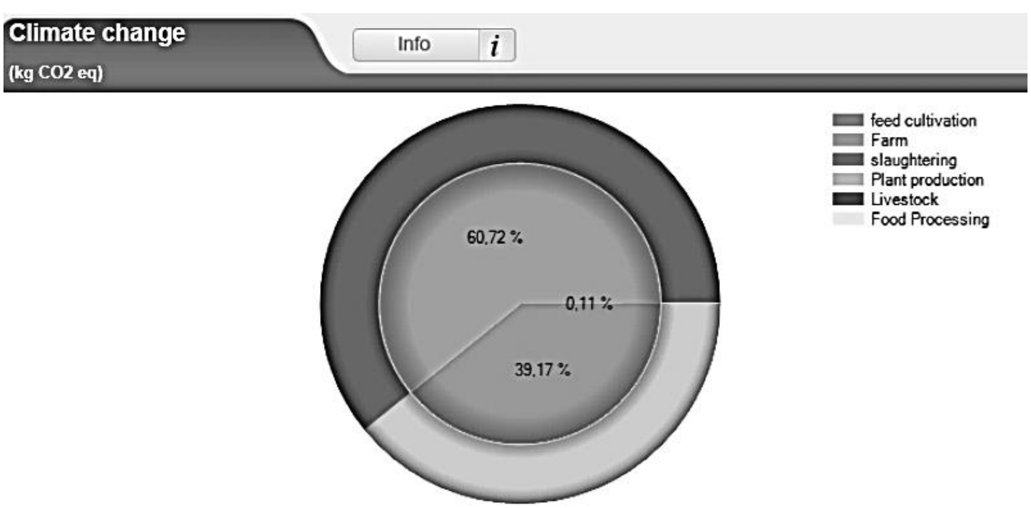

Figure 3. Captured figure of the sense-tool results for climate change potential characterization for a dairy production chain expressed in pie chart.

The contribution (%) of each process to the final impact is shown.

- Compare products. It is possible to compare product by process or by impact. When comparing the environmental impact by process, the weight of the different processes on the final impact of each product will be shown for each impact category. When comparing by impact, a complete graph will be shown comparing the final impact of each product.
- Evolution of the product impact. A line chart is shown with the evolution of the environmental impacts of the product along the years. With this data the tendency can be assessed.
- Product benchmarking: In the future this option will allow the user to benchmark its products internally (comparison between the same products in different years) and externally (with other similar products). When selecting benchmarking a spider graph will be shown with the deviation of the actual product impact assessment from the average value for that product. For the moment, there is no enough data for the external benchmarking; however the tool is ready for the future improvements.

Coupled with those graphics, there is a possibility to extract the Environmental Identification Document (EID). In this document a summary of main environmental results is described.

4. Discussion

4.1. Validation of the tool

The tool has been technically validated in two case studies by comparing the outcome of the SENSE tool with calculations performed by SimaPro commercial software Simapro. The functionality of the SENSE tool was tested when entering data for the beef-and-dairy, orange juice. Acuaculture chain has been also validated with GaBi software, but the results of this comparison are out of the scope of this publication. The validation is based on using only pre-selected input data (e.g. energy use, material use, etc.) which have been defined in the project as key performance indicators (KEPIs). The KEPIs were chosen based on their contribution to the key environmental impacts of the food supply chains studied namely, beef and dairy, orange juice and aquaculture fish (Doublet et al., 2014). This iterative process was important to ensure that the developed SENSE tool would be fully functional and validated before it was delivered for implementing and testing by SMEs.

The relative percentage difference between the environmental impacts of the SENSE tool and the LCA on Romanian beef and dairy products (Doublet et al. 2013a) is highly dependent on the impact category. Results for climate change, human toxicity cancer and non-cancer effects, ecotoxicity, freshwater and land use have a difference smaller than 10 %. However, differences in the modelling of the emissions due to the land use and the application of, manure as well as the additional data taken into account in the complete LCA for the pesticides can explain the large deviation in the results of the acidification, eutrophication terrestrial and marine.

For the orange juice supply chain, the difference between the environmental impacts calculated in the SENSE tool and the LCA is below 10 % for climate change, human toxicity, acidification, eutrophication terrestrial, eutrophication marine, abiotic resource depletion and water depletion.

4.2. Allocation procedures

Since the aim of the project is to obtain a simplified environmental analysis of the food and drink products, some limitations have been identified. The method used when distributing the environmental burden between the main product and its by-product can have a significant impact on the final results of a LCA (Svanes et al., 2011). Although it may be controversial, economic allocation is chosen as the default allocation approach in the SENSE tool.

The allocation procedures applied in the LCA on beef and dairy products in Romania are beyond the common knowledge of SMEs. The allocation procedures recommended by the international dairy federation to allocate the environmental impacts of beef and milk production at farm as well as the allocation matrix to distribute the environmental impacts of the individual dairy products are too complex and time-consuming for somebody not familiar with the field of life cycle assessment. Witczak et al. (2014) conclude that SMEs do not have time to collect and evaluate data and expect quick results based on a small amount of data. ISO recommends avoiding allocation by expanding the system but this is out of the scope of an internet tool to be used by SMEs. Allocation cannot be avoided and allocation rules should be made as simple as possible. The easiest allocation approaches are mass and economic allocation.

The results for single dairy products are quite sensitive to the allocation approach chosen (Feitz et al. 2007). Physico-chemical allocation, mass allocation, protein allocation and economic allocation were used to assess the environmental impacts of individual dairy products. Mass allocation may be discredited in the dairy production chain since it results in considerable deviations from physicochemical allocation. Economic allocation introduces similar order of magnitude sized variations. Feitz et al. (2007) suggested using economic allocation for inter-industry sectorial flows. Kim et al. (2013) allocated the incoming raw milk to the individual dairy products on a milk solids basis. Energy and resource use were allocated based on an economic allocation.

The allocation of environmental impacts to by-products is also an issue for the slaughtering process in the beef chain. Due to lack of comprehensive global data, Opio et al. (2013) could not perform an allocation to slaughter by-products. Cederberg et al. (2009) explained that no greenhouse gas emissions were allocated to the meat production by-products. In our case study, this approach was followed and all environmental impacts are allocated to the beef.

In the aquaculture chain, the use of economic allocation has been criticized as it does not reflect the biophysical properties of the production system and is sensitive to changes in market prices (Pelletier & Tyedmers, 2011; Svanes et al., 2011; Ytrestøyl et al., 2011). Mass allocation methods have been applied in studies on feed and aquaculture as well as fisheries (Boissy et al., 2011) while others have used gross nutritional energy (Pelletier et al., 2009) or economic allocation (Ellingsen et al., 2009). Winther et al. (2009) justified the use of mass allocation for salmon after evaluating both economic allocation and gross nutritional energy. In mass allocation, the environmental cost associated with the by-products is the same as for the products for human consumption. Using mass allocation in LCA is beneficial for producers of products for human consumption if they can recycle their by-products into other production systems. Therefore, mass allocation creates a positive incentive for full utilization of by-products compared to economic allocation, where by-products of insignificant value otherwise carry a zero environmental burden. However, the use of by-products from environmentally costly productions such as livestock production or demersal fish trimmings in salmon feed production contribute substantially to the outcome of an LCA analysis in terms of energy use and CO2 emissions (Pelletier et al., 2009; Ytrestøyl et al., 2011). Currently about a quarter of the fish meal produced comes from by-products from fish processing for human consumption (i.e., by-products from fish filleting plants). In the case study, the economic allocation was used in the LCA on aquaculture. It gives a higher burden on the main product than if mass allocation would have been used. At the aquaculture farm 10 % of the biomass at the farm is guts which are given away for free. The by-product, guts, therefore has zero environmental loads. If mass allocation would have been used the impacts of the salmon product would be reduced by 10 %.

The recommendation regarding economic allocation rules for the SENSE tool may be the simplest approach for SMEs. However, since the SENSE tool offer the possibility to implement different allocation factors for the incoming product; this is a good approach that could be used if SMEs are willing to invest more time to obtain a more scientific environmental assessment.

4.3. Usefulness in SMEs

Additional case studies where the SENSE tool is tested by users are currently ongoing in the project in at least 30 companies and their supply chains. First impressions with the SMEs state that the companies are quite reluctant to implement the SENSE-tool into their company mainly due to lack of resources (time or people). However, after this first obstacle, those companies which are taking part of this validation find it very useful. Main benefits of the tool for those companies are i) the possibility to identify the hot-spot of their processes and ii) the benchmarking possibility (not implemented yet).

5. Conclusion

In conclusion the SENSE tool has been designed to be suitable for the food and drink SMEs. However, it is important to remark that the main aim is to obtain a simplified tool, and thus it won’t be an alternative for the complete LCA studies.

For future developing two mains aspects will be considered. First the Certification Scheme Concept voluntary system (CSC) for use of the EID in food and drink products will be developed. This Scheme will be based on the different voluntary systems (ISO, EMAS, others). The CSC will define the rules for development of its own regulations for the certification process, the definition of the requirements (independence, transparency, etc.) and the protocol of the regulatory/certification system which will be in charge of the approval and updating of the EID. The second important aspect to develop in the future is the communication systems which will be differentiate between business-to-business (B2B) and business-to-consumer (B2C) communication levels.

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