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Interuniversity Research Centre for the Life Cycle of Products, Processes and Services

FINAL REPORT

ENVIRONMENTAL SUSTAINABILITY ATTRIBUTES OF BIOMASS

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By:

CIRAIG-AGÉCO

Submitted by:

BUREAU DE LA RECHERCHE ET CENTRE DE DÉVELOPPEMENT TECHNOLOGIQUE (B.R.C.D.T.)

ÉCOLE POLYTECHNIQUE DE MONTRÉAL

Université de Montréal Campus

P.O. box 6079, Station Centre-ville

Montréal (Québec) H3C 3A7

GROUPE AGÉCO

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CIRAIG

Interuniversity Research Centre for the Life Cycle of Products, Processes and Services

École Polytechnique de Montréal

Chemical Engineering Department

2900 Édouard-Montpetit

Montreal (Quebec) Canada

P.O. Box 6079, Station Centre-ville

H3C 3A7

www.ciraig.org

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Working Group

Authors

Dominique Maxime, Ph.D.,
Environmental Senior Analyst, CIRAIG

Cyril Michaud, Senior Analyst -
Environmental Economics, AGECO

Annie Levasseur, Eng., Ph.D., Research
officer, CIRAIG

Thomas Dandres, Ph.D., Postdoctoral
fellow, Consequential LCA expert, CIRAIG

Pr. Jean-Pierre Revéret, Ph.D, Social LCA
Expert, CIRAIG-AGECO

Collaborators

Valérie Patreau, M.Sc.A.,
Senior Project Manager, CIRAIG
Project coordination

Pr. Manuele Margni, Ph.D,
LCA Expert, CIRAIG
Quality Control

Direction

Pr. Réjean Samson, Eng., Ph.D., CIRAIG
Project director

Table of Contents

Tables List

Figures List

Abbreviations and Acronyms

AAFC	Agriculture and Agri-Food Canada
BFSCI	Bioenergy and Food Security Criteria and Indicators
BMP	Best Management Practice
CCME	Canadian Council of Ministers of the Environment
CDP	Carbon Disclosure Project
CIRAIG	Interuniversity Research Centre for the Life Cycle of Products, Processes and Services
CSBP	Council on Sustainable Biomass Production
DDG	Dried Distillers Grains
dLUC	Direct Land-use change
EFP	Environmental Farm Plans
EGS	Ecosystem Goods and Services
eLCA	Environmental Life Cycle Assessment
ERPA	Environmentally Responsible Product Assessment
EU	European Union
EUC	European Union Commission
FAO	Food and Agriculture Organization
GBEP	Global Bioenergy Partnership
GHG	Greenhouse Gas
GMO	Genetically Modified Organism
GRI	Global Reporting Initiative
GWP	Global Warming Potential
ILCD	International Reference Life Cycle Data System
ILO	International Labour Organization
iLUC	Indirect Land-use change
IPCC	Intergovernmental Panel on Climate Change
ISCC	International Sustainability and Carbon Certification
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LUC	Land-Use Change

NAHARP	National Agri-environmental Health Analysis and Reporting Program
NGO	Non-Governmental Organization
NRCan	Natural Resources Canada
NRT	National Round Table
OECD	Organisation for Economic Co-operation and Development
OFA	Ontario Federation of Agriculture
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
ON	Ontario
PCR	Product Category Rules
PM	Particulate Matter
RED	Renewable Energy Directive
RFS	Renewable Fuel Standard
RSB	Roundtable on Sustainable Biofuels
SAFA	Sustainability Assessment of Food and Agriculture
SETAC	Society of Environmental Toxicology and Chemistry
SIA	Social Impact Assessment
SIPs	Standards, Initiatives and Programs
sLCA	Social Life Cycle Assessment
SOC	Soil Organic Carbon
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
U.S.	United States
U.S. EPA	United States Environmental Protection Agency
WBCSD	World Business Council for Sustainable Development
WCI	Western Climate Initiative
WFN	Water Footprint Network
WRI	World Resource Institute

Executive Summary

The Ontario Federation of Agriculture (OFA) has commissioned the CIRAIG to conduct a study on the environmental and social sustainability attributes of purpose grown biomass (miscanthus, switchgrass, polyculture native grasses, willow, poplar) and crop residues (corn stover, wheat straw), and to elaborate a sustainability framework based on the Ontario environmental farm plan platform. Envisioned end-use of biomass is primarily energy (e.g. as a substitute for natural gas), but also green chemicals (e.g. succinic acid), or processed bio-products (e.g. for the processed wood market). This report focuses on how life cycle assessment (LCA) methodology could help evaluate biomass environmental and socio-economic attributes within the context of current regulatory and commercial sustainability schemes.

A literature review was performed from several perspectives. The first was to review the existing standards, initiatives and programs (SIPs) for the sustainability certification of agricultural biomass and to identify the attributes they are addressing. Most SIPs are actually related to the use of biomass for energy purpose, mainly biofuels. In relation to the requirements of the SIP identified, another perspective was to evaluate the capabilities and the current shortcomings of LCA methodologies, as well as the availability of data for LCA that are representative of the Ontario context. Even though LCA goes beyond climate change assessment (i.e. carbon footprinting), emphasis is put on the capability to account for local climate-related and soil-related specificities for a robust assessment of agricultural greenhouse gases (GHG) emissions and of the relevance of a carbon offset protocol. In order to identify the relevant stakeholders' categories and the socio-economic attributes of sustainability of purpose grown agricultural biomass, this literature review also aims at following and adapting the Guidelines for Social Life Cycle Assessment of Products published by the United Nations Environment Program (UNEP) in collaboration with the Society of Environmental Toxicology and Chemistry (SETAC) in 2009. More precisely, the review focused on the stakeholder categories and the social issues of concern (subcategories) that are relevant to agricultural biomass production, but that are not actually covered by the Guidelines and also used academic papers as well as existing voluntary or mandatory sustainability standards relevant for biomass production to complement the Guidelines.

Key LCA findings and their relevance for farmers and potential biomass energy users.

The review reveals that none of the current SIPs requires a multi-criteria environmental LCA for assessing the sustainability of a bioenergy. Only GHG climate change impact has to be quantified through a life cycle perspective. All other environmental issues have to be addressed through qualitative statements and evidence that measures have been implemented on the farm (e.g. best management practices, reduction projects, environmental farm plans). These measures cover most of the environmental issues related to crop production, such as the conservation of land areas with high carbon stock and biodiversity, and the maintenance or the enhancement of soil quality, of water resource and water quality, and of air quality. LCA is also capable of addressing such issues and of estimating further detailed impact through indicators related e.g. to soil and aquatic ecotoxicity and eutrophication, to respiratory effects from ammonia and particulate matter, or to water use. Thus, LCA can provide a deeper insight, quantitatively, and offers a valuable way to report a comprehensive sustainability profile of biomass production, beyond GHG, and on improvements with time. Inventorying farm emissions and resources use can be a tedious task and some data gaps may need to be filled with generic data. However, for GHG, specific Canadian methodologies and Ontario emissions factors exist for a contextualized Tier II approach at the ecodistrict geographical scale, like those used in Alberta for carbon offset projects. The OFA could show strong leadership in the perspective of regulations or coalitions' initiative that would require a more exhaustive demonstration of the sustainability of biomass. One of the main findings is the fact that socio-economic criteria are scarcely used in Canadian or U.S. mandatory sustainability standards regarding biofuels. However, these criteria are more common in voluntary standards and in European or international standards. These criteria deal with issues such as workers' rights, socio-economic impacts on local communities, fair competition within the value chain and a broad range of issues. Given that several sustainability SIPs apply to the biofuel production as a whole, including at the biomass production level, social criteria derived from a sLCA could be useful at the farm level in order to provide a common framework to assess the sustainability of biomass-derived products along the value chain.

Relevance of key findings for governments in terms of energy supplies and carbon footprint or LCA.
LCA is already recognized worldwide as a useful decision-support tool for policy making. For energy-related policies, GHG LCA is already implemented through several countries' standards to qualify biofuel pathways and research is ongoing to improve its relevance regarding different biomass-related issues. Furthermore, NGOs and scientists are increasingly debating public issues related to direct and indirect land use (and competition with food), and more recently to the water footprint of bioenergy, which is generally lower for fossil fuels when land irrigation comes into play. We believe that in the coming years, providing the sole carbon footprint of a feedstock or of a bioenergy will be insufficient to comply with mandatory standards and initiatives from corporate supply chain coalitions. LCA is positioned as a relevant tool for assessing multiple and interconnected issues within a single framework, and for ensuring that any potential transfer of impact is assessed in a comprehensive way. Such a risk is not impossible if environmental monitoring is limited to qualitative measures and to separate assessments. The sLCA approach would also be a useful tool in order to compare the respective social impacts of the various options regarding Ontario energy mix. The social impacts' categories may include concerns such as workers' rights, local employment or impacts on society such as access to material resources and energy independence, etc. This study proposes a framework in line with sLCA and eLCA standards and guidelines, and provides examples of indicators that could be used.It is important to note that sLCA is still an evolving field and that the relevant stakeholders should be part of the process itself of selecting impact sub-categories and defining indicators in order for the sLCA results to be meaningful for the broadest audience possible. As well, eLCA methods are steadily improving towards a finer assessment of soil-related local impacts and ecosystems services. Pending the full operationalization of such regional assessments, the framework proposes a hybrid approach where a multicriteria eLCA is strengthened with auxiliary indicators for temporarily filling up current LCA methodological gaps. It is estimated that data and models necessary to elaborate such indicators for the biomass within the Ontario context are available through the Environmental Farm Plans' data ecosystem, current ongoing research projects about Ontario biomass, and the expertise from identified scientists.

1 Literature review of the sustainability attributes for biological systems

While biomass has emerged as a substitute of petroleum-based fuels and chemicals and that large-scale production is envisaged, the sustainability of feedstock is logically challenged. Past experiences with ethanol produced from corn and sugar cane have indeed raised several ecological and social issues debated on the scientific and mainstream press such as the deforestation of primary forest and the competition with farmland with the indirect result of land use change elsewhere (the *food vs fuel* issue). Nowadays, any alternative pathways and new bio-product development involving the use of biomass implies addressing economic, social and environmental challenges concurrently.

There is probably no unambiguous definition of sustainability since it involves several debatable concepts and perspectives. However, the most widespread accepted definition from 1987 Brundtland Commission is "*meeting the needs of the present while improving the ability of future generations to meet their own needs.*" Obviously, environmental, economic, and social dimensions are involved, and humans have thus the duty to manage their activities and their consequences in a responsible way to ensure that sustainability can be effectively achieved. The Canadian's National Round Table on the Environment and the Economy (NRT)[1] states "*sustainable development demands that the environment be included alongside society's pursuit of economic and social goals, and that the needs of future generations are considered along with those of the present.*"[2]

Regarding the social and economic dimensions at the local level, Natural Resources Canada states a guiding principle where the biofuel industry shall provide market opportunities for regional biomass producers, thereby contributing to social and economic development (NRCan, 2010). Overall, it is also important to implement a perennial framework where continuous changes towards improved sustainability and reduced impacts can be 1) estimated, 2) monitored, 3) benchmarked against either previous results or forecasted target, 4) transparently documented, and possibly published, and 5) can serve effectively to promote the overall economic, social and environmental performance of the value chain, from feedstock to marketed product. The above points 2 to 4 are in line with a cross-cutting principle commonly found within most sustainability standards, schemes and certification initiatives requiring e.g. "planning, monitoring and continuous improvement" (Roundtable on Sustainable Biofuels RSB, 2010) or "Integrated resource management planning" (CSBP, 2011).

1.1 Economic and social attributes

This section offers a review of the literature that aims to adapt the Guidelines for Social Life Cycle Assessment of Products (the Guidelines), published by the United Nations Environment Program (UNEP) in collaboration with the Society of Environmental Toxicology and Chemistry (SETAC) in 2009. This literature review aims to identify the socio-economic attributes of sustainability of purpose grown agricultural biomass in a life-cycle perspective. More precisely, the review will focus on the stakeholder categories and the social issues of concern (subcategories) that are relevant to agricultural biomass production, but that are not actually covered by the Guidelines.

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[1] The NRT (formerly NRTEE) is "the only national organization with a direct mandate from Parliament to engage Canadians in the generation and promotion of sustainable development advice and solutions."

[2] http://nrtee-trnee.ca/governance/the-sustainability-project.

While Social Life Cycle Assessment (sLCA) is a relatively new research discipline, much work has been carried out in the last decade in relation to the domain of social impact analysis and sustainability analysis. For this reason, our review takes into account a vast array of sources, including fields of research such as Social Impact Assessment (SIA), multi-criteria analysis and Corporate Social Responsibility, as well as different assessment models, such as the one developed by the Global Reporting Initiative (GRI), or more specifically to the bioenergy sector, by the Global Bioenergy Partnership (GBEP). Given the interest for Ontario farmers in market-oriented standards, various regulatory frameworks and voluntary standards have also been reviewed for this project.

In the following sections, the vast literature will thus be reviewed and the identified frameworks will be covered in a stepwise manner, beginning with a discussion on the stakeholder categories commonly used (section 1.1.1), followed by an overview of the issues of concern (section 1.1.2). The socio-economic sustainability attributes and criteria already being used in regulatory framework and voluntary standards will also be presented (section 1.4).

1.1.1 Stakeholders identification

According to the Guidelines, stakeholders are "those groups and individuals that can affect, or are affected by, the accomplishment of organizational purpose" (Freeman R., 1984 cited by UNEP/SETAC 2009, p.47). The selection of the stakeholder categories in a sLCA depends on the scope of the study, but might also vary within each step of the supply chain. The Guidelines propose, however, a list of five stakeholder categories that are usually impacted by the life cycle of a product (cf. Appendix A).

The review performed shows that, notwithstanding the specific terms and definitions used, similar categorizations were used in studies that apply a sLCA framework to the agricultural sector (Franze and Ciroth, 2011; Paragahawewa *et al.*, 2009; Blom, 2009). Stakeholder categories such as "workers", "local communities", "value chain actors" and "society" are also commonly referred to in many studies analysing the social impacts related to agricultural production (see among others van Dam *et al.* 2009, Bokkers *et al.* 2008; Caldeira Monteiro *et al.* 2006; Van Calker *et al.* 2003). The main difference with the sLCA framework is that the "consumers" category is less frequently used in the studies and voluntary standards applied to the bioenergy sector reviewed for this project. One can guess that this category is included most of the time within the "society" category. This indicates that the list of stakeholder categories proposed by the Guidelines is globally adequate and exhaustive in regards to the existing literature.

Some authors like Paragahawewa *et al.* (2009), following Labuschage and Brent (2006) and Kölsch *et al.* (2008), are concerned about the inclusion of "Company" and "Future generations" as major stakeholder categories that should be included in a sLCA. Lähtinen *et al.* (2011) also propose to include future generations within its framework by using the "equality within and between generations" as one of the indicators of the social sustainability of forest-based bioenergy production systems. However, the current review does not propose to include them as distinct stakeholder categories. First, a sLCA is not intended to evaluate the sustainability of the firm itself, but rather its social impacts induced by its activities over the other stakeholders in order to promote sustainability. It is thus important to distinguish the sLCA approach from other research programs that focus rather on the sustainability of the farm itself and the social impacts that farming induces on the producer and his family (Zahm *et al.* 2005; Van Cauwenberg *et al.* 2007; Parent *et al.* 2010; Hayashi and Sato, 2010; Lord, 2011). Second, while Paragahawewa *et al.* (2009) justify the inclusion of "Future generations" by the fact that sLCA is being developed as a tool for sustainable development and the recognized definition of this notion specifically refers to the protection of the needs of future generations (pp.17-18). There are, however, many challenges related to the inclusion of this category, among which the specification of what should be considered as the future generations as well as the way to conceptualize the social impacts they will have to support.

This literature review also allowed noting that the scope of the actors considered for each category varies depending on the case study and the sustainability standards considered. For example, the “workers” category may include farm workers only or all the workers within the value chain, from the feedstock producers to the biofuel producers, through the feedstock processors’ activities. The same comment can be made regarding the “society” and “local communities” category. International standards such as the GBEP (2011) or the EU biofuel sustainability criteria (EUC 2009) have a special attention towards developing countries population within the “society” and “local communities” category. Other studies such as Lähtinen *et al.* (2011) or van Dam *et al.* (2009) focus on within country or regional population regarding the “local communities” category.

1.1.2 Issues of concern

In this section, the literature review documents a selection of impact categories that capture issues of concern that are relevant to agricultural biomass production. The Guidelines’ framework is adjusted accordingly. Each issue is classified in respect to one of the stakeholder categories retained for the study. Since the methodologies used in the literature covered are diverse and the frameworks proposed are not necessarily in line with the sLCA’s categorization, this allocation has sometimes been developed specifically for this study. The table presented in Appendix B summarizes the issues of concern that are relevant to the socio-economic sustainability attributes of biomass and associated criteria. However, one should note that some of the criteria could be more relevant at the farm/company level while others could be used for a sectorial approach or for a given functional unit. It is also important to remember that sLCA-based attributes and indicators do not necessarily serve the same purpose as those stemming from regulatory frameworks and voluntary standards. The indicators used within voluntary standards or regulatory frameworks can be compared with a floor-level of performance and are, by definition, normative (i.e. the minimum one has to achieve in order to comply with the regulation or standard). SLCA-based indicators, on the other hand, are helpful in comparing the relative performance of several options (i.e. regardless of what the floor or ceiling-level of performance should be) and they reflect a positive approach insofar as they aim to measure the actual performance, rather than what the performance should be. Further discussion regarding the choice of indicators and its methodology is provided in section 2.1.3. Thus, the indicators listed in Appendix B should be taken as an illustration of the existing options regarding social indicators and criteria. It is important to note that the selection of the criteria should be based on a participatory approach with the stakeholders involved or potentially impacted by biomass production.

The vast majority of the studies reviewed grant a significant importance to the **workers and their “working conditions.”** Globally, the issues of concern considered such as working hours, social security, health and safety, etc., are similar to those found in the Guidelines. Even impact subcategories that are not necessarily associated with the developed countries’ socioeconomic context, like “child labour” and “forced labour”, are included in frameworks and voluntary standards such as those proposed by the Council on Sustainable Biomass Production (CSBP, 2011), RSB (2011) and the Nordic EcoLabel (BEFSCI 2011). Consequently, it seems irrelevant at this point to subtract from the proposed framework any of the actual impact subcategories used in the Guidelines in relation to the Workers category.

It is, however, possible to consider the inclusion of some other issues of concern in order to improve our framework, especially in relation to our focus on agricultural biomass production. In this regards, the works of Paragahawewa *et al.* (2009) and Labuschage and Brent (2006) offer an interesting point of view by suggesting the inclusion of “employment stability” and “capacity development” as two additional impact subcategories. According to Labuschage and Brent, the first issue “addresses a business initiative's impact on work opportunities within the company, the stability thereof as well as evaluating the fairness of compensation”, while the second “addresses two different aspects namely research and development, and career development” (p.6). Lähtinen (2011) also proposes a “seasonal variation of the workforce hired” and a “work satisfaction” criterion. Thus, while Paragahawewa *et al.* (2009) and Labuschage and Brent (2006), and Lähtinen’s first criteria focus on the professional growth opportunities created by business and offered to its employees, Lähtinen’s second criteria suggests including workers’ personal growth and well-being.

There are many ways from which **local communities** can be affected by a given production process. Also, the Guidelines propose nine different impact subcategories (Appendix A). According to the nature and scope of the research project, some of them can naturally be subtracted. For example, Franze and Ciroth (2011) have only considered “indigenous rights”, “safe and healthy living conditions” and “local employment” in the sLCA they conducted on the production of cut roses in the Netherlands and Ecuador. Similarly, some adjustments might also be needed in relation to our own study.

It has been noted that impact subcategories such as “Delocalization and Migration”, “Cultural heritage”, “Respect of indigenous rights” and “Secure living conditions” have been used in the context of agricultural biomass production (Blom, 2009). However, these impacts subcategories are more relevant in developing countries settings than in Canada’s. It could be, therefore, possible to remove from the Guidelines’ list those impact subcategories that are irrelevant to the context of biomass production in Ontario.

On the other hand, the other issues listed in the Guidelines are clearly compatible within the context of purpose-grown biomass in Ontario. In this regards, ”Local economy” and “Community engagement” are two impact subcategories that are widely cited in the studies applying to the agricultural sector, as it is the case with authors such as Van Dam *et al.* (2009), Lähtinen (2011) and Lord (2011).

The “Access to material resources” subcategory is also worthy of interest. The use of water for bioenergy production can be a source of impact for surrounding communities and some voluntary standards, such as CSBP (2011), recommend that feedstock producers respect water use regulation. The economic effects of biomass production on food security and land-use are also hotly debated. They are frequently mentioned as issue of concerns regarding the sustainability of biomass production, either for the “local communities” category or the “society” category. For example, the EU directive on sustainability criteria mentions that EU countries must regularly follow-up on the impact of their biomass production and imports policy on other countries, especially developing countries. Van Dam *et al.* (2009), in their impact assessment of soybean and miscanthus production, take as a sustainability principle that “biomass production must not endanger food supply and local applications” and the Nordic Ecolabel (2011) explicitly mentions corn as an unsustainable source of biofuel. However, while the results of van Dam *et al.* (2009) suggest that bioenergy production could have an impact on land prices, it is inconclusive regarding food prices and availability. Indeed, many debates regarding the direction and size of the food/energy debate are inconclusive since food security and prices depend on many other factors than agricultural production. It is highly unlikely that food availability, either at the local or national level, could be impacted by the production of purpose grown biomass in Ontario[3]. Thus, food security could be ignored as a sub-indicator for "access to material resources." However, land prices could be considered as a sub-indicator for this subcategory, given that biomass production in Ontario could take place not only on marginal land but also on current agricultural land. The "access to material resources" sub-category also encompasses notions such as "Landscape quality" and "multifunctionality" of agriculture (Van Calker *et al.*, 2003). Meul *et al.* (2008) also refer to "Landscape management" and its corresponding notions (visual nuisance, nature conservation, architectural quality, etc.) as one crucial social aspect to tackle in relation with agricultural activity.

For authors such as Caldeira Monteiro *et al.* (2006) and Lord (2011), the "Safe & healthy living conditions" issue is also one major concern. These authors use the expressions of "Occupational safety and health" and "Quality of the living environment" respectively to encompass social impacts related to the risk exposure and the specific inconveniences (noise, vibration, dust, etc.) associated with agricultural production.

Moreover, Lord (2011) uses the expression "Quality of living environment" to relate to the "liveability of the built and natural environment in which people live and work" (p.67), including the social (hospitals, counselling services, police, education) and physical (roads, water supply, sewage, harbour, gear storage) infrastructures. Using a monetised proxy, Paragahawewa *et al.* (2009) have for their part coined this concern about impacts on social infrastructures by referring to the "Tax allocation to social infrastructure" category. In sum, given the relevance granted to this issue in the literature, but also the specificity of its associated concepts, we propose to include this impact subcategory to our framework under the expression "Landscape management."

On the basis of our review, it would also seem relevant to bring a similar adjustment to the Guidelines' impact subcategory "Access to immaterial resources" in order to encompass some specific concerns that are not actually taken into account in the UNEP's framework. According to the Guidelines' Methodological sheets, immaterial resources are defined as "community services, intellectual property rights, freedom of expression and access to information" (p.34). Although most of these concerns are not necessarily relevant in relation to biomass production in Canada, many studies raise concerns relative to "immaterial resources" that are of significant importance for the agricultural sector.

Among these concerns we find what Caldeira Monteiro *et al.* (2006) call "Social capital", Lord (2011) describes as "Family and community impacts", Van Cauwenbergh *et al.* (2007) as well as Lemay *et al.* (2008) refer to as "Social acceptability", and Meul and col. (2008) define as "Social services." Globally, all these notions are aimed to account for what factors affect the degree of harmony, acceptability and cohesion between the farmer and his surrounding community. The transparency principle proposed by CSBP (2011) can be related to this concern too as the publication of the summary audit reports can enhance the trust and support towards the sustainability of biomass production. Given that such a "Social capital" is an issue of considerable relevance in assessing social impacts of

[3] Many factors could explain the potential weakness of the link between biomass production and the price of the food basket in the specific case of Ontario : the small scale of potential biomass production relative to total agricultural production in Ontario; the share of locally-grown food consumption compared within overall food consumption in Ontario; the relative power of food transformers, retailers and agricultural producers within the value chain; the relative share of disposable income spend on food; and the evolution of global demand for agricultural products, etc. Ontario's context regarding these factors is very different than the prevailing context in developing countries, making the link between biomass production and food availability and affordability less strong in Ontario than in developing countries.

agricultural production, we propose to include this issue in our framework instead of using the category “Access to immaterial resources.”

As for the previous stakeholder categories, our review of the existing literature on social impact assessment in agricultural leads us to propose some adjustments to the Guidelines’ list of impact subcategories related to **“Society.”** Therefore, since issues such as “Contribution to economic development”, “Corruption” and “Technology development” are three undisputable impact subcategories to consider in regards to the production of agricultural biomass for biofuels, it doesn’t seem relevant to include “Prevention & mitigation of armed conflicts”, given this issue should assess for “the organization´s role in armed conflicts or situations that might in the future develop into armed conflicts” (Society’s Methodological sheets, p.7).

Most of the studies reviewed focus, however, directly or indirectly on concerns related to the “Public commitments to sustainability issues” category. According to the Society’s Methodological sheets, “a public commitment is a promise or agreement made by an organization or a group of organizations, to its customers, employees, shareholders, local community or the general public whose fulfilment can be evidenced in a transparent and open way” (p.1).

We also find in the work of Van Calker *et al.* (2003) and Maloni and Brown (2006) a similar preoccupation related to the use of genetically modified organisms (GMOs) and artificial agricultural inputs (fertilizers, pesticides, etc.). Although these concerns are not, as such, directly “sustainability issues” and that they are not usually directly related to “public commitments”, we consider that they should be coupled to this impact subcategory. We justify this choice by the fact that these concerns have become a societal preoccupation against which every supply chain actor must now positioned itself. Besides, the EU sustainability criteria for biofuels take into account the ratification of the international agreement related to biosafety, by countries producing raw material destined to the EU biofuel market. Known as the Cartagena Protocol on Biosafety, this international agreement aims to prevent biotechnological risks and includes provisions regarding the use, transport and production of GMOs. Although the government of Canada has signed the Cartagena Protocol, it has not ratified it yet. In addition, the RSB (2010) platform also mentions the impact of GMO use as an issue of concern, and contains criteria regarding information transparency and risk minimization with respect to GMO use and handling along the value chain (i.e. for feedstock producers and processors and biofuel producers).

Most of the generic impact subcategories associated to the **“value chain actors”** are relevant for this study. It should be noted that most of the voluntary standards (RSB 2010, GBEP 2011, Nordic Ecolabel 2011, CSBP 2010) and the EU regulation (2009) cover a large part of the players in the biofuel production sector, thus justifying maintaining the “promoting social responsibility” sub-category.

Blom (2009) proposes adding the existence of government incentives as an issue to be included within the “fair competition” sub-category. Although not specifically focused on the agricultural sector, the recent ISO 26000’s Guidance on social responsibility includes likewise “fair operating practices” among the core subjects that should address any organizations concerned by social responsibility (ISO 2010). This broad category encompasses in turn specific issues that overlap those found in the Guidelines’ framework i.e. “Anti-corruption”, “Responsible political involvement”, “Fair competition”, “Promoting social responsibility in the value chain” and “Respect for property rights.”

1.2 Ecological attributes

When focusing on biological systems, being sustainable means seeking to maintain the diversity and the productivity over time of agricultural and surrounding natural or managed lands. In other words, the functions and services that the ecosystem provides locally have to be maintained while land is used to satisfy current human needs. Thus, the environmental attributes of a productive agro-ecosystem are linked to the ecological constraints imposed by resources limitations, ecosystem and human health risks, climate change, nutrient-cycle disruption, water demand and land use (McKone *et al.*, 2011). Of particular importance are the conservation and the restoration of the soil resource and the protection of the organic matter content of soils, which is the key to soil health, fertility, productivity, and erosion avoidance. For this reason, land use types and land use change restrictions, in addition to Greenhouse Gas (GHG) quantification, is required by all regulatory and voluntary biomass-for-biofuel sustainability standards ((S&T)[2] and Cheminfo, 2011). However, sustainability attributes other than these two are rarely required by current standards such as the US Environmental Protection Agency Renewable Fuel Standard (US EPA, 2007) or the EU Renewable Energy Directive (EU, 2009) although voluntary schemes tend to go beyond and include other environmental criteria (e.g. RSB (2010); CSBP (2011)). The implementation of the Environmental Life Cycle Assessment (eLCA) approach within standards has been driven by the potential of a biofuel or a bioenergy to reduce GHG emissions as compared to a fossil fuel. Thus, GHG are to be quantified beyond the feedstock producer's gate, over the whole life cycle of the biofuel, to enable comparison with a fossil fuel (e.g. on a MJ basis). Currently, only GHG emissions are required by biofuel standards to be assessed according a lifecycle perspective. In other words, no multi-criteria eLCA has been required yet.

Ecological (or environmental) attributes related to biomass production are often grouped into categories, principles or areas of concern. These are related to soil, water, air and conservation (of specific areas and biodiversity). For sustainable production, the initial state of quality of these areas of concern has to be maintained or enhanced, and any change is to be documented according to the previously mentioned crosscutting principle of integrated e.g. "planning, monitoring and continuous improvement" (RSB, 2010) or "Integrated resource management planning" (CSBP, 2011).

The following sections provide detailed information gathered from the literature for each area of concern. As far as possible, the focus is to document the potential impacts and consequences caused by agricultural operations rather than to provide a list of commitments to best practices, which are often either too informal or too specific ((S&T)[2] and Cheminfo, 2011). The idea is to reveal some relevant metrics (for instance, an estimate of soil organic carbon change). These metrics should be evaluated as part of the "Integrated resource management planning", first to establish a "baseline" and then to assess whether the practices implemented (whose purpose is obviously to reduce the impacts) lead to an actual reduction of impacts, i.e. towards a more sustainable production of the biomass.

1.2.1 Conservation

First, the conservation principle refers to the type of land (primary forest, protected area, highly bio diverse grassland, areas with high above ground and underground carbon stock, or peat lands) on which sustainable biomass cannot be grown, and to the cut-off date for any changes in land use (e.g. January 1st, 2008 as stated in the EU Directives (EU, 2009).

Second, and more generally, the biomass production should not destroy or damage high biodiversity areas, and efforts should be made to protect, restore or create buffer zones where necessary, and to protect ecological corridors to minimize habitat fragmentation. As well, producers should prevent any invasive species they are harvesting or using from invading any areas outside of the production site. The underlying principle is to maintain and enhance the ecosystem functions and services that are directly affected by feedstock production. Hence, areas of high conservation values must be identified through a land-use planning process.

1.2.2 Soil quality

Soil quality indicates the soil's ability to support crop growth without a resulting degradation to the soil or other harm to the environment. Severe soil degradation can prevent crop growth and can contribute to the degradation of other aspects of the environment. Soil quality can be degraded by natural processes such as erosion, salinization, loss of soil organic carbon (or soil organic matter) and the accumulation of metals. Each of these processes is influenced by agricultural practices.

Erosion removes topsoil, reduces soil organic matter and contributes to the breakdown of soil structure. This adversely affects soil fertility, causes the movement of water into and from the soil surface and, ultimately, affects crop yields because of inefficient use of cropping inputs. Erosion can also have significant off-farm adverse impacts on the environment through the physical transport and deposition of soil particles in other locations and through the release via erosion of nutrients, pesticides, pathogens and toxins. Management of the combined effects of wind, water and tillage erosion is required to maintain soil health.

Soil organic matter helps hold soil particles together and stabilizes the soil structure, making the soil less prone to erosion and improving the ability of soil to store and convey air and water. Improved soil structure helps maintain soil workability and permeability. Soil organic matter stores and supplies many nutrients needed for the growth of plants and soil organisms and it binds potentially harmful substances, such as heavy metals and pesticides. Finally, it acts as storage for CO_2 captured from the atmosphere. Loss of soil organic carbon contributes to degraded soil structure, increased soil vulnerability to erosion and lower fertility, ultimately leading to lower yields and reduced sustainability of soils. Soil Organic Carbon (SOC) change is an indicator of soil health and is an estimate of the amount of CO_2 that is either removed from the air and sequestered as SOC in agricultural soils or emitted to the atmosphere.

Small annual additions of metals to soil from organic and synthetic fertilizers or municipal biosolids inputs may result in increasing concentrations that could potentially reach levels toxic to plants and subsequently to animals and human.

Soil salinization and soil desertification are two other issues of soil quality in dry or semi-arid Canadian regions (e.g. in the Prairies Provinces). Thus, they are not a concern in Ontario.

1.2.3 Water quality and Water use

This area of concern addresses both the vulnerability of the water supply and the quality of the water resource. Biomass production should not contribute to the depletion of ground or surface water supplies, i.e. water use should be managed in such a way that the replenishment of the same supply source is ensured. When irrigation is necessary, the most efficient irrigation technology appropriate to the circumstance should be used. For instance, highly efficient drip nozzle systems should replace flood irrigation methods.

From the many inputs used by agriculture (nitrogen and phosphorus nutrients added to crops in the form of fertilizers and manure, pesticides), there exists a true risk for these inputs to find their way particularly into ground and surface water bodies. Excess nitrogen and residual soil nitrogen is at risk of leaching into nearby water bodies as nitrate (NO_3^-) where high levels in surface water can contribute to algae growth and eutrophication. Similarly, phosphorus may move in a dissolved form or bind to soil particles, and excessive phosphorus in surface water can also contribute to eutrophication of rivers and lakes and to algal blooms*,* which reduces water quality and leads to limitations on water use. Animal manure can also become a source of pathogens into the environment including viruses, bacteria and protozoa. Water contamination by these pathogens can lead to increased costs for water treatment, loss of use of recreational waters, constraints to the expansion of the livestock industry and potential negative human health effects. Lastly, there is also concern that pesticides applied to land may move into the broader environment and eventually contaminate surface and ground waters, with potential human-health implications.

1.2.4 Air quality and Climate change

Atmospheric emission of GHG, ammonia (NH_3), suspended particulate matter (PM) and odour from agricultural activities can cause climate change and affect air quality.

Agriculture can be both a source and a sink of GHG since, apart from nitrous oxide (N_2O) and methane (CH_4), carbon dioxide (CO_2) can be either emitted or absorbed. Agricultural activities inevitably result in GHG emissions. Nitrous oxide emissions can originate directly from field-applied organic and inorganic fertilizers, crop residue decomposition, and cultivation of organic soils. Indirect N_2O emissions can originate from N moved offsite such as from the volatilization and re-deposition of ammonia and from N leaching and run-off. Agricultural soils can either emit or absorb CO_2. The difference is determined by the net effect of CO_2 absorption from the atmosphere by growing crops, and subsequent storage in the soil in the form of crop residues and soil organic matter, and the emission of CO_2 to the atmosphere via decomposition of crop residue and soil organic matter, as well as net CO_2 emissions due to land conversion. Management practices that typically sequester carbon in soils include decreasing tillage intensity, reducing the frequency of summer fallow and converting annual crops to perennial crops. Carbon dioxide is emitted directly during fossil fuel combustion by farm machinery and indirectly, according to the life cycle perspective, from the manufacture of fertilizers and machinery used in agriculture.

Twenty two percent (22%) of agricultural emissions of ammonia in Canada come from nitrogen fertilizer inputs (Sheppard *et al.*, 2010). Ammonia is a gas that in excessive amounts can be harmful to animals and plants, can react with other pollutants to generate secondary particles contributing to smog*,* can be a eutrophying nutrient in sensitive aquatic ecosystems, and can also be a plant nutrient beneficially used by agricultural crops as dissolved ammonium.

The emission of particulate matter (PM) from agricultural operations is an emerging air quality issue, especially for agricultural workers (Pattey *et al.*, 2010). Primary PM is emitted from animal-feeding operations, wind erosion, land preparation, crop harvest, fertilizer application, grain handling and pollen. Suspended PM decreases visibility, contributes to stratospheric ozone depletion, acid rain and smog formation, and can influence climate by altering the surface energy balance. Inhalation of PM, particularly fine PM, is associated with adverse health effects.

Lastly, odour nuisance can adversely affect quality of life, can lead to social issues with alternate land users and can cause genuine physical symptoms. Although these symptoms are triggered at concentrations often well below those that may cause toxic reactions, they cannot be dissociated from the concept of human health. Odour emissions are present in all agricultural activities, not only in livestock activities.

1.3 Canadian federal initiatives for Life Cycle Assessment (LCA) and sustainability definition for biological systems

As far as we know, there is no evidence of federal initiatives to define social and environmental LCA (sLCA and eLCA) methods for biological systems. Actually, the federal ministries' interest in LCA is rather recent and limited to some of them (e.g. Environment Canada, Natural Resources Canada). Hence, there are no national and interdepartmental legal requirements about methodologies or impact assessment methods to be used to conduct an LCA that could make any external LCA "null and void." Practically, ISO 14040 standards series about eLCA (ISO, 2006) have to be followed by LCA practitioners, especially if public disclosure of comparative assessments is envisioned. No international standards exist for sLCA yet, but practitioners refer generally to the Social LCA Guidelines (UNEP/SETAC, 2009). Those standards and Guidelines allow a rather wide range of freedom for methodological choices, assumptions, and for the environmental impact assessment method to be chosen, provided they are clearly stated and documented within LCA results.

Agriculture and Agri-Food Canada (AAFC) added very recently an eLCA component to its National Agri-environmental Health Analysis and Reporting Program (NAHARP) research program for the upcoming Growing Forward II strategic plan (AAFC, 2012). Research and development is ongoing for including LCA in the next generation of NAHARP's set of agri-environmental indicators. Regarding a definition of sustainability of the agriculture, AAFC considers that "*sustainable agricultural systems can only result from sound management of natural, economic and human resources*" and that "*implementation of beneficial management practices for the preservation of soil, land and water resources and development of effective policy for promoting these practices contribute to the goal of an environmentally responsible and competitive agricultural sector in Canada*." More practically, AAFC's agri-environmental indicators is a system of quantifiable performance indicators that is addressing several environmental issues (farm management, soil health, air quality, water quality, and also eco-efficiency within the food industry) (Eilers *et al.*, 2010) and tries also to link them up with policy and program design (AAFC, 2012). Hence, one might think that specific methods, guidelines or recommendation for LCA of agricultural commodities and food and non-food biomass-based products will be addressed by AAFC later on.

For the specific case of biofuels, Natural Resources Canada has presented guiding principles for sustainable biofuels in Canada as a result of a collaborative initiative involving multiple stakeholders, government (Federal-Provincial Working Group on Renewable Fuels) and industry (the Sustainability Committee of the Canadian Renewable Fuels Association) (NRCan, 2010). The guiding principles do not serve the purpose of standards or law but enounces qualitative principles such as "*the biofuel industry shall respect natural resource rights, such as land and water rights*"; "*the biofuel industry shall respect the protection of human rights and labour rights, and shall ensure safe and decent working conditions*"; "*the biofuel industry shall respect environmentally sensitive lands, ecosystems, and the quality of natural resources such as soil, air, water, and biodiversity*." As an advanced principle, NRCan also mentions "*Biofuels shall contribute to climate change mitigation by reducing life cycle greenhouse gas emissions as compared against the relevant fossil fuel baseline. Life cycle analysis of biofuels and fossil fuels shall utilize equivalent full life cycle system boundaries*." Although it does not provide a quantitative reduction target as the EU Renewable Energy Directive and the US EPA Renewable Fuel Standards do, this principle is in line with these standards and directive in that GHG shall be calculated from cradle to grave, hence including the agricultural production step of the feedstock.

The Canadian Council of Ministers of the Environment (CCME, which is comprised of the environment ministers from the federal, provincial and territorial governments) has not published LCA methods, guidelines or recommendations yet, except encouraging producers to use life cycle approaches to ensure minimizing the environmental footprint of their products at the end of their life, in the context of the Canada-wide Principles for Extended Producer Responsibility.

Lastly, it is worth noting that the National Round Table on the Environment and the Economy (NRT) just achieved a consultative process with federal departments' representatives and external experts and stakeholders about LCA (NRT, 2012). The objectives are to better understand the drivers for life cycle approaches, the risks of not using such approaches and the opportunities associated with life cycle approaches. A report is expected for release in the spring 2012 with which the NRT will give advice and recommendations to help the Government of Canada assess how Life Cycle Approaches could contribute to long-term sustainability in Canada. The role the Government could play to facilitate successful take-up of Life Cycle Approaches within government and in the private sector will be assessed in the report. Apart from this outcome about LCA, the NRT has also addressed the policy side of the issue of sustainable water use in Canada by the natural resources sectors. A report proposes several potential avenues of solutions in four areas (NRT, 2011): improved understanding of water-demand forecasts, new policy tools, information and data improvements, and more effective collaborative governance approaches.

1.4 Attributes currently used by certifications schemes, regulatory frameworks, and other initiatives, or contemplated in Canada and on export markets

1.4.1 Socio-economic focus

1.4.1.1 Canada and U.S.

The situation in Canada and the U.S. can be characterized by the relative scarcity of social criteria within certification schemes and regulatory frameworks. For example, the U.S. EPA renewable fuel standard (RSF2) address mostly life cycle GHG emissions as well as the land use change issue at the agricultural production step. Similarly, in Canada, one provincial standard exists in British Columbia, which addresses GHG assessment but not any socio-economic issues. This situation is similar to California's regulation regarding low carbon fuels.

The CSBP proposed standard is one of those contemplated in the U.S.. Its socio-economic criteria are listed within the Appendix B along the relevant stakeholders, and its environmental criteria are summarized in Table 1. With respect to socio-economic, one must note that it covers most of the stakeholders' categories listed within the Guidelines. Namely, workers' attributes such as environment, health and safety, fair treatment of workers, compliance with labour laws, and employment and wages are detailed in this voluntary standard. Other criteria regarding monitoring and transparency can be related to the value chain sector. Interestingly, this standard is aimed at dedicated fuel crops, crop residues, and native vegetation.

1.4.1.2 Europe

The EU regulatory framework (i.e. the Renewable Energy Directive, RED) lists several international regulations related to labour rights such as International Labour Organization (ILO) conventions regarding forced and child labour, gender equity, labour organization, etc. The same ILO regulations are also mention within the Nordic Ecolabel (2010) and the RSB platform. These regulations can be linked to social attributes related to the "workers" category as mentioned within the Guidelines. Of particular interest is the fact that Canada has not ratified all of the ILO conventions mentioned in the

RED framework, more specifically, the C29 Convention addressing Forced Labour, the C98 Convention regarding the Right to Organise and Collective Bargaining and the C138 Minimum Age Convention.

It is important to note that the EU framework does consider food security – in terms of availability of food at a reasonable price, both within the EU and within developing countries – as an issue of interest regarding the sustainability of biofuels. However, although the EU regulation describes its environmental criteria in explicit terms, it only requires a monitoring of the impacts of biofuels on food security and does not mention any social targets to be reached or thresholds to be maintained. As we have seen in section 1.1.2, land-use rights are also an attribute considered within the EU regulation and some European standards (RSB and EUC, 2009). It is also important to remark that some voluntary standards such as the RSB standard have been officially recognized by the EU regulators as compatible with the EU regulatory framework.

The Table 1 below summarizes the list of impact categories considered within different regulatory frameworks and standards reviewed for this project. One can remark that the scope of the various standards vary greatly. For example, while the U.S. EPA RFS do not explicitly mention social issues, the EU RED contains several norms regarding workers' issues and objectives related to local economies and society.

Table 1 - International standards, initiatives and programs (SIP) related to biomass and bioenergy socio-economic issues

Impact subcategories	U.S. EPA Clean Air Act – Renewable Fuel Standard 2	California Air Resources Board: Low Carbon Fuel Sandard	CSBP	Field to Market Initiative	British Columbia Low Carbon Fuel Standard	Alberta Renewable Fuel Standard	European Union: Renewable Energy Directive 2009/28/EC (RED)	German BLE Production of Sustainable Biomass	Switzerland Mineral Fuel Tax Exemption	Nordic Ecolabel	RSB	ISCC	GBP
Workers													
Freedom of Association and Collective Bargaining			X				X		X		X		
Child Labour							X		X	X	X		
Fair Salary											X		X
Working hours											X		
Forced Labour							X		X	X	X		
Equal opportunities / Discrimination							X		X		X		
Health and Safety			X								X		X
Social Benefits/Social Security													
Professional accomplishment													X

Local communities													
Local economy											X		X
Community engagement													
Safe & healthy living conditions													
Landscape management and access to material resources			X				X				X		
Society													
Public commitments to sustainability issue													X
Contribution to economic development							X						X
Technology development													
Corruption													

Value Chain Actors													
Fair competition													
Promoting social responsibility											X		
Supplier relationships													
Respect of intellectual property rights													

1.4.2 Environmental focus

Table 1 presents various mandatory and voluntary standards, initiatives and programs (SIP) currently in use or in development worldwide. This table has been simplified purposely for a quick comparison and to put every SIP against general capabilities of the environmental LCA method. General concepts of the LCA method are presented in the next sections as well as its shortcomings relative to specific issues and areas of concern. A more thorough review and detailed side-by-side comparisons of these SIPs can be found in (S&T)[2] and Cheminfo (2011) and in the project of the Food and Agriculture Organization (FAO) regarding Bioenergy and Food Security Criteria and Indicators BFSCI (FAO, 2011).

Where a program exists at a high level of jurisdiction (e.g. nation-wide, or within the European Union), a sublevel program (e.g. for an U.S. state, or for a country from the EU, respectively) must meet, at least, the requirements from the parent jurisdiction. Two features commonly found within all SIPs are related 1) to land use (referred to as *conservation* of land with high biodiversity value or high carbon stock), and 2) life cycle GHG emissions (or *GHG intensity* or *carbon footprint*) including general land use change emissions and indirect land use change emissions. In practice, the duty to conduct the carbon footprint is for the bioproduct producer or the biofuel blender, or for the jurisdiction. For instance, in the USA, the U.S. EPA performs itself the life cycle assessment). Feedstock producers have generally to provide the necessary data relevant to the biomass production at the request of the person who needs to provide the footprint study for compliance. Feedstock producers may also challenge the default pathways used in the life cycle model used, and provide proactively their own data.

Noteworthy is the Swiss' Mineral Fuel Tax Exemption (within mandatory programs), which is the only SIP to require, in addition to life cycle GHG assessment and reduction target, impacts other than climate change to be assessed. The Ordinance on Proof of the Positive Aggregate Environmental Impact of Fuels from Renewable Feedstocks *(Biofuels Life Cycle Assessment Ordinance, BLCAO)* states that the Ecological Scarcity life cycle impact assessment method has to be used to compare a biofuel with a petrol of fossil origin (Swiss Confederation, 2009). As any typical LCIA method, the Ecological Scarcity method considers impacts from emissions to air, surface and groundwater, and to soil as well as the consumption of energy, land and water resources (Frischknecht *et al.*, 2009).

Also noteworthy is the International Sustainability and Carbon Certification (ISCC) framed around the EU RED Directive. The ISCC stands out from other initiatives by a larger demand for quantitative data on agricultural inputs (e.g. pesticides, fertilizers) or characteristics at the field level (e.g. soil organic matter content and balance). In this sense, it makes it closer to the inventory phase of the LCA where amounts of inputs and outputs are to be inventoried. A quantitative assessment is also within the scope of the *Field to Market* U.S. initiative from The Keystone Alliance for Sustainable Agriculture (2009), which is developing a baseline for a sustainability Index made of several indicators. Currently, metrics have been defined at the national scale although regional and local scales assessments are envisioned with five environmental indicators: land use, soil loss, irrigation water use, energy use, and climate impact (GHG emissions). Future development will consider water quality and biodiversity whose metrics development is more challenging.

Although they cannot be defined as SIPs, it is worth mentioning some very recent developments of methodologies and guidelines that tackle both environmental and socio-economic issues for reporting on sustainability attributes. The company BASF has developed the AgBalance™ methodology (Schoeneboom *et al.*, 2012), and more recently the FAO has published a test version of the Sustainability Assessment of Food and Agriculture systems (SAFA) guidelines (FAO, 2012). Both have in common their incorporating eLCA standards (ISO, 2006), sLCA guidelines (UNEP/SETAC, 2009) and/or other reporting guidelines, such as the indicators from the GRI (2010). Note however that strict compliance with standards and LCA practices is not always achieved. For instance, the AgBalance™ methodology uses implicit characterization factors and considers solid waste generation as an auxiliary indicator while such waste could (and should) be inventoried within LCA model for consistency with the LCA practices, and proposes some impact assessment methodologies that are not in line with state-of-the-art ones (e.g. the use of the critical volumes approach and the use of risk analysis for (eco)toxicity characterization).

		CA	U.S.				E.U.									
Mandatory (M) / Voluntary (V)		M	M	M	V	V	M	V	M	V	V	M	M	V	M	
Area of concern	**Type of criteria**	British Columbia: Low Carbon Fuel Standard (LCFS)	U.S. EPA: Renewable Fuels Standard 2 (RFS2)	California: Low Carbon Fuel Standard (LCFS)	Council on Sustainable Biomass production	Field To Market	European Union: Renewable Energy Directive 2009/28/EC (RED)	German: REDcert program	Germany: BLE Biokraft-NachV	ISCC requirements for the production of biomass	Roundtable for Sustainable Biofuels	UK: RTFO and Carbon Sustainability Reporting	Netherlands: NTA 8080/8081 Sustainability Criteria	Nordic Ecolabelling of fuels	Switzerland: Mineral Fuel Tax Exemption	**Would LCA be sensitive to the criteria?**
Management Plan			R	R	R		R	R	R	R++	X	R+	R	R	R	
Conservation	Qualitative		X	X	X		X	X	X	X	X	X	X+	X	X	
	Quantitative					X-										See note (4)
Soil Quality	Qualitative									X+	X	X	X			
	Quantitative					X				X			X			Y
Water quality and Water use	Qualitative									X	X	X	X			
	Quantitative					X-							X			Y
Air quality	Qualitative									X+	X	X	X	X		
	Quantitative												X			Y
Climate change	C footprint	X	X	X		X	X	X	X	X	X	X	X	X	X	Y
	Qualitative											X	X			

Table 2 - International standards, initiatives and programs (SIP) related to biomass and bioenergy environmental sustainability

Notes:

(1) R: record keeping, e.g. for proof of compliance, to ease verification process by an independent body.

(2) A “+” symbol denotes that a more exhaustive level of information is required; A “-“ denotes that the area of concern is not completely covered (e.g. biodiversity is not quantitatively assessed within the area of concern Conservation for the Field To market SIP.

(3) The UK RTFO defines several levels of standards (*Qualifying, Meta, and RED-ready standards*). Here the Meta-Standard has been evaluated.

(4) Partly because of shortcomings for biodiversity

2 Assessment of the sustainability of Ontario agricultural biomass

2.1 Life cycle assessment (LCA) and Life cycle impact assessment (LCIA) indicators

2.1.1 Environmental LCA (eLCA) and LCIA

eLCA is a structured, comprehensive and internationally standardised method. It quantifies all relevant emissions and resources consumed and the related environmental and health impacts and resource depletion issues that are associated with any goods or services. eLCA takes into account a product's full life cycle: from the extraction of resources, through production, use, and recycling, up to the disposal of remaining waste. Critically, LCA studies thereby help to avoid resolving one environmental problem while creating others. This unwanted "shifting of burdens" denotes reducing the environmental impact at one point in the life cycle, only to increase it at another point. Therefore, eLCA helps to avoid, for example, causing waste-related issues while improving production technologies, increasing land use or acid rain while reducing greenhouse gases. LCA is therefore a vital and powerful decision support tool, complementing other methods, which are equally necessary to help effectively and efficiently make consumption and production more sustainable.

According to ISO 14040 and 14044 standards (ISO, 2006), LCA methodology is an iterative process involving 4 phases: goal and scope definition, life cycle inventory (LCI), life cycle impact assessment (LCIA), and the Interpretation and analysis phase. The goal and scope phase aims to define what will be analysed and how, what will be the functional unit relative to which the inventory and the calculated impacts will be reported (e.g. 1 MJ of useful energy from biofuel fro a cradle-to-grave LCA, 1 kg wheat straw at farm for a cradle-to-farm gate LCA). The LCI phase is about collecting the necessary data and compiling the data inventory within the system boundaries previously defined. Generally, specific data are collected for the foreground system and average or generic data from LCI database are used for the background system (Figure 1)[4]. In the end, the LCI data is a quantified list of natural resources extracted from the environment (including area of land transformation and area of land occupation) and of polluting substances emitted into the air, the soil and the water.

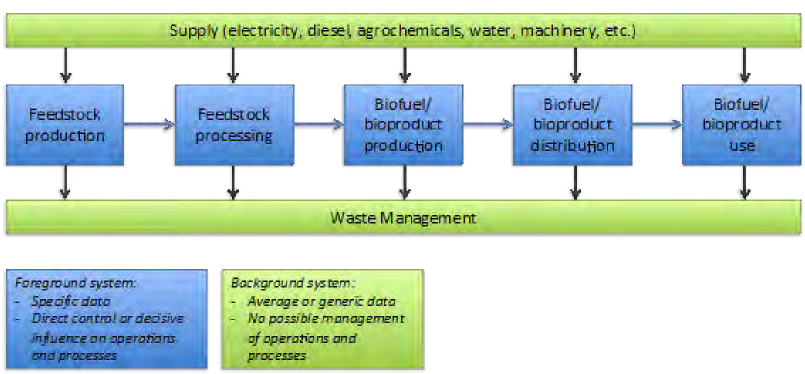


Figure 1 - Foreground and background systems and flows within LCA modelling.

[4] It should be noted that some background systems' flows reputed to contribute significantly to the environmental impact of a product (e.g. typically electricity or waste recycling rates) are modelled with specific data or adapted from LCI database. For instance, the Ontario electricity grid-mix shall always be modelled for processes taking place in Ontario.

Once the inventory has been compiled, impacts are calculated using one or several LCIA methods. Figure 2 presents a typical LCIA framework which links every inventoried resources and substances collected during the LCI phase to impact indicators, either as midpoint indicators (i.e. problem-oriented impact categories) or as further aggregated endpoint indicators (i.e. damage-oriented impact categories, or also “Areas of protection”).

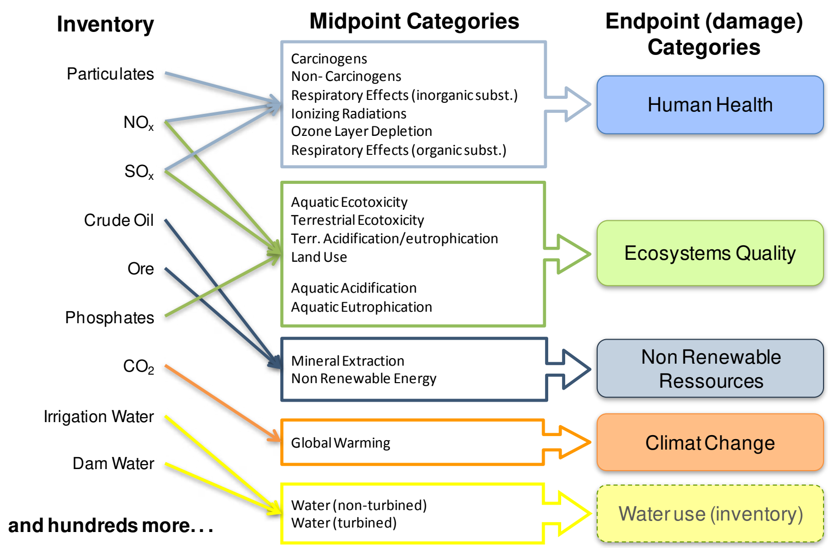


Figure 2 - IMPACT2002+ life cycle impact assessment (LCIA) framework (Jolliet *et al.*, 2003; as of 2011 update).

In practice, an LCIA method is a set of characterization factors. For instance, global warming potentials calculated by the Intergovernmental Panel on Climate Change (IPCC) are actually a well-known set of characterization factors specific to translating individual amounts of GHG into the metric of the climate change impact category (i.e. CO_2-equivalent) (see details in 2.1.2 below). Impact experts calculate every characterization factor through the modeling of complex pathways of cause-to-effect. Figure 3 is an example of state-of-the science pathways modeling from land transformation and land occupation data inventory (actually specified according to land use classes).

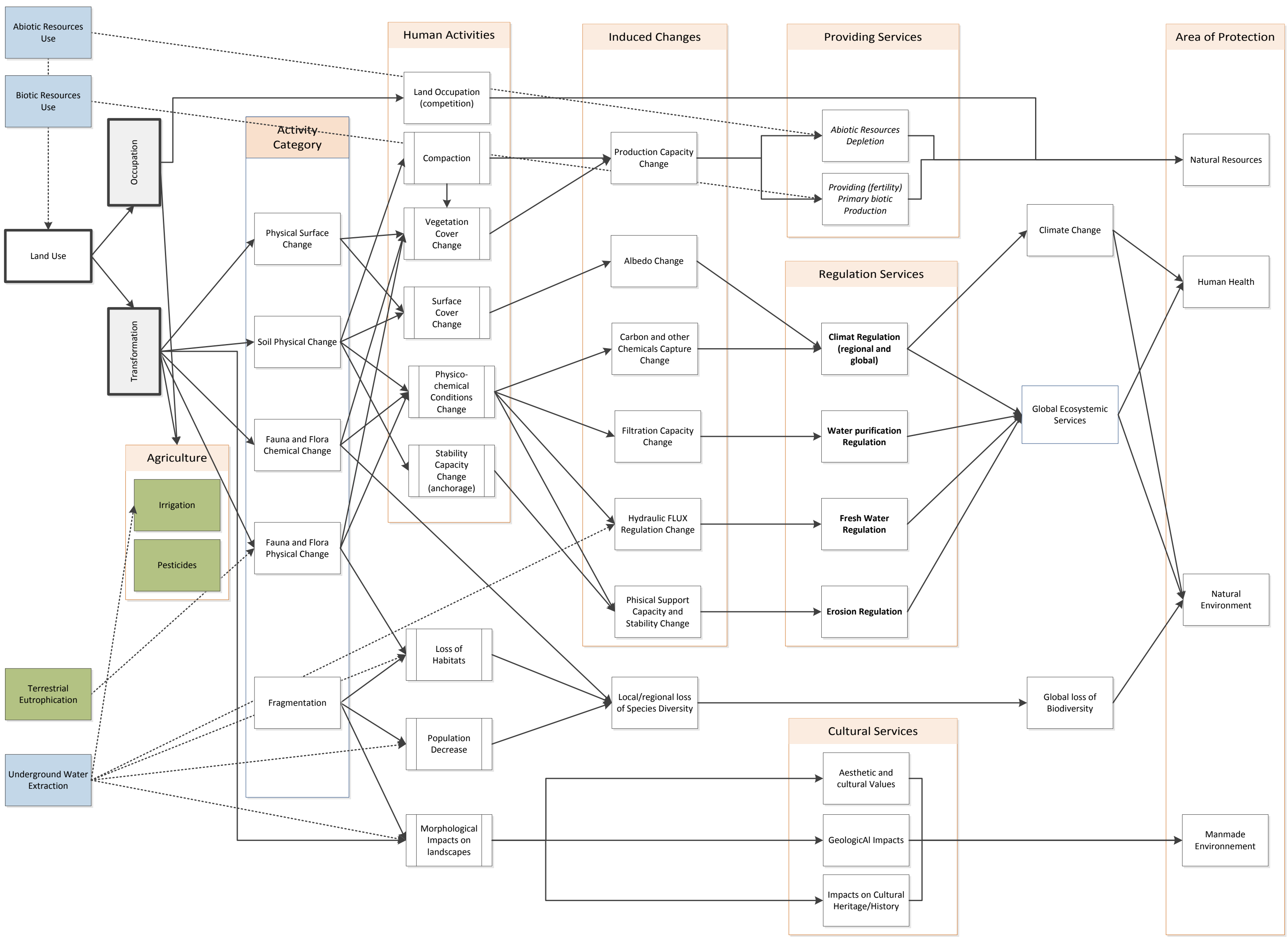


Figure 3 - Land use impacts pathways in *IMPACT WORLD+* LCIA method (Cao (2011), adapted from Saad *et al.* (2011)).

2.1.2 Current practice in assessment of greenhouse gas emissions

The current consensus in eLCA is to use global warming potential (GWP), adopted by the Intergovernmental Panel on Climate Change (IPCC), to assess the impact of life cycle greenhouse gas (GHG) emissions. GWP expresses the cumulative radiative forcing caused by the emission of a unit mass of a given GHG over a defined time horizon, relative to the equivalent value for carbon dioxide (CO_2) (Forster *et al.*, 2007). In an LCA, all the GHG emissions are multiplied by their GWP value and then summed to get a single result in kg CO_2-equivalent.

The only difference between LCIA methods regarding global warming impact category is the time horizon selected for the calculation of GWP. As shown in Table 3, the relative impact of a GHG emission compared to an equivalent CO_2 emission varies with the time horizon. Most LCIA methods use 100 years because it is the value chosen by the United Nations Framework Convention on Climate Change (UNFCCC) for the application of the Kyoto Protocol. Other methods, such as IMPACT2002+ (500 years), use a longer time horizon in order to account for long-term effects (Jolliet *et al.*, 2003).

Table 3 - GWP values for three common GHGs for the three time horizons selected by the IPCC as published in the Fourth Assessment Report (Forster *et al.*, 2007)

	GWP (kg CO_2-eq / kg)		
	20 years	**100 years**	**500 years**
Carbon dioxide (CO_2)	1	1	1
Methane (CH_4)	72	25	7.6
Nitrous oxide (N_2O)	289	298	153

2.1.2.1 Carbon footprint methods and standards

Global warming caused by anthropogenic GHG emissions is one of the most talked about environmental issues nowadays. Industries and institutions have expressed the need for a consistent approach for the specific assessment of life cycle GHG emissions, also called carbon footprint. In the past few years, a few methods and standards have been published to provide guidelines for the calculation of carbon footprint of products and services. These methods are increasingly used to quantify, compare and communicate the potential impact of different products and services on global warming.

The first life cycle based carbon footprint method to be published in 2008 was the British publicly available specification PAS 2050 (BSI, 2008), which had been reviewed in 2011 (BSI, 2011a). The GHG Protocol, a partnership between the World Resource Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), also published a standard for accounting and reporting of product life cycle GHG emissions in 2011 (WRI/WBCSD, 2011). Finally, the International Organization for Standardization (ISO) is presently developing a standard for carbon footprint calculation of products. The process has not been finished yet; a draft standard is currently available for comment (ISO/DIS 14067, 2012).

The revision of the PAS 2050 specification was done during the development of the GHG protocol and efforts have been made to harmonize methodologies. Developers of both methods have also been involved in the development of the ISO standard. A fact sheet can be found on the PAS 2050 web site comparing this method with the GHG Protocol. This fact sheet will be updated when the final ISO standard will be published (BSI, 2011b). Because of this desire for harmonization between the three initiatives, the differences between them are relatively minor.

A few methods and standards have also been published to calculate the corporate carbon footprint of organisations. The ISO 14064 standard is widely used to quantify and report GHG emissions at the organisation level (ISO 14064-1, 2006), as well as the GHG Protocol Corporate Standard (WRI/WBCSD, 2004). Corporate GHG emissions are categorized into three scopes: 1) direct emissions, 2) indirect emissions from consumption of purchased electricity, heat or steam, and 3) other indirect emissions (emissions from suppliers, transport, waste disposal, etc.).

2.1.2.2 Business drivers for carbon footprint and life cycle GHG assessment

An increasing number of companies are reporting their corporate GHG emissions in annual report and/or through different initiatives such as the Carbon Disclosure Project (CDP) (Carbon Disclosure Project, 2012). The CDP is a not-for-profit organization helping companies to measure, disclose, manage and share information about GHG emissions and other environmental issues. In order to measure and reduce their scope 3 GHG emissions, organizations may ask their suppliers to provide data about their own GHG emissions or to meet some reduction targets. For instance, the CDP has created a supply chain program to gather information about GHG emissions coming from different supply chains in order to drive action on climate change amongst both purchasing companies and their suppliers (Carbon Disclosure Project, 2012). Over 50 companies are currently working with the CDP in the supply chain program. Some of them such as PepsiCo, Unilever, Coca-Cola, Colgate-Palmolive, to name a few, are also members of the Sustainability Consortium which aims at developing accurate quantification and communication tools on the sustainability of products (Sustainability Consortium, 2011).

Walmart is a good example of this kind of initiative since they announced in 2009 their intention to develop a sustainability index for their suppliers (Walmart, 2012). Walmart is now at the first stage of this initiative, which is the supplier sustainability assessment, a survey that suppliers have to complete to provide an overview of their sustainability practices. To get a good score for the energy and climate indicator, a supplier must 1) measure and take steps to reduce its corporate GHG emissions, 2) report its scope 1 and 2 GHG emissions and climate change strategy to the Carbon Disclosure Project, 3) report its scope 1 and 2 GHG emissions in its most recent annual report, and 4) set publicly available GHG reduction targets. The final step of sustainability index initiative will be to provide consumers with information regarding sustainability of products sold at Walmart.

2.1.2.3 Carbon footprint and labeling

Different programs have been developed in the last few years regarding carbon footprint labeling of products, and others are yet to come. These programs can be divided into two categories: 1) carbon footprint certification from an independent organism and 2) governmental initiatives. The Carbon Trust, a not-for-profit organization, has developed the Carbon Reduction Label (The Carbon Trust, 2010). The carbon footprint of the product to assess is determined using the PAS 2050 specification. Once the carbon footprint has been measured and certified, the company producing the good has to commit to reducing the product’s GHG emissions. To keep its label, the product must be assessed every two years and a GHG emission reduction must have been achieved. Another voluntary program for companies that would like to get a certification for their product's carbon footprint has been recently developed by SGS (SGS, 2012). Three levels of carbon label will be used: carbon footprint, carbon reduction and carbon neutral. The details of this program have not been published yet.

The first carbon labeling programs from governmental organizations have been initiated in Japan and South Korea (PCF World Forum, 2011; Ministry of Economy Trade and Industry of Japan, 2012). These countries have developed particular guidelines for the calculation of the carbon footprint, as well as a given number of product category rules (PCR) that account for characteristics differentiating categories of products. France is also developing a national program for environmental labeling including carbon footprint and other environmental indicators (ADEME/AFNOR, 2008). A pilot project has begun in 2011 and calculations are based on methodological guidelines developed for this purpose (AFNOR, 2009). In Canada, the province of Québec has also started a pilot project on carbon footprint of products to study different methodological issues before extending the initiative to a broader range of products and companies (CIRAIG/MDEIE, 2012).

2.1.3 Social LCA (sLCA) and LCIA

The United Nation Environment Program (UNEP) in collaboration with Society of Environmental Toxicology and Chemistry (SETAC) released the Guidelines for Social Life Cycle Assessment of Products (sLCA) in May 2009. These guidelines have been produced in order to provide to the stakeholders engaged in a sLCA a description of this tool and its scope, a framework of its design and, finally, a "flash light" that highlights areas where further research is needed (UNEP/SETAC, p.5).

The Guidelines already offer a foundation – based upon a categorization of impacts categories, of subcategories and indicators – that allows researchers and practitioners to assess the impacts incurred to different stakeholders (see Appendix A). However, as the Guidelines point out, "further developments of impact assessment methods, socio and socio-economic mechanisms and scoring systems are greatly needed" (p.84). This requirement is indeed essential to assess the social impacts caused by the production of a specific product such as agricultural biomass grown for biofuels or bioproducts. The following section proposes a discussion of indicators' characteristics to be considered in order to perform a sLCA of Ontario agricultural biomass. Following this discussion, a list of indicators is proposed within Appendix B, in order to provide examples of the kind of indicators that could be used within the Ontario agricultural biomass context. We emphasize that this list should be used only as a guidelines and should be adapted according to the scope and boundaries of the sLCA for a given functional unit related to agricultural biomass production.

Methodological choices would have to be made when developing the list of impact indicators for an actual sLCA. These choices involve 1) the selection criteria, 2) the categorization of indicators, 3) methods development and 4) the formulation of indicators. Since there are various alternatives regarding these choices, and hence flexibility, one of the key recommendations when performing a sLCA is to be transparent when making these choices and provide the rationale for choosing an option over another in order to be able to justify these methodological choices with stakeholders or the broader public.

Other issues regarding the choice of indicators relate to 1) the access to the data necessary to inform the indicators and, 2) the choice of the Performance Reference Points (PRP) – or benchmarks – against which the performance is assessed (cf. UNEP 2009, p.69). PRPs are acknowledged social standards, norms or practices. A given indicator can be related to a vast array of PRPs, such as a national or international minimal legal standard, a "best available practice", an average performance of an enterprise or a group of enterprises, etc. For example, within the context of a sLCA of biofuel production and for an impact subcategory such as "fair salary", various PRPs could be chosen such as the relevant Provincial minimal hourly wage, or the farm sector average hourly wage, or a composite average hourly wage calculated across the biofuel production chain. This theoretical example illustrates the kind of choices that would have to be made and justified by the analyst performing the sLCA.

In order to perform a sLCA or any other social impact assessment analysis, a list of concrete and measurable indicators related to each of the impact subcategories chosen is required. It is those indicators that allow the estimation and then the comparison, on a common basis, of the results obtained from the assessment. This component of the framework is consequently crucial. Given that, as Abbing (2010, p.16) points out, there is no universally accepted set of sustainability indicators that could be referred to in order to conduct a social impact assessment, the indicators categorisation's process thus deserves a particular attention.

The reason is that the identification and selection of an indicator sets depend on the nature and the scope of the study, as well as on the social impact measurement methods considered. Consequently, although it is possible to identify within the literature a large range of social indicator sets, it is more relevant to discuss in the first place the methodological issues related to the identification and utilisation of those indicators. A classification of generic indicators could then be proposed on the basis of our review in order to complete our normative framework, knowing that, given the focus of our study, it will have to be subsequently adjusted in relation to these methodological issues.

To discuss the methodological issues related to the identification and selection of social indicators, we refer to the study of Meul *et al.* (2008). They selected in their study five criteria - "causality", "sensitivity", "solidness", "use of benchmarks" and "comprehensibility"- but other criteria could be retained, especially in relation to the sLCA methodology. For example, Kruse *et al.* (2009) have developed, for their sLCA applied to salmon production systems, a list of three criteria for indicators identification. These are "relevance", "practicability" and "validity." Paragahawewa *et al.* (2009) have instead chosen their indicators on the basis of their relevance to the area of protection, i.e. human dignity and well-being.

The second parameter concerns the indicator design, that is, the methods upon which the indicators selection is based. In their study, Meul *et al.* (2008) referred to three distinct methods namely, existing literature, experts' opinion and fundamental research. Nevertheless, most of the covered studies were rather based upon an experts' opinion method, referred as the "bottom-up" approach, as opposed to the "top-down" approach. Both are, however, considered complementary since they allow, as Kruse *et al.* (2009) point out, encompassing broadly recognized societal value to include specific concerns for the industry/stakeholders and to adjust to data availability (p.10). The expert's opinion approach has been used by Lähtinen *et al.* (2011) for the social sustainability of forest-based bioenergy production in Finland.

Moreover, data availability is considered by Meul *et al.* (2008) as the third parameter to take into account. Given the lack of publicly available database for social issues and the need to have access to qualitative data and subjective information in order to perform a sLCA, this issue is even regarded as one of the major challenges related to the conduct of such an assessment and thus, it influences deeply the kind of indicators to be chosen. Indeed, the more aggregated and generic the data are, the less the indicators can measure precisely the corresponding social concerns. On the contrary, site-specific and primary data enable to develop precise indicators able to cope with specific social issues. However, the latter are difficult to obtain, which restricts the list of indicators that can be proposed. In fact, given that it is very costly, time consuming and not always relevant to collect site-specific or primary data, the Guidelines recommend that the degree of data's precision, and thus the level of detail of indicators, should be the function of the sphere of influence of the organization for which the product is being assessed (UNEP/SETAC 2009, p.57). However, in Meul *et al.* (2008) as in many cases covered, data availability, rather than scientific soundness and methodological coherence, has determined the list of indicators included in the framework.

The indicator typology is another important parameter to consider. Three types of indicators can be found in the sLCA literature, namely “quantitative”, “semi-quantitative” and “qualitative” indicators (Paragahawewa *et al.*, 2009, p.14). Most often, the choice of one type of indicator is a function of data availability, quantitative and qualitative data being usually expressed in a quantitative and qualitative form – or translated into a semi-quantitative indicator. Whilst all types of indicators can be included in a sLCA according to the Guidelines, the use of qualitative and semi-quantitative indicators raises however a methodological challenge since they can hardly be expressed per functional unit, i.e. the unit of output associated to a standardised function.

The Guidelines considered this issue (p.40), but do not discuss in detail the question of the causal relationship between the indicators and the functional unit of the study. Paragahawewa *et al.* (2009, p.11) recall however that there is an ongoing debate in the literature concerning the inclusion of indicators that are not directly related to the product or process, but rather to the conduct of the company. The issue is that, unlike biophysical flows measured in traditional LCA, social impacts induced by the company’s conduct often can neither be directly connected to the product/process nor, in some cases, easily quantifiable. Nevertheless, these characteristics are essential in order to aggregate and compare the overall social impacts of a given product or process.

Given that a number of widely recognized socioeconomic sustainability concerns do not fit with these criteria but are nonetheless relevant, some authors like Dreyer *et al.* (2006) have proposed to circumvent this issue by sharing the total amount of impacts created by the company according to the weight that the company is given in the products/process in the whole chain. To avoid arbitrary weighting and reductive quantification, Kruse *et al.* (2009) suggest rather a categorization of indicators depending on whether they are additive or descriptive. The former are those indicators that meet two criteria, namely 1) they can be measured quantitatively and 2) they relate to the functional unit. Thereby, the latter are those that can be 1) quantitatively or quantitatively described/measured but 2) cannot be related to functional unit. In order to enable the most possible comparisons, the authors further distinguish the descriptive indicators that are general, that is, common to all cases and related to international conventions, from those that are specific, i.e. specifically related to the company, product or process of interest.

Unfortunately, since this concern is specific to the LCA methodology, most of the covered studies did not take this issue into consideration, thus limiting the possibility to compare the applicability of these methods. Besides, referring to three the sLCA studies reviewed, no clear pattern emerges either. Naturally, Kruse *et al.* (2009) proposed an illustration of their framework in the case of the salmon industry, whereas Paragahawewa *et al.* (2009) have envisaged using the approach of Dreyer *et al.* (2006), though in both cases, their analysis ended before reaching the indicators specification step. As for Franze and Ciroth (2011), they defined a functional unit, but their social indicators assessment method, based on hot spots identification, is hardly connected to it.

The last parameter addressed by Meul *et al.* (2008) is about the scoring methods, i.e. the type of benchmark against which the score of indicators are compared in order to assess the relative performance of the product, process or company. Given the diversity of the indicators employed to cover the range of social impacts included in their model, these authors referred to a large number of methods. These are either based on “scientific knowledge or legislative standards”, “comparison to a reference group”, “Best Available Techniques (BAT)”, ”questionnaire”, “expert judgement” or “a production possibility curve.”

In order to standardise these measures and allow mutual comparison of indicators, Meul *et al.* (2008) also quantified and rescaled each indicator using a 0-100 value scale, according to the most relevant benchmark. For example, an economic indicator such as “value added per unit of farm capital” was evaluated using a reference group, the higher note (100) being granted to a farm that was among the 10% best-performing farms. When the indicator focused rather on a more subjective item, a self-evaluation questionnaire was used or an expert judgement was asked, also using the same scoring system. Finally, these authors used a weighting method to aggregate all results in order to obtain a unique and final score. To do so, they weighted the indicators according to the assumption that all selected sustainability themes are equally important – unless there was a considerable proof according to experts or the literature that certain indicators were more important than others.

It stems from the applied papers reviewed that the choice of the scoring methods is highly dependent of the scope of the study, especially in regards to its intended purpose, i.e. whether it is to identify hot spots, to assess a particular company/product’ social impacts or to obtain results comparable “universally.” No clear pattern thus emerges regarding the best method to adopt, although it is relevant to stress that the methodological framework proposed by Meul *et al.* (2008) is by far the most exhaustive among those reviewed in that matter. As for the sole study reviewed that concretely performed a sLCA in relation to the agricultural sector, we note that the authors developed an assessment method relying on a five colors’ system to evaluate the social impacts based on a “intuitive” interpretation of the situation observed compared to international accepted standards (Franze and Ciroth, 2011). Neither quantification nor aggregation of results has thus been proposed, their objective being only of testing the new Guidelines framework and to identify social hot spots.

The **identification and selection of the right set of indicators** to assess the social impacts of one product or activity was one of the main objectives pursued in the studies covered by our review, whether they intended to develop a conceptual framework or to assess effective social impacts of one production in particular. As discussed previously, a wide range of methodological issues has been considered in each case in order to elaborate a list of social indicators relevant to each corresponding situation.

The sets of social indicators needed to develop a sLCA framework are inherently case-specific and depend, among other things, of data availability and methodological choices. Accordingly, it is difficult to rely on the existing literature to develop a concrete list of formal indicators. It is, however, appropriate to propose a list of generic indicators based upon the literature in order to target those that are the most commonly used, as well as some others that are more specific yet relevant to our study. In turn, this “normative” set of indicators could be used in order to be further developed and adjusted using, for instance, a “bottom-up” approach.

Note that the indicators’ classification is made according to the list of impact subcategories and stakeholder categories withheld for our framework. For each impact subcategory, at least one indicator is expressed in a general form, i.e. using a form that allows a wide application as well as easy reporting. The idea is to avoid having to discriminate at this stage among the numerous formulation possibilities, given that a same indicator can be expressed in different manners not only according to the scope of the study but also in the course of the study itself depending, for instance, on the position of a firm compared to the sphere of influence. When possible, more specific indicators are also suggested to give an idea of how they are usually defined in the literature. Of course, the “type” and “unit” categories are only indicative, since they vary according to the indicator’s concrete and final specification. The “causal relationship” and “scoring methods” issues are not tackled at this stage either for the same reason. We can however already note that most of these indicators could be expressed by functional units, as well as be measured using diverse quantification methods and benchmarks, as in Meul *et al.* (2008). Besides, in each case we give an example of source used to specify these indicators, the term "generic" being used when they cannot be associated to an author in particular.

2.2 LCA and LCIA challenges and issues

LCA has the potential to address many of the social, economical, and environmental areas of concern mentioned in the previous sections but it shows also some limitations.

It should be kept in mind that, in contrast to environmental risk analysis which focus on a very specific location (e.g. an industrial site) and where only few very specific pollutants are tracked down and their impacts on a specific media (e.g. local population affected) are measured, LCA proceeds from a broader scope. Owing to the life cycle perspective and the multicriteria approach, LCA seeks the comprehensiveness. This involves actually thousands of operations along the supply chain to be considered, and thousands of resources consumed and pollutants emitted at different moments, in numerous places locally, regionally and even globally. In practice, the use of less representative average and generic data from available LCI database, the use of some mass cut-off in the accounting, the exclusion of some minor processes from system boundaries, all lead to an LCI which is not the complete representation of the reality. Although the trend is towards regionalization of LCIA methods, which will offer region-specific characterization factors datasets, these latter remain developed based on probabilistic data (e.g. from epidemiologic studies). Also, the geographical scale of regionalization varies from one indicator to another[5]. Ultimately, LCA results and any environmental footprint are said potential impacts, and not true impact assessments.

Before addressing generic issues and shortcomings of LCA, we would like to mention that the U.S. EPA might consider utilizing LCA in a broader context (i.e. beyond the scope of GHG), as part of the 2013 assessment[6]. Future evaluation of biofuel for qualifying the Renewable Fuel Standard (RFS2) program might thus require full multicriteria LCA instead of a carbon footprint.

2.2.1 General issues and challenges regarding agricultural biomass systems in LCA

Specific shortcomings are presented in the sections below with respect to carbon footprinting (2.2.2) and water footprinting (2.2.3). Here, general LCA challenges are presented.

2.2.1.1 Shortcomings regarding biodiversity assessment

Despite ongoing efforts to improve the assessment of impacts related to land transformation and land occupation and the coverage of most impact pathways from land use (see Figure 3), the biodiversity is rather simplistically assessed through LCIA methods because of limited species consideration. This is a current limitation of all operational LCIA methods (IMPACT2002+, its upcoming global and regionalized version IMPACT WORLD, ReCiPe in Europe, TRACI in the U.S.). To address such a complex and local issue, the best practice would be either to develop a separate

[5] The temporality of emissions is another issue, which is discussed later on with a focus on GHG.

[6] This assertion should be used with caution since it is excerpt from a non reviewed draft document from the U.S. EPA, publicly available from the Agency's website: "Biofuels and the Environment: First Triennial Report to Congress" EPA/600/R-10/183A, January 2011, Chapter 7, section 7.2.1.

indicator to address such a local biodiversity issue[7] or to adopt a quantitative assessment approach such as proposed by some of the SIPs.

2.2.1.2 Shortcomings regarding soil quality assessment

Soil quality is also a very local issue and several factors of influence have to be recorded or estimated for a robust assessment (e.g. erosion, compaction, organic matter and nutrient balance especially when crop residues are removed). An avenue for better assessment of soil quality within LCIA method would be to adapt a current LCIA land use framework (e.g. that of IMPACT WORLD, see Figure 3) with customized characterisation factors calculated with specific soil parameters estimated with e.g. Universal Soil Loss Equation model.

Saad *et al.* (2011) have developed Canadian-regionalized characterization factors (CF) for life cycle impact assessment up to the ecoregion spatial scale (i.e. 193 ecoregions in Canada) for 4 midpoint indicators related to soil quality and ecosystems services (erosion resistance potential, mechanical water purification potential, physico-chemical water purification potential, and freshwater recharge potential). However, the agricultural land use types to which those CF can be applied do not allow discriminating between permanent and annual crops (see Appendix C). Three additional land use-related midpoint indicators exist for assessing impacts on the biotic production potential, the carbon sequestration potential and the biodiversity. Because the method is embracing a global scope, they will be provided within the IMPACT WORLD+ impact assessment method for 9 land cover types and 16 biomes; here the spatial resolution is likely too coarse for the local representativeness required.

2.2.1.3 Dealing with crop allocation in the case of crop residues harvested for biomass

The EU RED methodology for biofuel life cycle GHG assessment mentions that "*agricultural crop residues, including straw, bagasse, husks, cobs and nut shells, and residues from processing, including crude glycerine (glycerine that is not refined), shall be considered to have zero life-cycle greenhouse gas emissions up to the process of collection of those materials*." The Directive considers that crop residues are waste material conveying no impact. However, in practice, crop residues let on field provide remaining nutrients such as N, which are actually a co-product of the crop since they are an input for the production of the next crop. Therefore, IPCC methodology accounts for crop residues N input when modeling N_2O emissions from a cropland system (IPCC, 2006; and see 2.2.4.2). Hence, LCA guidelines state that the modeling shall account for this multifunctionality and allocate impacts between coproducts, i.e. between grains and crop residues (European Commission, 2010).

A decision will have to be made before conducting any LCA whether to adopt LCA standards and approved guidance, or to follow a methodology from SIPs such as e.g. the EU RED or U.S. EPA RFS2 program. The following question will have to be answered: does the harvesting of crop residues for feedstock imply a true deficit of N nutrient for the next crop? If yes, then the life cycle impacts from N input (e.g. mineral or organic fertilizers) to compensate this deficit would have to be accounted for and allocated to the crop residues. The same issue of compensation may apply to corn stover in the event the animal feed market is affected by its use as feedstock.

[7] This is the chosen approach for assessing biodiversity impacts from peat production in Canada in the context of an ongoing project (Phase II) for the Canadian Sphagnum Peat Moss Association, involving the CIRAIG and Université Laval (QC).

2.2.2 Shortcomings regarding agricultural biomass systems in LCA and carbon footprint

Agricultural biomass systems are particularly concerned by three major shortcomings of current LCA practices and carbon footprint methods: 1) carbon neutrality of biogenic CO_2 emissions, 2) temporal aspects of GHG emissions and removals, and 3) land use change emissions.

2.2.2.1 Carbon neutrality of biogenic CO_2 emissions

In LCA and carbon accounting, biogenic CO_2 emissions are typically not considered following the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). Indeed, CO_2 released from biomass combustion or decomposition has been previously sequestered while biomass was growing, resulting in a net zero emission. Recent publications have questioned biogenic CO_2 carbon neutrality, saying that it could lead to serious accounting errors (Searchinger *et al.*, 2009; Bird *et al.*, 2010) or to biased LCA results (Christensen *et al.*, 2009; Guinee *et al.*, 2009).

A simple example to illustrate this shortcoming is the comparison between storing and burning wood. Burning wood leads to the release of its carbon content to the atmosphere, mostly as biogenic CO_2 emissions. These emissions are avoided in the case when wood is stored. This means that burning wood has in reality a higher impact on climate than storing it. However, since biogenic CO_2 emissions are assumed neutral, both scenarios would have the same carbon footprint result (ignoring other GHGs released from wood partial combustion such as methane).

The first edition of the PAS 2050 specification followed the IPCC guidelines not requiring accounting for biogenic CO_2 emissions and removals. However, as a result of the recent questioning and to be in line with the GHG Protocol Standard, the second edition of the PAS 2050 specification requires the inclusion of biogenic CO_2 emissions and removals. The draft ISO 14067 standard also requires the inclusion of biogenic CO_2 emissions and removals. In LCA, biogenic CO_2 emissions are still frequently not considered. However, a few guidebooks discuss the importance of considering them in particular cases such as agricultural systems (Hischier *et al.*, 2010).

2.2.2.2 Temporal aspects of GHG emissions and removals

The second shortcoming concerns the temporal aspects of GHG emissions and removals. In LCA and carbon accounting, GHG emissions are summed regardless of the moment they occur. This lack of consideration for the timing of emissions has been frequently criticized in the past few years for different reasons. First, there is an increasing will in policies and communities to give value to temporary carbon storage in long-lived products. To assess the climate impact of keeping carbon out of the atmosphere for a given period of time, one must consider the timing of GHG emissions (Levasseur *et al.*, 2012). Indeed, with current carbon accounting, releasing the carbon content of a product made from biomass in 100 years is equivalent as releasing it now. Thus, giving value to temporary carbon storage implies assessing GHG emissions depending on the moment when they occur.

These temporal issues particularly concern biomass systems. In addition to temporary carbon storage in biomass-based products, the consideration for the timing of GHG emissions and removal arises in several cases where biomass is grown. As explained in some recent publications, when biomass is burned, released CO_2 spends some time in the atmosphere contributing to global warming before being captured by growing biomass (Cherubini *et al.*, 2011; Chum *et al.*, 2011). Even if the amount of biogenic CO_2 released is entirely recaptured by growing biomass, the delay occurring between the emission and the removal leads to an impact on climate, strengthening the idea that biogenic CO_2 emissions must not be considered carbon neutral.

The concept of carbon debt associated to forest bioenergy also appeared in recent publications (Manomet Center for Conservation Sciences, 2010; Chum *et al.*, 2011). Biomass releases more CO_2 than fossil fuels to produce an equivalent amount of energy, leading to a carbon debt. As trees are growing, carbon is removed from the atmosphere. After a given period of time (payback time), the biomass scenario becomes better than the fossil fuel scenario. Payback times vary greatly across different scenarios and depend on the type of biomass burned, the efficiency of the energy conversion technology, and the type of fossil fuel replaced. By their nature, biomass plantations have no carbon debt as described here, since biomass is planted and grown before it is being used as a fuel. However, bioenergy from biomass plantations can be subject to a carbon debt caused by land use change emissions since these emissions occur on the first year biomass in produces (Fargione *et al.*, 2008). The particular case of land-use change is discussed in section 2.2.2.3.

Current LCA methodology is unequipped to account for the temporal aspects of GHG emissions and removals. To overcome this limitation, a dynamic LCA approach has been recently proposed to account for the timing of emissions in LCA (Levasseur *et al.*, 2010; Levasseur, 2011). The dynamic LCA methodology has first been applied to global warming impact assessments. In its International Reference Life Cycle Data System (ILCD) Handbook, the Joint Research Centre (JRC) of the European Commission proposes a method to account for temporary carbon storage and delayed GHG emissions in LCA (European Commission - Joint Research Centre - Institute for Environment and Sustainability, 2010). The JRC has also organized an expert workshop to discuss how to account for temporary carbon storage and delayed GHG emissions in LCA and carbon footprint (Brandão et Levasseur, 2011). Several important points of discussion have been raised in this workshop. However, no consensus has been reach on the method to use and the different value judgements inherent to the use of these methods, as more research is needed on the subject.

The first edition of the PAS 2050 specification requires accounting for temporary carbon storage and delayed GHG emissions using a weighting approach based on a working paper written by Clift and Brandão (2008). According to the GHG Protocol, temporary carbon storage and emission delays must not be considered in the calculation of carbon footprints. However, one can use a weighting approach and report these results separately. A time period over which emissions are not considered must also be chosen by the user, 100-year being the minimum recommended time frame. In its second edition, the PAS 2050 specification does not require any more accounting for temporary carbon storage and delayed GHG emissions. As for the GHG Protocol, a weighted approach can be used and the results must be reported separately. The time period for assessment is fixed to 100-year and cannot be changed by the user, unlike the GHG Protocol. Any emission occurring beyond this time period must not be considered in the carbon footprint calculation. The draft ISO 14067 standard also prohibits accounting for the timing of GHG emissions and removals in the carbon footprint calculation. As for the last two methods, a weighting approach can be used and results must be reported separately. However, emissions occurring ten years or less after the product has been brought into use must not be weighted for timing.

Even if there is still no consensus on the best way to consider the timing of emissions in LCA and carbon footprint, the subject is now part of decision making when the issue is undeniable. For instance, the Massachusetts state government has modified its legislation regarding the selection of bioenergy projects to promote following new knowledge on bioenergy carbon debt (Massachusetts, 2011). The scientific committee of the European Environment Agency recently published a paper criticizing the principle of carbon neutrality of biomass and explaining the importance of the reference scenario (what would be happening with biomass in the fossil fuel baseline scenario), of land use change emissions and of the bioenergy carbon debt (European Environment Agency

Scientific Committee, 2011). In this paper, the committee makes recommendations to the European Union in order to guide policies related to bioenergy.

2.2.2.3 Direct and indirect land-use change (LUC) emissions

Land-use change (LUC) emissions refer to GHG emissions occurring from human activities that change the way land is used, affecting the amount of biomass in existing stocks (IPCC, 2000). When a new biomass plantation is created for bioenergy production, two possibilities may occur: 1) a land is converted into cropland to produce biomass, resulting in direct land-use change (dLUC) emissions caused by the removal of existing vegetation and the release of carbon in soil or 2) an existing food crop is converted into a biomass crop to produce energy, resulting in a decreased supply for food, which causes indirect land-use change (iLUC) emissions coming from the conversion of a new land into food crop elsewhere to compensate for this supply loss (Searchinger *et al.*, 2008). The intensity of LUC emissions associated with bioenergy production varies greatly with several parameters such as the type of land converted into crops, the productivity of biomass plantation, food and biomass market characteristics, etc. In opposition, bioenergy produced from waste biomass or from biomass grown on degraded and abandoned crop lands causes no or very low LUC emissions (Fargione *et al.*, 2008). LUC can also affect other environmental and social aspects not covered in this section such as biodiversity, water quality, food prices, land tenure, etc. (Gnansounou *et al.*, 2008).

By their nature, dLUC emissions are easier to quantify than iLUC as they depend entirely on the characteristics of the land used for the specific bioenergy feedstock production. Carbon stock data needed for dLUC quantification, although uncertain, can still be used to quantify dLUC emissions with sufficient confidence (Chum *et al.*, 2011). Determining which lands are converted into crops in the case of iLUC can be very complicated and requires the use of general equilibrium models that take into account several factors such as the supply and demand of agricultural commodities and land availability. While these lands are identified, iLUC emissions are quantified using the same techniques as for dLUC emissions (Chum *et al.*, 2011).

LUC emissions - particularly dLUC - are increasingly considered in LCAs performed on bioenergy systems. However, LUC emissions can result from other types of product systems involving land-use changes. The different carbon footprint methods give guidelines on the way LUC emissions should be considered for any concerned product. The PAS 2050 specification, the GHG Protocol and the ISO draft standard all require the consideration of dLUC emissions in carbon footprint calculation. The rules provided to quantify dLUC emissions are coming from IPCC guidance (IPCC, 2000). The quantification of iLUC emissions is not a requirement for the PAS 2050 and the GHG Protocol methods but can be reported separately in the case of the GHG Protocol. The ISO draft standard requires the consideration of iLUC emissions once an internationally agreed procedure exists.

LUC emissions are also part of different regulations regarding biofuels. The California Low-Carbon Fuel Standard (LCFS) that took effect in January 2011 requires the inclusion of dLUC and iLUC emissions in the calculation of biofuels carbon intensity (California Air Resources Board, 2012). In the United States (U.S.), the Energy Independence and Security Act (EISA) of 2007 sets targets for GHG emissions reduction from biofuels and mandated the US Environmental Protection Agency (EPA) to include dLUC and iLUC emissions in their life cycle GHG assessment of biofuels (U.S. EPA, 2009). In 2010, US EPA issued its final Renewable Fuel Standard (RFS2), including dLUC and iLUC emissions (U.S. EPA, 2012).

In 2009, the European Commission adopted the Directive on renewable energy 2009/28/EC introducing a requirement on fuel suppliers to reduce GHG emissions from transportation fuels, including land-use change emissions (Commission, 2012). The sustainability criteria set by this directive have applied since December 2010. The Commission asks industry and governments to set up voluntary certification schemes for biofuels, using independent auditors. They also published a report on indirect land-use change in December 2010 in which they acknowledge that iLUC emissions can reduce the savings associated with biofuels and that the models used to quantify them have important uncertainties. The Commission continues working on that topic in order to provide policy makers with the best available science. The appropriate methodology to account for iLUC emissions has not been determined yet.

Schmidt and Weidema (2008) have developed a method adapted to life cycle assessment following the consequential approach (life cycle assessment made to study a change occurring in a life cycle and its consequences occurring in and out the considered life cycle). This method is easy to apply but because its theory is very simplified regarding real phenomena involving land use changes, its results may be highly uncertain. Additionally, this method is adapted to study only small variations of land use changes, which makes it unsuitable to study large-scale biofuel policies.

Another approach has been developed by various economists and consists in using macroeconomic models. These models can be run to compute competition for land use between energy crops and agriculture. The economic theory of general or partial equilibrium behind these models is far more complex than the one used by Schmidt and Weidema (2008). Therefore, it is expected these models provide better assessments of indirect land use changes caused by energy crops. However, because the economy is not influenced by only economic parameters, results of these models remain uncertain. Also, these models require significant resources to be used (expertise, money to cover the license fees, and time to setup the simulations). Nevertheless, it appears that an increasing number of governmental institutions use these models to compute greenhouse gas emissions of indirect land use changes caused by biofuel policies: European Commission using IFPRI-MIRAGE-BioF model, U.S. EPA using FASOM-FAPRI and California EPA using GTAP. Also, it should be mentioned that more and more macroeconomic models are being used in LCA to compute indirect land use changes (Dandres *et al.,* 2011, 2012; Kloverpris, 2008; Kloverpris *et al.,* 2010; Mason Earles *et al.,* 2012; U.S. EPA, 2011).

2.2.3 Shortcomings regarding agricultural biomass systems in LCA and water footprint

As for carbon footprinting and the LCA of other impacts according to LCIA methodologies, water footprinting theoretically involves first to inventory the volume and the quality (i.e. the type of water source and of water receptor) of every water input and output flows and then to assess the subsequent impacts from water withdrawal, water consumption and water discharge. The science beyond the assessment of water use impact is quite young. Several approaches exist and no strict consensual models exist yet on how to report water use inventory data within typical area of protection used in LCA such as human health, ecosystem quality and resources. The use of water can generate potential impacts to humans, to the biotic and to the abiotic environment, and these impacts can be related to water scarcity, water functionality, water quality, water ecological value and water renewability rate. Existing LCIA methods or methods in development address only one or a limited number of impact pathways. As well, not all of them are fully compliant with ISO 14040 standards on LCA (ISO, 2006), since some are only inventory (i.e. accounting for m^3) methods. As a sort of in-between, the Water Footprint Network (WFN) approach is to report volumes of blue water (freshwater withdrawn from lakes, rivers and aquifers), green water and grey water. Of importance for cropping systems and biomass production is green water, which is the volume of rainwater consumed during the production process, i.e. the total rainwater evapotranspiration (from fields and plantations) plus the water incorporated into the harvested crop. Grey water is actually the “virtual water” volume that would be required to dilute wastewater pollution so as to reach a level tolerated by local jurisdiction.

Because of the current shortcomings of LCIA methods, and in the expectation of a robust and consensual LCIA methodology for water use impact assessment, it is recommended to conduct a rigorous inventory of water withdrawals and discharges, including information on the types of water compartment affected by these water flows, and to collect basic pollution data of any wastewater (e.g. biochemical oxygen demand analysis). Also, green water estimates could be based on default data from WFN's database unless Canadian-specific estimates are available (McConkey, 2012). As a trade-off, in the expectation of a consensual and robust method, an assessment framework can be developed to integrate a comprehensive state-of-the-science compilation of methods/approaches (including the WFN one), addressing the major issues related to water use in LCA. As a first approach, this framework could be used to apply to all methods/approaches and to identify all possible hotspots, advantages and drawbacks of each method. Following this first approach, a refined methodology would be defined, depending on the goal of the LCA project, and the best-suited method would be selected.

2.2.4 Carbon offsetting protocols and application

2.2.4.1 Cap-and-trade and climate offset programs

The Canadian federal government announced in 2009 the creation of Canada's Offset System for Greenhouse Gases (Government of Canada, 2008). The objective of this program was to issue credits for GHG emission reductions and removals from activities or sectors that are not covered by planned federal regulations such as agricultural soil management (Environment Canada, 2009). However, it is likely that the current federal government has cancelled this initiative as the official web site is no longer active and no information was found on the subject following 2009.

The Ontario provincial government is working with other provinces and U.S. states through the Western Climate Initiative (WCI) in order to implement a GHG cap-and-trade system. In a cap-and-trade system, a limit is determined to control the total amount of GHG emitted. Allowances are then distributed between selected emitters until the limit is reached. If one emits less than its total allowances allow, it can sell its excess allowances on the market. If one emits more, it must purchase allowances or carbon offsets on the market. Offsets are given to projects that reduce or remove GHGs by non-regulated industries. Farmers, for instance, can develop offset projects by adopting agricultural practices that lead to a reduction in GHG emissions (Environment, 2009).

The WCI is developing a cap-and-trade program in order to reduce GHG emissions by 15 percent below 2005 levels by 2020. The program will be fully implemented in 2015 and will cover 90% of GHG emissions in WCI partner states and provinces. It will cover emissions of seven GHGs from electricity generation, industrial fuel combustion, industrial processes, transportation fuel use, and residential and commercial fuel use (Western Climate Initiative, 2012). California and Québec have already adopted regulations and will both be part of the cap-and-trade system in its first year of implementation (2012). Other partner states and provinces should join the program in the following years.

Agriculture is not a sector targeted by the cap-and-trade regulation. However, as stated previously, offset projects can be developed in this sector. To receive an offset certificate, a project must lead to a GHG reduction or removal that is real (quantified using accurate and conservative methodologies), additional (GHG reduction of removal would not happen under a baseline scenario), permanent (not reversible), and verifiable (well documented, transparent, and reviewed by a qualified verifier) (Western Climate Initiative, 2010).

2.2.4.2 *Data and data gaps to support the development of offset protocols for agricultural biomass under Ontario conditions*

In conformity with IPCC Tier 2 methodology for GHG assessment from agricultural managed lands (IPPC, 2006), a Canadian-specific methodology has been developed and applied by Rochette *et al.* (2008a; 2008b) for estimating N_2O emissions at the ecodistrict geographical scale[8], hence accounting as much as possible for specific climatic and soil conditions and practices at that scale. Direct N_2O emissions estimates can thus take into account any type of nitrogen inputs (synthetic and organic fertilizers, crop residues, mineralized nitrogen as a result of loss of organic matter from land conversion), as well as tillage intensity, practice of irrigation, position in landscape, soil texture, practice of summer fallow, and the cultivation of organic soils. Nevertheless, this Canadian methodology suffers of some limitations due to research progress, especially regarding indirect N_2O emissions where IPCC default emission factor for leaching and run-off of nitrogen and atmospheric nitrogen redeposition are to be used (Rochette *et al.*, 2008a ; Desjardins *et al.*, 2010). However, this is a state-of art available methodology, which is followed by Alberta offset projects protocol (Government of Alberta, 2010).

These latest developments for estimating GHG at the farm level based on the Canadian-specific methodology have been made available to the public throughout Holos, a farm GHG calculator developed by Agriculture and Agri-Food Canada[9]. Holos also includes CO_2 emissions estimates from energy use, and net storage and loss from changes in land use and management, and methane emissions, if any. The tool is designed to calculate GHG emissions based on farmer's operations (i.e. its own activity data) and allows assessing various mitigation scenarios (e.g. changing level of tillage practice, riparian buffer plantations).

To overcome the current limitations, we propose to organize a technical meeting with AAFC's scientists to 1) review the latest methodological developments for the calculation of GHG emissions within the Ontario context, 2) discuss the possibility of estimating/developing Canadian or Ontarian emissions factors to substitute IPCC default factors, and 3) determine whether using an even more precise geographic scale could be used. Relevant scientific expertise could be found by Agriculture and Agri-Food Canada' Environmental health science program (Eastern Cereal and Oilseed Research Centre in Ottawa, and Soils and Crops Research and Development Centre in Quebec)

[8] The ecodistrict is a subdivision of an ecoregion characterized by a distinctive assemblage of relief, landforms, geology, soil, vegetation, water bodies and fauna. The ecoregion is a mapping unit in Canada's ecological classification system. It is a subdivision of a larger ecological classification unit characterized by distinctive regional ecological factors, including climate, physical geography, vegetation, soil, water and fauna.

[9] http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1226606460726&lang=eng

3 Update on the food-energy debate in relation to second generation biofuel systems

The use of agricultural land and / or agricultural products for energy production is strongly questioned by many players from different backgrounds: environmentalists, development economists, consumer organizations, farmers' organizations, Non-Governmental Organizations (NGOs), governments, citizens. The rapid production increase of biofuels from energy crops under the influence of incentive regulation and massive subsidies in Western states raised a highly emotional debate on competition between energy and food. Indeed, bioenergy has often been fingered as one of the main causes of the "food crisis" that occurred in 2007-2008 as a result of the drastic increase in the prices of basic commodities.

While pilot projects have shown that perennial crops, wood and crop residue biomass can adequately serve as a substitute for petroleum-based fuels and chemicals and pilot-projects, the sustainability of the feedstock supply for second-generation biofuels is challenged despite improvements in technologies and access to cellulosic materials. Past experiences with soy, corn, palm oil and sugar cane-based ethanol and biodiesel have indeed raised several ecological and social issues such as the competition for farmland between food production and energy production (the *food vs fuel* issue), deforestation of primary forest, the conversion of grassland, etc. have been debated in the scientific and mainstream press These debates exist at the global level as well as in Canada and may sometimes pit farm organizations against each other (Daynard 2011 and Grier *et al.* 2012).

The increasing criticism of the sustainability of first-generation biofuels[10] has raised attention to the potential of second-generation biofuels (IEA, 2010). While the first generation of biofuels mostly relied on crops such as corn, soy and palm oil, the second generation of biofuels uses agricultural residues such as wheat straw and forestry residues or non-food crops. Hence, the second generation of biofuels has gathered interest initially because it does not compete directly with food-use for its feedstock, at first sight at least. Besides, depending on the feedstock choice and the cultivation technique, second-generation biofuel production could provide benefits such as making valuable use of abandoned land and waste residues.

Although an important body of research has been produced to document the relationship between first-generation biofuels and the food crisis, little research is available about the role of second-generation biofuels. This can be partly explained by the fact that the second generation of biofuels is still in its infancy: several pilot projects are under way, but the production of second-generation of biofuels has not reached a level important enough to influence global markets. In order to put into perspective the potential challenges facing the next generation of biofuels with regard to the food vs. energy debate, this chapter first presents a summary of the economic literature on the perceived role of biofuels in the food crisis of 2007-2008. Secondly, recent studies that include second-generation of biofuels and that try to assess their potential and/or their impacts are reviewed. The last section summarizes the positions taken by environmental interest groups and NGOs in the food vs. energy debate.

[10] Broadly speaking, this first generation of biofuels is produced primarily from food crops such as grains (notably corn), sugar cane and vegetable oils.

3.1 Origins of the 2007-2008 food crisis

An analysis of changes in commodity prices over the past 15 years shows the rapid inflation of agricultural prices observed during the period from June 2007 to November 2008. Between 2004 and 2008, world prices of major crops soared: from 65% for soybeans, 85% for wheat, 99% for maize and 185% for rice. This significant increase in world agricultural prices during the period 2007-2008 has had a significant impact on food prices in developing countries where the share of household budgets devoted to food expenditures may reach 75% in some countries, compared to 15% in Canada (WRI, 2010). The concept of "food crisis" refers specifically to the situation of consumers in poor countries and not to slight increases in prices that has affected the food consumed in developed countries. Unlike consumers in poor countries, consumers in rich countries are buying mostly processed products. However, the purchase of agricultural commodities (cereals, oils, etc.) represents only a fraction of the production costs of such processed products. Hence, the impact of increased prices of staple foods is diluted in the total manufacturing cost. By comparison, consumers in poor countries buy unprocessed commodities and any increase in the prices for these commodities is directly transmitted to the consumers.

This increase in prices can be explained by the following 10 factors (Headey and Fan, 2008):

1. The demand growth in China and India;
2. The slowdown in productivity gains and more specifically the decline in global aggregate yield growth[11];
3. Climatic hazards;
4. The decline in stocks;
5. Barriers to export;
6. Speculation in financial markets;
7. The weaker U.S. dollar;
8. Rising oil prices;
9. The low interest rates;
10. The growth in demand for biofuels.

In the literature examined, there is no consensus in the proportion of changes in agricultural prices due to these factors. For purposes of understanding the interconnectedness of all these factors, they can be grouped in the following three major economic forces:

1. Global changes in the production (supply) and consumption (demand) of major agricultural products;
2. The weaker U.S. dollar and rising oil prices;
3. The growth of biofuel production.

Discussion over the relative importance of these forces can be found in FAO / OECD (2008), Mitchell (2008) or Daynard (2011). In this report, we will focus on the growth of biofuel production. American and European policies supporting the use of biofuels to replace fossil fuels have spawned an industry

[11] See Trostle R., 2008. *Global Agricultural supply and Demand: Factors Contributing to the Recent Increase in Food Commodity Prices*. ERS/USDA, WRS-0801, May 2008.

of biofuels (ethanol and biodiesel) based on the use of corn (mostly) and vegetable oils (Mitchell, 2008; USDA, 2008). This industry, which remains in competition with the oil industry, reached break even when the price of oil exceeded $ 60 USD approximately. When oil prices soared, the combined effect of these high prices and government incentives boosted the development of the biofuels industry. Thus, in recent years, a large share of the demand growth for corn came from its increased use for ethanol production, contributing to price increases for corn (Mitchell, 2008, IFPRI, 2008).

The high price of corn then led to an inflationary spiral for other agricultural commodities (IFPRI, 2008). Research results have produced estimates showing that the overall impact of biofuels on food prices vary greatly depending on the methodology used, the period analyzed and commodities investigated. The results reported impacts varying between 10 and 75% (Mitchell, 2008, IFPRI, 2008). Methodologically, it is difficult to estimate the contribution of different factors to rising food prices to consumers because the price changes are not transmitted directly, but with a time lag. Besides, as food becomes more processed, the causal link from agricultural production and prices to food prices becomes difficult to accurately quantify. Although there is no consensus over the size of the impact, it is nevertheless undeniable that higher prices of oil, and hence the first generation of biofuels, have had an impact on the prices of grains and food during the 2007-2008 food price spike and still play a role in maintaining a high level for agricultural commodities' prices today.

3.2 Recent estimates of future impacts of first and second generation biofuels

The economic literature that assess the future impact of biofuels does not necessary distinguish between first and second generation of biofuels despite very different environmental context. For example, Taheripour *et al.* (2010) assess the impact of EU and U.S. biofuel mandates without disaggregating the results for the first and second generation of biofuels. Blanco Fonseca *et al.* (2010) models account for the impact of the introduction of second-generation biofuels at a commercial level within the EU, but only after 2015[12]. Up until now, most second-generation biofuels are still at the development stage or small-scale commercial stage, which means that:

i) Economic studies assessing their impacts are mostly ex-ante studies (IEA 2010, Taheripour *et al.* 2010, Blanco Fonseca *et al.* 2010);
ii) These studies take into account the fact that first and second-generation biofuels are likely to coexist on the fuel market.

This means that the impact of second-generation biofuels has been assessed through modeling work and thus, the results available depend on several factors:

i) The specific issues being assessed by the authors. For example, Blanco Fonseca *et al.* (2010) focus on the impacts of the EU biofuels mandate while IEA (2010) deals with the impacts on developing countries stemming from the demand at the global scale. Hence, the studies' results can be presented on different levels and for various sub-component (e.g. within EU impacts or extra-EU impacts, global or regional impacts; impacts on energy balance or impacts on crops and energy trade; impacts on biodiversity and GHG emissions, etc.);
ii) The characteristics of the macroeconomic models used for the assessment (Blanco Fonseca *et al.* 2010);

[12] Within Blanco Fonseca's report, first-generation biofuels still represent a majority of biofuels after 2015.

iii) The hypothesis being used in the model (for example, the commodity balance and land-use impacts vary according to the type of land conversion allowed by the modeller[13], the evolution of yields, demand and supply for food crops, etc. – See Perlack et al, 2005. in Sanderson, 2008).

Although these parameters vary for each study assessing biofuels, some general remarks can be drawn from their results:

iv) The scale of the projected demand for biofuels, including second-generation biofuels, and in particular EU and U.S. demand stemming from their policy goals regarding biofuels will have a significant impact on biofuel production. The impact on second-generation biofuels, and thus dedicated energy crops, will also depend on their price-competitiveness relative to over biofuels. Since Canada is connected with the global market, the EU and U.S. biofuel policies will impact Canada's energy crops and biofuel production. For example, one of Blanco Fonseca (2010)'s results estimate that Canada's wheat production and acreage could decrease and rapeseed/canola production and acreage increase due to the pull of global biofuel markets, by 2020.

v) A parallel could be drawn between some developing countries' results and the potential results for Canada. For example, although it is claimed that some dedicated energy crops can "grow well on marginal lands, survive under adverse climatic conditions and need no irrigation or fertiliser to grow well", it is nevertheless true that "to obtain good returns, the best land possible is often acquired" (OECD, 2011). Thus, in selecting feedstock production sites, a farmer "may consider a wide array of factors including rainfall patterns, accessibility to infrastructure, proximity to transportation routes to access target markets" and the farmer's opportunity costs. "Since marginal land tend to give unpredictable feedstock yields", it is not always certain that marginal land will be the first choice for any given farmer to grow dedicated energy crops.

vi) The potential impacts on animal production can sometimes be contradictory and depend on assumptions and caveats posited by authors such as Perlack *et al.* (2005 in Sanderson 2008) and Blanco Fonseca *et al.* (2010). These assumptions are related to the implications on how existing forage and grazing lands could be used in the future, on the one hand, and the relative potential use of Dried Distillers Grains (DDG) on the other hand. For example, if the hypothesized increase in grain yields and crop residue removal are not met in the future, then much more land area will be required to produce the biomass required to meet the U.S. or EU objectives regarding second-generation biofuels. Similarly, if one assumes that meat demand will increase at the global level and that cereal acreage to meet this demand will at least be maintained, then the likelihood of cropland conversion to perennial energy crops could be reduced and the "production of perennial energy crops could be forced to more marginal lands" (Sanderson *et al.* 2008). Similarly, a replacement of pasture and hay land with perennial energy crops such as switch grass would force forage-livestock production to other regions or cause greater intensification of confined animal production. "All of these aspects will place tremendous pressures on hay, forage, and pastureland in the future and the expanding land base necessary for biomass production would probably force forage and grazing lands production to ever more marginal lands. This could have very important implications for the forage-livestock industry" (Sanderson *et al.* 2008). On the other hand,

[13] For example, one may allow conversion from forage and food-crop land to energy crop land but not conversion of primary forest and marginal land.

biofuel production also generate by-products such as DDG which can be used in the livestock industry as animal feeds and can substitute, to a certain degree for the cereal crops in animal rations. However, this potential substitution does not affect all livestock industries in the same way since ruminants (dairy and beef) are better able to make use of DDG in their feed rations than non-ruminant (poultry and pork) (Taheripour *et al.* 2010).

3.3 The positions of social actors to debate energy-diet

Environmental groups are generally unfavourable to first-generation biofuels and their arguments are twofold. First, citing the results of studies based on LCA, these groups challenge the actual performance of biofuels regarding net GHG emissions. Furthermore, these groups also claim that the land use for energy crops has devastating effects on food security in the underdeveloped countries (South).

The type of arguments taken differs depending on whether the organizations are active at the international level or domestically. The arguments of international groups such as Greenpeace, Oxfam International and Friends of the Earth are mostly focused on environmental and social damage of crops grown in the South to supply the rest of the world, such as sugar cane and sugar cane based ethanol. Their principal objections to biofuels are related to their impacts – potential or actual - on deforestation, and thus biodiversity, the diversion of land used for food crops towards crops for energy purposes (including palm oil), the negligible impacts on climate change, poor working conditions and the lack of respect of human rights in plantations in developing countries.

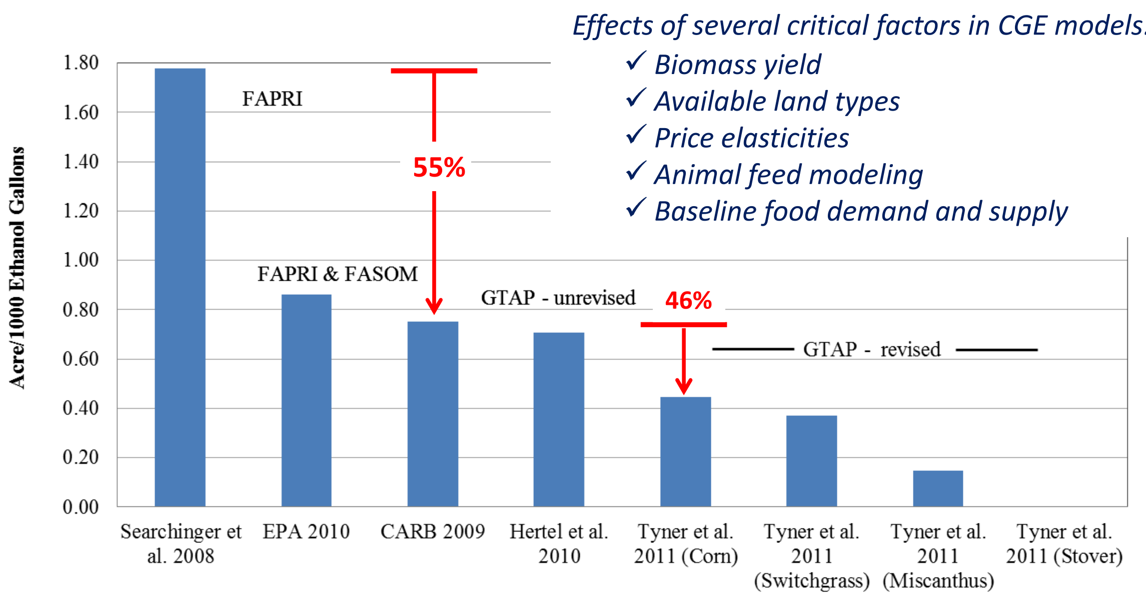
Groups active across Canada (Greenpeace, David Suzuki Foundation) have until recently put a bigger emphasis on the production of corn-based ethanol[14]. They denounce the poor - or even negative - energy balance of this production, and the agricultural practices associated with growing corn (monoculture and the use of GMOs resulting in loss of biodiversity, the use of synthetic fertilizers and soil degradation, contamination of rivers). They also denounce the effect on food prices due to the competition from energy crops over food crops for agricultural land use. So far, the specific position of these organizations regarding second-generation biofuels is unclear. For example, Oxfam-Quebec and Oxfam-Canada made no distinction between first and second generation of biofuels in their opposition to government support to biofuels during the 2012 budget pre-brief (Oxfam 2012).

3.4 The challenge of quantifying agricultural land conversion

Drawing out quantitative conclusions from comprehensive scientific studies about whether the development of bioenergy policies has an influence on food availability remains difficult. As mentioned above, the factors are numerous. Consequential life cycle-based studies addressing direct and indirect land use changes could theoretically provide an answer about the impact of a market-driven and/or policy-driven decision on the availability of farmland. Modeling such a complicated cause-to-effect relationship is complex, sometimes poorly conducted, involves questionable assumptions due to no standardized and consensual methodologies and the results vary widely from one study to another. The main reason is that the boundaries of the system to model have to be largely expanded to account for indirect consequences, including the displacement caused by co-

[14] See for example Greenpeace Canada campaign against biofuels in 2008: http://www.greenpeace.org/canada/en/campaigns/ge/archive/latest-developments/say-no-to-bill-c-33/#a1

products (Kendall and Chang, 2009; Wang *et al.*, 2011). A mix of physical and economic models (among which computable general equilibrium models are the most sophisticated) is involved. The refinement of such models over time (from FAPRI to revised-GTAP, see Figure 4) to better take into account indirect effects of land use associated with the production of ethanol from corn, however, shows that early studies significantly overestimated the area needed to support ethanol and biodiesel production (Wang, 2011; O'Connor, 2012). Also, many numbers suggest that the increased demand for corn ethanol in the U.S. from 2002 to 2011, and for biodiesel in Europe, is satisfied by increased yields while the domestic agricultural land area decreased and the forest land area increased, and while U.S. exports have increased (O'Connor, 2012). Other economic studies point out that the food crisis observed in 2007-2008 could be more a consequence of the use of commodities by financial investors (the so-called "financialization of commodities") rather than an intrinsic impact of biofuel policies and markets on food prices (Baffes and Haniotis, 2010).



CGE – Computable General Equilibrium
GTAP – Global Trade Analysis Project (Purdue University)
FAPRI – Food and Agricultural Policy Research Institute (Iowa State)
FASOM – Forest and Agricultural Sector Optimization Model (Texas A&M)

Figure 4 - Land use change (direct and indirect) simulated for U.S. biofuel production from some completed studies (Wang, 2011).

Discussions about land use consequences are probably not sufficiently extended, as noted by Rodriguez and O'Connell (2011). Increasing global demand for food and energy means that discussions of land use should include the whole energy sector, not just the minor biofuel component. Other energy industries such as coal-bed methane producers, bituminous sands, and shale gas, as well as urbanization, are also competing for arable land and potable water.

3.5 Conclusion on the food-energy debate

The evidence reveals that the *food vs. fuel* issue is a hot topic, and public and scientific discussions are very active on this issue. Unfortunately, the scientific evidence to support the arguments of all parties is not yet available. Encompassing within a model all physical (environmental and technological) and socio-economic variables is complex and far from realized, despite recent progress towards combining computable general equilibrium models with LCA. As a result, there is still no standardized methodology and tool enabling to draw out consensual answers.

Hence, communicating on this topic is sensitive. The OFA and the stakeholders should be discussing this matter with caution and it is recommended to avoid making strong opinions. The communication should state that:

- Environmental, economic and social sciences are facing a very challenging issues when trying to predict indirect consequences from biofuel policies on (farm) land use, water and food availability at the global scale, to name only a few of the most controversial consequences;
- The scientific knowledge is improving steadily. For instance, with respect to first generation corn bioethanol in the USA, it seems that previous quantification of loss of arable land was probably overestimated and mostly related to exogenous factors;
- From a farming perspective, integrating food crops, bioenergy feedstock and carbon farming could be an important strategy to counter economic and environmental variability. The notion that agriculture is for food only, forestry for wood only, etc. should change for good. Agriculture can be sustainable with diversified productions supplying various needs and markets. Through technology, careful land management and considered use of resources, biofuels and food can coexist. With this respect, the OFA is committed to support decision making through sustainability assessments using the best scientific knowledge.

4 The positioning of the Ontario agricultural biomass

The Ontario biomass foreseen to supply new industrial value chain opportunities such as heat and power generation, biofuels, bio-chemicals and bio-composite materials is crop-residues biomass such as corn stover and winter wheat straw, and purpose-grown biomass (Western Sarnia-Lambton Research Park, 2012a, 2012b). More precisely, the purpose-grown biomass is either woody biomass (short rotation coppices such as willow and poplar) or herbaceous crops, mostly perennial crops, such as miscanthus, switchgrass, tall grass prairies, Indian grass, reed canary grass, or big blue stem; an exception is sorghum, which is an annual crop (Kludze *et al.*, 2011 ; Western Sarnia-Lambton Research Park, 2012b).

Such biomass does not directly raise the major sustainability concerns discussed globally in the public place with the first generation biofuels (e.g. the use of food crops for non-food use, the appropriation of arable land and the indirect land use change), but rather presents assets (e.g. the valorization of agricultural residues, the use of marginal land, the benefits of perennials to maintain soil quality and some ecosystem services, with a limited level of inputs). However, the net benefit must be proven and communicated to stakeholders and general public, and to potential buyers and export markets that require satisfying voluntary or mandatory sustainability criteria.

The following sections aim to qualify Ontario agricultural biomass sustainability and to identify sustainability issues through a literature review. This literature review has been complimented with a series of focus group with various stakeholders, involved with sustainability and/or biomass supply chain, held in Toronto on July 30th, 2012. Appendix D provides the list of participants to these focus groups.

4.1 Qualifying the Ontario agricultural biomass sustainability with respect to current Corporate Supply Chain initiatives and Sustainability Coalitions.

As presented earlier, sustainability standards and criteria are proliferating (section 1.4). Various stakeholder groups have undertaken a wide range of initiatives as steps towards the development of sustainability standards and biomass certification systems. Between them, there seems to be a general agreement that it is important to include economic, social and environmental criteria. However, mutual differences are also visible in the strictness, extent and level of detail of these criteria due to various interests and priorities.

With respect to current supply chain initiatives and sustainability coalitions, Ontario producers committed to an Environmental Farm Plans (EFP) would be positioned favourably. An EFP establishes a baseline reference of various environmental risks, commit producers to implement best management practices that will reduce the risks identified, and require the producers to report on planning and monitoring. Furthermore, EFP are peer-reviewed and validated by agri-environmentalists and agronomists (OMAFRA, 2012). Hence, from an agri-environmental perspective, most qualitative principles and criteria of SIPs are met thanks to EFPs. Figure 5 puts into perspective the two approaches, using a virtual sustainability standard derived from merging the principles of the U.S. CSBP standard (Council on Sustainable Biomass Production) with those from the RSB (Roundtable on Sustainable Biofuels). The RSB version 2.0 has been chosen because it appears as the more comprehensive one so far; it demonstrates a solid scientific background (e.g. its life cycle GHG calculation methodology is critically reviewed), offers detailed tools and guidelines, and has been continuously developed and improved since 2006, including for e.g. indirect impact assessment and social guidelines. Furthermore, its governance is based on an open membership divided into Chambers representing different actors along the supply chain, as well as different types of civil society and government groups, globally. Although recent, the CSBP biomass standard is less mature, but the membership is U.S.-oriented and the advisory board is composed of the U.S. Department of Agriculture and Department of Energy.

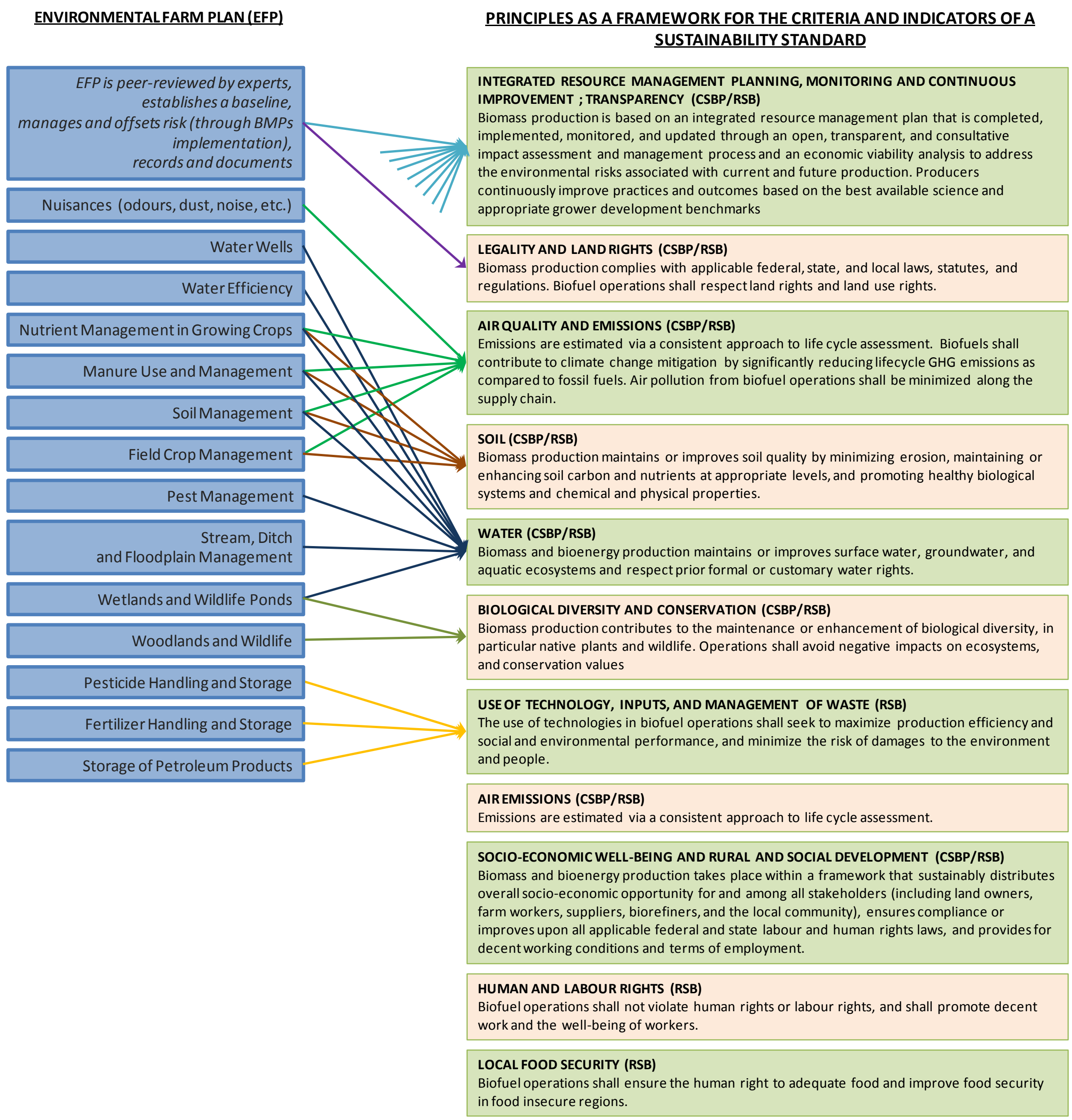


Figure 5 – Linkages between Ontario Environment Farm Plan's areas and the principles of a biomass certification standard, here defined as a merge of the CSBP (Council on Sustainable Biomass Production) and the RSB (Roundtable on Sustainable Biofuels) standards.

As depicted on Figure 5, if the Ontario biomass originates from producers committed to EFPs, a large number of standard's criteria are met, regarding 1) the awareness of potential agri-environmental risks to protect the environment and 2) commitments towards reducing those risks through the implementation of Best Management Practices (BMPs). Indeed, since no quantitative assessment except for GHG and soil loss level are currently required by standards from feedstock producers, EFPs are a powerful tool to qualify Ontario biomass regarding most of the environmental principles. Thus, the OFA should definitely require its members who wish to market biomass to commit themselves to an EFP. Focusing on crop residues, attention should be paid on harvesting the "sustainable" amount so as to maintain a sufficient cover for erosion control, to provide the building blocks for soil organic matter, and to benefit from a reduced quantity of synthetic nutrients inputs (Johnson *et al.*, 2010 ; Western Sarnia-Lambton Research Park, 2012a ; Williams *et al.*, 2009). In this respect, as well in regards to the calculation of soil loss from erosion, it is recommended to agree upon the draft framework for the determination of environmentally sustainable agricultural biomass production and removal proposed by the OMAFRA (2011a), which also states as criterion No. 1 that a biomass crop producer must have a peer-reviewed EFP.

However, in addition to the life cycle assessment of GHG from biomass production, principles and criteria related to socio-economic well-being and rural and social development, to human and labour rights, and to local food security which are not included within the EFP framework will need to be addressed as well as qualifying Ontario biomass to a rigorous and comprehensive biomass standard (unlinked principles in Figure 5). Requirements for calculating life cycle GHG of biomass production are mentioned in quite different ways from one standard to another. The CSBP (2012) states that emissions are estimated via a consistent approach to LCA, and that producers either have to provide data needed for the biofuel or biopower producer to conduct an LCA that accurately reflects emissions from the production and pre-conversion processing of biomass on the acres under consideration for certification (Table 4) or may provide their own GHG emissions factor by utilizing the CSBP Producer GHG modeling tool which is currently subject to an audit review. The RSB version 2.0 offers a very detailed and critically reviewed methodology (RSB, 2011) as well as a free online tool allowing choosing among three methodologies (the global RSB, the EU RED and the Swiss methodology).

Data listed in Table 4 are typical activity data necessary to perform a GHG LCA with the help of additional data from a life cycle inventory (LCI) database such as *ecoinvent* or the U.S. LCI database, or from a database of emission factors to account for the GHG embedded with inputs and supplies (e.g. diesel, fertilizers) and with the operation of machinery (e.g. tractor fuel consumption per hour) and trucks. Such additional data are generally included in the tools provided by the above-mentioned standards. They are also provided within other tools such as GHGenius, a Canadian Excel workbook for assessing life cycle GHG of transportation fuels and biofuels (www.ghgenius.ca). Most of the data listed in Table 4 are likely to be compiled by producers engaged in an EFP, except data related to transportation. Also, from our point of view, collecting fuel consumption data as well from producers will allow a more representative assessment than relying on generic emission factors.

Table 4 - Data necessary for the CSBP GHG modeling tool developed for biomass consumers (CSBP, 2012)

Operation	Data
Yield data	Yield reported on as delivered basis (yield in weight and percent moisture) or as stated on contract documents between producers and their consumers.
Production inputs	Amount and type of nutrient amendments and the chemistry (product name and active ingredient per unit of production) of pesticides applied to the biomass production acres.
Planting and tillage	Name or type or equipment and the number of passes for each tillage fertilization, spraying, or planting tools taken during the establishment of the biomass acres. Producers provide an estimated fuel usage for each equipment choice for each operation (gallons per acre or gallons per hour).
Soil carbon depletion and organic matter	Provide documentation of the soil organic matter as determined by the latest soil tests taken from the biomass production acres or by applied research.
Harvesting, collection, handling, processing, and storage	Name or type of equipment and the number of trips or machine hours as appropriate for each on farm collection, harvesting, road siding, stacking, pre-processing, or processing tool taken during the harvesting of the biomass acres.
Transportation	Name or type of transportation equipment and the number of trips or miles of each known event associated with the biomass acres or production or the delivery of the biomass while under the care custody or control of the Producer.

Lastly, as mentioned earlier in this report, the direct and indirect N_2O emissions from soil from nitrogen inputs as well as soil organic carbon change are key contributors to GHG assessment of crop systems. An IPCC Tier 2 or Tier 3 methodology representative of the Ontario context for the specific cropping systems and practices is highly recommended for a reliable assessment of these GHG. Such methodologies are available for annual crops such as corn and wheat from AAFC scientists. However, methodologies for perennials are still underway. It is expected that the outcomes from various projects about LCA modelling and assessment of miscanthus and willow in Ontario involving LCA experts from the University of Guelph and the University of Toronto, and OMAFRA will provide the necessary knowledge for filling data gaps (OMAFRA, 2011b).

4.2 Qualifying the ON agricultural biomass sustainability through an Ecological Goods and Services (EGS) concept

The Ecosystem Goods and Services (EGS) are commonly defined as the direct and indirect contributions of ecosystems to human well-being. One can distinguish between provisioning, regulating, supporting and cultural services provided by ecosystems (TEEB 2010). Although agroecosystems have been traditionally considered primarily as sources of provisioning services such as food, fibre or bioenergy, their contributions to other types of ecosystem services have been recognized recently (Power, 2010).

In order to qualify biomass production sustainability through its contribution in terms of EGS, one must consider two issues or dimensions:

- Trade-offs between EGS, and particularly agricultural systems EGS;
- The importance of local context and place-based EGS.

Power (2010) highlights that "ecosystem processes within agricultural systems can provide services that support the provisioning services, including pollination, pest control, genetic diversity for future agricultural use, soil retention, regulation of soil fertility and nutrient cycling" and these ecosystem processes can be influenced by human management decisions such as crop rotation and diversity, tillage practices, field size and location, etc. This author also explains that these management decisions are influenced by the balance between short-term and long-term benefits. Management practices also influence the potential for negative externalities or 'disservices' from agriculture, including loss of habitat for conserving biodiversity, nutrient runoff, soil degradation and sedimentation of waterways, and overuse of pesticide. Appropriate management can ameliorate many of the negative impacts of agriculture while largely maintaining provisioning services. Thus, it is more appropriate to speak in terms of sustainable production practices and management decisions than sustainable production per se. In this regard, a comprehensive Environmental Farm Plan and the adoption of Best Management Practices is a key tool in order to support the provision of EGS within biomass production systems.

Figure 6 below illustrates the ecosystem services that could be influenced by agricultural biomass production.

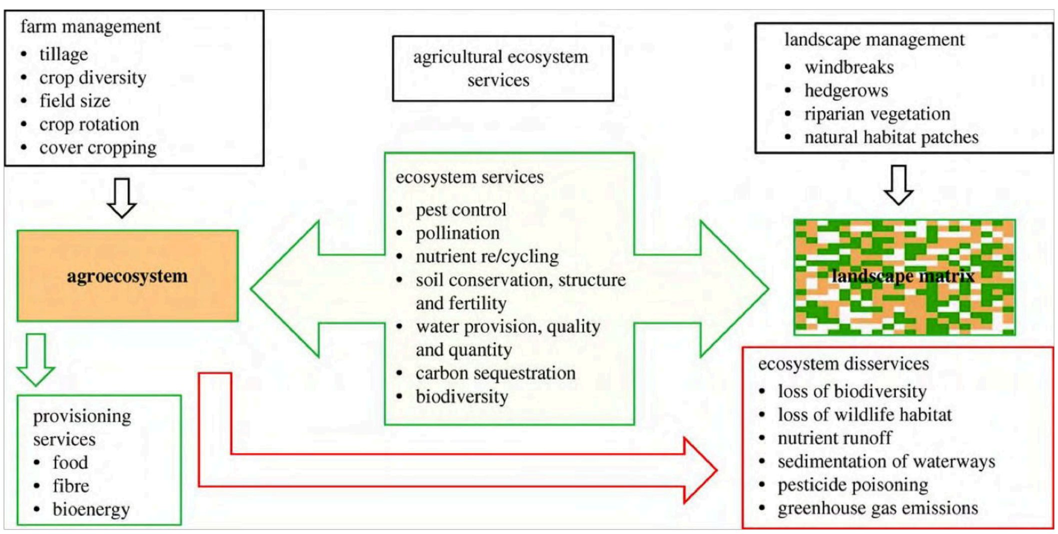


Figure 6 - Impacts of farm management and landscape management on the flow of ecosystem services and disservices to and from agroecosystems (Source: Power, 2010)

For example, if biomass production is developed at the expense of wetland areas or wooded areas, biomass production could have negative impacts on the provision of habitat services for wildlife, carbon sequestration or water quality regulation. Conversely, if biomass production is introduced within intensive agroecosystems such as corn-soya production areas, as a rotation crop or a cover crop along riparian banks, for example, then biomass production could contribute to the provision of EGS such as habitat services, soil conservation and nutrient control. One should note, however, that the introduction of biomass production on prime agricultural land could potentially displace a portion of the land used for food production such as corn or soya (Kludze *et al.*, undated). Thus it could potentially revive, although indirectly,the food vs. fuel debate. Such a potential trade-off also exists if marginal land is to be used for biomass production. For example, Kludze *et al.* also show that the acreage of marginal land required to establish a provincial biomass industry would be more important than on prime land. Given the geographic location and distribution of marginal lands in Ontario, a "policy that restricts biomass production to marginal land" may be economically unsound. Furthermore, the displacement of primarily pastures and other forages could minimize potential environmental benefits in terms of soil carbon associated with biomass crops such as switchgrass and miscanthus. As Kludze *et al.* say "while soil carbon benefits have been demonstrated when annual row crops are displaced, conversion of pastures and forage may not realize a benefit."

This concern regarding environmental trade-offs also appears in a study by John and Watson (2007). For them, as far as marginal land and "areas of lower productivity are currently, by neglect or design, in permanent cover, they may well be providing considerable habitat and hydrologic benefit. Unless biomass production standards and/or a system of payments for ecosystem services are put in place to protect existing habitat and hydrologic functions, the demand for biomass may actually diminish the quality of the landscape by encouraging maximization of biomass yield without regard for possible adverse environmental impacts." (John and Watson 2007)

Other trade-offs include the potential threat to biodiversity if biomass production requires the introduction of invasive species, GMOs or an increase in the use of pesticides.

As has been highlighted in previous sections, support for the development and production of purpose-grown biomass has been linked with potential reduction of GHG emissions through the displacement of fossil fuel consumption. Thus, since its inception, agricultural biomass production has been tightly linked with the EGS concept through its carbon credit payments. However, as has been highlighted during our focus groups, the absence of an actual "carbon price" in Ontario is a hurdle to the development of the biomass supply chain for biofuels. The table 5 below presents various EGS that could be impacted by the development of biomass production in Ontario and the relevant level at which they could be valued. For example, while carbon sequestration and storage is a service that benefits the global population, water quality regulation is a service that is used at a local level such as a municipality or a watershed.

Thus a place-based approach is increasingly adopted by policymakers when implementing EGS policies (AAFC, 2011). This kind of approach is also being taken at the federal level reflecting the following on-the field issues:

- Demand for EGS varies from place to place, depending on factors such as incomes, cultural preferences, local priorities and environmental issues, etc;
- Efficiency of farm practices and their impact on EGS provisioning varies from place to place;

These key aspects mean that the scope or range of EGS potentially impacted by biomass production and the farm practices for this production will vary from place to place, as well as the scale of the impact on EGS. The value of these EGS will also vary from place to place depending on the population valuing these EGS. A third aspect to be considered is the following:

- Governance structures vary from place to place.

Overall, this means that policies and potential Payments for Ecosystem Services (PES) mechanisms will have to be adapted to local administrative structures. Thus different stakeholders could be involved to enhance EGS related to biomass production and for a PES scheme to be established**.**

Table 5 - Economic value of potential environmental goods and services (EGS) impacted by biomass production, according to users level.

	EGS	Local level	Regional level	Global level
Direct use	Provisioning goods (e.g. wood, biofuel, materials, food)	X	X	X
	Cultural services (e.g. tourism, aesthetic value, recreational activities	X	X	X
Indirect use	Flood control and water level regulation	X	X	
	Water quality and quantity regulation	X	X	
	Carbon storage and sequestration			X
	Local air quality regulation	X		
	Erosion control and soil quality regulation	X	X	
	Pollination	X	X	
	Habitat and genetic diversity	X	X	X
Options	Future direct and indirect use of above mentioned EGS	X	X	X
Non-use value	Existence and altruistic value	X	X	X

4.3 Assessment of stakeholder consensus regarding the positioning of ON agricultural biomass

4.3.1 Main concerns and objections

The focus group participants have highlighted some general aspects:

- Sustainability is complex and issues are interconnected;
- Given the complexity of these issues, it is difficult and it takes time to engage the public at large;
- Sustainability assessment should be assessed in a given context and to compare different options. It is more relevant to assess whether “Option A or option B is more sustainable” rather than say “Option A is sustainable.”

The sustainability issues most often cited during the focus groups were related mostly to environmental issues. More precisely, greenhouse gases emissions and resource depletion/renewability of the resources were the most common. The other environmental issues mentioned were impacts on biodiversity, water quantity and quality (including groundwater), soil quality and soil conservation, pesticides use and potential indirect land-use change.

There is a delay between current agricultural practices and their potential environmental impacts. This delay makes it difficult to evaluate how beneficial or detrimental one agricultural practice or crop is. For example, it is necessary to have a holistic approach to evaluate whether biofuels are carbo-neutral or not.

Social issues had a less prominent place than environmental issues. Impacts on local infrastructures, local jobs and neighbouring relationships have been cited. Social impacts depend on context (e.g. neighbouring relationships may vary if "new" rural inhabitants). Workers' conditions were not cited by the various stakeholders. It could be that the biomass production in Ontario is not labor-intensive at the farm level (and especially compared to some other biofuel crops such as sugarcane in developing countries), it could also be that it is not an obvious problem in Ontario (e.g. no child labour, etc.). However, we know little about working conditions along the value chain and especially at processing plants.

Two other positive social aspects of biomass production have been mentioned that could contribute to a better quality of life for farmers:

- Biomass production is relatively easy to produce and does not require a lot of capital investment from the producer. Hence, it can be presented as a way to retire progressively, which is a "plus" considering the aging agricultural population;
- The production cycle of biomass crops (e.g. switchgrass) does not conflict with other crops cycle (i.e. it requires time during a period that is otherwise a "down" time for the producer and allows for an easier time management).

However, the need to improve the management capacity among Ontario farmers and executives has also been cited as an issue to be considered in order for the biomass value chain to be really successful.

Economic issues cited included jobs, profits and value-added along the value chain. From the biomass processors' point of view, sustainability issues revolve around the supply safety. For example, is there a guaranteed supply to keep the plant running? Is there a need for a guaranteed price for the farmer and for the processor? Knowledge regarding how the raw biomass has been produced allows to better market the processed biomass. Transportation issues and proximity to plants are also important component of the biomass producer/processor relationship. Guaranteed price at the gate of the plant, monetization of carbon to the end-user and who can cash on it are also issues that are integral to the economic viability of the value-chain.

4.3.2 Public policy and role of governments

Integration of all these dimensions is governments' responsibility. There is an interest in increasing the value added (e.g. biomass fuel has low added value compared with transportation fuel vs. bioproducts).

"There are also potentially conflicting interests between stakeholders, government must be the one levelling the playing field, eventually compensating the stakeholders providing real value.", for example through the implementation of measures allowing for cost internalization - with regard to GHG emissions, biodiversity impacts or other ecological goods and services. The lack of a carbon price is one of the biggest hurdles to the development of biomass supply chain identified during the focus groups.

"There is also a question of conflicting goals in terms of public policy: what is the aim of agriculture, is it to feed people, to produce agricultural commodities, or are there other goals? ("there is a corn shortage but not a food shortage"). It is easier to find new arrangements in a new value chain; there is a need for a better, smarter regulatory approach (e.g. Green Energy Act)

4.3.3 Communication

One of the difficulties mentioned by the stakeholders is the gap between reality/facts and public perception when engaging with the public at large (“this is not a discussion with rational individuals”, “consumers are not necessarily well informed”). Perception regarding impact on food security will always be there; again it is also a question of educating the public at large.

5 Recommendations to the OFA

A key goal of this project is to determine the best framework for Ontario to report about the sustainability attributes of biomass and to assist with the positioning of Ontario products within regulatory and commercial sustainability schemes. Considering the strong public leadership role the Ontario agriculture wants to assume through the OFA and its partners, an inspiring framework is proposed below which tackles a **full life cycle perspective approach to address both environmental and socio-economic issues**.

5.1 An environmental framework

5.1.1 A multicriteria LCA as a starting point

A multicriteria eLCA-based framework is proposed for reporting and communicating on the environmental sustainability attributes of biomass and the sustainable practices of Ontario producers. Although limitations exist which would imply the use of additional indicators (presented thereafter), drivers and arguments pushing in favor of a multicriteria eLCA approach (i.e. beyond the GHG and the single climate change issue) are:

- Water footprinting, in addition to carbon footprinting, is becoming a hot topic for food and non-food bioproducts, and communication on this topic is increasing. There is a growing concern about how sustainable biofuels are regarding water use and water appropriation compared to fossil fuels. Recent U.S. studies in this area showed that U.S. cellulosic ethanol from non-irrigated perennial grass involves, for blue water only, the same range than petroleum gasoline over the full life cycle of the fuel, but 3 to 30 times less (depending on the U.S. location) than corn ethanol (Wu, 2012). New generation biofuels and bioproducts will definitely need to be positioned with respect to both conventional and previous generation ones.
- As previously mentioned, multicriteria eLCA is already enforced in the Swiss jurisdiction for the qualification of a biofuel, and the U.S. EPA might consider utilizing it as part of the 2013 assessment of the Renewable Fuel Standard (RFS2) program.
- There is an increasing lobbying of NGOs on the limits of current standards, criteria, and schemes for industrial biomass certification with respect to overlooked impacts on water and soils, as well as all emissions from indirect land use change (Ernsting, 2012). Despite all limits of current LCA methodologies, LCA demonstrates a strong commitment towards a more comprehensive assessment of all types of impacts, from direct and indirect origin.
- Current studies specifically carried out on the modelling and the assessment of environmental emissions from cropping perennials in Ontario (OMAFRA, 2011b) offer a valuable pool of data that could complement the specific farm data collected throughout the EFPs. Extending the scope of an LCA from the GHG up to a multicriteria assessment requires only a small additional number of data to be collected.
- Agricultural biomass for energy can also be challenged with respect to the high concentration of inorganic nutrients it contains (alkali metals, alkaline earth metals, chlorine, and Silica) that hinder combustion efficiency and end up as air emission (Cennatek, 2011) with potential impact on human health or ecosystem quality. This concern is also beyond the GHG issue.

Furthermore, assessing various technologies to solve this issue (e.g. field leaching, electrostatic separation, reverse osmosis with return of the concentrate for land fertilizing) would make the LCA approach particularly relevant in order to identify the most environmental friendly options that minimize pollution transfers.

- Lastly, LCA can be seen as a tool within an ongoing process for organizing information and knowledge regarding impacts of the biomass for bioenergy and bioproducts. While the LCA methodology is regularly improved with research progress, it nonetheless provides a starting point for discussion and debate regarding potential trade-offs and how to achieve greater sustainability. As LCA science is improved regarding impact assessment methods or data gaps, an existing LCA model can be quickly updated for better representativeness and comprehensiveness of assessment.

Implementing within the OFA strategy an LCA would ease the process of **reporting** and **communicating** to stakeholders and to actors downstream in the supply chain. Thanks to a limited numbers of LCA endpoint indicators related to Human health, Ecosystems quality, Climate change (or carbon footprint), Resources, and Water footprint (see e.g. Figure 2), communication is facilitated. A typical example of efficient communication of such LCA results for the production of the Canadian sphagnum peat moss can be consulted at http://www.tourbehorticole.com/en/responsible-production/analysis.php.

Furthermore, implementing a multicriteria eLCA paves the way to **more comprehensive and objective comparative assessments** of bioenergies, bioproducts and bio-based chemicals **with fossil fuels and petroleum-based products**, especially regarding the use of primary resources.

5.1.2 Auxiliary indicators for temporarily filling up current LCA methodological gaps

Current limitations regarding the granularity of both the spatial scale of assessment of soil-related issues and the archetype of soil cover is a key challenge for the usefulness of LCA for the envisioned biomass production where discriminating between arable land and marginal land characteristics and between annual and permanent cropping characteristics is desired. This issue has been discussed in section 2.2.1.2, including the limitation of existing Canada-specific characterization factors for life cycle impact assessment phase of an LCA.

Introducing auxiliary indicators in addition to typical LCA indicators poses no concerns provided that the resulting information is communicated carefully and transparently. A similar approach is used within the AgBalance™ methodology (Schoeneboom *et al.*, 2012) to assess the sustainability for agricultural products and processes although this specific methodology has scientific limitations, some of which are presented in section 1.4.2. Furthermore, the envisioned auxiliary indicators are also in agreement with those proposed for instance 1) by the *Field To Market, the Keystone Alliance* (2009) in the U.S. and also adapted within a Canadian context for seven crops by Pulse Canada and the major associations of producers in Western Canada (Pulse Canada, 2011), and 2) by Agriculture and Agri-Food Canada's agri-environmental indicators series (Eilers *et al.*, 2010). The main soil-related auxiliary indicators relevant in the context of the Ontario biomass production would be related to:

- Land occupation, by land cover types and quality (as ha.year) with information about marginal vs. arable land use;
- The soil organic matter balance or change from a baseline reference (as kg of C/ha);
- Soil erosion (as t of eroded soil/ha.year), which could eventually be disaggregated between wind, water, and soil tillage erosion;
- The nutrient content balance or change from a baseline reference (as kg of nutrient/ha).

Preferably, these indicators should be calculated according to a Canadian methodology. Hence, the above-mentioned Canadian methodological descriptions should be used, together with the OMAFRA framework (2011a) when it will be finalized (especially regarding the use of the revised Universal Soil Loss Equation 2). Noteworthy is that most of these indicators are addressing the issues covered by the land use midpoint indicators that are currently being developed by most advanced life cycle impact assessment methods, except the water purification and freshwater recharge services provided by soil. Additional indicators for these latter could be developed from life cycle impact assessment science if judged relevant to the context of Ontario biomass.

5.2 A socio-economic framework

A social LCA of Ontario biomass production would also help position Ontario biomass production relative to other competitive resources. As has been noted in previous sections, various standards are already in place in Europe and in the U.S., which qualify sustainability performance with regard to social criteria. A sLCA of biomass production in Ontario would define and document sustainability criteria and indicators regarding the following issues of concern:

- Socio-economic well-being;
- Local development;
- Human and labour rights;
- Potential land and resource conflicts;
- Local food security.

The mere fact of gathering and analyzing socio-economic data from actual activities in Ontario would allow the OFA and other Ontario biomass value-chain stakeholders to present decision-makers with objective data that may not have been documented for competing resources. For example, an sLCA of Ontario biomass production could present the local economic impact stemming from biomass production and processing and compare it with non-domestic fuel/gas supply, or fossil-fuel based chemicals. As land-use and resource conflicts regarding fossil fuels extraction are getting more controversial, an assessment of locally produced and renewable alternatives would be useful for decision-makers.

The sLCA framework proposed would be based on the UNEP/SETAC framework as well as the FAO SAFA guidelines (2012) and could be adapted to Ontario context, along the lines proposed in section 2.1.3. One should note that a sLCA of Ontario biomass production could be useful not only for Ontario biomass producers, but also for the other stakeholders downstream along the supply chain in order to qualify their sustainability performance with objective data.

5.3 Conclusion and Further steps

An inspiring framework based on LCA is proposed to address the environmental and socio-economic attributes of the Ontario biomass. Such a framework, combining eLCA, auxiliary environmental indicators and sLCA, ensures the compliance with eLCA 14040 standards series (ISO, 2006), sLCA guidelines (UNEP/SETAC, 2009), and with most sophisticated certification schemes mentioned throughout this report. Furthermore, it also meets the features of the most innovative sustainability schemes that are emerging which combine environmental and socio-economic assessment and are also based on LCA standards (e.g. the AgBalance™ methodology, the SAFA guidelines from the FAO).

The proposed framework should offer the OFA and its partners the opportunity to assume a strong public leadership role for Ontario agriculture. It is believed that Ontario-contextualized data is available for calculating the key-contributing life cycle inventory (LCI) data necessary for building up quite representative LCA models for perennial crops and for residues from crops. For reporting purposes, additional ecological indicators can complete the eLCA results. The LCI data or LCA results (possibly limited to GHG) could be provided to actors downstream the supply-chain in charge of assessment of products processed from the biomass. Most advanced standards for certification (e.g. the RSB standard) allow some freedom about the way the eLCA is technically performed, provided it is done transparently, with consistency, and that the compliance with LCA standards is ensured. It is recommended to address some key modelling issues cautiously with the help of the most advanced LCA guidelines, such as the ILCD handbook (European Commission, 2010). An example is the way co-products (e.g. crop residues remove from the field) are considered and accounted for within the LCA model.

Lastly, it is recommended to be cautious about the level of aggregation of the information reported to stakeholders and to the large public. For instance, reporting a single score of sustainability as proposed by the AgBalance™ methodology may convey too many subjective weighing assumptions, and is likely to reduce the expected credibility.

5.3.1 Towards a single assessment tool

As mentioned, implementing a multicriteria LCA completed with auxiliary indicators where current weaknesses of LCA is advised as a starting point. LCA is *per se* an iterative process where assumptions, model, analysis and interpretation are improved along when performing the LCA, but also when revising and updating it. The final decision about which auxiliary indicators to add should be taken at the moment of the first realization of the LCA, considering data gaps and impact assessment method(s) limitations.

Given that work is underway regarding the development of specific data about Ontario perennials production that will be required for life cycle inventory (OMAFRA, 2011b), as well as regarding ongoing research developments aiming at enhancing characterization models for direct land use and their aggregation into a simplified indicator through ecosystem service modeling (Cao *et al.* (2012) and his current PhD work at CIRAIG), there are already opportunities in the short- and mid-term for performing quite robust LCAs where initial auxiliary soil-related indicators could be removed from the reporting framework.

5.3.2 Responsible biomass production instead of carbo-neutrality

Considering indirect land use changes (iLUC) is a step towards a systems approach where a complex landscape system that produces a variety of ecosystem services is also linked to large scale energy and crop models. Such a true system approach allows for proper accounting of market and non-market feedbacks, and for a better understanding of the full ramifications, direct and indirect, of actions (Dodder *et al.*, 2011). As discussed previously (section 2.2.2.3), not accounting for iLUC GHG emissions within LCA is acknowledged by scientists, policy people and NGOs as a key issue for bio-based product, and especially for bioenergy when compared with fossil fuels. Methodologies exist but the appropriate, consensual, and easy-to-implement one has not been determined yet. How iLUC GHG will be accounted for within the OFA framework for Ontario biomass will have to be discussed.

Furthermore, considering the criticism of the principle of carbon neutrality of biomass because of the questioning about temporal aspects of GHG emissions and removals, and of the incomplete consideration of indirect land use change GHG (section 2.2.2), it is recommended to avoid communicating using the term of *carboneutral* when speaking about biomass feedstock and bioenergy. Instead, **communicating about *responsible biomass production*** would be a wiser approach, since economical and social sustainability aspects will also be considered together with environmental attributes.

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Appendix A - Stakeholders Categories

Stakeholders categories	Impact subcategories (impact categories[1])
Workers	Freedom of Association and Collective Bargaining (HR) Child Labour (HR) Fair Salary (WC) Working Hours (WC) Forced Labour (HR) Equal opportunities/Discrimination (GV) Health and Safety (HS) Social Benefits/Social Security (WC)
Consumers	Health & Safety (HS) Feedback Mechanism (GV) Consumer Privacy(HR) Transparency (GV) End of life responsibility (GV)
Local communities	Access to material resources (HR) Access to immaterial resources (HR) Delocalization and Migration (HR) Cultural Heritage (HC) Safe & healthy living conditions (HS) Respect of indigenous rights (HC) Community engagement (SR) Local employment (SR) Secure living conditions (HR)
Society	Public commitments to sustainability issues (GV) Contribution to economic development (SR) Prevention & mitigation of armed conflicts (GV) Technology development (SR) Corruption (GV)
Value chain actors	Fair competition (GV) Promoting social responsibility (GV) Supplier relationships (GV) Respect of intellectual property rights (GV)

[1] HR – Human Rights; WC – Work conditions; HS – Health and Safety; CH – Cultural Heritage; GV – Governance; SR – Socio-economic Repercussions.

Source: UNEP/SETAC 2009, p.49 and adapted by **AG**ECO Group.

B -
List of Selected Indicators

Impact subcategories	Indicators	Type	Unit	Selected sources(*)
Workers				
Freedom of Association and Collective Bargaining	Possibility to negotiate collectively wages and working conditions	Binary	Yes/No	**RSB 2010, EUC (2009), CSBP (2011)**
	Compliance with labour laws	Binary	Yes/No	**CSBP (2011), RSB (2010)**
	Use of labour contracts	Binary	Yes/No	**CSBP (2011), RSB (2010)**
	Percentage of employees covered by collective bargaining agreements	*Quantitative*	*%*	*GRI (2010)*
Child Labour	Use of underage workers	Binary	Yes/No	**EUC (2009), RSB (2010), Nordic Ecolabel**
Fair Salary	Fair wage (wage adequate for a person to survive on)	Binary	Yes/No	Kruse *et al.* (2009)
	Employees' average wages vs. national minimum salary	Quantitative	Ratio	Paragahawewa *et al.* (2009), **GBEP (2011)**
Working hours	Working hours do not exceed the legal threshold	Binary	Yes/No	Caldeira Monteiro *et al.* (2008), **RSB (2010)**
	Employees' average working hours vs. national norms	Quantitative	Ratio	Generic
Forced Labour	Use of forced labour	Binary	Yes/No	Franze and Ciroth (2011), **EUC (2009), RSB (2010), Nordic Ecolabel**
Equal opportunities /	Policy on equal employment and against	Binary	Yes/No	GRI (2010), **EUC (2009), RSB**

Discrimination	discrimination			**(2010)**
	Employees' average wages according to gender, age group, minority group membership, and other indicators of diversity.	Quantitative	$/h by category	GRI (2010) **EUC (2009), RSB (2010)**
	Ratio of basic salary of men to women in industry sector/region	Quantitative	Ratio	**Blom (2009)**
	Composition of governance bodies according to gender, age group, minority group membership, and other indicators of diversity.	Quantitative	% by category	GRI (2010)
Health and Safety	Policy on health and safety training	Binary	Yes/No	GRI (2010), **CSBP (2011), RSB (2010)**
	Rate of (fatal) accidents	Quantitative	Number of accidents	Kruse *et al.* (2009), **Blom (2009), GBEP 2011)**
	Compliance with ILO convention 184	Binary	Yes/No	**RSB (2010)**
	Level of exposure to hazardous substances or tasks	Semi-quantitative	Ordinal scale of level of exposure	Lord (2011)
	Insurance against workplace injury	Binary	Yes/No	**CSBP (2011)**
	Additional benefits	Binary	Yes/No	**CSBP (2011)**
Social Benefits/Social Security	Policy on social security (retirement; unemployment; health; accident; disability; etc.)	Binary	Yes/No	Kruse *et al.* (2009), **Blom (2009)**

Professional accomplishment	Career progression plan policy (training, education, job opportunities, etc.)	Binary	Yes/No	Paragahawewa *et al.* (2009)
	Company's level of training and development opportunities offered to employees	Semi-quantitative	Ordinal scale of level of opportunities offered	GRI (2010)
	Work satisfaction	Qualitative		Lähtinen (2011)
	Share of trained workers in the bioenergy sector out of total bioenergy workforce	Quantitative	%	**GBEP (2011)**
Local communities				
Local economy	Policy on local supply and hiring	Binary	Yes/No	GRI (2010), **RSB (2010)**
	Contribution to local employment and economy	Quantitative	%	GRI (2010), **GBEP (2011)**
	Contribution to skill-training program	Quantitative	$	**RSB (2010)**
	Net tax contribution to the local community	Quantitative	$	Paragahawewa *et al.* (2009)
Community engagement	Policy of altruistic donations within the community (sponsorship, etc.)	Binary	Yes/No	Paragahawewa *et al.* (2009)
	Company's degree of dialog with the local community	Semi-quantitative	Ordinal scale of degree of dialog	Hayashi and Sato (2010)
	Level of participation to networks disseminating social capital (local groups /	Semi-quantitative	Ordinal scale of level of	**Generic, Lähtinen *et al.* (2011)**

	associations / comities)		participation	
Safe & healthy living conditions	Level of inconveniences (noise, vibration, dust, moist, etc.) and risk exposure induced by the company on local community	Semi-quantitative	Ordinal scale of level of inconvenience and risk exposure	Caldeira Monteiro *et al.* (2008)
	Company's efforts to prevent and mitigate potential or actual negative impacts of its activities on local communities	Semi-quantitative	Ordinal scale of level of efforts	GRI (2010)
	Health and safety effects caused by operation	Qualitative		**Blom (2009)**
Landscape management and access to material resources	Estimated level of the company's contribution to local infrastructures and services	Semi-quantitative	Ordinal scale of level of estimated contribution	Van Calker *et al.* (2005)
	The company contributes in a significant manner to the development or the upkeep of local living environment (architectural quality / landscape / visual amenity etc)	Binary	Yes/No	Lord (2011)
	Estimated level of the company's contribution to local living environment	*Semi-quantitative*	*Ordinal scale of level of estimated contribution*	*Van Calker et al. (2005)*
	Usage of scarce resources	Binary	Yes/No	***Blom (2009)***
	Water quantity - Company uses for irrigation only water for which it held legally valid use rights before	Binary	Yes/No	**CSBP (2011)**

	commencement of biomass production or rights that have been subsequently acquired through legal means			
	Multiple-use (e.g. recreation) of biomass production site	Qualitative		**Lähtinen *et al.* (2011)**
	Maintenance or enhancement of ecosystem services	Qualitative		**CSBP (2011)**
	Land price	Quantitative	$	**Van Dam *et al.* (2009)**
	Impact on food availability at a reasonable price	Qualitative		**EUC (2009), RSB (2010**
	Water use per functional unit	Quantitative	L/functional unit	**Blom (2009)**
Land acquisition, delocalisation and migration	The company respects existing land-use rights	Binary	Yes/No	**EUC (2009), RSB (2010)**
	Percentage of land used for new bioenergy production where a legal instrument or domestic authority establishes title and procedures for change of title; and the current domestic legal system and/or socially accepted practices provide due process and the established procedures are followed for determining legal title	*Quantitative*	Percentage	**GBEP (2011)**
	Area of land required per functional unit	Quantitative	ha	**Blom (2009)**
	Land acquisition expansion	*Quantitative*	*ha*	**Blom (2009)**

	Delocalisation of other feedstock	*Quantitative*	*ha*	**Blom (2009)**
	Migration	*Quantitative*	*ha*	**Blom (2009)**
Social capital	Existence of cohabitation issues (noise, vibration, dust, etc.)	Binary	Yes/No	Hayashi and Sato (2010)
	Transparency – availability of results of certification audits and general information related to producing sustainable biomass	Binary	Yes/No	**CSBP (2011)**
	Collaboration with neighbors, regulatory and conservation authorities and local stakeholders in the monitoring of the impacts of GMO	Binary	Yes/No	**RSB (2010)**
SOCIETY				
Public commitments to sustainability issue	Company has contracted commitments in regards to sustainability issues	Binary	Yes/No	Paragahawewa *et al.* (2009)
	Number of commitments	Quantitative	Number	Generic
	Share of the company's activities covered by the commitments	Quantitative	% value of production	Generic
	Coercion degree of the commitments	Semi-quantitative	Ordinal scale of degree of coercion	Generic
	Company has been or is presently sanctioned for noncompliance with laws and regulations associated to sustainability issues	Binary	Yes/No	GRI (2010)

	Number of sanctions or total value of fines incurred by the company for its noncompliance	Quantitative	Number or value ($)	Idem
	Company is committed toward ecological or biological specifications in regards to use of GMOs or chemicals in production process	Binary	Yes/No	Idem
	Energy diversity - Change in diversity of total primary energy supply due to bioenergy	Semi-quantitative	Index ranging 0-1	**GBEP (2011)**
Contribution to economic development	Company (or product) has a significant impact on the economy	Binary	Yes/No	UNEP/SETAC's methodological sheets
	Total contribution to employment and economy	Quantitative	%	Generic, **GBEP (2011)**
		Quantitative	Number per MJ or MW	**GBEP (2011)**
	Total net tax contribution to the State	Quantitative	$	Generic
	Price and supply of a national food basket	Quantitative	$	**GBEP 2011**
Technology development	Program (funding) in R&D aiming at improving the efficiency and environmental soundness of the product	Binary	Yes/No	UNEP/SETAC's methodological sheets
	Total investment in R&D	*Quantitative*	*$*	*Generic*
Corruption	Company has been or is presently sanctioned for corruption	Binary	Yes/No	GRI (2010)

	Evaluation program and training policy to prevent and fight corruption	Binary	Yes/No	Idem
VALUE CHAIN ACTORS				
Fair competition	Company can influence market prices	Binary	Yes/No	Franze and Ciroth (2011)
	Existence of government incentives	Binary	Yes/No	**Blom (2009)**
	Company has been or is presently sanctioned for anticompetitive behaviour	Binary	Yes/No	GRI (2010)
	Number of sanctions	*Quantitative*	*Number*	*Idem*
	Severity of the sanctions	*Semi-quantitative*	*Ordinal scale of the severity of sanctions*	*Idem*
	Compliance with the regulatory rules of the supply management policy	Binary	Yes/No	Generic
Promoting social responsibility	Policy promoting social responsibility	Binary	Yes/No	GRI (2010)
	Share of total purchases that is subject to social responsibility criteria	Quantitative	%	Idem
	Share of total suppliers that are subject to control from the company in regards to social responsibility	Quantitative	%	Idem
	Monitoring procedure in place to ensure the respect of labour rights and human rights when labour is contracted through third parties	Binary	Yes/No	**RSB 2010**

Supplier relationships	Company has been or is presently prosecuted for non-compliance to contractual agreements	Binary	Yes/No	Generic
	Company is involved in inter-sectorial associations or marketing board comities	Binary	Yes/No	Generic
	Compliance to policies or initiatives that promote transparency and fairness in the supply chain	Binary	Yes/No	Generic
Respect of intellectual property rights	Company has been or is presently prosecuted for violation of intellectual property rights	Binary	Yes/No	UNEP/SETAC's methodological sheets

(*) Note: Standards and articles specific to biomass production are highlighted (bold). The other sources are related to sustainability indicators in general but do not focus on biomass supply chain.

Appendix C - Land use midpoint indicators in life cycle assessment method; land use types and spatial resolution of Canadian characterization factors

Input parameters for the development of Canadian characterization factors for 4 soil-related land use midpoint indicators (erosion resistance potential, mechanical water purification potential, physico-chemical water purification potential, and freshwater recharge potential) at the Canada (x 1), ecozone (x 15), and ecoregion (x 193) scales (Saad *et al.*, 2011).

Table 3 Spatially resolved input parameters for the three scale levels

Input parameter		Data range value			Description and source
		Canada generic	Ecozone	Ecoregion	
Soil properties	Soil texture	Loam	All	All	Harmonized Soil Database data sets[a], Canada Ecoatlas[b]
	Organic matter content (%)	8.57	1.85 to 59.03	1.12 to 70.52	SOM can range from 48 to 58% C (Nelson and Sommers 1996). SOM was calculated based on an approximate factor of 1.8 times SOC. The latter was calculated using the Harmonized Soil Database datasets[a]
	Gravel content (%)	11.69	1.12 to 18.27	1.08 to 26.0	Harmonized Soil Database datasets[a]
	CEC ($cmol_c$/kg)	19.97	8.99 to 99.18	5.00 to 120.97	Harmonized Soil Database datasets[a]
	pH	5.89	4.77 to 7.18	4.50 to 11.49	Harmonized Soil Database datasets[a]
Landscape and climatic conditions	Depth to groundwater (m)	Fixed value to 3 m[c]			Since water table levels are highly dynamic and fluctuate over time and seasons, depth to groundwater was considered constant in the model
	Annual precipitation rate (mm/year)	473.84	184.40 to 1914. 90	149.40 to 2202.60	Terrestrial Ecoregions Base Global datasets[d], Canada Ecoatlas[b]
	Annual evapo-transpiration rate (mm/year)	234.02	77.76 to 523.69	25.20 to 580.95	Terrestrial Ecoregions Base Global datasets[d], Canada Ecoatlas[b]
	Slope (°)	1	0 to 25	0 to 25	HYDRO1k Elevation Derivative Database[e]

[a] (FAO et al. 2008)
[b] (Marshall et al. 1999)
[c] Average value (Stone and Myslik 2007)
[d] (Olson et al. 2001)
[e] (US Geological Survey and Earth Resources Observation and Science (EROS) 2009)

Land cover classification used to develop Canadian characterization factors for 4 soil-related land use midpoint indicators (erosion resistance potential, mechanical water purification potential, physico-chemical water purification potential, and freshwater recharge potential) at the Canada (x 1), ecozone (x 15), and ecoregion (x 193) scales (Saad *et al.*, 2011).

Table 2 Selected land use types from CORINE land cover classification

Level 1	Level 2
Artificial	Urban
	Artificial non-agriculture vegetated area
Agriculture	Permanent and annual crops
	Pastures
Forest	Forest
	Grassland
	Shrubland
Wetlands	Excluded

Appendix D - Focus Groups Participants (Toronto, 30th of July 2012)

List of participants:

- Agricultural Adaptation Council;
- Agriculture and Agri-food Canada;
- Canadian Federation of Agriculture;
- Ontario Agri-Food Techonologies consortium;
- Ontario Biomass Producers Co-op;
- Ontario Ministry of Agriculture Food and Rural Affairs;
- Ontario Ministry of Environment;
- Ontario Power Workers' Union;
- Remasco;
- Sustainable Chemistry Alliance.