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The Economic, Environmental and Social Impact of Biofuel Production

Strategic Sustainability of Biofuel Production in Brazil and Canada

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## List of Acronyms

<b>GHG</b>	Greenhouse Gas
<b>GMO</b>	Genetically Modified Organism
<b>Ha</b>	Hectare
<b>LCA</b>	Life Cycle Assessment
<b>MSPD</b>	Method for Sustainable Product Development
<b>NGO</b>	Non-Government Organization
<b>SLCM</b>	Strategic Life Cycle Management
<b>SPD</b>	Sustainable Product Development
<b>SSD</b>	Strategic Sustainable Development
<b>TSPD</b>	Template for Sustainable Product Development

# 1- Introduction

Issues associated with our dependence on fossil fuels, such as energy security, and green house gas (GHG) emissions, has driven global interest in the displacement of fossil fuels by Biofuel. Demand for transportation energy is expected to increase the most in the coming decades, over electricity or industrial uses (IEA 2004), and this demand will largely be for liquid fuels.

Biofuel do present an opportunity to displace fossil fuel use in meeting some of the energy demand for current transportation needs, and provide a solution to the challenge of transitioning to a sustainable society.

Currently Biofuel meet a variety of human needs, including:

- 1- Energy for mobility using existing infrastructure
- 2- Energy for electricity, and domestic heating
- 3- Cleaner atmosphere from reduced emissions
- 4- National security by using more local energy production
- 5- Poverty alleviation, as Biofuel could provide greater income for the agricultural sector, employment in rural areas, and community development.
- 5- Additional needs met by other products from Biofuel and associated co-products include: paint; lubricants; bio-plastics; biopolymers; pesticides; glycerin; organic fertilizers; and also biomass for electricity generation.

Transportation energy demands are expected to surpass that of other energy sectors in the coming decades, based on current trends, and current ethanol and bio-diesel production is not sufficient to displace all fossil fuels at current or projected consumption rates (IEA 2004).

The issues that are associated with Biofuel production could include but not limited to the followings:

- 1- The net greenhouse gas effect of Biofuel is positive
- 2- Development might require the use of 11.1 million hectares of *set-aside* land in our case study (Brazil and Canada)
- 3- A regulated approach to Biofuel development could save approximately 15.1 Million m<sup>3</sup> of ethanol in Brazil and 91 Million litter in Canada
- 4- Biofuel remain more expensive than their fossil fuel equivalents
- 5- A regulated approach to Biofuel development could be a good source of employments
- 6- The food/fuel issue required further understanding.

This paper will discuss the methanol and bio-diesel production and its implication in for sustainable development in Brazil and Canada in term of its potential and challenges and sustainability.

## **2- Description**

Many concerns have been raised about the competition between land for food versus energy production, especially in the context of future rising populations, increasingly shortage of resources, and the perpetuation of ecologically and socially unsustainable agricultural practices. The International Energy Agency predicts that, based on current trends, the increased demand for oil in the coming decades will come largely from the transportation sector, and Biofuel are expected to play a large part in displacing fossil fuels for transportation. With the fast growth of the industry comes the urgency for a strategy of sustainable Biofuel production, while it is still in relatively infantry stages, in order to maximize ecological and social returns.

This paper attempts to answer three main questions, with a scope limited to bio-ethanol production in Brazil and bio-diesel production in Canada:

- 1- What are some major sustainability opportunities and challenges of the Biofuel industry?
- 2- What is the current state of Biofuel operations in Brazil and Canada,
- 3- What first steps toward sustainable Biofuel development can be identified?

The response to these questions was researched using tools incorporating a strategic sustainable development (SSD) approach, as conceived by The Natural Step Framework. Strategic Sustainable Development (SSD) is a planning tool using back-casting from sustainability principles, which assists in dealing with problems strategically rather than one by one as they appear. Back-casting is the approach where a successful outcome is imagined followed by a plan of action of how to get there from today.

Sustainability Principles are defined by The Natural Step Framework as:

In a sustainable society, nature is *not* subject to systematically increasing...

- 1- Concentrations of substances extracted from the Earth's crust.
- 2- Concentrations of substances produced by society
- 3- Degradation by physical means, and, in that society
- 4- People are *not* subject to conditions that systematically undermine their capacity to meet their needs.

The paper also explored the combination of scientifically traditional and non-traditional approaches of sustainability. Traditional Life Cycle Analysis (LCA) is a tool that evaluates impacts of a product throughout its life cycle, from product design to end use, or "cradle to grave." Strategic Life Cycle Management is based on LCA, however has incorporated SSD by including back-casting from sustainability principles. This allows for an analysis of the industry from a bird's eye perspective, capturing broadly the industry's sustainability opportunities and challenges. Establishing this initial broad perspective provided a sustainability direction at the outset, from which a traditional LCA can later proceed.

Sustainable design of products and services has been described as a critical intervention point in moving society toward sustainability. Sustainable Product Development (SPD) methodology, combined with back-casting from sustainability principles was also extensively explored in this paper. Templates, or questionnaires, were created for certain stages of Biofuel design and development, which provided a venue of engagement for industry, stakeholders (such as regulators and nongovernmental organizations), and sustainability experts. The result was the Template for Sustainable Product Development (TSPD) for Biofuel, intended to simplify and strategically guide industry's efforts toward sustainability. The TSPD can be used by anyone involved or interested in the industry, and can be continually updated as the industry evolves.

First steps toward sustainable Biofuel production involve new technologies and feed stocks, government policies and support, sustainable certification systems, and further research and development by industry.

Incentives for sustainable Biofuel production are lacking for industry, and there is much work to be done in this area. Governments have not used public policy instruments enough to address sustainability challenges of Biofuel. Both Canada and Brazil currently mandate the inclusion of Biofuel blends as a percent of total fuel sales. This could be coupled with a requirement that Biofuel be sustainably produced, according to an

independent certified body's standards. Beside, research and development efforts of emerging Biofuel technologies should also be supported by governments to address a product's sustainability performance.

The TSPD for Biofuel developed in an attempted to provide a tool for industry that would reduce the complexity involved in improving a product's sustainability performance at various life-cycle stages. The TSPD approach originally was developed to guide and simplify sustainable product development for other sectors of industry. While the TSPD for Biofuel did improve stakeholder participants understanding of Biofuel sustainability issues, the approach itself still requires further research to determine its full potential.

Educational institutions and non-government organizations could play an important role in developing sustainable production certification systems for Biofuel. Without them, the adoption of sustainable production practices on the part of industry will only occur at an unacceptably slow pace. Efforts in this area are ongoing and due to the complexity involved in standards and certification systems, along with the lack of attention and support of government and the public, will likely not influence production practices for some time.

### **3- General Analysis**

Despite the problems posed by broad-scale use and production of Biofuel like ethanol and bio-diesel such as, among others, the requirements of a large area of land to be set aside, food shortage, child labor, and others, the advantages they offer in the transition to a sustainable society cannot be ignored. Liquid Biofuel are not only a viable alternative to fossil fuels, they may offer the only alternative available in meeting today's transportation energy needs (providing energy conservation and efficiency also play an equally significant role) and present an excellent transitional technology to more sustainable long-term options. They do not require huge social and economical transformations in meeting energy needs, for example in requiring large changes in our current infrastructure for producing the energy, or in the technology necessary for using the energy (with some exceptions they can be used with existing vehicles). For this reason they are considered a transitional technology, allowing society the opportunity to immediately begin moving away from the use of fossil fuels, as we explore and develop the commercial and technological viability of longer term sustainability alternatives.

Emerging alternatives to current feed-stocks and technologies for the production of liquid Biofuel must provide improvements to current sustainability challenges. Currently, cellulose and wood crops are the most promising of these new technologies, potentially producing ethanol more efficiently than current technologies, and using much less fossil fuels in production (IEA 2003). Further research, led by industry, is needed to make this option economically viable, and assistance by governments is crucial to help lower costs and assist in the transition to a more sustainable transportation options (Gielen & Unander 2005).

However, many products initially considered safe are often introduced without a thorough understanding of their social and ecological implications. This has often resulted in costly damage to the biosphere, as discovered with freons (CFCs) and their subsequent damage to the ozone layer (Geiser 2001).

Many of these environmental problems can be eliminated through strategic planning mechanisms early at the product or process design stage, rather than through “end-of-pipe” solutions, as is so often the case. Companies believe that beyond a certain point in the design process, it is extremely difficult to alter certain product features that are key to the environmental performance (Bhamra et al 1999). Improving a product’s environmental performance can be achieved through the “upstream” approach of sustainable product development (SPD).

SPD provides a powerful leverage point in not only addressing the sustainable design of a product, but also the sustainable development of an entire industry. This paper explored the usage of the SPD tool referred to create the Template for SPD (TSPD) (Ny et al.). The template could be developed through engagement of experts knowledgeable both in sustainability, and in the product under assessment. Through a series of sustainability-based questions and statements about the product, the social, ecological and economic/strategic sustainability data / information for that product evolves, and the resulting “template” can be used as a communication or educational tool, by industry or stakeholders.

To date, application of TSPD has been limited to a single producer, Matsushita Electric Group (Matsushita) in Japan (Ny et al.), and three of its representative products; televisions, refrigerators and recycling plants. The initial success of this project however has led to plans to expand the template to other applications (Grierson and Durgin 2005). The approach developed for the product category of televisions was applied to ethanol and bio-diesel categories.



Using the SPD approach would provide a huge numbers of tools for environmental management and monitoring of sustainable development. Taken together they can be complex, however many can complement each other, and be made more strategic. For example, Life Cycle Analysis (LCA) is a traditional tool used to determine environmental impacts throughout the life cycle of a product or process, from design to end use, or “cradle to grave.” This tool however does not offer a sustainability perspective or assist in strategic planning (Andersson et al. 1998).

By applying strategic sustainable development (SSD) to the LCA analysis, the industry’s main sustainability opportunities and challenges are captured, and strategic planning with a sustainability objective is then possible. This approach is called Strategic Life Cycle Management (SLCM) (Ny et al. 2006) that can be used in the development of the TSPD for Biofuel.

SSD is based on “back-casting from sustainability principles,” which involves envisioning a sustainable future, and asking the question, what can we do now to get there from here (J.B. Robinson 1990)?

The general outlines of sustainability questionnaires, with regard to ethanol production in Brazil, and bio-diesel production in Canada could be as follows:

- A- What are some major sustainability opportunities and challenges of the Biofuel industry?
- B- What is the current state of Biofuel operations in Brazil and Canada?
- C- What first steps toward sustainable Biofuel development can be identified?

Through the development of such templates within the relatively new Biofuel sector, the aim to further refines this approach and methodology to improve its effectiveness to be used by the industry or stakeholders.

## **4- Actualization - Case Study**

The review of the current state of the industry has revealed that there are already a number of sustainability opportunities being used by the industry, and many challenges remain. In the following sections, the current reality of the Biofuel industry, in terms of sustainability opportunities and challenges, are analyzed for bio-ethanol production in Brazil, and bio-diesel production in Canada, according to our predetermined project scope.

### **4.1- Sustainability Analysis of Ethanol Production in Brazil**

#### **4.1.1 Sugarcane Agricultural Production**

The sugarcane agricultural industry in Brazil was analyzed using the SLCM tool, with life cycle processes and activities scrutinized using the four sustainability principles. Sugarcane is the main feedstock cultivated for ethanol production in Brazil. It is cultivated on about 5.5 million hectares, in 27 states of Brazil. A variety of species are available and production technology has been continuously refined to increase productivity of tones per hectare and also to increase sucrose content (Macedo and Nogueira 2005).

The sugarcane agro-industry employs more than 1 million Brazilians, including sixty thousand sugarcane producers and 300 ethanol plants (Macedo and Nogueira 2005). Over 80% of the cane harvest is cut manually, and burning the sugarcane fields before harvesting is a practice used to enhance productivity at the mill by avoiding extra cleaning operations. Burning also reduces the risk of workers encountering poisonous snakes. Legislation has been introduced to phase out burning and mechanized harvest is gradually increasing, consequently resulting in loss of jobs. This requires realistic government policies to address labour issues, as well as the consequences that follow mechanization practices, such as soil erosion, fossil fuel consumption, and its environmental consequences.

Diseases in sugarcane are avoided by using an appropriate selection of resistant varieties and biological control of pests and insects, but today persistent agrochemicals are also used. Chemical fertilizers are applied and their performance improved when used with bio-fertilizers from sugarcane processing activities, such as filter pie. To avoid soil degradation and contamination of water resources it is necessary to minimize and control the use of both biological and chemical products.

This is a practice that has already been implemented. There is no need for irrigation in most areas as the Brazilian climate is well suited to the growing requirements for sugarcane cultivation with a rainy period for development, followed by a dry period for maturation and harvest.

Initiatives to expand the industry have resulted in a need to double current levels of ethanol production, to 230 million tons of cane/year, by 2013. This represents an additional agricultural area of 2.2 to 3 million hectares for agriculture. This expansion must be linked with sustainable technologies for electric energy generation, including use of cane residues in agriculture (according to Brazilian Governmental Strategies) (Macedo and Nogueira 2005).

#### **4.1.2 Ethanol Processing Industry**

The industry in Brazil was analyzed according to the four sustainability principles. Ethanol in Brazil is currently produced by more than 320 processing units which own approximately 70% of planted area that supplies its needs for sugarcane. The remaining 30% is supplied by 60 thousand producers, most of them small. The total volume produced during 1995/96 represents around 15.5 Mm<sup>3</sup> (million cubic meters) (Macedo and Nogueira 2005).

Almost all equipment used for industrial processes is produced by national companies that are capable of supplying the previously identified expansion needs. Despite dependence on fossil fuels to expand production infrastructure its important to consider that industrial emissions in general have decreased significantly due to current legislation and are currently substantially controlled compared to the beginning of the ethanol program in the 1980's (Macedo and Nogueira 2005).

The levels of intake and effluent of water for industrial use have been substantially reduced in recent years and treatment efficiency of effluent are above 98%. The sector target is zero effluent emissions, reusing residual water for irrigation. Also technology for cleaning the raw cane was substituted for dry cleaning, without liquid effluents, reducing the water demand (UNICA – Sugarcane Producers Association 2004).

The sector currently produces more than 1,500 MW of electrical energy from combustion of biogases residues, contributing to producer's self sufficiency and representing a long term potential to produce up to 12,000 MW for the national grid (Pereira 2005).

It is also important to consider that the whole range of products obtained from petroleum oil can also be obtained within the same ethanol

production structure. Several biopolymers are produced from ethanol today as polystyrene, acetone, styrene, acetic acid. Products for use in beverage, pharmaceutical and paint industries. Fertilizers such as filter pie, biodegradable components for fungicides, pesticides and herbicides, animal food and several types of paper can be produced from biogases. Syrup for cosmetics production and also the mix of sugar and biogases is used to produce biodegradable plastics.

#### **4.1.3 Ethanol Combustion**

Ethanol combustion was analyzed according to the four sustainability principles. Ethanol use contributes to the reduction of GHG and the sector promotes the reduction of approximately 18% of fossil fuel emissions in Brazil (Nastari et al. 2005). Ethanol is responsible for significant reductions of atmospheric pollution in urban areas, enabling the elimination of lead in gasoline, sulfur, sulfates compounds, reduction of Volatile Organic Compounds (VOC's) emissions, and consequently toxicity. It is estimated that the social costs avoided due to these environmental benefits in order of 167 million euros per year (Nastari et al 2005).

## **4.2 Sustainability Analysis of Bio-diesel Production in Canada**

Current bio-diesel production in Canada has both sustainability opportunities and challenges in all life cycle stages. These are outlined in the following sections.

### **4.2.1 Bio-diesel Agricultural Feedstock Production**

Sustainability impacts are linked to the manipulation of natural systems and processes through physical and mechanical processes and chemical alterations of soil and water resources. Within the agricultural production process the following sub-processes with significant issues associated with them were identified.

- Seed Application
- Fertilizer Application
- Land Preparation
- Fertilizer, herbicide and pesticide application
- Irrigation
- Harvesting

Canola, also known as *Brassica rapa*, and as “rape seed” in Europe, is the dominant oilseed produced in Canada accounting for 2/3 of Canadian

oilseed acreage of 5.6 million Ha in the year 2000 (Natural Resources Canada 2005) and is currently primarily produced from transgenic seeds (Canola Council of Canada 2001).

While this paper focused primarily on bio-diesel from canola, many of the sustainability aspects with respect to soybean production, which is Canada's second largest oilseed crop, are similar. As of 2004-2005, Canada's soy production reached an all time high of over 3 million tonnes produced on 1.17 million hectares.

While Genetically Modified Organism (GMO)'s do offer the potential to maximize crop yields through the selection of traits such as increased oil production, increased hardiness, and pest and chemical resistance, some current variants also pose significant social and economical risks (Pilson and Prendeville 2004, Dunfield and Germida 2004). Ecological risks include increased pesticide use, increased weed and insect resistance, invasion of wild habitats, and the disruption of natural biological communities. Fertilizer production has become virtually synonymous with modern industrial agricultural processes, which compares the fertilization rates for transgenic and conventional varieties with the soil nutrient removal rates for canola.

There are 11 nitrogen fertilizer production facilities in Canada, which collectively produced 8.1 million tonnes of nitrogen based fertilizer in 2004 (Canadian Fertilizer Institute 2004). There are 8 major forms of nitrogen fertilizer but urea, the most commonly used form globally, and ammonia, which is produced from natural gas through a process called steam reforming, are the dominant sources in Canada. On an industry wide basis nitrogen fertilizer in Canada requires 10,000 BTU of energy per lb of fertilizer produced (NRCAN 2005).

In Canada, phosphate fertilizer is produced at a single site in Ontario, through open pit mining techniques. This site produces over 1 million tonnes of phosphate concentrate annually for use both domestically and for export. Potassium fertilizer, which is commonly referred to with the generic term potash, is comprised of potassium chloride which is extracted both through underground solution mining and traditional underground ore mining techniques.

In addition to the energy consumption and associated GHG emissions associated with fertilizer production, mineral based fertilizer as previously identified disturbs natural landscapes and disrupts ecological process through mining operations. The changes in soil structure and chemistry as

a result of agricultural processes, and excessive fertilizer application rates in particular, are responsible for 60% of the net GHG emissions associated with canola production (NRCAN 2005).

Degradation of biodiversity, and impairment of natural processes in both surface and groundwater resources, has been observed to be a significant concern due to sediment and impurities in the water of many modern agricultural effluents entering the watercourses. These effluents can damage fish and invertebrate habitat through siltation, or in the case of nutrient rich water, cause excessive nutrient level fluctuations, further endangering aquatic habitats (Myers, Marion, O'Meara 1993, Narayanaswamy et al. 2002, Tillman 1999).

In addition to fertilizer inputs, modern agriculture has also introduced numerous chemical inputs to control nuisance weed and insect species. Canola production in Canada currently uses in the order of 0.033lbs of pesticide active ingredients per bushel of production (NRCAN 2005). The impacts of these chemical inputs on human health and ecosystem biodiversity are increasingly being felt (Narayanaswamy et al. 2002, Benyus 1998).

While it is necessary to keep the issue of systemic poverty in the Canadian agricultural sector in perspective, compared to the extreme poverty associated with landless laborers and small scale subsistence farmers in the world, Canadian farm income levels are a serious concern. Years of depressed commodity prices coupled with rapidly increasing input costs for fuel, equipment, seed and fertilizer have made many family farm operations un-economical. A survey conducted by the Canadian Wheat Board in March 2006, illustrates how serious the situation is with 70% of farmers polled anticipating their input costs to exceed their revenue during this upcoming season with 50% stating they will leave farming in the next couple of years if profitability does not increase (Canadian Broadcasting Corporation 2006).

#### **4.2.2 Bio-diesel Processing Industry**

Impacts, or sustainability “hot spots” from processing of feed stocks in the production of bio-diesel, are focused around energy use, GHG emissions, and release of by-products. For bio-diesel production, the data available on energy consumption during the processing stages vary between operations, and particular stages are very energy intensive, such as seed crushing. There is general consensus that some of the processes have become increasingly energy efficient in recent years (Natural Resources

Canada 2005). However the energy for such processes often is supplied from non-renewable sources. For soybean crushing for example, natural gas or coal generates the steam required for this process stage. Canadian production capacity was anticipated to reach 91 million liters in 2006, with the majority coming from two facilities in eastern Canada (Canadian Renewable Fuels Association 2006).

Hexane, a product of petroleum, is widely used around the world as a solvent in the production of vegetable oils. It is more economical and efficient at extracting oil from seeds than expeller-pressed methods. It can only be produced from fossil fuels however, and is considered a hazardous air pollutant by the US EPA (Environmental Protection Agency 1995). Fugitive emissions are commonplace at oil extraction plants. The status of hexane as a GHG is not fully understood; however its degradation results in a rapid release of carbon dioxide into the atmosphere, and may in the future be more officially considered a GHG in Canada (Environment Canada 2000).

The use of hexane could be substituted with expeller processes already in use elsewhere in the industry. While yields using the expeller process are lower than those from the hexane process, research and development could be supported with a focus on improving this technology for higher yields.

#### **4.2.3 Bio-diesel Combustion**

A number of studies on bio-diesel exhaust have shown reductions in tailpipe emissions of particulate matter, hydrocarbons, and carbon dioxide for bio-diesel and bio-diesel blended with petroleum diesel relative to petroleum diesel. However, most studies also show an increase in nitrogen oxides (NO<sub>x</sub>) emissions for both bio-diesel and ethanol (Environmental Protection Agency 2002). For example, one study showed 2% more NO<sub>x</sub> emissions in a B20 bio-diesel blend compared to conventional diesel. While many emissions are reduced with Biofuel generally, they are still often of concern at any level. Further, CO<sub>2</sub> emissions are not an issue if they result in neutral emissions.

## **5- Discussion – Strategic Sustainable Development**

Sustainable production of Biofuel requires methods to deal with various complex social, ecological and economical activities, serving to guide planning and production processes towards sustainability. The methods used for investigating, acquisition of new knowledge, and integrating previous studies were based on: Logic and Inference; Literature Review; Back-Casting from sustainability principles (Holmberg and Robèrt 2000); MSPD (Byggeth et al. 2006); and SLCM, (Ny et al.).

For this specific study “back-casting from sustainability principles” is the methodology defining system conditions that must be met in a sustainable society. SLCM is a combination of traditional LCA, and bac-kcasting from principles. MSPD is a method intended to complement existing sustainability management tools and quantitative product analysis tools. From this approach the TSPD emerged, as a simplified technique to addresses specific questions that are aligned with the sustainable product development processes.

### **5.1 Back-casting from Sustainability Principles**

SSD is the process of planning ahead with the ultimate objective of sustainability in mind, instead of dealing with the problems one by one as they appear. Backcasting is the approach where a successful outcome is imagined followed by the question “what shall we do today to get there?” The international non-governmental organization, The Natural Step (TNS), developed and tested this approach to help organizations incorporate SSD into their operations.

The Natural Step Sustainability Principles were mentioned in section 2 , however, these principles were designed to fit a set of strict criteria including that they should:

- (A) Be based on a scientific world view.
- (B) Describe what is necessary to achieve sustainability
- (C) Be general enough to include all activities relevant to sustainability.
- (D) Not overlap to allow comprehension and develop indicators for the monitoring of transitions.
- (E) Concrete enough to guide problem analysis and decision making (Holmberg and Robèrt 2000).



### 5.1.1 The ABCD Planning Method

Also called ABCD analysis, this is a specific tool to apply "back-casting from basic principles of success" through four logical steps:

#### Awareness - A

The first step aims to involve and align organizations and projects around a shared mental model or a common understanding of sustainability, demonstrating how society and organizations are part of the whole system, the biosphere and what the main mechanisms societies are contributing to violate in our living system.

#### *Baseline Mapping - B*

What does society or organization look like today? This stage consists of an analysis of current reality to identify major flows and impacts of the organization. Sustainability principles are used to scrutinize process and activities and to allow identification of critical sustainability issues, their threats and opportunities. This includes the impacts of the entire supply chain and evaluation of products and services, energy, capital and the social context, providing a basic platform to understand how changes can be introduced further on.

#### *Creating a Vision - C*

What does organization look like in a sustainable society? In this stage a compelling long term vision for a sustainable organization is created and solutions to problems are identified.

From the vision, organizations develop strategies and action plans for moving towards sustainability. Strategies are developed based on a principal vision of success. This approach prevents decision makers setting a direction based on addressing today's problems; instead they develop a shared vision and goal of sustainability with a series of actions to move the organization towards the eventual sustainability vision. At this stage opportunities and potential actions are identified and priority is given to measures that move the organization toward sustainability fastest.

#### *Down to Action – D*

Suggestions from the C-list are prioritized according to their potential to serve as stepping stones to move the organization towards sustainability.

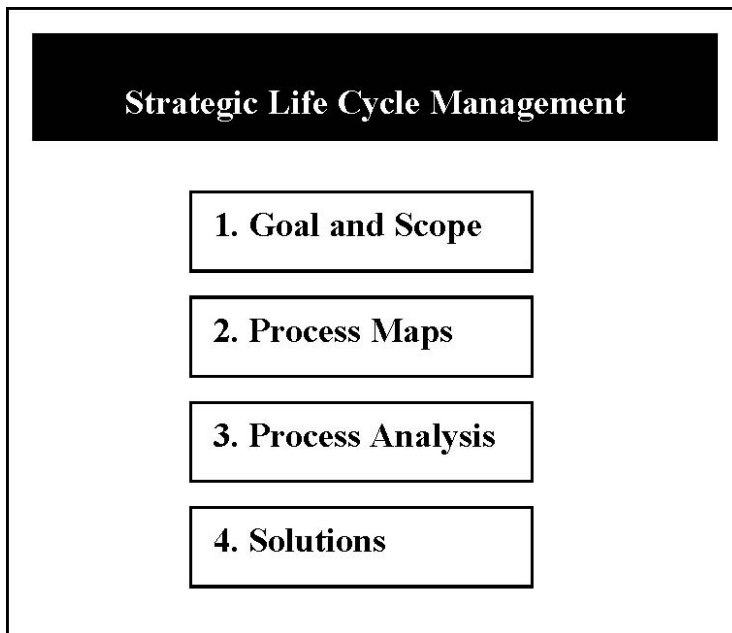
## 5.2 Strategic Life Cycle Management (SLCM)

SLCM is a combination of traditional LCA and back-casting that provides an overall view, with a long enough timescale to identify major future sustainability challenges and opportunities.

LCA is a tool for assessing the environmental impact of products, processes or services from raw materials to waste products, which is sometimes used to identify “hot spots”, or parts of the life cycle that are critical to the total environmental impact. Much of the current studies uses a traditional LCA methodology, which has the strength of being an operational tool for quick improvements, but does not in itself offer a function for strategic planning (Andersson et al. 1998). The SLCM addresses the challenges of traditional LCA by integrating a back-casting approach.

The SLCM approach is not meant to offer an exhaustive list of every potential problem that may be encountered with Biofuel now or in the future, rather it is meant to provide a strategic direction for sustainable Biofuel development.

The stages 1, 2, 3 and 4 illustrated in figure 1, describe the step by step approach of the SLCM planning method that was used to gather the necessary information for development of a TSPD for Biofuel.

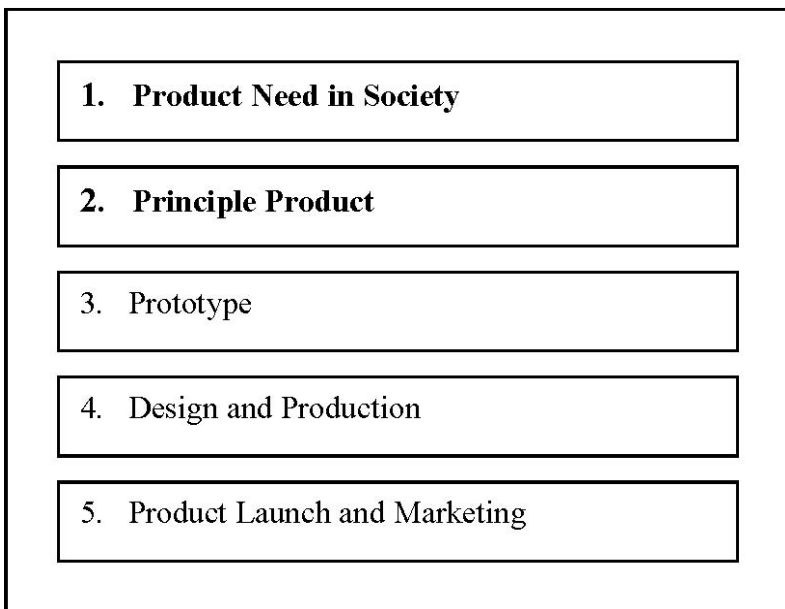


**Figure 1- SLCM Framework.**

### 5.3 Template for Sustainable Product Development (TSPD)

The TSPD approach was originally developed from the MSPD (Byggeth 2001). The first TSPD was created for the television industry (Ny et al.). Similar method could be used for the development of the Biofuel template. The television template, however, originally consisting of 3 templates, was further reduced to 2 templates for the Biofuel industry. The TSPD for bio-fuels adopted traditional product developments stages aligned with A-B-C-D planning method to address specific questions. The first two stages (figure 2) provide a large perspective: an overview of how to create a principle product. Steps three, four and five that are related to more specific activities in industries such as, production, launching and marketing processes and will not be covered in this paper.

The data and information collected during the SLCM research phase could be used to inform the development of the TSPD for bio-fuels, and in many cases could be incorporated into the guidance provided to prospective users. The templates for Biofuel using the A-B-C-D process applied through back-casting. The steps ABCD process can be structured in a way with selected questionnaires on each step. Once the answers are collected, the TSPD can be created to be used by everyone in the industry and / or the stakeholders.



**Figure 2- TSPD Development Stages**

## 6- General Recommendation

All stakeholders including industry, government, NGOs, and educational institutions have a role to play in ensuring the Biofuel industry develops sustainably. Of greatest importance is that all stakeholders acknowledge and address the need for reducing all transportation energy consumption, in addition to the following recommendations specific to the Biofuel industry. Industry could adopt sustainable agricultural practices that both protect ecological systems, and promote local economies. By adopting a strategic sustainable approach now while the industry is still in infancy stages, sustainability can be more easily realized.

Traditionally, NGOs have spearheaded efforts at fair trade and sustainable certification of products. Currently, no certification systems exist for sustainable Biofuel, and this is a gap that NGOs, in partnership with other stakeholders, would ideally be suited to fill. Certification is extremely urgent, as this is an important incentive for companies to produce sustainable Biofuel credibly, at a certified, independent body's standards.

Further research is required in the following areas:

- 1- Substitution and dematerialization of materials and activities of various life cycle stages
- 2- Sustainable Product Development for Biofuel, with greater assistance and broader involvement of stakeholders in new TSPD research
- 3- Sustainable Biofuel certification, using a strategic sustainable development approach -Standardized methods for calculating energy balances
- 4- Sustainability challenges and opportunities of genetically modified organisms
- 5- Research on key leverage points for sustainable Biofuel production
- 6- Impacts of Biofuel production on biodiversity and food security

## **7- Conclusion**

This paper provided the concept of an overall, bird's eye view of the industry (Biofuel Production) that will be able to assist in determining a strategic direction on how the industry is to develop sustainably. Without an initial broad view, the analysis becomes bogged down in details and actions toward sustainability become unfocused and uncontrolled. Several first steps toward sustainability were identified for both Canada and Brazil, and support a strategic direction.

Sustainability challenges aside, current Biofuel production provides an important transitional technology, and an immediate alternative to fossil fuels in meeting our transportation energy needs, until more sustainable options become viable for large-scale use in the future. Emerging technologies with higher sustainability attributes are not expected to replace current Biofuel production technologies for some time, and therefore the sustainability challenges of today's Biofuel still need to be addressed.

The paper did not examine the more "upstream" sustainability consideration of overall energy consumption patterns. It is acknowledged that switching to liquid Biofuel alone will not be adequate in a sustainable society as long as overall consumption rates are not reduced.

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