Assessment of the current biofuel industry in India and Canada

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Abstract

The biofuel industry is developing rapidly on a global scale, and both the Canadian and Indian government are currently increasing production of the renewable energy option. The industry has the potential to improve the rural economy, reduce greenhouse gas (GHG) emissions and meet the country's energy security requirements. The locally produced bioenergy can reduce dependence on foreign oil and provide the requirements for agricultural, industrial and household uses in urban and rural areas of the country. At the same time however, it has contributed to reduced food availability and an increase in food prices. The report looks at the current situation in both countries by investigating the available technology for conversion and its efficiency, and the biofuel resources available. It also investigates whether biofuels are a sustainable energy option by looking at their future potential in terms of the amount of energy that needs to be produced in future years and the area of land required to grow the biofuel crops. Finally, the environmental and socio-economic impacts of the biofuel industry are analysed. The two countries want to blend 5% ethanol with gasoline for vehicle use by 2010. Canada wants to achieve 2% of diesel requirements by increasing biodiesel development; India is aiming for 20% by 2012. Ethanol is predominately obtained from corn in Canada and both soybean and canola oil are being used as feedstock for biodiesel. In India, sugarcane molasses is utilized for ethanol and the government is also looking into using *Jatropha Curcas* seeds for biodiesel production on wastelands. Both countries have the potential of meeting future blending requirements but will require an increase in crop land area. The use of cellulosic ethanol derived from switchgrass and agricultural residues is being investigated but is not yet commercially available. The biofuel industry creates both positive and negative environmental and socio-economic impacts. Biofuels can mitigate carbon from the atmosphere through crop sequestration. However, deforestation and land use change in response to increased agricultural land requirements may increase GHG emissions over the long term. Furthermore, large quantities of water, land and chemicals are required to cultivate biofuel crops. In terms of social sustainability, the biofuel industry has the potential of creating employment opportunities in rural areas and can raise farm income. However, there are also socio-economic impacts through the competition of land required for food crops. The increase in grain prices is posing a threat to food security in many developing nations. The environmental and social sustainability issues need to be considered by policy makers when implementing the production of biofuels on a local and global scale.

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1) Introduction

Biofuels as an alternative energy source are gaining much interest politically among many countries in the world. Claims are made that they can be a sustainable solution in reducing greenhouse gas (GHG) emissions, improving the local economy and assisting countries to become independent from foreign oil sources. Biofuels, such as ethanol and biodiesel, are seen as a good strategy in meeting the Kyoto targets of reducing GHG emission levels by 6% below 1990 levels. In contrast to other renewable energy forms such as hydro, solar or wind power, biofuels can be converted to any energy service, including electricity, process heat (for spacing heat, industrial processes, cooking and drying), mechanical power and steam production (UN, 2007). World ethanol production has been increasing rapidly in the past ten years and biofuels may be providing 25% of the world's energy needs over the next 15 to 20 years (UN, 2007). According to Klein and LeRoy (2007), global ethanol production was 20 billion litres in 2000, and has more than doubled to 45 billion litres in 2005, accounting for 3% of the worlds' vehicle fuel consumption (Figure 1).

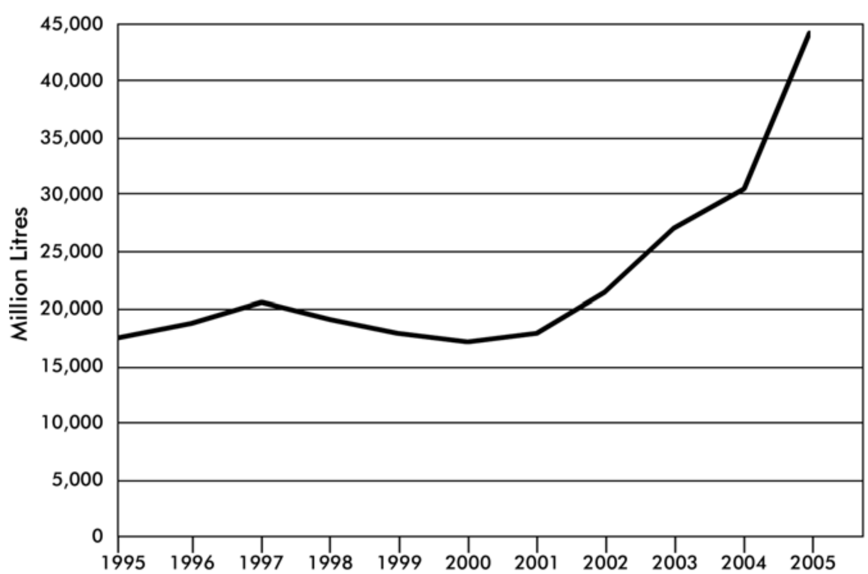


Fig 1. World ethanol production (million L) from 1995 to 2005 (Source: Klein and LeRoy, 2007)

Today biofuels are already widely used as supplements in diesel- and gasoline-powered vehicles. Ethanol and biodiesel can be blended with petroleum to varying quantities of up to 20% and used as an automotive fuel. Currently, both the Canadian and Indian government are enforcing the blending of 5% ethanol for vehicle use, a quantity that is applicable for most vehicle engines. There are many government interventions that stimulate world production of biofuels through market tools such as subsidizing construction and operating of biofuel facilities, mandatory proportions of biofuel contents in liquid fuels, and changing taxing regimes (Klein and LeRoy, 2007). However, biofuels have been criticized of competing with food crops for agricultural land. Food prices have been increasing on a global scale and this may impose issues of food security in many nations, especially in developing countries of the world. The current technology and industry of modern bioenergy forms such as starch-based and cellulose-based ethanol and biodiesel will be discussed in this paper by looking at the situation in high-income country Canada and low-income country India. The environmental and social impacts will be investigated by looking at aspects of greenhouse gases, land use change and the impacts on local and global food supplies. The traditional use of bioenergy as is done in many poor rural areas in form of inefficient direct combustion will also be analysed in this paper. The main data and research findings for the project where derived from an extensive literature review. Sources that were used include academic literature obtained from scholarly journals, scientific reports, government websites and NGO resources.

2) Biofuels in Canada

Biofuels are liquid or gaseous fuels derived from biomass. Sources of biomass include starches from cereals, grains and sugar crops as well as cellulosic materials from grass, trees and agricultural waste products. Ethanol can be obtained through the conversion of starch-based forms of biomass using grains such as corn or wheat or from lignocellulosic materials including switchgrass, corn stover and other agricultural residues. Currently, corn is the most common feedstock used for ethanol in North America. In response to the increased demand of ethanol as a gasoline additive, efforts are being undertaken to increase the supply in order to meet the requirements that have been legislated in Canada. In 2006, the nine existing ethanol plants in the country produced about 600 million litres annually with an announcement of eight additional plants to be built that have the capacity of producing an additional 810 million litres per year (Klein and LeRoy, 2007). Pilot-scale demonstration plants exist to improve the technology of lignocellulosic ethanol from sources such as switchgrass and the technology is expected to become commercially available by 2015 (UN, 2007). Biodiesel, produced from vegetable oil, is another form of biofuels that can reduce the use of petroleum fuels and be used as a heating fuel.

2.1 Corn ethanol

Ethanol, also known as ethyl alcohol or grain alcohol is a carbon-based fuel with the chemical formula C_2H_5OH. Corn ethanol is produced from the kernels of corn, which contain a large amount of starch. Corn is currently the most commonly used source for ethanol production in North America. Starch is a storage polymer consisting of a single sugar (glucose) unit; it is easily hydrolyzed to produce the monomeric sugar which can then be converted to ethanol (Spatari et al., 2005).

Ethanol production begins with milling the grain. Currently both wet- and dry-milling technologies are used in the industry. Wet-milling is more complex yielding multiple coproducts (oil, corn gluten field CGF and corn gluten meal CGM) but is less energy consuming than dry-milling (Hammerschlag, 2006). Ethanol conversion from biomass is achieved through fermentation of the milled product using biocatalysts (such as yeast and bacteria). During the process, glucose is decomposed into ethanol and carbon dioxide. For the ethanol to be usable as a fuel, water must be removed from the dilute aqueous solution by disitillation in order to yield fuel-grade ethanol and by-products (EERE, 2008). Upon combustion, ethanol reacts with oxygen to produce carbon dioxide, water and heat. The reaction is the reverse of photosynthesis, thus creating a renewable energy form through the conversion of solar energy into a usable form.

Fermentation: $C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2CO_2$

Combustion: $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$

Ethanol development in Canada has been somewhat slower than in the United States, and has only been increasing only in the past two decades from 100 million L/year in 1990 to the current capacity of about 600 million L (Klein and LeRoy, 2007). Currently, about nine Canadian ethanol plants exist with the announced plan of building an additional eight (Figure 2).

Fig 2. Existing and projected ethanol plants in Canada (Source: Klein and LeRoy, 2007).

2.2 Cellulosic (lignocellulosic) ethanol

Cellulosic ethanol is made from cellulose and hemicellulose, which are the two main components of stalk, stems and leaves of plants. Cellulose is a linear polysaccharide polymer containing many glucose monosaccharide units. Advanced bioethanol technology is required to break down the long molecular chains into their component sugars which can then be fermented to produce ethanol (EERE, 2008). Lignin, another major component of this part of the plant is a byproduct and can be combusted as a fuel that is required to produce heat needed for the industrial process of fermentation. The two types of technologies that can turn low-value plant matter like switchgrass, corn stover, sawdust or waste paper into fuel ethanol include cellulolysis and the gasification process (McMillan, 1994). Cellulolysis is a biological approach where the pretreated lignocellulosic materials are hydrolyzed in order to break down the long chains of molecules into sugar. Further steps include fermentation and distillation to produce alcohol. Besides converting cellulosic biomass into ethanol, is also possible to employ gasification and

Fischer-Tropsch synthesis, also called FT diesel or biomass-to-liquids, BtL to convert woody biomass into synthetic biodiesel and potentially other products (UN, 2007). Gasification is a thermochemical process where the carbon raw material is converted to synthetic gas (carbon monoxide and hydrogen), which is then turned into ethanol through fermentation or chemical catalysis (i.e. Fisher-Tropsch process).

Cellulosic ethanol manufacturing is still undergoing research and ethanol is not currently produced using this technology on an industrial scale. Iogen Corporation, a Canadian-based company, has developed an advanced new technology that combines innovations in pre-treatment, state-of-the-art enzyme technology, and advanced fermentation. After successfully operating a pilot plant in Ottawa, the company is considering alternative sites for full-scale operating plants (Klein and LeRoy, 2007).

2.3 Biodiesel

Biodiesel is a methyl ester produced from vegetable oils, animal fats and waste from the pulp and paper industry. It is generated by transesterification, a process where the oils or fats react with methanol (Klein and LeRoy, 2007). Biodiesel as a renewable energy source, can reduce the use of petroleum based fuels and lower greenhouse gas emissions. It can be blended up to 20% with unmodified diesel engines can improve the fuel lubricity, extend the engine life and reduce fuel consumption when mixed with diesel fuel (Prakash, 1998). However, some technical difficulties can occur due to the quality and cost of biodiesel. The choice of feedstock can affect fuel related properties such as the cetane number (CN), viscosity, cloud and pour points and the degree of saturation (Table 1). Low cloud and pour points are especially important in Canada because its cold climate can cause flow problems. Biodiesel has a higher CN, viscosity and cloud and pour points than conventional diesel, which can cause problems when blending with diesel fuels (Prakash, 1998). Common feedstocks used in Canada include soybean and canola oil. It has been estimated that about 600 million liters of biodiesel could be produced annually from surplus canola, soy, tallow and tall oil in the country (Prakash, 1998). This is a much greater amount than the diesel consumed in the country every year.

Table 1: Fossil diesel and biodiesel properties derived from different feedstocks (Source: GTZ, 2005)

Fuel	Kinematic viscosity (mm2/s)	Cetane No.	Lower heating value (MJ/kg)	Cloud point (°C)	Pour point (°C)	Flash point (°C)	Density (Kg/l)
Soybean biodiesel	4.5	45	33.5	1	-7	178	0.885
Sunflower biodiesel	4.6	49	33.5	1	-	183	0.860
Diesel	3.06	50	43.8	-	-16	76	0.855

2.4 Projected biofuel requirements

The federal government has set out the mandate of using 3.1 billion litres of renewable fuel (derived from corn ethanol) to meet projected requirements by 2010. The total projected gasoline use by 2010 is 60 billion litres and this amount of ethanol represents 5% of the required gasoline (Klein and LeRoy, 2007). Furthermore, 600 million litres of diesel fuel and heating oil should be derived from biodiesel by 2012, consisting of 2% of the total requirements of 30 billion litres by 2012 (Government of Canada, 2008). As noted, the production capacity of existing Canadian ethanol plants has increased in the past years and in 2006 reached a capacity of 600 million litres (Figure 3). In order to meet the renewable fuel standards an additional capacity of 2.5 billion litres would need to be produced in the next three years (Klein and LeRoy, 2007).

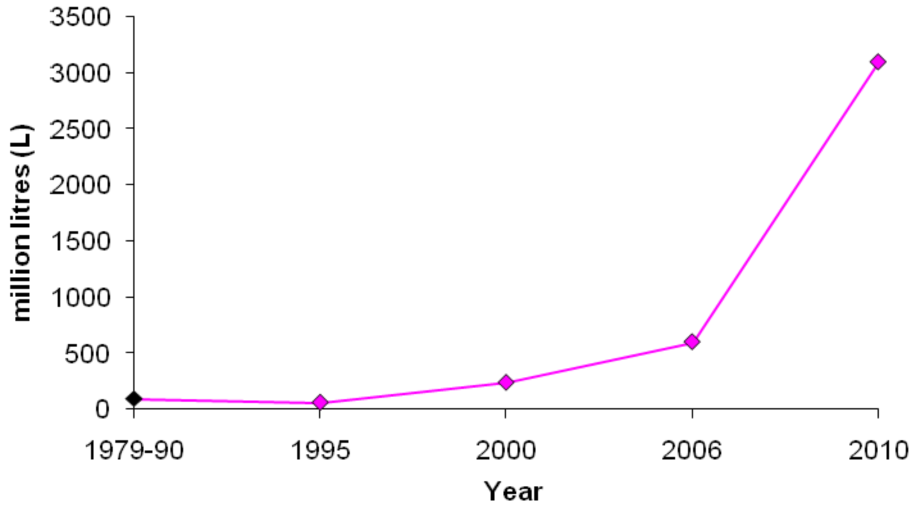


Fig 3. Ethanol produced in Canada (million L). Amount in 2010 represents requirements to meet 5% demand of transportation fuels (Source: Klein and LeRoy, 2007).

For biodiesel, the current capacity is 56 million litres, and therefore to meet the requirement of 600 million litres by 2012, production would have to be increased by 544 million litres (Table 2). The amount of ethanol currently produced contributes to 1% of the total gasoline requirements in 2010. Biodiesel currently amounts to 0.2% of the total diesel demand in 2010.

Table 2: Implications of production mandates on biofuel requirements in Canada

	Total requirements (L)	Renewable fuel requirements (L)	2006 biofuel production capacity (L)	Required increase in capacity (L)
Ethanol (2010)	60 billion	3.1 billion	601 million	2.5 billion
Biodiesel (2012)	30 billion	600 million	56 million	544 million

Making cellulosic ethanol a commercially available energy source could help contribute to the projected energy requirements in Canada. Further research is required to investigate how much energy could be produced with the currently available feedstocks such as corn stover and switchgrass and whether this energy source could significantly contribute to the renewable energy requirements in Canada.

3) Biofuels in India

India has major energy requirements, ranking sixth in the world in terms of energy needs, and accounting for 3.5% of the world commercial energy demand in 2001 (Gonsalves, 2006). Traditional biomass use such as burning of fuel wood meets about 75% of India's rural energy needs (Ramachandra et al., 2004). The majority of the country's requirements are derived from crude oil imports. With an expected growth rate of 6% per year, petroleum imports for the Indian economy are expected to rise from 98.26 million tonnes (MT) in 2005 to 166 MT in 2019 and 622 MT by 2047 (GTZ, 2005). Oil resources are declining on a global scale and therefore an expansion of the biofuel industry must be considered as a possible option to meet the needs of the country. The locally produced bioenergy can reduce dependence on foreign oil and provide the requirements for agricultural, industrial and household uses in urban and rural areas of the country. Consequently, the Minister of Petroleum and Natural Gas has mandated a 5% ethanol blend beginning in October 2006. Furthermore, the Indian government wants to meet 20% of diesel requirements by increasing biodiesel development by 2012 (Gonsalves, 2006). The current biofuel feedstocks in use include sugarcane molasses and tropical sugar beet for ethanol. For biodiesel, the use of non-edible *Jatropha Curcas* oil seeds is currently being investigated in India. This section will look at the modern bioenergy forms and the projected energy requirements in India. Non-commercial forms that are being used in many rural areas of the country will also investigated.

3.1 Modern bioenergy forms

3.1.1 Ethanol

Ethanol in India is currently produced by the fermentation of sugarcane molasses, a byproduct of sugar. In the process, Zymase, an enzyme from yeast, converts the diluted sugarcane molasses into 6-8% ethanol, while releasing carbon dioxide. After fermentation, the cell free broth is distilled in two stages to yield 96% alcohol (Tewaria et al., 2007).

According to Gonsalves (2006), the average yield of sugarcane in India is 77 tonnes/ha in tropical and 53 tonnes/ha in subtropical states. Each tonne of cane yields 105 kg of sugar and 40kg of its byproduct molasses, which can be used to obtain 10 litres of ethanol per tonne of molasses. In India, about 60% of the cane is used for the production of sugar as a food source, 30% for alternate sweeteners (gur and khandsari) and 10% for seed cane. Because of the high demand for sugar, only molasses is currently utilized for the production of ethanol. If the entire sugarcane plant was used, 70 litres of ethanol per tonne could be obtained (Gonsalves, 2006).

Ethanol production is currently limited due to its dependence on the single source of sugarcane molasses. Sugarcane crops are known to be resource-intensive, requiring a large amount of fertilizers, pesticides and water supply through irrigation throughout the growing period of 12 to 13 months. As alternatives to sugarcane, tropical sweet sorghum and sugar beet can be used as feedstock inputs (GPZ, 2007). Table 3 compares agricultural factors of the three crops. Accordingly, both tropical sugar beet and sweet sorghum offer advantages over sugarcane as the crops are less resource-intense and more drought-tolerant and the harvesting process is simpler. Sweet sorghum crops have a four-month growing cycle, allowing two crops to be grown per year in some locations (Gonsalves, 2006).

Table 3: Agricultural factors of sugarcane, tropical sugar beet and sweet sorghum crops

(Source: Gonsalves, 2006)

	Sugarcane	*Tropical Sugar Beet*	*Sweet Sorghum*
Crop duration	About 12 – 13 months	About 5 – 6 months	About 3 ½ months
Growing season	Only one season	Throughout the year (10 months), except rainy period	All season - Kharif, Rabi and summer
Soil requirement	Grows well in loamy soil	Grows well in sandy loam. Also tolerates alkalinity.	All types of drained soil
Water management	Requires water throughout the year	Less water requirement. 40 –60 per cent compared to sugarcane	Less water requirement. Can be grown as rain-fed crop.
Crop management	Requires good management. Low fertilizer required. Less pest and disease complex.	More fertilizer requirement. Requires moderate management.	Low fertilizer requirement and less pest and disease complex. Easy management.
	Sugarcane	*Tropical sugar beet*	*Sweet sorghum*
Yield per acre	25 to 30 tons	30 to 40 tons	20 to 25 tons
Sugar content on weight	8 to 12 per cent	15 to 18 per cent	8 to 10 per cent
Sugar yield	2.5-4.8 tons /acre	4.5-7.2 tons/acre	2-3 tons /acre
Ethanol production directly from juice	1700 to 2700 litre / acre	2800 to 4100 litre / acre	1140 to 1640 litre / acre
Harvesting	Difficult and laborious	Very simple. Both manual and with simple small mechanical machine can be used.	Very simple. Both manual and with simple small mechanical machine can be used.

As in Canada, research is currently directed to investigating the potential of using lingo-cellulosic raw materials for ethanol. Feedstock inputs would be rice straw, rise husk, bagasse, agricultural residues and perennial grasses, which may emerge as more sustainable feedstock for ethanol production in the long term. In 2001, it was estimated that the total annual agro-residue production in India is approximately 800 million tonnes – where 6% can be used to produce 9 million kilolitres of ethanol (EthanolIndia, 2007).

3.1.2 Biodiesel

Diesel demand in India is five times higher compared to petroleum (Gonsalves, 2006). However, in contrast to the ethanol sector, the biodiesel industry is still very small. Biodiesel is produced through the transesterification of vegetable oil using an alcohol such as methanol. In the process, glycerol is produces as a byproduct along with the methyl ester (biodiesel) fuel. With a short supply of edible oil, the government is currently promoting biodiesel production from non-edible oil such as *Jatropha Curcas* seeds. This kind of feedstock is advantageous as it requires less water and fertilizer for cultivation, has a high seed yield and oil content and is not used as cattle or sheep feed (Gonsalves, 2006). The technology for the preparation of biodiesel from low free fatty acids (FFA) content and high quality oils is well established; the challenge in India is to handle feedstocks such as Jatropha that contain low FFA (GPZ, 2007).

The Ministry of Rural Development proposes a National Biodiesel Program, where 0.4 million ha of wasteland are planned to be established for *Jatropha* plantations in a demonstration phase. Initially, the planting stock would have to be seed, because cuttings are not available in such large quantities (GPZ, 2007). *Jatropha* seed production is assumed to be between 1 to 5 tonnes / hectare with a final product yield of 0.2 to 1.1 tonnes per ha (Table 4). These estimates are based on extrapolation of yields obtained from individual plants or small demonstration plants (GTZ, 2005).

Table 4: Biodiesel obtained from different seed yields (Source: GTZ, 2005)

Annual Yield (t of seeds/ha)	Biodiesel yield t/ha (21.6% of seed weight)
1	0.216
2	0.432
3	0.648
4	0.864
5	1.08

Glycerol, a byproduct of biodiesel, can be used for applications such as cosmetics, soaps, biosurfactants and biopolymers. However, the 12% of glycerol that is being produced during the biodiesel process, is an oversupply and has rapidly reduced the price of the byproduct (Gonsalves, 2006).

Current research in India focused on developing high oil-yielding *Jatropha* seeds by the use of biotechnology. Pilot plants on transesterification are also being set up by the Indian Oil Corporation (R&B), the Indian Institute of Technology (IIT) in Delhi and other organizations (Gonsalves, 2006). Naturol Bioenergy Limited (NBL) has allocated 120,000ha of land for *Jatropha* cultivation and set up a biodiesel plant in Kakinada, Andhra Pradesh in 2005 (NBL, 2008).

3.3 Prospective biofuel requirements

There exist about 300 units of alcohol distilleries which are located mainly in sugarcane growing regions of India (Tewaria et al, 2007). In 2006-07, the country's production capacity was 822 million litres, after meeting the needs of the chemical industry and potable sectors (Table 5).

Table 5: Alcohol production in India in million L (Source: EthanolIndia, 2007)

Year	Molasses Prod.	Production of Alcohol	Industrial Use	Potable Use	Other Uses	Surplus Availability
1998-99	7.00	1411.8	534.4	5840	55.2	238.2
1999-00	8.02	1654.0	518.9	622.7	576	455.8
2000-01	8.33	1685.9	529.3	635.1	588	462.7
2001-02	8.77	1775.2	5398	647.8	59.9	527.7
2002-03	9.23	1869.7	550.5	660.7	61.0	597.5
2003-04	9.73	1969.2	578.0	693.7	70.0	627.5
2004-05	10.24	2074.5	606.9	728.3	73.5	665.8
2005-06	10.79	2187.0	619.0	746.5	77.2	742.3
2006-07	11.36	2300.4	631.4	765.2	81.0	822.8

In order to meet the gasoline requirements of 17.5 billion litres in 2012, a 5% ethanol blend (as established by the Indian government) would require 822 million litres (GTZ, 2005). The current availability of molasses and alcohol is adequate to meet the future requirement (Table 7).

Diesel consumption in 2003-04 was about 38 million tonnes[1] that was used for transportation (60%) as well as the industrial and agricultural sector (GTZ, 2005). Requirements are projected to increase rapidly and in order to reduce dependence on foreign oil imports, the country is developing renewable options such as biodiesel. Based on future estimates of diesel demand, biodiesel requirements under different blending options were obtained (Table 6).

Table 6: Diesel demand and prospective biodiesel requirements in million tonnes (Source: GTZ, 2005)

Year	Diesel requirement (MT)	Biodiesel @ 5%	Biodiesel @ 10%	Biodiesel @ 20%
2005	46.97	2.3485	4.697	9.394
2006	49.56	2.478	4.956	9.912
2007	52.33	2.6165	5.233	10.466
2010	66.07	3.3035	6.607	13.214
2020	111.92	5.596	11.192	22.384
2030	202.84	10.142	20.284	40.568

In 2010, India will have to meet of the capacity of 13.2 million tonnes of biodiesel to meet the Planning Commissions' 20% blending requirements with fossil diesel (Table 7). Since biodiesel production currently only consists of pilot scale projects and lab experiments, this form of renewable energy is not yet available on a commercially scale and large-scale *Jatropha Curcas* plantations would be required to meet the requirements.

[1] For conversion: density of diesel and biodiesel is 0.8 kg/L

Table 7: Implications of production mandates on biofuel requirements in India (Source: GTZ, 2005)

	Total requirements	Renewable fuel requirements	2006 biofuel production capacity (L)	Required increase in capacity (T)
5% Ethanol (2012)	17.5 billion L	822 million L	822 million	-
20% Biodiesel (2010)	66.07 million T	13.2 million T	-	13.2 million

3.4 Non-commercial forms

Direct biomass burning is a major source of energy in many rural areas. According to Ramachandra et al. (2004) open biomass burning currently meets 75% of India's rural energy needs. The continued dependence on biofuels such as fuelwood is affecting forest and agricultural systems in rural areas. In 1991 alone, at least 180 million tonnes of firewood, 40 million tonnes of dungcakes and 30 million tonnes of agricultural residues were consumed in the rural sector in order to meet domestic thermal energy requirements on a national scale (Sinha et al., 1998).

For the poorest households energy requirements for household services such as cooking and heating, lighting, communication, water pumping, and food processing are essential (UN, 2007). Modern biofuels produced on a commercial scale have the ability to provide energy services to the poor and at the same time reduce the use of traditional bioenergy which are often inefficient and health-damaging. Especially women and girls are affected by indoor smoke inhalation from cooking with traditional biomass. According the UN, the so called 'kitchen killer' is one of the leading causes of disease and death in developing countries (2007). The use of modern energy sources and efficient technology can reduce these health and safety problems and enable people of poverty to have more productive, enjoyable lives. More efficient cook stoves are one example that can reduce biomass demand. Biofermentation systems and liquid biofuels such as biodiesel offer opportunity to power production at local scales (UN, 2007). The renewable energy options could enable a decentralized distribution generation of electricity and motive power applications such as water pumping and milling in rural areas. However, shifting towards modern fuel is one of the most important and long-lasting challenges. The resource availability in poor areas needs to be assessed as there may higher priorities among rural populations in using biomass resources such as agricultural residues for animal feed and bedding, fertilizer and construction materials. A detailed resource assessment is required to see if there will be a competition with modern biomass energy systems.

4) Environmental impacts of biofuels

Production and use of biofuels can have both positive and negative effects on the environment. Here, some of the advantages and disadvantages will be discussed. The environmental issues investigated include conversion efficiency of biofuels, greenhouse gas (GHG) emissions and land requirements.

4.1 Conversion efficiencies of biofuels

Biofuel production requires energy to grow crops and additional energy to convert them to ethanol and biodiesel. Energy inputs for production include: energy embodied in inputs like fertilizers, machine and fuel energy used in cultivating and harvesting the crops, energy for transportation of crops to production facilities and for operation of the buildings, and energy to carry out the processes of fermentation and distillation (Hill et al., 2006). As an example, biofuel production requires fertilizer and pesticide inputs, which are products of fuels themselves. Nitrogen fertilizer is an energy-intensive product, usually produced from natural gas (CH_4), and is therefore considered as an upstream energy input (Hammerschlag, 2006). Farmers are expected to use more fertilizers and chemicals to increase their yields. Biofuels have a negative impact by moving pesticides and fertilizers such as nitrogen and phosphate from food production to other energy crops and increasing the area of land where chemical inputs are used. These nutrients are potentially leached into groundwater and run-off into water bodies, leading to eutrophication. Furthermore, the conversion of natural forests into single crop production contributes to loss of biodiversity. The increased intensity of crop production, often through unsustainable agricultural practices has also been shown to generate additional soil erosion (Klein and LeRoy, 2007).

Determining the life cycle energy balance is one way to assess the environmental impacts of biofuels. Conversion efficiencies of biofuel production, is determined by the energy return on investment (r); defined by Hammerschlag (2006) as the ratio of renewable energy in a liter of ethanol to the nonrenewable energy required to produce it (oil, natural gas, coal, nuclear energy).

$$r = E_{out} / E_{in}$$

$r = 1$: no renewable energy produced

$r < 1$: more nonrenewable energy consumed than renewable energy produced

$r > 1$: renewable energy produced

As the r value increases, the operation in producing renewable energy becomes more efficient. The return on investment for the different forms of biofuels was found in a comprehensive analysis of six studies. Results obtained in five of the studies of energy balance, show an energy return on investment of $r = 1.29$ to 1.65, indicating some renewable energy was produced on investment (Hammerschlag, 2006). Only one study resulted in an r value lower than 1 (Table 8). In that particular case, the more conservative assumptions regarding efficiency led to higher upstream energy input values (such as nitrogen fertilizer inputs, electricity intense industrial processes, energy required for seed production and to manufacture equipment). In general, the majority of the studies conclude that corn ethanol can displace some gasoline and therefore slightly reduce fossil fuel consumption (Hammerschlag, 2006).

Table 8: Energy return on investment based on six corn ethanol studies (Source: Hammerschlag, 2006).

	Marland & Turhollow 1991	Lorenz & Morris 1995	Graboski 2002	Shapouri et al. 2002	Pimentel & Patzek 2005	Kim & Dale 2005
milling technology:	wet	mixed	mixed	dry	dry	dry
	all values in MJ per liter ethanol unless otherwise noted					
	fuel and electricity					
agriculture						
fuel	2.0	0.7	2.2	2.7	2.0	0.8
electricity	0.2	2.0	0.5	0.6	0.5	0.1
feedstock transport		0.4	0.5	0.6	1.5	0.5
industrial process						
fuel	10.5	10.9	11.8	10.0	11.7	12.5
electricity	3.5	3.2	2.9	3.6	5.3	2.2
ethanol distribution			0.4	0.4		0.6
total fuel and electricity	16.1	17.1	18.4	17.9	21.0	16.8
	upstream energy					
agriculture						
fertilizer	4.2	3.6	2.6	2.3	4.7	2.0
biocides	0.3	0.3	0.2	0.4	1.3	0.4
other		0.9	0.3	0.1	3.1	0.1
other nonagriculture					0.1	
total upstream energy	4.5	4.9	3.2	2.8	9.2	2.5
	calculation of r_E					
gross energy input	20.6	22.0	21.6	20.7	30.1	19.3
coproduct energy input	(2.3)	(7.7)	(4.5)	(3.7)	(2.0)	(4.8)
net energy input	18.3	14.3	17.1	17.1	28.1	14.5
allocation factor (%)	89%	65%	79%	82%	93%	75%
r_E (unitless)	**1.29**	**1.65**	**1.38**	**1.38**	**0.84**	**1.62**
	reference data					
upstream fuel included?	yes	no	yes	yes	yes	yes
electricity heat rate	3.0	2.4	3.0	2.7	3.3	3.2–3.4
corn yield (Mg/ha)	7.5	7.5	8.8	7.7	8.7	9.0
ethanol yield (L/kg)	0.37	0.38	0.39	0.39	0.37	0.39
oil reduction (%)			94%	84%		
projected r_E (unitless)	1.67	2.51	1.40			1.91

During the production of cellulosic ethanol, the combustion of lignin releases more heat than is required to produce ethanol. This surplus can be used to generate electricity, and in the calculation, it was considered as an additional component of energy output (Eout) (Hammerschlag, 2006). The obtained r values for cellulosic ethanol range from 4.4 to 6.61 in three studies (Table 9). The variations can be explained by different energy inputs due to the widely developing technologies and the different feedstock inputs in the various studies (Hammerschlag, 2006). In general, the analysis shows a good return of renewable energy on nonrenewable investment. Obviously, cellulosic ethanol can displace even more nonrenewable energy than corn ethanol. It must be emphasized, however, that technical problems remain and the technology has not yet been applied to a full-scale plant operation.

Table 9: Energy return on investment for cellulose ethanol studies (Source: Hammerschlag, 2006).

	Tyson et al. 1993	Lynd & Wang 2004	Sheehan et al. 2004	Pimentel & Patzek 2005
fuel:	various	poplar	corn stover	switchgrass
	all values in MJ/L unless otherwise noted			
	fuel and electricity			
agriculture				
fuel	0.8	1.1	0.8	{ 1.1
electricity				
feedstock transport	0.4	1.3	0.5	1.4
industrial process				
fuel	0.2	2.9		20.1
electricity	0.1		0.3	8.9
ethanol distribution	1.4			
total fuel and electricity	2.9	5.4	1.5	31.5
	upstream energy			
agriculture				
fertilizer	1.1	0.1	4.0	0.9
biocides		0.0		0.3
other				0.8
other nonagriculture	0.5	0.4	0.3	0.5
total upstream energy	1.5	0.5	4.3	2.5
	calculation of r_E			
gross energy input	4.4	5.9	5.8	34.0
surplus electricity	5.4	3.3	1.9	
gross energy output	29.0	26.9	25.5	23.6
r_E (unitless)	**6.61**	**4.55**	**4.40**	**0.69**
	reference data			
upstream fuel included?	yes	?	yes	yes
nominal electric multiplier	3.3	2.7	3.0	3.3
feedstock yield (Mg/ha-yr)	11.2−33.6		8.2	10.0
ethanol yield (L/kg)	0.37−0.41	0.34	0.34	0.40
oil reduction (%)			95%	

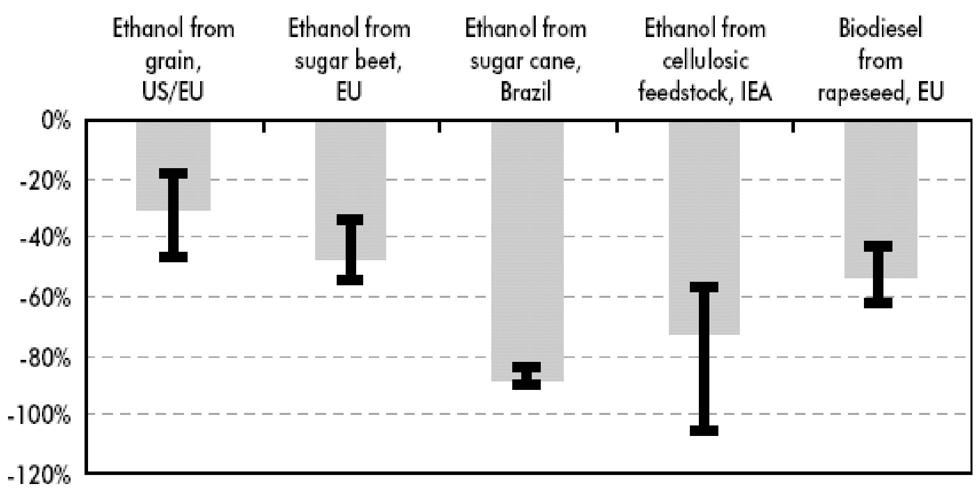
In general, the studies show that bioethanol can create environmental benefits by producing more renewable energy based on nonrenewable investment. Detailed analysis of the energy balance for biodiesel is not currently available.

4.2 Greenhouse gas emissions

One of the main rationales for biofuel development is the potential of mitigating greenhouse gases when replacing fossil fuels used for transportation, electrical generation and heating applications. The renewable energy resource is being promoted as a clean energy option that can reduce the negative environmental impacts of climate change. In 2005, CO_2 emissions in Canada amounted to a total of 747 million tonnes, which is 25.3% greater than the emissions in 1990 and 32.7% above the Kyoto Protocol targets (Samson et al., 2008). Biofuel crops can sequester carbon during photosynthesis and therefore reduce the amount of CO_2 in the atmosphere.

Ethanol and biodiesel are oxygenated compounds that contain no sulphur. Using biofuels in vehicles therefore results in reduced emissions of carbon monoxide (CO), sulphur dioxide (SO_2), particulate matter and unburned hydrocarbons (Klein, 2007). Biodiesel is said to be generally cleaner than petroleum-based diesel and in the United States it is the only alternative fuel that has successfully completed the Health Effects Testing requirements (Tier I and Tier II) of the Clean Air Act. Accordingly, it contains fewer aromatic hydrocarbons and reduces particulate emissions compared to fossil-sourced diesel (EPA, 2007).

In order to estimate the full life cycle, GHG emitted from growing the feedstock, transportation, fuel production, combustion, and fuel consumption need to be considered (IEA, 2004). Included are GHG emission from agricultural processes such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), and air pollutants emitted, such as CO, NO_x, nonmethane organic compounds (NMOC), SO_x and particulate matter (Spatari et al., 2005). Life cycle studies show that overall, greenhouse gases are reduced by 20-40% when using corn ethanol, 70-90% with cellulosic ethanol and 40-60% to produce biodiesel compared to petroleum diesel (Figure 4, IEA 2004). Cellulosic ethanol has a higher value because of the fewer inputs required for feedstock production. Life cycle assessments of corn stover and switchgrass for cellulosic ethanol, found that GHG emissions can be reduced by 65% for ethanol derived from corn stover and by 57% for switchgrass compared to petroleum fuels (Spatari et al., 2005). The difference can be explained by the reduced production emissions of corn stover as it is a byproduct of conventional crop production.



Note: This figure shows reductions in well-to-wheels CO_2-equivalent GHG emissions per kilometre from various biofuel/feedstock combinations, compared to conventional-fuelled vehicles. Ethanol is compared to gasoline vehicles and biodiesel to diesel vehicles. Blends provide proportional reductions; *e.g.* a 10% ethanol blend would provide reductions one-tenth those shown here. Vertical black lines indicate range of estimates; see Chapter 3 for discussion.

Fig 4: Estimates of greenhouse gas reduction percentages from biofuels (ethanol and biodiesel) (Source: IEA, 2004)

Contrary to other findings, in a very recent study Searchinger et al. (2008) claim that greenhouse gas emissions actually increase when considering the conversion of forest to grassland in response to an increased demand for biofuel feedstocks. Using a worldwide agricultural model that estimates emissions from land use change, it was shown that corn-based ethanol nearly doubles greenhouse emissions over 30 years (Table 10). Furthermore, cellulose ethanol from switchgrass increases emissions by 50%, if grown on U.S. corn lands (Searchinger et al., 2008). The study takes into account the indirect emissions caused by the additional crop land requirements in response to higher food prices. Most replacement grains are projected to be provided by increases in crop lands as there are many convertible acres worldwide.

Table 10: **Corn ethanol and gasoline greenhouse gas emissions with and without land use change (g of GHGs CO_2 eq. / MJ of fuel energy (Source: Searchinger et al., 2008)**

Source of Fuel*	Making Feedstock	Refining Fuel	Vehicle Operation (Burning Fuel)	Net Land Use Effects: Feedstock Uptake from Atmosphere (GREET)	Net Land Use Effects: Land Use Change †	Total GHGs*	% Change in Net GHGs vs. Gasoline
Gasoline	+4	+15	+72	0	–	+92	–
Corn Ethanol (GREET)	+24	+40	+71	-62	–	+74	-20%
						+135 without feedstock credit	+47% without feedstock credit
Corn Ethanol + Land Use Change	+24	+40	+71	-62	+104	+177	+93%
Biomass Ethanol (GREET)	+10	+9	+71	-62	–	+27	-70%
Biomass Ethanol + Land Use Change	+10	+9	+71	-62	+111	+138	+50%

*Figures in total may not sum perfectly due to rounding in each column.
†Amortized over 30 years

As shown in Table 10, the total GHG emissions of corn ethanol when considering land use change (104g GHG CO_2 eq. / MJ of fuel energy) and feedstock uptake from the atmosphere amounts to 177g GHG / MJ compared to the 92 g / MJ emitted by gasoline fuel. Furthermore, cellulose ethanol emissions amount to 138 g / MJ when considering land use change.

Biofuels can offset greenhouse gases by fixing carbon from the atmosphere. However, consideration of land use impacts results in higher overall GHG emissions compared to petroleum fuels. In order to achieve greenhouse "benefits", biofuel crops would have to be from waste products or carbon-poor lands where little carbon is presently sequestered.

4.3 Land use

One of the greatest environmental impacts of biofuels in both India and Canada is related to land use. Large-scale ethanol and biodiesel production can compete with agricultural land that has been devoted to food production. The United States is now removing marginal quality crop land from the Conservation Reserve Program in order to provide more land to plant corn (Klein and LeRoy, 2007). Increase in biofuel production will also potentially lead to the conversion of forest to cropland in many locations of the world. The following chapter will look at the area of land needed for biofuel crops to meet the proposed future mandates in both countries.

4.3.1 Land requirements in Canada

Canada's land mass covers a total area of 998 million ha, of which 42% is forest cover and 6.8% (67.5 million ha) is agricultural land devoted to raising livestock and their feed. Of this, 36.4 million ha is entirely used to grow plant crops (Klein and LeRoy, 2007). Projected land requirements can be determined using previous estimates of ethanol demand in 2010. Given the yield of corn and switchgrass (Table 11), the required crop land can be calculated using the given 5% ethanol requirements from 1980-2010. [2]

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[2] Land requirement in a given year calculated by dividing 5% ethanol requirements (million L) with the mean yield of corn and switchgrass (L/ha) respectively.

Sample calculation for year 2000: land requirement for corn = $(238*10^6$ L) / ((3100+3900 L/ha) / 2) = $0.068*10^6$ ha

Table 11: Annual yield of ethanol feedstocks in Canada (Source: Marris, 2006)

Feedstock	Annual yield (L/ha)
Corn	3100–3900
Switchgrass	3100–7600

In order to meet the 5% requirements for transportation fuels in Canada, 0.87 million ha of crop land would be needed for corn production and 0.58 ha for switchgrass in 2010 (Table 12, Figure 5). With a total crop land availability of 36.4 million ha, this amounts to 2.4% of the total crop land for corn and 1.6% for switch grass.

Table 12: Area of cropland (million ha) required to meet 5% ethanol mandate

Year	Land requirement (million ha)	
	Corn	Switchgrass
1979-1990	0.029	0.019
1995	0.017	0.011
2000	0.068	0.044
2006	0.172	0.112
2010	0.886	0.579

In 2007, the total area under corn crops was 1.39 million ha in Canada and therefore an additional 2/3 of the current land under corn production would be required for ethanol (Statistics Canada, 2007).

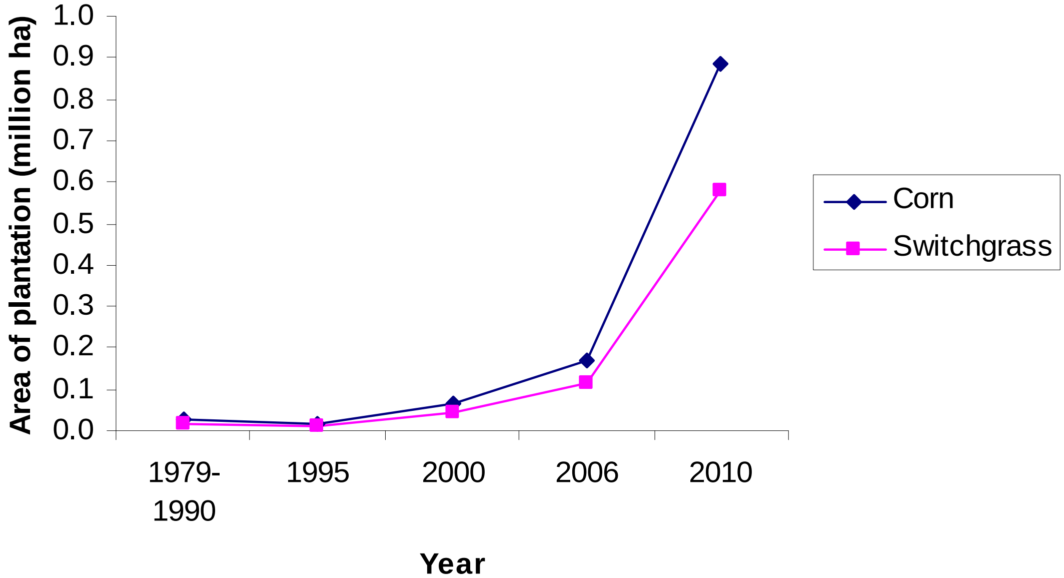

Fig 5: Land requirements to meet 5% of transportation fuel derived from corn and switchgrass in Canada

As shown in Figure 5, switchgrass would require less land to meet the requirements. Therefore, assuming technology is available, ethanol production from cellulose material could be a better option to reduce land use impacts. Agricultural residues (such as corn stover) would require no additional land by maximizing the use of all plant materials through the use of the lignocellulosic portion of the starch crops for ethanol production. This approach would also have a smaller carbon footprint, since the energy-intensive fertilizer inputs remain the same for a higher output of usable material.

4.3.2 Land requirements in India

The area under sugarcane plantations is currently 2% of the total cultivable land and 3% of the irrigated area in the country (EthanolIndia, 2007). The following Table shows the change in area of sugarcane crops in India (Table 13).

Table 13: Area under sugarcane plantation (thousand ha) from 1950 to 2003 (Source: GTZ, 2005).

Year	Area (thousand hectare)	Yield (tonnes/ha)
1950-51	1,707	32.1
1960-61	2,415	45.5
1970-71	2,615	48.3
1980-81	2,667	57.8
1990-91	3,686	65.4
1995-96	4,147	67.8
2002-03	4,361	64.6

Accordingly, the area under sugarcane has increased by 2.5 times since 1950. However, in recent years both the yield and area planted to sugarcane has been much smaller. The Planning Commission envisions an increase of sugarcane area to 5 million ha during the 10th Plan period for a production target of 21.3 million tonnes (EthanolIndia, 2007). Using alternate feedstocks such as sweet sorghum for ethanol production is also currently being investigated.

Land availability is an important requirement needed to implement large-scale *Jatropha* plantations for biodiesel in India. The current strategy of the Government is to utilize wasteland for biodiesel plantations in order not to affect the food security in the country. However, some private industries and state governments are also considering using agricultural land for biodiesel production (GTZ, 2005). In a demonstration phase, the National Biodiesel Program plans to establish 400,000 hectares of *Jatropha* plantations. The planting stock used would be seed, because cuttings wouldn't be available in such a large quantity (GTZ, 2005). A total of 2000 tonnes of seed would then be required for the plantation, which would require a substantial investment.

Assuming the yield of J*atropha* seeds is 2 tonnes/ha (0.432 t biodiesel/ha), the required land can be calculated for different biodiesel blending percentages (Table 14, Figure 6)

Table 14: Land requirements (million ha) to meet various biodiesel blending percentages (seed yield: 2t/ha)

Year	Land for 5% (million ha)	Land for 10% (million ha)	Land for 20% (million ha)
2005	5.44	10.87	21.75
2006	5.74	11.47	22.94
2007	6.06	12.11	24.23
2010	7.65	15.29	30.59
2020	12.95	25.91	51.81
2030	23.48	46.95	93.91

The total amount of wasteland available is 63.85 million ha of the 392 million ha land mass in India (GTZ, 2005). Since the area of plantation required to meet the 20% biodiesel blending in 2030 is 94 million ha, there would not be sufficient land available to meet this requirement using waste land alone (Figure 6). However, if the entire wasteland was used for biodiesel crop plantations, given a biodiesel yield of 0.432 t/ha, 27.6 million tonnes of biodiesel could be produced. This quantity could make a significant contribution to the diesel fuel needs in the country.

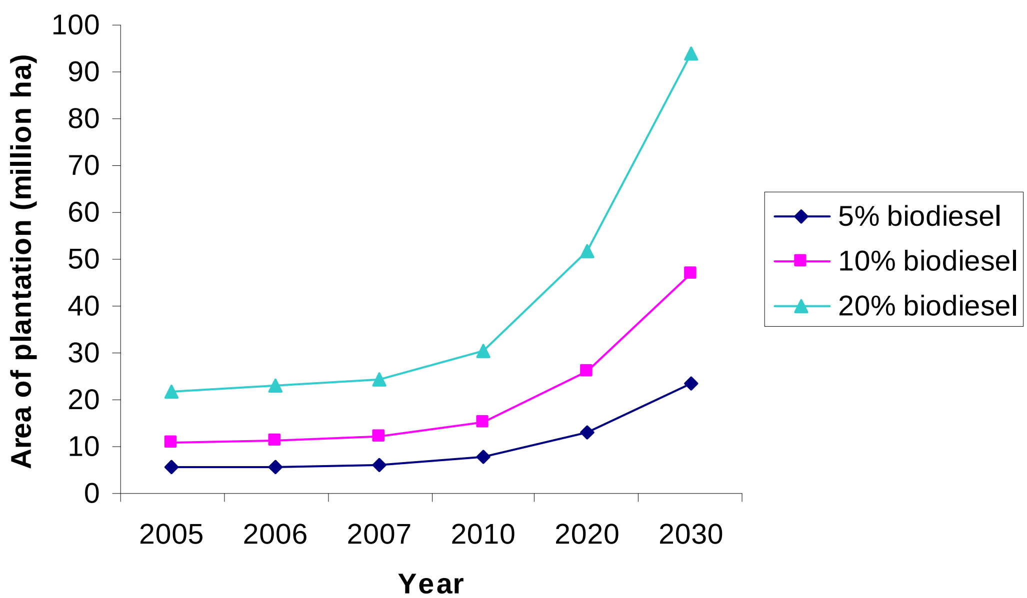

Fig 6. Land requirements (million ha) in India for different biodiesel blendings assuming a *Jatropha* seed yield of 2t/ha.

The estimated 63.8 million ha of wasteland is debatable because there is no information available on the number of people who live in these areas and how they are used. Furthermore, the different agro-ecological regions in the country may not all be suitable for biodiesel plantations. Therefore, it is not correct to assume that the entire wasteland area is available for the National Biodiesel Program (GTZ, 2005).

4.4 Water use

Water use is another major issue to consider when planting biofuel crops. Many parts of India are experience growing water scarcity and reduced water quality. Water-intense crops such as sugarcane are often cultivated in drought-prone areas, leading to an overexploitation of the scarce groundwater resources (Figure 7).

Low yields have resulted from lack of irrigation systems, depletion of ground water resources, and excessive dependence on monsoons, which can be unreliable. Improving agricultural practices can increase yields by using different water saving irrigation methods, implementing drought management practices, inter-cropping with other crops and cultivating alternate ethanol feedstocks such as sweet sorghum and tropical sugar beet, which require less water inputs.

Molasses-based alcohol distilleries, as exist in India, require large amounts of water (Tewaria et al., 2007). The water consumption in distillieries during the manufacturing process is shown in Table 15. 70% of the raw water use is used for non-process applications, the rest is for process applications. The water source varies upon location and can come from surface water, ground water, municipal supply or a combination of these (Tewaria et al., 2007). Surface water is generally used in the western region (Maharashtra) whereas northern India (Uttar Pradesh) usually uses ground water as a main source.

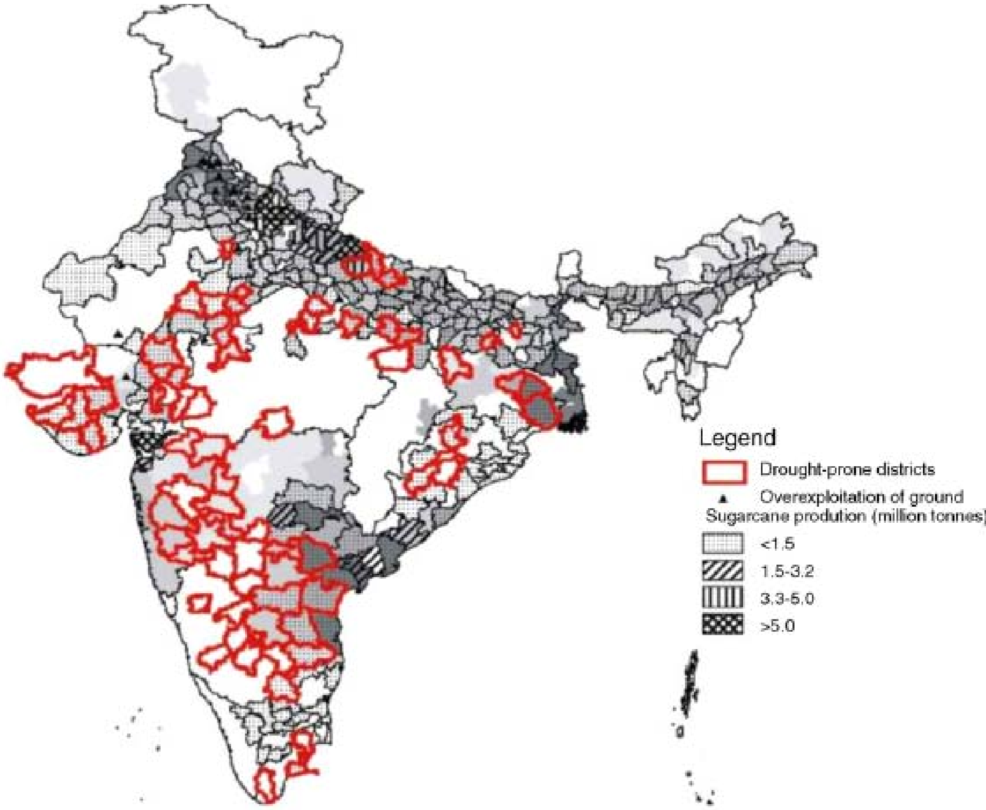

Fig 7. Sugarcane growing region (million tonnes per given area) and drought-prone areas in India. (Source: Tewaria et al, 2007)

Table 15: Water consumption in Indian distillieries (Source: Tewaria et al., 2007)

Stage	Average water consumed[a] (kLD/distillery)	Specific water consumption (kL water/kL alcohol)
Process use		
Yeast preparation	45.9	0.4
Molasses dilution	505.5	11.4
Non-process use		
Condenser	605.7	13.4
Spentwash dilution	281.2	2.2
Potable alcohol preparation	71.9	1.1
Washing	97.9	2.8
Miscellaneous	333.6	5.2
Total	1941.8	36.5

[a] Data based on 36 distilleries, with average installed capacity of 53.5 kLD.

Alcohol distilleries are also known to be one of the most polluting industries in the country. Large volumes of wastewater are generated (8-15 kL / kL of alcohol) containing a high BOD (45,000-60,000 mg/L) content (Tewaria et al., 2007). The Central Pollution Control Board

(CPCB), a national agency for environmental compliance in India, has been enforcing mandatory discharge standards that need to be met by the distilleries. Efficient water management in agricultural processes as well as distilleries is thus of critical importance to ensure sustainable water use.

The use of water to produce biofuels has also become a major issue in Canada. Ethanol companies are purchasing many hectares of additional land to ensure enough surface area is available for annual rainfall to cover the amount of water required for the plants (Klein and LeRoy, 2007). In Canada, production of one litre of ethanol requires 4 to 8 litres of water, which comes mostly from underground sources that consequently reduce underlying aquifer water tables (Klein and LeRoy, 2007). Corporations are currently improving technology so that less water is required during the production process.

In general, there has been an increasing concern over the environmental consequences that growing biofuel crops may pose. It will require an increase in land, water and chemical inputs to grow crops to make ethanol and biodiesel. The next chapter will look at the social and economic impacts of the industry in both Canada and India.

5) Socio-economic implications

Biofuels have become a central feature of national energy strategies in North America, the European Union, Brazil, India and several other countries. Both Canada and India have a high annual ethanol production compared to other countries in the world (Table 16). However, as mentioned earlier, the biofuel industry has socio-economic consequences by competing with land required for food crops, which have been consequently increasing in price. This section will look at the impacts of the industry in terms of domestic production, international trade, and the impacts on local and global food supplies for both India and Canada.

Table 16: Annual world ethanol production (million L) by country (Source: Klein and LeRoy, 2007)

COUNTRY	2005	COUNTRY	2005
U.S	16,139	Australia	125
Brazil	16,000	Saudi Arabia	121
China	3,800	Japan	114
India	1,700	Sweden	110
France	908	Pakistan	91
Russia	750	Philippines	83
Germany	431	South Korea	64
South Africa	390	Guatemala	64
Spain	352	Ecuador	53
U.K.	348	Cuba	45
Thailand	300	Mexico	45
Ukraine	246	Nicaragua	26
Canada	**231**	Zimbabwe	19
Poland	220	Kenya	15
Indonesia	170	Others	2700
Argentina	167	**TOTAL**	**45,989**
Italy	151		

5.1 Domestic production in Canada

The development of a biofuel industry in Canada has proceeded more slowly compared to Europe and the United States, mainly because of less government subsidies and a lack of investor confidence (Klein and LeRoy, 2007). However, recently the federal and provincial government has shown a greater interest in the development of a viable biofuel industry in Canada. In July 2006, the Canadian government announced their plan of ensuring 5% of Canada's transportation fuel come from renewable resources by 2010. This would require 3 billion litres of biofuel produced from 8 million tonnes of grain, oilseeds and biomass every year. Thus the government is boosting corn, canola, wheat and oil production as resources for ethanol. According to Hill et al. (2006), in 2005 14.3% of US corn harvest and 1.5% of US soybean harvest were used for ethanol and biodiesel and replaced 1.72% of gasoline and 1.5% of diesel usage respectively. If all U.S. corn was used, 12% of ethanol and 6% of diesel would have been offset. Domestic production of energy appears to be an attractive option as it makes the country independent of foreign oil sources. However, the increasing corn demand for ethanol is having negative impacts on the domestic food market. Commodity prices of both corn and sugar have been rising due to ethanol production from these feedstocks (Klein and LeRoy, 2007). The Ministry of Agriculture's (government) main interest for promoting ethanol is the creation of new market opportunities in rural areas. The mitigation of greenhouse gases is only a minor reason for investing in the renewable energy source. The biofuel industry has the benefit of promoting economic development in rural communities, and can therefore increase farm income. However, it is criticized that the economic activity is overstated and that many modern biofuel plants provide only a limited number of jobs. Accordingly, only 35 employees are hired in a plant that produces 190 million litres per year (Klein and LeRoy, 2007). In Canada, many individual farmers are active in participating in new biofuel businesses that support the local economy. In the United States however, the industry is largely owned by larger players such as money-center banks and international corporations.

Cellulosic ethanol from agricultural residues such as corn stover could be a viable option to avoid the rise of grain prices as no additional land is required for the feedstock. However, currently there is no system in place to collect stover from the field to use for cellulose ethanol in Canada (Spatari et al., 2005)._As mentioned earlier, Canada will have to increase its corn production in order to meet the renewable energy mandates set out by the government. Currently, Eastern Canada is a net importer of increasingly expensive corn from the United States (Klein and LeRoy, 2007). In general, the Canadian government is interested in increasing production of biofuels to create market opportunities in rural areas and will continue producing and distributing ethanol and biodiesel feedstock to meet the renewable energy requirements.

5.2 Domestic production in India

India has the sixth highest energy demand in the world and currently imports 70% (110 million tons) of its crude oil requirements (EthanolIndia, 2007). Domestic production of crude oil only covers about 25% of its energy consumption (Gonsalves, 2006). With a price of about US$100 per barrel, the countries foreign exchange reserves are greatly impacted and therefore shifting to biofuels can help increase the nations energy security in a cost-effective way. Consequently, the Indian government is showing increased interest in the biofuel industry, especially in biodiesel. Its planning commission created the National Biodiesel Mission to increase biodiesel development and commercialization. The goal is to meet 20% of the countries diesel requirements by 2011-12 (Gonsalves, 2006). However, one of the challenges the country currently faces is to encourage farmers to become involved with the *Jatropha* cultivation business. The profits aren't as high compared to the sugarcane plantations, which yield 70 tonnes / ha providing an income of INR 70,000 / ha. *Jatropha* plantations typically yield only about 2 tonnes / ha with an income of INR 18,750 per hectare[3] (Gonsalves, 2006). Furthermore, *Jatropha* seeds are expensive, being sold at a premium price of INR 12-60/ kg. The cost might further increase due to the increased demand for biodiesel production.

[3] US $1 are equal to 45 Indian rupees (INR)

The ethanol industry is also facing challenges. In India, the sugar industry is currently the biggest agroindustry of the country. 45 million farmers and their dependants are involved with the business. Being the largest sugar consumer in the world, the ethanol industry is reducing the supply of the sugarcane crop. Therefore, using alternative feed stocks for ethanol such as sweet sorghum and tropical sugar beet may be more viable options to meet the demands of the nations economy (Gonsalves, 2006). The current alcohol distilleries in practice have the capacity to meet the 5% ethanol blending requirements, however well knit policies are still lacking to establish the purchasing and blending of ethanol in the oil sector.

Bioenergy services are currently limited in rural areas due to high cost and limited distribution of modern bioenergy forms. Instead direct burning of wood fuels and agricultural residues are being used as an energy source. Biofuels could enable a decentralised distribution generation of electricity as well as motive power applications like water pumping and milling in energy deficient rural areas (GTZ, 2005). Currently, reliability and accessibility of the required technologies is limiting the use of such energy forms and government support is required for financial development of poor areas (UN, 2007). In general, the development of new bioenergy industries could provide clean energy services to millions of people who currently lack them. Furthermore, it would create jobs in poorer areas and boost the local economy in rural areas. However, the current agricultural markets are structured in a way where the bulk of the profit goes to a small proportion of the population and therefore ownership needs to be shared more equitably. Improved policies need to be adopted to make the biofuel development more sustainable by protecting threatened lands and securing socially acceptable land use. Otherwise, the environmental and social damage might outweigh the benefits (UN, 2007).

5.3 International trade

Canada is a large net exporter of many types of energy such as oil, natural gas, coal, uranium and hydro-electricity, due to its great surplus compared to many other industrialized countries. There is therefore no immediate necessity for promoting the biofuel industry in terms of national energy security except to meet the renewable energy mandates enforced by the government and to provide a stable income to farmers. The United States on the other hand faces energy security problems and thus expansion of the biofuel industry is contributing to their independence from foreign sources. However, according to Klein, the increased development of biofuels will only displace 15% of their gasoline use in the United States (2007). Thus, foreign dependence on imported oil in the U.S. and Western Europe will continue into the future.

Production is being encouraged in low income countries like India, due to their lower land and labour costs. Production costs are expected to drop further with improved conversion facilities, making the long-term outlook for cane ethanol promising (IEA, 2004). International trade of biofuels could thus pose a cost advantage, however many HI countries like the United States, European Union and Canada have imposed tariffs and other barriers on imports of biofuels. Social welfare effects could be enhanced through multilateral negotiations that reduce or even eliminate such trade barriers of biofuels (Klein and LeRoy, 2007).

The international trade of biofuels to meet global demands is having negative impacts especially in tropical rainforest areas. Biodiesel plants require additional cropland through logging and burning of rainforests, thus threatening the most biologically diverse plants in the world (Klein and LeRoy, 2007). Furthermore, the increased land requirements for biofuel crops is competing with food crops and leading to higher grain prices. The next two sections will look at the production costs and impacts on food security.

5.4 Production costs and impacts on local & global food supplies

The Canadian federal and provincial governments have recently announced plans to increase biofuel expansion through subsidies and consumption mandates (Klein and LeRoy, 2007). In 2005, production cost for ethanol was $0.46 per L whereas an energy equivalent liter of gasoline was $0.44. For soybean biodiesel, one litre averaged $0.55 compared to $0.46 for diesel (Hill, 2006). Thus, the cost of producing biofuels is currently higher than the cost of producing petroleum fuels. Roughly 75 to 90% of the cost of biofuels is in the raw materials required for manufacturing. The cost of biodiesel in Canada could be vastly reduced by using lower quality, non-edible canola oil, such as canola seeds that were over-heated or frost-damaged. This type of oil from lower quality feedstock does not have any adverse effects on the quality of the ester product (Prakash, 1998).

Production costs in developing countries are much lower due to the low land and labour costs. On-going research is being promoted in all countries active in biofuel production and is contributing to more efficient technology for converting biomass to energy. This production-oriented research is reducing the price of ethanol and it is estimated that within 10 years, the cost of producing a litre of ethanol from cellulose will be half the amount and producing a litre of ethanol from corn will decline by 14% in the United States (Klein and LeRoy, 2007).

The increased demand for corn is reducing the supply of this grain as a food product and for other crops and consequently raising their price. According to Klein and LeRoy (2007), the past year has seen a major increase in grain prices for corn (86%), soybeans (32%), oats (39%), barley (54%) and feed wheat (59%). Furthermore, Canadian beef and poultry producers have been facing major increases in costs for supplying their meat products. This will make it more difficult for new farmers to enter the market as they face higher prices for land and other farm inputs. With Canada and the United States being large food exporters in the world, food prices are also expected to rise on a global scale, through the booming ethanol industry in North America. (Klein and LeRoy, 2007). The use of agricultural land for energy crops means less will be available for food crops. The total global harvest of grains in 2006 was estimated to 1.79 billion tonnes, which is 4% less than global consumption of 1.85 billion. It is the sixth time in the last seven years that world grain production is lower than consumption (Klein and LeRoy, 2007). The lack of supply has caused increase in grain and oil seed prices. Low income families will be the most affected by the much higher food prices. It will have major implications for the worlds poorest who will experience increased hunger.

India, with only 2.4% of the total land, and 4% of total water resource has to support 16% of the global population (GTZ, 2005). Between 1992 and 2002 the average population size in the country has increased but the average per capita food availability has declined (Table 17). India will have to increase its food production by over 50% in the next two decades in order to meet the demands. Large-scale biofuel development will consequently have to ensure that it doesn't compete with the country's food security issues.

Table 17: Food production and availability in India (Source; GTZ, 2005)

Year	Average area under food production (million ha)	Average population (million)	Average annual per capita food availability (kg)
1992-97	122	901	173.75
1997-02	122	1008	151.15

In general, the long term economic impacts and the cost and benefits of the biofuel industry are still largely unknown and further research is required to establish policies that maximize social welfare, economic growth as well as environmental amenities. The issue is creating a moral dilemma of whether agricultural crops should be grown to supply food for people or to supply fuel for automobiles.

6) Conclusion

- Biofuel production is being promoted as a renewable energy option in India to contribute to the country's energy security needs without depending on foreign oil imports. India produces sufficient sugarcane annually to achieve the required 5% ethanol blending for 2010. However, in order to meet the goals of its National biodiesel program, it would have to assign land to large-scale *Jatropha* seed plantations. In Canada, the expansion of the biofuel industry can be attributed to a view that it is as a renewable energy form that can improve the rural economy and increase farm income. Currently, domestic production of corn ethanol and soybean biodiesel makes only minor contributions to the energy needs in Canada. The development of technology for producing cellulosic ethanol derived from grass and agricultural residues has greater potential for contributing to the bioenergy requirements in the country.
- Biofuels are able to produce renewable energy forms based on a nonrenewable investment. However, large quantities of land, water, fuel and other chemical inputs are required to produce the required feedstocks. This reduces the energy gain and greenhouse gas emissions savings to a relatively small value. When considering carbon emissions through land use change, biofuel use may actually results in net greenhouse gas emissions to a greater extent than fossil fuels. Consequently, the use of biofuels can have both environmental gains as well as environmental losses.

- To meet its ethanol requirements for 2010, Canada would have to expand its corn production to 170% of the current amount. The plantation of biofuel crops in North America is raising the price of other food crops, an issue that has major implications on global food security. In India, *Jatropha* plantations for biodiesel are being considered on wastelands in order to avoid competition with the country's food production. However, there may not be sufficient wasteland available in India to meet its future biodiesel requirements. The country will also have to increase its food production to meet the needs of the growing population. The implementation of cellulose ethanol such as corn stover has the benefit of reducing further land requirements and may therefore be a more sustainable option in terms of the environmental impacts (less deforestation, reduced GHG emissions) as well as the social impacts in terms of food security. Further research is required to investigate the availability of agricultural residues as potential feedstocks in both countries. It is also essential that the economic impacts and policy interventions are fully examined. Production cost of biofuels is currently higher than petroleum fuels but with technology advancements and higher feedstock yields the cost could be reduced. In general, both countries need to carefully evaluate policy developments of biofuels, including the social and environmental consequences they may pose on a local and global scale.

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