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Sustainable Bioenergy Production Potential of Second - Generation Perennial Crops from Marginal lands in Canada

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ABSTRACT:

The rapid rate of worldwide consumption of non-renewable fossil fuels has led to the introduction of bioenergy from second generation perennial biomass feedstock sources over the years. These crops have the capacity to produce large volume of biomass, have high energy potential, and can be grown in marginal soils. Biomass is recognized as the oldest form of renewable energy used by humans for thousands of years as the primary source of energy in the form of heat. However, much has changed with the realization of environmental burdens and energy security associated with fossil fuel energy sources that have led to the need for more sustainable energy options to fuel production development and research in the twenty first century. The current controversies and debates on bioenergy production lies within ensuring the sustainability of this emerging industry from issues of greenhouse gases emission (GHG), food and energy security, social exclusion, and ecosystem deterioration if it is to achieve its global production potentials. This paper presents a comprehensive assessment of the potentials of bioenergy production from perennial energy crops under the strict criteria of sustainable development.

Key words: *Bioenergy, Biomass, Feedstock, Greenhouse gas emissions (GHG), integrated framework, perennial, sustainability, Sustainable development, second- generation biofuel,*

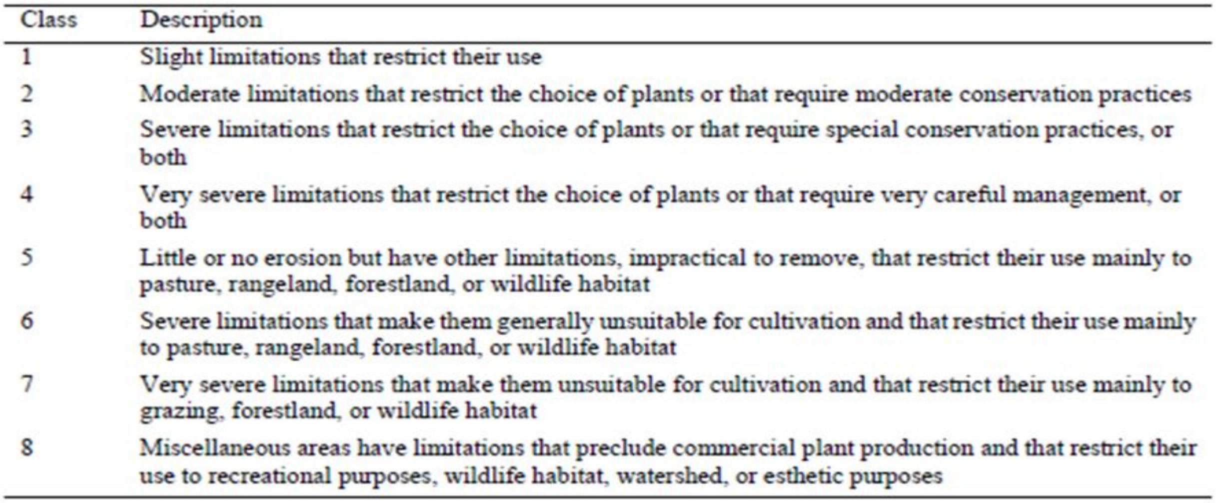
1. INTRODUCTION

Energy, it has become the most critical resources for the continuation human existence and development as a species, without it; life would cease. Throughout the twentieth century major research and development was given to petroleum based products such as coal, oil and natural gas as a cheap and high density source of energy that would meet all our needs **[34].** The global economy is currently dependent on these fossil fuel feedstock to generate electricity, heat and fuels to produce the majority of our energy demands. They drive our global economy forward but are finite in nature; with the current major proven reserves of oil and gas being located in politically unstable or environmentally sensitive environments such as the arctic region. Our consumption of these fossil fuels has felt us addicted and so we have become dependent on these products to meet our most basic needs of survival. However, over the years of production and consumption of fossil fuel has become very unsustainable and detrimental to the healthy and the safety of this world and its inhabitants. This growing realization of the global crisis has forged the production and investment of new, renewable and sustainable alternative sources that would carry us into the next generation of our energy future. With the world's continuous growth in population and the declining reserves of fossil fuels, the imminent concerns for global climate change and a growing energy demand has become the great challenges of the modern era. Bioenergy from biomass feedstock has been considered as one of the most important sources of renewable energy with the potential to supply the global market with a limitless supply of raw material or feedstock. After all it has been a part of human history for over thousands of years through the most basic process known as combustion to produce heat. However, much has changed from mankind's early days and have developed the means in which to harness the true power and potential of this wondrous energy source through science and technology. First generation bioenergy systems are currently commercially accepted in the global market but are limited to land use problems, soil, economic and environmental restrictions stunting the growth as a lasting sustainable solution. Therefore, the production of new bioenergy options are need that would account for the production fo fuel that does not compromise the futures ability to do the same. Hence, the production of second generation perennial energy crops has been seen as the next generation of bioenergy to supply the future demand for energy. Production of these renewable energy not only contribute to the energy supply, but also on the economic, environmental, and social benefits towards sustainable development.

The concept of sustainability within systems has become of great interest for the preservation of resources and optimization of effective results and productivity that would benefit both human and environmental ecosystems. These energy crops are considers as the future of bioenergy research and development and hold the greatest promise and potential for commercial success. The question we must ask is what are these potentials? And how can the production of second generation perennial crop supply the necessary energy requirements on the basis of economic, social and environmental sustainable development from available land to displace or reduce the extensive of fossil fuel consumption in the foreseeable future? This paper presents a comprehensive sustainability assessment of second generation bioenergy production potentials based on the current research, development and conversion technologies, available for the deployment of a dedicated bioenergy market from marginal or degraded lands in Canada. The main objective of this study is to evaluate and estimate the various potentials, risks and challenges associated with the production of perennial energy crops from the economic, environmental and social dimensions of sustainability. The paper also seeks to recommend the appropriate guidelines for the establishment of an integrated policy framework in Canada with the support of its stakeholders in the decision making process on a regional and global scale. The study is divided into five separate sections that evaluate the technical potentials, economic viability, environmental and social risks and challenges facing the industry today. Section 1 following this introduction discuss the technical potentials while sections, 2, 3, 4 assesses the environmental, economic and social dimensions of bioenergy production The final section deals with the implementation potential through bioenergy policies to create a sustainable system and suggests recommendations to the establishment of an integrated policy framework in Canada for the support of industry stakeholders in the decision making process for future deployment.

2. METHODOLOGY

Finding available land to supply the emerging biofuel industry without compromising pre-existing agricultural lands for food production is of the utmost concerns when following the criteria of sustainability. Marginal Land or degraded lands has received the most attention, as a viable alternative resource for bioenergy feedstock cultivation on a large sale. The assessment suggests a multi-criteria analysis for the identification of available marginal lands in Canada for the production of second generation energy crops based on geographic information systems. Geographic information systems (GIS) are a powerful set of tools for site suitability models that incorporate numerous input models and datasets **[26] [33] [12].** The creation of GIS analysis have become increasingly attractive in identifying available land and providing visual response to the major opportunities and constraints on marginal land cultivation. This study proposes the methodology for visual identification based on a procedural and conceptual GIS multi-criteria suitability analysis across Canada (Figure 1). Multi-criteria analysis (MCA) is very effective tool when assessing the potential of production capacity and offers a unique form of approach to decision making **[3].** Therefore, it is the primarily used tool when formulating a sustainable assessment for bioenergy production potential when faced with uncertainty. Buchholz, T. 2008 defines MCA as “formal approaches which seeks to take explicit account of multiple criteria which seek to take explicit account of multiple criteria in helping individuals and groups explore decisions that matter”. The approach is achieved by assessing the biophysical data such as soil, climate and topography or landscapes in Canada to classify the most productive non-crop lands based on recognized land capability classification data (table 1). The need for an integrated methodological framework for sustainability assessment has been widely discussed and is urgent due to the increasingly complex environmental problems [3]. However, the assessment of bioenergy potentials from industry to environmental perspectives is a very complex and multidimensional task that requires the integration of numerous models and datasets that expand well beyond the scope of this study. Nevertheless, the proposal of a MCA in an integrated framework may just be the strongest tool in our arsenal to achieve sustainable energy success.



Class	Description
1	Slight limitations that restrict their use
2	Moderate limitations that restrict the choice of plants or that require moderate conservation practices
3	Severe limitations that restrict the choice of plants or that require special conservation practices, or both
4	Very severe limitations that restrict the choice of plants or that require very careful management, or both
5	Little or no erosion but have other limitations, impractical to remove, that restrict their use mainly to pasture, rangeland, forestland, or wildlife habitat
6	Severe limitations that make them generally unsuitable for cultivation and that restrict their use mainly to pasture, rangeland, forestland, or wildlife habitat
7	Very severe limitations that make them unsuitable for cultivation and that restrict their use mainly to grazing, forestland, or wildlife habitat
8	Miscellaneous areas have limitations that preclude commercial plant production and that restrict their use to recreational purposes, wildlife habitat, watershed, or esthetic purposes

Table 1. Land capability classification

2.1 Assessing Land Availability

The availability of land is one of the key variables in determining the potential production of biomass for energy [6]. The availability of land for bioenergy production is considered to be the most crucial constraint when assessing the potential of energy crops which are estimated to deliver the greatest amount of future bioenergy potential. Land and the use of land provide a key link between human activity and the natural environment [9]. Recently, the discussion over the production of bioenergy crops for biofuels has put forward a new challenge for land use and the means by which to find sustainable ways to manage these new bioenergy systems. Marginal lands have been proposed to increase the land availability to supply biomass production form dedicated energy corps. It is estimated that the global abandoned agricultural land ranges from 430-580 Mha, which is part of marginal land. **[22].** A number of energy crops can potentially be grown on marginal lands to provide feedstock for bioenergy, non-food products and biofuel. Switchgrass and Miscanthus which requires limited fertilizer, fewer inputs and has been recorded in some studies to distribute significant amounts of organic matter back to the soil composition. In the US, these marginal lands are enrolled in conservation programs such as the conservation reserve program (CRP) in an effort to address soil, water, and related natural resource concerns while providing farmers with technical and financial assistance **[47].** Some marginal lands have never been cultivated and are the location of intact native ecosystems such as prairies, shrub lands and wet meadows. In particular, marginal lands have been chosen as potentially suitable resources for production of perennial grasses that would not compete directly with food production.

2.2 Defining Marginal Land

Marginal lands generally refer to the areas with low production, but also with limitations that make them unsuitable for conventional agricultural practices and ecosystem function. Marginal lands have received wide attention for their potential to improve food security and support bioenergy production. However, environmental issues, ecosystem services, and sustainability have been widely raised over the use of these degraded or marginal lands. They are generally fragile and at high environmental risk **[22].** The debate on marginal land use is a serious topic associated with the trilemma of land use planning: food security, bioenergy, and environmental concerns **[22] [46].** Although the concept of marginal land has been broadly applied, a generalized understanding and knowledge of marginal land concept, assessment and management are limited and deserving of further attention **[22].** The problem with defining marginal lands lies in misconception and clear understanding as to what is considered marginal which vary significantly within different regions. The concept is also most often used interchangeably with other terms such as unproductive lands, waste lands, under-utilized lands, idle lands, and abandoned lands or more popularly as degraded lands that are not capable of traditional agricultural production. On the other hand, Prime agricultural farmland is defined as "the land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber and oilseed crops" **[22].**

SECTION I: Technical potential of dedicated perennial bioenergy feedstock from conversion technologies

3. RESULTS

Sustainable bioenergy systems are, by definition, embedded in social, economic and environmental contexts and depend on the support of industry stakeholders. The components of a complete bioenergy system include feedstock production, conversion technology, and energy allocation **[4].** These processes are each embedded in diverse social, economic, and environmental contexts. The literature distinguishes between various types of biomass potential such as technical, geographical, economic and implementation. This study focus primarily on the technical potentials of bioenergy production along with the economic, environmental and social and political implications proposed by principles of sustainable development. Renewable energy technical potential represents the achievable energy generation of a particular technology given system performance, topographic limitations, environmental and land-use constraints. However, before the industry can proceed from its current developmental phase, a range of technical barriers must be mentioned before biomass becomes a commercially viable substitute for fossil feedstock in 2nd generation biofuel production **[30].**

3.1 Land use assessment on marginal lands

The land capability classes shown in table 1 generally characterizes marginal lands from classes 4 to 8 by high soil erosion **[22].** The marginal land concept has evolved to meet multiple management goals and to incorporate the trade-offs of environmental protection, preservation of ecosystem services and long-term sustainability. The main challenges in relation to the use of marginal/degraded land for bioenergy include (1) the large efforts and long time periods required for the reclamation and maintenance of more degraded land (2) the low productivity levels of these soils and (3) ensuring that the needs of local populations that use degraded lands for their subsistence are carefully addressed. The decrease of land rent and increases of market demands change marginal profits, and breakeven prices may finally lead to conversion of marginal lands to production. Marginal lands in Europe have been declining as a result of increasing labor costs and intensification of agriculture. Certainly, policies, incentives and regulations are currently the identified driving variables causing land use changes. All these driving variables obviously push farmers to reclaim or abandon marginal lands because of changing breakeven prices. Hence, marginal lands may not remain marginal in time when management and assessment become a staple in the industry.

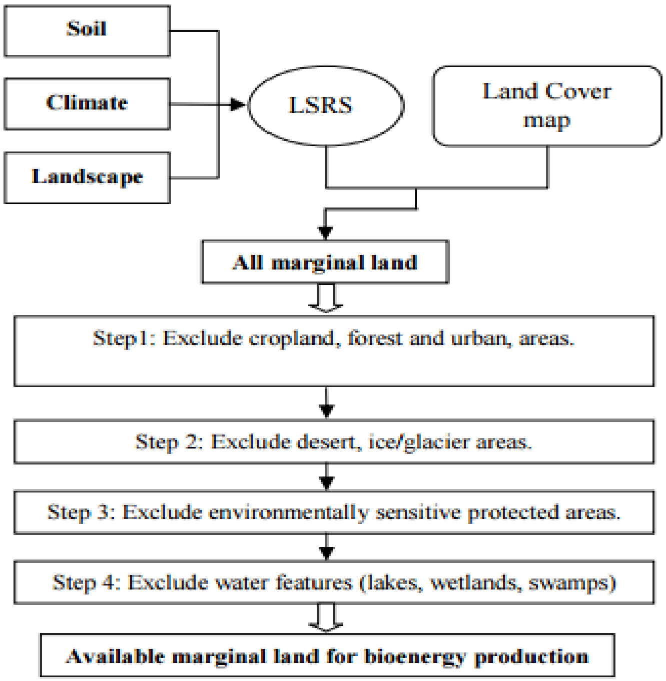


Figure 1: Conceptual model of the GIS multi-criteria analysis

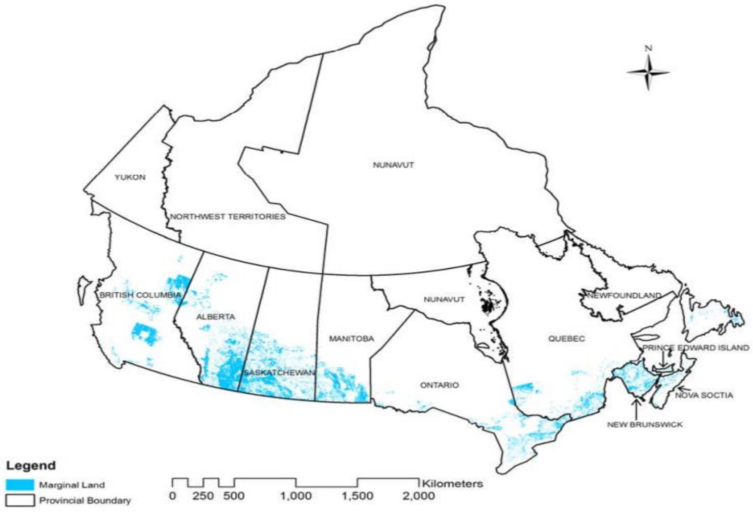


Figure 2: Map of potential areas of marginal lands across Canada

3.2 Selection of Dedicated Energy crops

A number of proposed candidates for dedicated energy feedstock are currently being development around the world. The study proposes the establishment of two very promising herbaceous and perennial energy crops for suitable cultivation of biofuels from marginal lands in Canada due to their unique morphology. These two crops are commonly known as Switchgrass and Miscanthus. This paper assesses the bioenergy potential of these energy crops from current research and development in Canada based on the criteria of sustainability from marginally proposed lands available. Some of the various crops and tree species considered sustainable for energy production are as follows: sugar crops, cereals, oil crops, Switchgrass, Miscanthus, eucalyptus, willow and poplar [45]. Switchgrass and Miscanthus were originally introduced as energy crops for biomass production purposes due to their considerable productivity and stress tolerance to unfavorable environments such as marginal land. These two perennial crops could be potential biomass sources for cellulosic ethanol production. Agronomic ally these bioenergy crops have shown greater promise than agriculturally used feedstock for second generation production because they require low inputs for establishment, low fossil fuel inputs, adaptable to marginal lands, and most importantly provide high biomass and energy yield that is expected to reduce global warming and combat Global Climate Change [10]. Production of cellulosic ethanol using the harvested biomass is highly dependent on biomass to biofuel conversion technologies. As large-scale production of switch grass and Miscanthus commences, it will become necessary for the industries stakeholders to have a solid understanding of the effects and potentials these factors play in the overall system [43].

Switchgrass: Switchgrass (Panicum virgatum) is a warm-season prairie grass that is native to North America. As a perennial, Switchgrass requires less intensive management than most traditional crops. Switchgrass can grow in a variety of climate and soil conditions. It is most commonly associated with low productivity soils and other lands less suitable for crop production. It typically produces the most biomass on moderately well to well drained soils with a soil pH of 5.0 or above. Switchgrass is drought and heat tolerant, performing better under these conditions than many other plants. There are two types of Switchgrass, upland and lowland varieties. Lowland varieties typically grow much taller, seven to ten feet, and so produce more biomass than upland varieties. It grows primarily in the summer months between June to August and has relatively high efficiency of converting solar radiation to biomass and in using nutrients and water, and have good pest and disease resistance. It is planted using seeds and has a stand life of ten years or more where production during the first year or two could be only a fraction achieved during the remaining production years **[7].** The yields of Switchgrass could be about half as large as that of Miscanthus.

Miscanthus: Miscanthus (Miscanthus x giganteus) is a perennial rhizomatous grass with the potential for high yields, low input requirements and several environmental benefits **[7].** Miscanthus refers to a genus of several perennial grass species mostly native to the subtropical and tropical areas of Asia. The grass has a life span of 15 to 20 years. Like Switchgrass, Miscanthus are C4 perennial crops which allows the plant to have high efficiency when converting solar radiation to biomass and in using nutrients and water, and has good pest and disease resistance. It is planted using rhizomes and field trails indicate that Miscanthus has the potential for relatively high yields recorded in the rain fed regions of the US. There is much potential for these crops to become a part of the Canadian energy future.

3.3 Integrating sustainable bioenergy crop-production in Agroforestry systems

The concept of placing a perennial feedstock crop permanently dedicated to biomass production would seem to be an ideal goal and one the industry should be heading towards because (1) there would be no annual re-establishment costs (2) tillage would be eliminated, reducing input costs, and soil erosion and (3) a permanent vegetative cover would sustain soil conservation and water-quality protection. Perennials, however, are rarely permanent and some annual cropping or innovative combinations of annual and perennial bioenergy crops strategically deployed across the farm landscape and combined into synergistic rotations may be necessary in the future. Combining annual bioenergy crops such as corn and sorghum into rotations with perennial bioenergy crops, perhaps to jump start the establishment phase, may benefit bioenergy cropping systems **[42]**. Innovative combinations of cool-season and warm-season annual crops could be the basis for dedicated biomass double cropping. Relying on a diversity of crops and cropping systems in farm landscapes and larger scales would endow future bioenergy production systems with greater stability resistance, and resilience to climatic and other environmental stocks under agroforestry systems **[42].** Agroforestry is defined as the intentional integration of woody perennials with crops or livestock; it is a poly culture cropping strategy that has economic and environmental benefits over that of traditional monoculture production systems **[20]**. Agroforestry is a promising new avenue for land use practices to maintain or increase agricultural productivity while preserving or improving fertility. A perfect example of agroforestry systems that integrate perennial grasses with trees and shrubs suitable for marginal lands are alley cropping systems. Agroforestry systems like alley cropping is currently being researched and developed in Canada for dedicated bioenergy crop production that can potentially satisfy a broad suite of social, economic and environmental objectives. Strategic placement of such systems may help to maximize economic returns from marginal land and reduce agricultural non-point source pollution.

3.4 Classifying Biofuel Generations

First-generation Biofuels

First generation biofuels are biofuels which are on the market in considerable amounts today **[44].** These biofuels are produced from food crops by abstracting the oils for use in biodiesel or producing bioethanol through fermentation.**[10]**. Crops such as wheat and sugar are the most widely used feedstock for bioethanol while oil seeds has proved a very effective crop for use in biodiesel. However, first generation biofuels have a number of associated problems. There is much debate over their actual benefit in reducing greenhouse gas and CO2 emissions due to the fact that some biofuels can produce negative Net energy gains, releasing more carbon in their production than their feedstock can capture in their growth. However, the most contentious issues associated with first generation biofuels is primarily on the debate between fuel and food, discussed in section 4. As the majority of biofuels are produced directly from food crops the rise in demand for biofuels has led to an increase in the volumes of crops being diverted away from the global food market. This has been blamed for the global increase in food prices over the last couple of years.

Second-generation Biofuels

Second generation biofuels, on the other hand, are those biofuels produced from cellulose, hemicellulose or lignin **[44].** Second generation biofuels are produced from biomass in a more sustainable fashion, which is truly carbon neutral or even carbon negative in terms of its impact on CO2 concentrations **[34].** Second generation biofuels are expected to be more efficient than the first generation biofuels and to provide fuel made from cellulosic and non-oxygenated, pure hydro carbon fuels such as biomass to liquid fuel **[10].** Biofuels produced biochemically or thermo-chemically from lingo-cellulosic second generations have more energy content than most first generation biofuels **[34].** They also avoid many of the environmental concerns, and may offer greater cost reduction potential. Second generation biofuels have been developed to overcome the limitations of first generation biofuels. The biofuels are also aimed at being more cost competitive in relation to existing fossil fuels. Life cycle assessments of second-generation biofuels have also indicated that they will increase net energy gains over coming another of the main limitations of first generation biofuels.

3.5 Second-generation conversion technologies

The production of biofuels from lingo-cellulosic feedstock can be achieved through two very different processing routes **[18] [34] [44].**

- Biochemical- is the process in which enzymes and other micro-organisms are used to convert cellulosic and lignocellulose components of the feedstock of sugars prior to their fermentation to produce ethanol.
- Thermochemical- is the process where pyrolysis/gasification technologies produce a synthesis gas (CO + H2) from which a wide range of long carbon chain biofuels, such as synthetic diesel or aviation fuel can be reformed. The first step in the process is the gasification of the feedstock under high temperature into a synthesis gas **[44].**

These are not the only second generation biofuel pathways as several other variations and alternatives are under evaluation in research laboratories and pilot-plants. However, they are the most recognized within the developing market. This would allow government bodies to become better informed and address when taking strategic policy decisions for second generation development and deployment. Unfortunately given the nature and the complexity of the bioenergy system along with the technical and economic challenges involved, the reality would be that a commercially viable bioenergy plant would be not be operational before 2020 **[44].** However, there is much debate over the time span of deployment and depends on various factors including political support, consumer demand and dedicated energy supply of crops being grown. Both sets of technologies remain unproven at the fully commercial scale, and are under continual development and evaluation to ensure that all environmental hurdles, risks and uncertainties are addressed before the industry becomes commercialized be it on a local, national or even global scale. Only time will tell the preferred technology in the emerging bioenergy industry in Canada. The demand for certain types of bioenergy and the economics of each conversion route discussed will determine how available biomass resources will be used in the future [6].

3.6 Cellulosic ethanol

Cellulose is the major component in plant biomass and it is made of only dioglucopyranose or glucose residues, which can be converted to glucose and act as major source of hexoses in woody feedstock. Lignocellulose biomass consists of three main structural units: cellulose, hemicellulose and lignin. Cellulose is a crystalline glucose polymer and hemicellulose is amorphous polymers of xylose, arabinose, and lignin a large poly aromatic compounds. Biological conversion technologies are based on microbial and enzymatic processes for producing sugars from biomass such as lignocellulose, starch, cellulosic. The sugars later can be converted into alcohol and other solvents to produce those biofuels and other chemicals. The conversion of lignocellulose biomass to alcohol requires three step process such as pretreatment of biomass, acid or enzymatic hydrolysis and fertilization/ distillation. Fig below shows in more detail the steps required for the conversion of lignocellulose biomass to ethanol and the utilization of intermediate products for value added chemicals. Bioconversion of lignocelluloses into fermentable sugars is a bio-refining area in which enormous research labors have been invested, as it is a prerequisite for the subsequent bioethanol production [14].

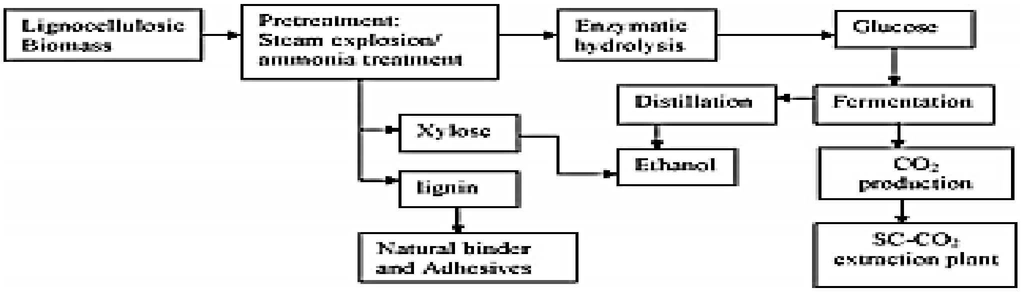


Fig 3. The conversion process of lignocellulose biomass to ethanol production

Current biomass to ethanol research and development project emphasis on the reduction of cost as the process from lignocellulose is much difficult to acquire than starch based feedstock. The research also seeks the improvement of cellulose and hemicellulose conversion to sugar, combined xylose and glucose fermentation, lower pretreatment energy requirements conversion of lignin to value added products, and efficient separation process for alcohol **[44].** Lignocellulose biomass is envisioned to provide a major portion of the raw materials for bioethanol production in the long term due to its low cost and high availability **[14].** Therefore, by accelerating research in these areas of bioenergy development we can make significant contributions to the sustainability and use of these lignocellulose feedstock.

SECTION II: Environmental Potential of bioenergy systems from controversial issues

4. DISCUSION

4.1 Greenhouse gas emissions

From an environmental perspective, the promotion of Bioenergy production offers significant potential to mitigate climate change by reducing life-cycle GHG emissions relative to fossil fuels**.** Although producing and burning biomass-based fuel releases carbon dioxide it also absorbs carbon dioxide from the atmosphere as it grows. On the other hand, local air quality can be impacted by feedstock production and biofuel use through the emission of dust and other deleterious compounds. Life-cycle analysis of the GHG emissions produced during production of different bioenergy alternatives demonstrates that renewable transportation technologies produce the highest GHG emission profiles followed by electrical power generation from renewable energy or green power. This paper supports the research and development of the life-cycle assessment methodology for dedicated energy crops in the bioenergy system that addresses the entire bioenergy supply chain through cradle to grave approaches **[40].** There is an emerging need for further research accounting for the analysis on life-cycle GHG emissions. A consensus within the literature review has been reached regarding the use of LCA on biofuels to contribute to the displacement from fossil fuel energy to reduce GHG emissions **[6]**. Therefore, it is of paramount importance that we discuss the reduction of these second generation biofuels ash content so as to facilitate their commercialization. High ash content is particularly troublesome and slows down the development and production of bio refineries and the bio economy. Warm season C2 perennial grasses are found to have lower silica levels than C3 grasses owing primarily to the fact that they utilize water 50% more efficiently **[38].** Clay soils produce higher levels of silica containing feedstock than sandy soils. Selection or higher stem content will help alleviate the plant's ash content, while increasing the desirable feedstock characteristics, such as cellulose content, which is important for ethanol markets **[38].** Plant breeding is another viable option to increase the stem fraction of grasses and help reduce ash outtake. Once better knowledge of factors influencing ash content of feedstock is incorporated into biomass feedstock research and development, and combined with improvements in combustion technology, herbaceous biomass crops have an excellent opportunity to emerge as a major energy supply option for renewable energy in Canada.

4.2 Soil health and agronomics

Besides from the mitigation option from bioenergy, growing biomass for fuels requires the management of healthy soils that can maintain productivity over time. Sustainable soil health involves minimizing soil erosion, maintaining soil carbon and other essential nutrients, and protecting the soil's physical and biological attributes. Several bioenergy feedstock currently being considered involve already show strong promising potential for increasing soil carbon and reducing erosion in certain areas and soil management should be present within the bioenergy cropping system.

4.3 Water quality and quantity

Expanding sustainable bioenergy production requires consideration of impacts on water quality and the quantity of water needed for growing biomass feedstock and bio refinery operations. Sustainable bioenergy production will rely heavily on aligning water demands with water availability, protecting water supplies and aquatic ecosystems, and maximizing the use of impaired rather than pristine water for growing feedstock. However, uncontrolled expansion of energy crop cultivation and inappropriate cultivation systems may also greatly increase the pressure force in the land-use sector, the major effects that they may have on future water use have as yet to be explored.

4.4 Biological diversity

The impact of dedicated energy crops on biodiversity are manifold and can be bath positive and negative. The replacement of native forests with mono-cropping plantations, for instance, significantly reduces plant biodiversity and may cause habitat loss for wildlife due to landscape and ecosystem changes, especially in tropical countries. Some typical species for wood energy production systems, eucalyptus, are considered invasive species in many countries and their plantation may cause proliferation and threaten local ecosystems. Generally, the production of second generation biofuels is expected to have a lower impact on biodiversity. However, dedicated plantations for energy crops on single marginal lands could lead to irreversible land use changes which can increase pressure on areas with a high biodiversity value, like native forests. Since the use of agricultural residues may have negative or positive impacts on biodiversity, depending on the cropping systems and the site-specific context, a general assessment is very difficult. However even in so-called “degraded” or marginal lands, cultivation of dedicated energy crops would have negative impacts upon biodiversity and ground water [11]. The possible effects of biomass cultivation a biodiversity are manifold, ranging from land use change related impacts to landscape level agro biodiversity effects. To avoid further pressure from incrementally cultivating dedicated bioenergy crops, it is necessary to protect high-biodiverse areas including existing protection areas. Biodiversity is fundamentally endangered by global climate change especially with regard to extended periods of drought changes in intensity and distribution of precipitation, higher ambient temperatures etc. which all can negatively affect ecosystems, and habitats [13].

SECTION III: Economic potential of growing fuel from marginal lands in Canada.

5. Economic potential

Economic viability is another crucial avenue for future use of marginal land for agricultural energy production and the promise of a smooth transition towards renewable and sustainable energy options. To be economically viable, energy crops must compete successfully both as crops and as fuels. Therefore, biomass must yield on income for a landowner that cover all the cost of producing them [23]. Owners of cropland will produce cellulosic feedstock only if they can receive an economic return that is equivalent to or preferably higher than the returns from the most profitable conventional crops, particularly if energy crop production is exposed to more price risks. In the case of energy crops, these costs should include not only the cost of growing these crops but also foregone returns from alternative uses of land [23]. The foregone returns from these conventional crops are the opportunity cost of using cropland for producing energy crops. Geographical variations in the costs of producing these crops and in the opportunity costs of land are likely to make the economic viability of cellulosic biofuels differ across locations. This viability, at given price for the final product, is decided by various items of cost, which are described below for both the switch grass and Miscanthus energy crop.

5.1 Cost of production

The estimation of production costs for second generation biofuels would depend on the plants complexity and biomass conversions technology efficiency. One of the biggest economic constraints for producing second-generation biofuel plants on a commercial scale is their capital intensive cost compare to first-generation biofuel refineries **[6].** Currently, biofuels provide for over 1.5% (about 34 mtoe) of the energy used for transport **[44].** Today, these same biofuels have been proposed the most productive sources of biomass and have been proposed as contributing to the overall reduction of greenhouse gas emissions in the transport sector. In Canada the production of these Biomass for the improvement of energy efficiency would vary greatly among its provinces. From the first table 1. Class 4 lands from the land classification inventory have higher productivity for various types of biomass. Overall biomass production on the class 6 lands is only 77.2% of that on class 4 lands. Class 5 lands are very close to class 4 lands in terms of productivity (99.7%) **[22].** Assuming that all available marginal lands are converted into Switchgrass or Miscanthus production, this will provide a total of 33 million tons of biomass about 3.49 t ha-1. Marginal lands are an important resource for providing feedstock for bioenergy. In Canada, there are 9.49 million ha of marginal lands. Every province in Canada has lands in this category, although the largest amount of this type of land is found in western Canada (Alberta, Saskatchewan and Manitoba) **[28].** These three Prairie Provinces contain 83% of the total Canadian marginal lands. Statistics Canada reports a total of 41.68 million ha of all types of land. Thus marginal lands constitute 22.8% of all agricultural lands. At present, it is assured cellulosic ethanol plants convert lignocellulose biomass into ethanol at 330 liters per ton. Cellulosic ethanol is a high capital cost technology, both on a per plant basis and per unit of renewable energy produced. In many countries, policymakers are becoming more and more aware of the huge economic potential and benefits that could be unlocked by commercial biomass use. Making bioenergy both affordable and accessible to an increasing proportion of the population will be the route to creating a long and sustainable future for biofuels, resulting in greater success and wider use. In doing so, we have confirmed that bioenergy can make an ever increasing contribution to the socio-economic success of many of our communities. Unfortunately, biofuels are still a relatively expensive form of energy when compared to fossil fuels.

5.2 Cost of greenhouse gas mitigation efforts

Governments at the federal and provincial levels have recognized the need for incentives to help renewable energy technologies to become comparable with fossil fuels in the market. Currently, there are no significant incentive programs for green heat although thermal energy such as heat for space, water heating and process energy applications represent Ontario's largest energy demand. The Analyzing Ontario biofuel options study highlights additional policy strategies which could be developed to more effectively encourage GHG abatement than those outlined by Bill C-33 **[40].** Current policies are based on the quantity of renewable energy produced with limited emphasis on the actual effectiveness of the technology on GHG emissions and reductions. A more effective approach is to focus policy efforts on CO2 abatement. In doing so, bioenergy systems that aim for both high output of renewable fuel per hectare and efficient GHG offsets form each wait of renewable fuel produced are encouraged. Large reduction in GHG emissions is possible in Canada using existing technologies.

SECTION IV: Social implications of bioenergy development in rural communities on a national and global level

6. Land-use changes

Another important criterion that has been mentioned to have negative effects on the development of bioenergy crops is the issue of land-use changes (LUC), which has be grouped into two facets that are direct and indirect. Direct land use is the change in status of the area that was previously in either a crop or abandoned land, to an energy crop **[33].** The other concern is indirect LUC as it is argued that increasing land in energy crops will require that food cultivation will have to be increased elsewhere, either by converting other land into agricultural production, intensifying existing land use for food, or reducing human food consumption **[33].** The landscape placement of second generation biofuel crops may have a positive or negative impact on the biological diversity, water sources and food production. Many of the current concerns surrounding biofuels stem from poor analysis of the materials, nutrient and energy flows involved in their production and use. Unfortunately, flawed assumptions about the greenhouse gas and ecological benefits of biofuels and bioenergy have resulted in poor options being promoted.

LCAs have been conducted for a range of biofuel pathways and have proven to be extremely useful for comparisons of different biofuels options for policy makers, and increasingly for industry benchmarking **[31].** LCAs are expected to become increasingly important to ensure compliance as bioenergy performance standards and certification schemes mature. Despite their obvious appeal and value for assessing the inputs and outputs along the process chain, the tool does have some limitations and drawbacks. They are generally complex, costly and time-consuming to conduct and may be beyond the capacity of many local producers or communities as oppose to large-scale operations. The province of Ontario in Canada has demonstrated its will to expand renewable energy production by encouraging energy conservation and creating new green jobs with the passing of the Green Energy Act of 2009. The province is also the first jurisdiction in North America with legislation in place to eliminate coal-fired thermoelectric production, making coal use illegal by the end of 2014. It is anticipated that these coal phase out policy changes will have socio-economic impacts in all regions where Ontario Power Generation operates coal-fired stations. Positive socio-economic impacts provided by a company’s involvement in a community can include creating jobs, including jobs in other sectors, providing physical infrastructure such as parks and recreation centers, paying municipal taxes and providing charitable donations to civic and community groups. Biofuels development does not only impact the environment but is also is associated with various social impacts and effect on the land being used for cultivation. Bioenergy projects are, in this way, similar to other projects and also need to be evaluated based on the benefits it can provide to the economy to society and the benefits and detrimental effects it will have on the environment.

6.1 Food vs fuel debate

The production and cultivation of dedicated energy crops bears the need to discuss the availability of land and what that implies for our food security within the much debated topic of food vs. fuel as additional land is demanded for their production **[6].** The study shows that available land resource for bioenergy production systems is limited across Canada and there is increasing competition for land between food and fuel. It has been estimated that in the future the demand for land resources devoted to bioenergy supply could equal the area currently used for crop cultivation. There are several ways to acquire feedstock without reducing cropland, such as by capturing biomass with very low or negative current economic value that is currently treated as either waste or a co product of existing production processes or by establishing energy crop plantations on marginal land. Most of these lands in Canada are currently treed, used for grazing livestock, or help at significant importance by indigenous people. The amount of land needed for future food production is also influenced by the land- intensive food consumption patterns of the land-intensive food consumption patterns of the industrialized countries, which are spreading to the growth regions of emerging economics such as china, India and Brazil. This demand can only partly be met by increasing productivity per unit of land in consequence the FAO estimates that the amount of land used for agriculture will need to be increased by 13 per cent by 2030 **[43].** It is therefore likely that there will be a significant increase in competition for the use of agricultural land and, consequently attends towards rising food prices. Furthermore, a significant increase in the cultivation of energy crops implies a close coupling of the markets for energy and food. As a result, food prices will in the future be linked to the dynamics of the new energy markets. For around one billion people in the world who live in absolute poverty, this situation poses additional risks to food security and these risks must be taken into consideration by policy makers to establish an integrated bioenergy cultivation system within rural communities.

6.2 The role and constraints of bioenergy in rural development

In developing countries, bioenergy is often used as the main source of energy. By providing energy at local level, bioenergy can make a significant contribution to social and economic development in rural areas globally. Farmers have demonstrated that they can produce far more food (and energy) if they are given the opportunity. To achieve that, they need be clear market incentives, availability of capital, energy, skills, credit, etc. The increased use of bioenergy will also bring many environmental benefits to the farmer and the community development at large. However, bioenergy should not be regarded as the solution for solving agricultural and energy problems in the rural areas, but as an actor that can play a significant role in improving agricultural productivity, energy supply, the environment and sustainability. Bioenergy production and use is an important agricultural activity, particularly in many rural areas of developing countries. Currently biomass energy provides about 55EJ (equivalent to 25 million of barrels oil/day), or about 14% of the world's energy **[37].** Much of this energy originates from various types of agricultural and forest residues, although in the future various types of dedicated energy crop plantations are expected to provide a much larger proportion.

If farmers choose the proper energy crop to grow such as those dedicated recommended in this paper on marginal lands in Canada then such development would only increase their incomes and improve the standards in rural economies. Bioenergy production on marginal lands has promising avenues for new opportunities for rural communities. The creation of new green jobs in the renewable energy economy supports the social sustainability of biomass cropping systems. Despite inconsistent government support, there are already more green jobs than biotechnology-related jobs, though biotech has seen steady government support **[15].** Consequently, bioenergy and biofuels in particular, have seen record levels of support in the form of subsidies, mandates and investments as governments seek to maximise the perceived synergies between the various opportunities offered by bioenergy. Whilst it is true that well-planted bioenergy development can reduce greenhouse gas emissions from a range of sources, increase rural incomes, reduce waste, improve access to energy, and improve overall energy security and independence-the reality is that current expansion of production, particularly of first-generation liquid biofuels is increasingly cause for concern. Recent research suggests that many of the concerns are at root triggered by demand for additional land for producing bioenergy, which may have a number of direct and indirect impacts on food prices/ security, increased GHG emissions, loss of biodiversity and land rights and other equity issues. In recent years many countries have developed policies and objectives for bioenergy and this includes the production of heat, electricity, and fuel. Growing energy crops at a large scale is bound to have significant effects on the countryside and on wildlife that lives in it such impacts may range from extremely negative to beneficial. Marginal land use planning would substantially alter communities and their development trends in the rural areas of developing countries. However, quantitative assessment of land marginality with respect to environmental suitability, ecological services, and sustainability is limited because of a lack of suitable metrics and criteria for multiple comparisons. The development of international markets for bioenergy has become an essential driver to develop available biomass resources and market potential, which are currently underutilized in many world regions. Exports of biomass-derived commodities for the world's energy market can provide a stable and reliable income for rural communities in many developing countries, thus creating an important incentive and market access.

6.3 Facing Uncertainty

The diverse perspectives of multi-stakeholders in the growing industry has created barriers that make communication of data and estimates a difficult task. Hence, bioenergy systems often have high levels of uncertainty and risk that are difficult to quantify because the data available is often limited, incomplete, or inconsistent **[4].** This uncertainty is further enhanced by the unpredictability of the immense realization of climate change implications on land use for bioenergy systems. Therefore, because of the dynamic nature and complexity of the issues discussed in this assessment, as well as the considerable scientific uncertainty and the multiplicity of interests involved, it has not as yet been possible to carry out an integrated assessment of the contribution of bioenergy systems, facing the inevitability of uncertainty

SECTION V: Implementation potential of bioenergy policies and the integration of a new policy framework for future research and sustainable development.

7. Policy implications

In summary, the promotion of second generation biofuels can help provide solutions to multiple issues including energy security, rural economic development, and GHG mitigation and help reduce the over impacts on sustainable development. Therefore, it is important that policies are the center of the industry to further the industries support in increased sustainable bioenergy production. Policies designed to support the promotion of second generation biofuels must be carefully developed if they are to avoid unwanted consequences and potentially delay the commercialization process even further. Currently the relatively high costs and support currently offered for many first generation biofuels has become an impediment to the development of second generation biofuels, as the goals of some current policies are not always in alignment with policies that foster its innovation as a viable industry. Nevertheless, in time second generation biofuels will come to benefit from the present support from first generation biofuel technology and infrastructure. This assumes that the future policy support will be carefully designed in order to foster the transition from first to second generation and take into account the specifications of generations of biofuels, the production of sustainable and dedicated feedstock for production, and other related policy goals that are to be considered. Taking into account the environmental impacts of CO2 emissions from liquid fuels derived from fossil fuels. It is also important to ensure that bioenergy feedstock are put to their highest value use, due to competition for the limited biomass resource for heat, power, bio-material applications etc. This entitles the industry to a more integrated policy approach needed to ensure the industries commercialization through the support of the government in the research, development and the advancements in technology for the dedicated energy crops proposed from marginal lands. This vision of an integrated policy approach, will not entirely eliminate economic risks but instead provide the certainty needed to invest with confidence in the emerging and promising new energy sector.

7.1 Integrated Policy Framework

Social sustainability of second- generation biofuels can only be achieved with the design of appropriate regulatory policies **[11]. **Food production should always be the first priority, and adherence to land allocation procedures is a critical step to help integrate local communities. This section makes certain recommendations for an integrated policy framework in Canada for the production of dedicated bioenergy crops from marginal lands. The recommended requirements of such a bold framework include:

- The Coordination between national and international stakeholders among key sectors invested in biofuel development and use of bioenergy production. This requires the integrated collaboration and flow of data and research from the agriculture, energy, environment and transport.
- Negotiations of a schedule to gradually eliminate the tariff and non-tariff barriers to biofuels trade.
- Agreement on internationally compatible fuel quality technical standards whilst recognizing that several countries are already engaged in efforts to harmonize these standards.
- Provide more transparency within the bioenergy system and process so as to blend other regulatory requirements at regional and global levels.
- Provide more public participation within the decision making process especially when assessing the environmental and social potential impacts of cultivating dedicated energy crops on marginal lands in Canada.
- Propose consultation with indigenous nations on the acquisition of land use for bioenergy systems.
- Review policies in agriculture, energy and the transport sectors that contribute to inefficient production and market misrepresentations in biofuels and their feedstock, and

- Adapt local, bilateral, regional and/or other integrated frameworks for biofuel trade agreements with the objective of collaborating with pre-existing frameworks to achieve convergence towards a more comprehensive international land use agreement.

7.2 Global potential

Biofuel support policies have always had a strong impact on global biofuel markets affecting both production and demand **[44].** On a global level, previous studies on biomass potential suggested that between 10% and 300% of current global energy consumption could be produced with much of the biomass coming from developing regions and emerging economies **[6].** Considerable amounts of second-generation biofuels could be produced from available agricultural and forestry residues. Until the new technologies are commercially available, developing countries could revitalise rural economies by investments into rural infrastructure, agricultural production and improved energy supply. Different bioenergy systems could play an important role in this regard by providing access to cheaper domestic energy with significant potential to improve productivity and the overall standard of living in rural communities. Bioenergy crops currently provide the only source of alternative energy with the potential to reduce the use of fossil fuels in the transportation sector in a way that is compatible with existing engine technology.

7.3 Biofuel trade: Moving towards sustainable global markets

As markets for bioenergy continue to grow and expand their knowledge and development, so does their interest in biofuel trade in the global market **[3].** The production and trade of feedstock for second-generation biofuels could be another option for emerging and developing countries to profit in cases where second-generation biofuel production takes place outside the country **[6].** This idea has led to the support of its multi- stakeholders for the harmonisation of standards and additional trade liberalisation. To provide a complete and comprehensive analysis of the development and production of second generation bioenergy in Canada, we must look beyond the narrow minded focus of cultivation of energy crops for the production in the transport sector and consider the full potential that would impact not only in the development of the countries rural areas but its contribution in the global market. The Future of a global biofuel markets could be characterized by a diverse set of supply and consumer regions. The balancing role of an open market where trade is prevalent could pose as a crucial precondition for developing biofuel production capacities worldwide. The existence of such an integrated global market requires policy instruments such as subsidies, tariffs, import, quotas, export taxes and non-tariff barriers**.** These measures will provide the necessary conditions to reduce risks and to attract investment to develop and expand sustainable production. However, they have not always resulted in effective deployment and efficient production and at times may seem to restrict the opportunities that biofuels present. This impedes on the image of biofuels and is provoked in part by a rather complex set of national public support schemes which threatens the fulfillment of their deployment. This is something that must be addressed in further research. In addition, the development of a global outline for sustainable production combined with technical and economic support are needed to facilitate compliance with the public to ensure that sustainability and trade agendas are in agreement with the recommended criteria.

7.4 Enhancing research and development in bioenergy technologies

The key challenge for developing the next generation technologies of biofuel production is acquiring economical feedstock that would appeal to the current market **[25][44].** The current production of first and second generation biofuels in the same market place is possible, with each broadening the opportunity for new feedstock introduction and technology options that would continue to improve biofuel performance. Based on current trends, it has been predicted that there will be a growing need for attractive and innovative new renewable energy options like that of perennial energy crops, bridging a new pathway towards sustainable energy. This study identified the immense potential of bioenergy production to establish a sustainable market in Canada and the idea of a thriving trade system. Achieving this vision would require the combination of numerous models, datasets and inputs from environmental, scientific and economic experts, far beyond the scope of this study. However, the government of Canada is dedicated to the research of innovative technological development for bioenergy that will elevate the countries stands on sustainability. If Canada is going to become a leader in research and development of bioenergy technologies then the federal government would need to embrace the production of dedicated perennial energy crops and abandon the use of annual crops as biofuels. Resource efficient agriculture production REAP Canada along with Agriculture and Agri-Food Canada, Natural resource Canada, Canadian Bioenergy Association and the international energy agency (IEA Bioenergy) are at the forefront of current research and development in the country, paving the way for future studies of next generation bioenergy production in Canada for the prosperity of new bio markets.

8. CONCLUSION:

Bioenergy has complex environmental, economic and social interactions, including climate change feedback, biomass production and land-use. The policy context for bioenergy and particularly biofuels has changed rapidly and dramatically in recent years. The food versus fuel debate and growing concerns about other conflicts are driving a strong push for the development and implementation of sustainability criteria and frameworks. While the primary environmental objective of future biofuel production research is to reduce greenhouse gas emissions, it is important that achieving this objective does not harm biodiversity or any other environmental, social or economic aspect. Bioenergy is noted as one of the most important source of renewable energy and are used promising new mechanism to mitigate global climate warming, by replacing fossil fuel energy with higher greenhouse gas emissions. The consumption of land and the competition for productive soils that could also be used for the production of edible goods will remain a crucial problem of biomass production **[27].** Many of other conflicts can be reduced if not avoided by encouraging synergisms in the management of natural resources, agricultural and livestock sectors as part of good governance of land use that increases rural development and contributes to poverty alleviation and a secure energy supply **[35][36].** Therefore, there is serious need to further the research and development of Bioenergy technologies into the future of sustainability. The question is no longer whether bioenergy can play a role in future energy supply, but more the extent, timing and cost of their contribution (IEA 2007).

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