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Biofuel Production in Developing Countries: A key to Sustainable Development?

Verfasser /Author

Shadi Mohebinejad

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Abstract English

One of the main issues that world is facing is population growth. One of the critical issues would be providing accessible, safe and reliable energy for the current population and the next generation. Since the greatest share of population growth is in developing countries, this study will focus on the biofuel production in developing countries. Biofuel is among those renewable energies that can be a substitute for fossil fuels. However, the consequences and effectiveness of biofuel on sustainable development is the subject of serious debate. For instance, the main discussion regarding biodiesel concerns its current environmental, economic and social impacts. Food security, deforestation, biodiversity extinction, monocropping, soil degradation and water depletion are fundamental issues and this study aims to address them. Therefore, this study used 2 series of indicators to evaluate the impact of biofuel production: (i) Energy Indicators for Sustainable Development (EISD); (ii) "GBEP Sustainability Indicators for Bioenergy" that both of them take into consideration three main themes, economic, social and environmental pillars. India has been selected as a case study to explore the economic, social and environmental aspects of biofuel production. India is the second most populated country in the world and is a strong producer of biofuels while at the same time facing serious issues, such as poverty and food security.

Abstract German

Eines der wichtigsten Probleme vor der die Welt steht ist das Bevölkerungswachstum. Eines der kritischsten Aspekte wäre die Bereitstellung von zugänglicher, sicherer und verlässlicher Energie für die derzeitige Bevölkerung und für die kommende Generation. Da der größte Anteil am Bevölkerungswachstum in den Entwicklungsländern liegt, wird diese Studie den Fokus auf die Produktion von Biotreibstoff in sich entwickelnden Ländern legen. Biotreibstoff ist einer jener erneuerbaren Energiestoffe die als Ersatz für fossile Brennstoffe gelten. Allerdings sind die Konsequenzen und Effizienz von Biotreibstoff für eine nachhaltige Entwicklung Thema ernster Debatten. Zum Beispiel drehen sich die Diskussionen bezüglich Biodiesel derzeit um Fragen der Auswirkungen auf Umwelt, Wirtschaft und Sozialem. Nahrungsmittelsicherheit, Abholzung, das Verschwinden der Biodiversität, Monokultur, Auslaugung der Böden und Wasserknappheit sind fundamentale Themen und diese Arbeit zielt darauf diese zu thematisieren. Daher verwendet diese Studie zwei Serien von Indikatoren zur Evaluierung des Einflusses der Produktion von Biotreibstoff: (i) Energieindikatoren für nachhaltige Entwicklung (EISD); (ii) „GBEP Nachhaltige Indikatoren für Bioenergie" die beide die drei Säulen berücksichtigen: Ökonomie, Soziales und Umwelt. Indien ist das Land

mit der zweitgrößten Bevölkerung in der Welt und ein großer Produzent von Biotreibstoffe, während es zeitgleich ernste Probleme wie Armut und Nahrungsmittelsicherheit lösen muss.

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1. INTRODUCTION

The main aim of a policy maker's decision in any country should be to establish adequate provisions for achieving sustainable development. One of the critical issues that the world is facing with is population growth and applying accurate solutions for coping with this reality. The world population is projected to reach 8 billion in 2025 (UN 2011) and the majority of this increase in the world population will occur in developing countries (Lal, et al. 2005, iv). The fact that the greatest share of population growth in the world belongs to developing countries reveals the need for more concerted efforts to find new, proper, and practical solutions to deal with this issue. To provide for the growing population's needs under the umbrella of sustainable development, one of the vital factors is energy supply. Providing safe, clean and affordable energy for the current population and the next generation is one of the highest priorities. The need for everyone to have access to affordable energy sources, a great dependence on fossil fuels, the depletion of finite resources, high oil import dependency, as well as the critiques of the negative impact of fossil fuels on environment are the most notable barriers that incite states to search for new options.

Since the transportation sector alone is 93% dependent on oil (IEA 2010), finding a reliable substitute is crucial in policymaking. Biofuel has been produced and used in various different countries. Biofuel offers, in comparison with other alternatives, several benefits; (i) it is usable in current engines without requiring sophisticated modification; (ii) the use of biofuels does not require time-consuming studies or research. However, the consequences and effectiveness of biofuel on sustainable development is the subject of serious debate. Therefore, biofuel production has not yet been implemented on a large scale with consistent performance.

For instance, the main discussion regarding biodiesel concerns its current environmental, economic and social impacts. Food security, deforestation, biodiversity extinction, monocropping, soil degradation and water depletion are fundamental issues and this study aims to address them. Also, one of the fundamental points is to have decent comprehension of what biofuel is. Therefore, the second chapter introduces biofuel.

Further, it is essential to know why there is a need for biofuel production Or, in other words, what the countries' incentives for biofuel production are. The next stage is understanding biofuel, how it is produced and what it is made of using which technologies; sub-chapters will explore these areas. The last discussion, which reveals the importance of the question of this study, discusses concerns regarding biofuel production and why there is a need to consider all impacts of biofuel production, including positive and negative effects.

Further, since all the arguments refer back to sustainable development, it is vital to have a comprehensive definition of sustainable development to have a clear and accurate prospective for answering this work's central question. Hence, the next action is to define sustainable development and its key indicators. One of the most comprehensive and complete documents on the subject is "Energy Indicators for Sustainable Development" which was issued by the International Atomic Energy Agency (IAEA) through cooperation with several international organizations such as the International Energy Agency (IEA), the United Nations Department of Economic and Social Affairs (UNDESA), Eurostat, and the European Environment Agency (EEA). The indicators presented in the document constitute a core set of Energy Indicators for Sustainable Development (EISD) with corresponding methodologies and guidelines for use among policymakers, energy analysts and statisticians (IAEA, et al. 2005, 3). In addition, the Food and Agriculture Organization of the United Nations (FAO) in cooperation with the Global Bio-Energy Partnership (GBEP) recently published a list of indicators under the title "GBEP Sustainability Indicators for Bioenergy" that takes into consideration three main themes, economic, social and environmental pillars. The main reason of to combine these two indicators is that FAO's indicators are directly related to bioenergy. Moreover, they cover some aspects that were not considered in the IAEA's indicators document. Therefore, the third chapter introduces the indicators and makes a comparison, considering the fact that IAEA's indicators are not only about bioenergy and the fact that most of the related indicators can be chosen out of all presented indicators. In order to best cover all aspects of biofuel production, a combined set of indicators will then be presented.

Based on the chosen definition of sustainable development and its related indicators, India has been selected as a case study to explore the economic, social and environmental aspects of biofuel production. India is the second most populated country in the world and is a strong producer of biofuels while at the same time facing serious issues, such as poverty and food security.

It will also assess recent research that shows that not all biofuels and technologies have remarkable environmental and social advantages when compared to fossil fuels (Melillo, et al. 2009) (Ulgiati 2001). The advantages and disadvantages depend on the local conditions of the region where biofuels production and consumption are implemented (Groom MJ, Gray EM, Townsend PA. 2008).

Therefore, the study will keep in mind the fact that biofuel production itself cannot be judged as simply being a good or bad solution: it depends on in which region, under which policies, and with which technology it is being produced and used. It is for this reason that a more precise answer to the question of the viability of biofuel can be achieved by focusing on the local level and considering the different characteristics of each region. The main objective of this study is therefore to determine under which circumstances biofuel production would work best for developing countries. Which prerequisites should countries have in order to establish viable biofuel industries? The fourth chapter addresses India's biofuel production conditions. A brief introduction to biofuel production in India will be presented. To have a clear view about biofuel production there, this chapter has been divided into two major sections: (i) Ethanol, and (ii) Biodiesel. Each section has two major parts; (i) Policy/targets, and (ii) Impacts. The aim is to elaborate the expectations of the government from biofuel production and their policies and programs to reach these goals. Further this chapter will examine the impacts of these policies in action on three main pillars of sustainable development: economy, society and environment. In order to examine the impacts, the indicators that have discussed in chapter three will be used.

In conclusion, a summary of the study will be reviewed. In addition, some suggestions for further needed research in this area will be presented.

2. BIOFUEL

2.1. Why Biofuel?

Undoubtedly, energy is one of the most essential factors for development and improvement of the population's life standards in any country. Nowadays, the world's energy use and supply cannot be seen as sustainable given the way existing technologies are implemented (Jovanovic, Afghan and Bakic 2010), based on the fact that much of energy supply and use are dependent on exhaustible resources or fossil fuels (United Nations 2007, 1). The world's primary energy demand has increased at rate of 2.0% on average per year since 1973 (IEA 2007). Moreover, approximately one third of the world's population are still dependent on non-commercial fuels (United Nations 2007, 1). Estimates show that 1.4 billion people, or more than 20% of the global population, has no access to electricity and that 2.7 billion people, around 40% of the global population, are dependent on traditional biomass for cooking (IEA 2010, 56).Accumulating scientific evidence for the urgent need to combat climate change has changed international and national awareness of these issues (IIASA, et al. 2009, 21).

The aforementioned issues have led countries to seek for other sources of energy that can contribute to climate change, reduce oil import dependence, and provide clean energy for less developed regions. Searching for such sources of energy that are compatible with the concept of sustainable development is the aim of policymakers. Biofuel is one of these substitute sources of energy.What is more, rising oil prices, national energy security concerns, the desire to increase rural incomes, and a host of new and improved technologies incite many governments to enact powerful incentives for using these fuels (Worldwatch 2007, xviii), Countries like the United States, Brazil, and European countries being examples. Biofuels have been acclaimed as the potential for reducing greenhouse gas emissions, enhancing energy security, and boosting rural development (IIASA, et al. 2009, 21).

The biofuel industry in most developing countries can be considered an opportunity to enhance economic growth and to create lasting jobs, especially in rural areas, particularly due to the transportation sector, which is one of the major consumers of fossil fuels and responsible for around 23% of GHG (Greenhouse Gases) energy-related emissions (Lora, et al. 2010). Estimates show that oil remains the dominant fuel in the transportation sector, with a share of 77% in all transportation fuels. Most of the oil savings occur in road transport, which accounts for more than 80% of all oil savings by 2035 (IEA 2010, 429). Biofuels can replace fossil fuels to reduce the adverse impacts on climate change (Lora, et al. 2010). Current biofuel targets for biofuels' share in transportation fuel are projected at 12 percent in developed countries and 8 percent fordeveloping countries by 2030 (IIASA, et al. 2009, 21). Biofuel production can reduce imports or bring export opportunities, provide local farmers with better opportunities and incomes, and boost national economies for developing countries. Suitable natural conditions, such as availability of land and water, plus low labor costs, and the fact that some crops such as sugarcane and palm oil (the most cost-effective and GHG-saving crops) grow best in tropical conditions, provide developing countries in tropical regions with a comparative advantage in growing biofuel feedstock (IIASA, et al. 2009, 21). In short, proponents of biofuel production claim that domestic biofuel production can replace expensive oil imports, help unburden developing countries from staggering energy import bills, stabilize currencies, and encourage foreign investment.

2.2. What is Biofuel?

It is essential to have a good comprehension of what exactly biofuel is and how it is being produced. Therefore, this chapter presents a brief description of biofuel production and its varied technologies.

Biofuel can be solid, liquid, or gaseous fuels that are produced from biomass materials (Worldwatch 2007, 34). Ethanol and biodiesel are the two main liquid biofuels used largely nowadays (Worldwatch 2007, 3) and can be blended with fossil gasoline and diesel respectively (IIASA, et al. 2009, 21). Currently, ethanol is produced from sugar and starch crops, while biodiesel is produced from vegetable oils or animal fats (Worldwatch 2007, 3). As it has been mentioned above, the two main biofuels that are globally considered for the transportation section are biodiesel and bioethanol.

In the early 1820s, American inventor Samuel Morey used ethanol and turpentine in the first internal combustion engine. Yet, at the beginning of the 1900s, when automobiles were becoming popular, the fuel market was flooded with cheap petroleum fuels (Worldwatch

2007, 5), whereas biofuel had only a small share of total fuel consumption during the early 20th century. They were, in several European countries such as France and Germany, supported by policies and, at times, they neared 5 percent of the fuel supply. Biofuels were often the favoured fuels in tropical areas with irregular supplies of petroleum and in enclosed settings such as mines. For instance, during World War I and II, ethanol was used to supplement petroleum in Europe, the U.S., and Brazil. However, the post-war period of military demobilization plus the development of new oil fields in the 1940's brought cheap oil that virtually eliminated biofuels from the world fuel market. However, the oil crisis of the 1970's once again stirred countries to search for an alternative to oil (Worldwatch 2007, 5).

Bioethanol

Bioethanol can be produced from a number of crops such as sugarcane, corn (maize), wheat, and sugar beets (Lora, et al. 2010) or any feedstock that contains high starch or sugar content. Maize, wheat, sugar cane and sugar beet are the main grains that produce energy through the fermentation of carbohydrates. Traditionally, ethanol has been used for alcohol production, yet it's increasingly being used in transportation fuels. Bioethanol, after fermentation and distillation, can be mixed with petrol/gasoline in different proportion. Low-level ethanol blends like E10, which means 10 percent ethanol and 90 percent gasoline, can be used in conventional vehicles. Other high-level blends, like E85, which means 85 percent ethanol and 15 percent gasoline, can only be used in specially motorized vehicles, such as flexible fuel vehicles (FFVs). The blending of ethanol diminishes carbon monoxide emissions. Ethanol production around the world has doubled since 2000 to 62 million liters in 2007, of which 86 percent is utilized as fuel ethanol (IIASA, et al. 2009, 34). Now, fuels can be 100% ethanol as well, which is being produced in Brazil. Most of the world's biofuel is used for transportation; however, heating homes is another use for it (Worldwatch 2007, 3).

Biodiesel

Biodiesel can be produced from straight vegetable oils (edible and inedible), recycled waste, vegetable oils, animal fat, and oils from biotechnological sources (yeasts, microalgae, etc.)

(Lora, et al. 2010). Biodiesel is produced through the transesterification of vegetable oils (a chemical process) such as oil palm, rapeseed, soya been, and jatropha. This process produces FAME, the chemical name for biodiesel and glycerol, or fatty acid methyl ester (FAME). Glycerol is traditionally used in soaps (IIASA, et al. 2009, 34).

Heating these vegetable oils leads to reduction of viscosity, enabling them to be used directly in diesel engines or, after chemical processing, for biodiesel production. Biodiesel can be used either purely or by blending it with diesel. B20, which means 20 percent bio diesel and 80 percent diesel, and lower blends, such as B2, which means 2 percent biodiesel and 98 percent diesel, and B5, which stands for 5 percent biodiesel and 95 percent diesel, can be used in diesel engines. B100, which is a pure biodiesel, and other high-level biodiesel blends have been used, since 1994, in specific engines. Globally, about 6.5 billion liters of biodiesel were produced in 2006, of which 75 percent was produced in the European Union (IIASA, et al. 2009, 34).

Regarding technological use, biofuels can be divided into two groups based on the feedstock used for production and the technologies used to convert that feedstock into fuel known as first and Second-generation biofuels. The term “first generation biofuels” refers to the technologies that usually utilize the sugar or starch portion of plants (e.g. sugarcane, sugar beet cereals, and cassava) as feedstock to produce ethanol and those utilizing oil seed crops (e.g, rapeseed, sunflower, soybean and palm oil) to produce biodiesel. (Rutz and Janssen 2007), (OECD_FAO 2008) Second-generation biofuels are those produced using technologies that convert lignocellulosic biomass (e.g., agricultural and forest residues) and advanced feedstock (e.g., Jatropha and micro-algae) (Worldwatch 2007). It is worth mentioning that first-generation biofuels have already been in commercial production in many countries for couple of years. Yet, Second-generation technologies just began commercial production, except some regions such as Jatropha in India (Timilsina and Shrestha 2010). The advantage of Second-generation tofirst generation is that Second-generation biofuels can produce both food and fuel together unless non-food crops are preferred; the first generation, by contrast, directly competes with food supply (Timilsina and Shrestha 2010).

The process of biofuel production at the moment produces fuel and some by-product fuel and residues simultaneously. The type and quantity of by-products are varied based on the biofuel production chain. By-products might serve as precious livestock feed (e.g. rapeseed cake, soybean meal, or Distillers' Dried Grains with Solubles (DDGS)) and residues such as straw and husks could be brought back to the field or used in co-firing. Some of the by-products can be used for further industrial processing and (it is presumed) eventually consumer goods. In this case, by-products should be acknowledged within the overall biofuel production chain (IIASA, et al. 2009, 34).

Biofuel First Generation Technologies:

First generation ethanol is produced from sugars and starches. Simple sugars in a variety of sugar crops are extracted and are the yeast ferments, the resulting wine is distilled into ethanol. However, starches require an additional step. First, they are converted into simple sugars through an enzymatic process under high heat. In this case energy consumption is higher and, consequently, the cost of production increases (BNDES 2008). Biodiesel is derived from lipids and is produced by mixing the oil with an alcohol like methanol or ethanol through the chemical process of transesterification[1]. The biodiesel, fatty-acid methyl ester (FAME) made from this process has 88-95% of the energy content of conventional diesel, but better lubricity and a higher cetane value, and so can deliver fuel economy close to that of conventional diesel (Timilsina and Shrestha 2010).

Nevertheless, biodiesel is not flawless. One of its characteristics is that it can be degraded by exposure to air, heat, light, water and some metals; also, plugged filters in vehicles is a common symptom (Ge, et al. 2009). Moreover, considering the fact that biodiesel has a higher cold point/pour point than petroleum diesel, it can cloud and gel in cold temperatures, which leads to difficulties in starting vehicles under cold conditions (Ge, et al. 2009).

Second-generation Technologies

Second-generation technologies are well-known for their low CO_2 emissions and the fact that they do not utilize feedstock. Instead, they use materials such as residues and by-products from agriculture and forestry as well as dedicated non-food related feed stocks, for instance,

[1]The action that is used to convert fats (triglycerides) into biodiesel.

woody and herbaceous plants (such as perennial grasses and fast growing tree species). The expectation of second-generation biofuel reducing CO_2 emissions is significant (IIASA, et al. 2009, 34). However, the cost of Second-generation pathway technology is notable and technological breakthroughs will be needed to reduce costs. Moreover, the large scale of operation and substantial transportation costs involved in getting the raw materials to the processing facilities should be considered as well. The estimates show that Second-generation biofuels may become commercially available in the next 10 to 20 years (IIASA, et al. 2009, 34).

2.3. Pro and Cons

The aim of this sub-chapter is to address the main debates surrounding biofuel production and its effects. More specifically, the factors that raise concerns for using biofuel production will be at the centre of this chapter's discussion. Evaluating biofuel production by considering both positive and negative impacts on the three main pillars (economic, social and environmental) will be presented to give an opportunity to policymakers to make the right decision. This chapter is crucial in that it reveals the importance surrounding the emergence of the central question in this study, which is: does biofuel production in developing countries foster sustainable development?

This discussion will help in choosing the best indicators for sustainable development in order to later conduct the quantitative section of this study. By knowing biofuel productions' effects on specific areas, it will be easier to choose the move relevant and useful indicators out of the whole basket of energy indicators for sustainable development.

In chapter 2.1, a brief description of the need for a new source of energy like biofuel will be presented. At first glance, biofuel production looks like a promising approach. However, recent research shows that caution is needed for countries' targets regarding biofuel production. The environmental benefits of expanded biofuel deployment and their contribution to sustainable development are at the centre of deep debates (Scharlemann and Laurance 2008). The main cons are: (i) first-generation biofuels compete with food crops in the long run; (ii) there are limited arable land resources; (iii) the expansion into forest, grassland and woodland areas; (iv) and land-use changes will result in notable carbon emissions, negating the primary justification for carbon avoidance with biofuels (IIASA, et al. 2009, 21).Particularly, biofuel expansion based on first-generation food crops needs more caution considering the speed of the biofuel increase balance with the increase in overall agricultural productivity. Otherwise, biofuel development leads to negative social consequences or harmful environmental impacts (IIASA, et al. 2009, 21).

Mayer AL argues that the sustainability of the human environment system is determined through three main characteristics: resilience to disturbances, both natural and anthropogenic; desirability to human societies; and temporal and spatial scale boundaries (Mayes 2008). Resilience and desirability present policy goals and the scale boundaries indicate the issues to be monitored and managed to reach those goals. Hence, concerning biofuels, such issues are:

1. Biofuels should be carbon neutral, considering the necessity of fossil fuel substitution and climate change mitigation.
2. Biofuel production should not have an effect on the quality, quantity and rational use of available natural resources such as water and soil.
3. Biofuel production should not lead to undesirable social consequences, such as starvation as a result of high food prices.
4. Biofuel production should contribute to society through economic development and equity as well.
5. Biofuel production should not affect biodiversity (Lora, et al. 2010).

As a matter of fact, biofuel sustainability has environmental, economic, and social facets that all interconnect. According to IISA research on biofuel and food security, sustainable biofuel production and its use should result in the following achievements:

1. *Significant greenhouse gas savings compared to the use of fossil fuels;*
2. *The use of environmentally sound agricultural and forestry management systems for biofuel feedstock production;*
3. *Preservation of landscapes with significant value for biodiversity, mature conservation, and cultural heritage;*
4. *Regard for the possibility of social exclusion; and*
5. *Integration with food, feed, and other biomass-use sectors considering economic, security, and environmental implications of supply and demand patterns* (IIASA, et al. 2009, 62)

In the following sections, the economic, social and environmental dimensions (or three pillars) will be explored in detail.

2.3.1. Economic Aspects

2.3.1.1. Oil Dependency and Security

The vital role of oil is not hidden from anybody since one of the most essential factors in supplying goods, food and labour is mobility (Worldwatch 2007, 101) and the transportation system overwhelming depends on a single fuel source: petroleum fuels provide an estimated 93 percent of global energy for transportation (IEA 2010). Oil reserves are concentrated in a small number of countries, many of which suffer from economic and political instabilities. Moreover, trade between oil exporters and oil importers is increasingly tense and vulnerable (Worldwatch 2007, 101). Hence, substituting petroleum for another source of energy is somehow unavoidable. Biofuel can be an alternative for oil in the transportation sector, though biofuel alone cannot meet the increasing global demands for transportation (Worldwatch 2007, 101). Furthermore, as converted oil supplies in many parts of the world begin to dwindle in the years ahead, dependence upon Middle Eastern oil is expected to grow, leaving the entire world more vulnerable to social and political developments in one of the world's least stable regions. In fact, of the world's known potential of conventional petroleum (364 billion tonnes), more than 70 percent is located in the so called 'strategic ellipse', an area spanning much of the Middle East and Central Asia that is also home to 69 percent of known natural gas reserves (German Federal Institute for Geosciences and Natural Resources 2006).

Some experts claim that compared with oil, biofuels can reduce many of the vulnerabilities associated with today's highly concentrated energy economy. Biofuel production, in contrast, is considerably less concentrated because of the large land area needed to cultivate feedstock and the low energy density of this feedstock that makes it less economical to transport long distances. As a result, biofuel processing facilities are more numerous and spread over a wider geographical area, contributing to a liquid fuel supply that is less vulnerable to disruption. Biofuels also offer an opportunity for a more dispersed and equitably distributed revenue stream (Worldwatch 2007, 106). Hence, for those countries with high dependencies on oil, biofuel can be a more crucial substitute. It is even possible in some cases that due to political securities and avoiding the negative effects of oil price vulnerabilities, decision-makers, despite high costs, intend to establish a more robust biofuel industry (Worldwatch 2007, 106).

2.3.1.2. Rural Development

In general, developed and developing countries around the world show that average incomes are lower and unemployment rates higher in rural areas than in their associated urban areas. In addition, in the developing world, 57 percent of the total population lives in rural areas; this portion will decrease to an estimated 33 percent by 2050. Moreover, over 70 percent of the world's poor and hungry live in rural areas. Therefore, increasing agricultural incomes and enhancing rural development are among the essential objectives of development policies. The solution could include a generation of employment opportunities out of increased biofuel production and the establishment of rural biofuel processing industries, in addition to biofuel marketing and distribution (IIASA, et al. 2009, 81). In this sense, Brazil is an example among biofuel producing countries. Brazil's experience has seen around 700,000 jobs generated in the biofuel industry since the mid-1970's. Estimations in other regions show that the EU biofuel program will create around 100,000 rural jobs by 2020 and in the USA around 200,000 jobs (IIASA, et al. 2009, 81).

In sum, the contribution of biofuel development to increasing agriculture value added is relatively insignificant. Estimations indicate approximately six to eight percent in developed countries and only some three percent in developing countries by 2030. However, claimed benefits of biofuel production to boost rural development should not rely only on feedstock production; it will also require the setting up of an entire biofuel production chain. More importantly, its impact can be found in fostering rural development (IIASA, et al. 2009, 23).

Potentially, biofuel production can have positive effects on rural habitants' economic conditions and offers them substantial rural economic benefits. However, it depends on whether processing facilities are owned and operated by the farmers or not. Moreover, it depends on whether the country as a whole only exports the raw material of biofuel production or has the facilities for processed products. Obviously, raw material production brings in less revenue (IIASA, et al. 2009, 118). On the other hand, some others claim that in countries where there has been a strong expansion in biofuel production, employment in farming appears to have decreased and a growing trend of workers employed in seasonal jobs is observed (Ziegler 2010).

2.3.1.3. Policies, Support Regimes and Mandates

A number of countries around the world have adopted biofuel development policies, including both developed and developing countries, such as the United States of America, members of the European Union, Japan, Canada and Australia. Developing countries such as China, India, the Philippines, and Thailand have also recently set domestic targets for biofuel use (IIASA, et al. 2009, 37). Biofuel programs have proliferated globally, whether driven by a desire to strengthen agricultural industries, achieve energy security, reduce GHG emissions, or improve urban air quality (Timilsina and Shrestha 2010).

There are varied types of public support for the biofuels industry and a wide range of different approaches to the type of government support implemented. Governments can provide substantial support to biofuels by enabling them to compete effectually with conventional gasoline and diesel. This support may include a combination of consumption incentives (fuel tax reductions), production incentives (tax incentives, loan guarantees, and direct subsidy payments) or mandatory consumption requirements (IIASA, et al. 2009, 37). The OECD's Economic Assessment of Biofuel Support Policies underlined that biofuels are, at the moment, largely dependent on public funding to be viable (IIASA, et al. 2009, 37). Based on the fact, it is politically challenging to remove biofuel incentives afterward. Another issue which should be taken into consideration is how to implement support.

There are varied critiques which claim that government support of biofuel production in OECD countries is costly, has an inadequate influence on reducing greenhouse gases and improving energy security, and further has a significant impact on world food prices (IIASA, et al. 2009, 36).

2.3.1.4. Technologies

Significantly, any country considering increased biofuel development needs to assess the feasibility of adopting different biofuel feedstocks and processing infrastructures based on its unique, natural resources, and economic context (IIASA, et al. 2009, 36). Without sufficient innovation to make different sectors more efficient by using biofuels, even the successful emergence of a biofuel industry is not able to have a significant effect on diminishing the use of oil-based fuels. For instance, one of the most important and anticipated innovation is the development of cellusios ethanol derived from plant stalks, leaves, and even wood to be introduced commercially. More importantly, they make it possible to produce biofuel out of agricultural and forestry wastes, as well as from non-food crops, such as switch grass, that can be grown on degraded lands. Development for more efficient vehicles also plays an important role in the transportation system (Worldwatch 2007, xix). Without smart, innovative, and practical policies, the biofuel industry realistically cannot go in the right direction.

2.3.1.5. Production, Consumption and Trade

Biofuel can be an option for oil imports reduction. But, are biofuels really cheaper than petroleum fuels? Historically, biofuels have been more expensive than petroleum fuels and today, nearly all biofuel industries still rely on extensive governmental support, mainly subsidies, to be viable. Keep in mind that most biofuel crops can displace only a limited amount of oil and, eventually, a rising demand for feedstock will put upward pressure on the agricultural and food commodities prices (Worldwatch 2007, 118). Apart from sugarcane based ethanol in Brazil, biofuels are not currently competitive without substantial government support if oil prices are below US$70 per barrel (Doornbosch and Streenblik 2007).

Ethanol Costs

Costs differ by world regions, feedstock types, feedstock supply costs, the scale of bioenergy production, and production time during the year, which is often seasonal (ipcc 2011). According to IEA, the costs of ethanol production in new plants in Brazil are the lowest in the world, which was $0.20 per liter in 2006 ($0.30 per liter for gasoline equivalents) (IEA

2006). This subsequently declined even further to $0.18 per liter (Worldwatch 2007). In comparison with the cost of sugarcane-based ethanol in Brazil, grains-based ethanol costs 50% more in the US and 100% more in the EU. Transportation, blending and distribution costs adds around $0.20 per liter to the retail price, whereas production costs for ethanol in China are around $0.28 and 0.46$ per liter, depending on the price of the feedstock. Moreover, sugar-based ethanol production in India costs is some $0.44 per liter (Worldwatch 2007). The IEA projects a reduction of one third in the cost of ethanol by 2030 as a result of technological improvements and lower costs of feedstock (IEA 2006). However, the increasing demand for ethanol due to mandates and targets, the influence of the fuel vs. food discussion on this supply, and recent trends of feedstock prices suggest that ethanol's cost may not decline. In addition, unless the price of oil is high, ethanol production may not be competitive without a substantial amount of subsidies (Timilsina and Shrestha 2010).

Biodiesel Costs

In general, biodiesel production from palm oil costs around $0.70 per liter, whereas rapeseed oil-based biodiesel may cost up to $1.00 per liter, with soybean diesel in between (IEA 2006). In China, biodiesel production costs, mainly from used cooking oil, range from $0.21 to $0.42 (Worldwatch 2007). According to IEA, biodiesel production costs will diminish more than 30% in the US and EU between 2005 and 2030 due to a decline in feedstock costs (IEA 2006), though it must be noted that the prices of biodiesel feedstock have, for the most part, been moving in opposite directions since the IEA's estimate was produced (Timilsina and Shrestha 2010).

Global production of ethanol fuel grew from 30.8 billion liters in 2004 to 76 billion liters in 2009, with an average annual growth rate of 20%. The U.S. and Brazil alone accounted for some 88% of the total in 2009 (Renewable Fuels Association 2008). Total global biodiesel production remains small in comparison to ethanol, but its growth is higher than that of ethanol, with an average annual growth rate of approximately50% between 2004 and 2009. Germany, the U.S., France, and Italy are the biggest producers (Timilsina and Shrestha 2010). Despite this significant growth in biofuel production, the share of biofuels in total transportation fuel was above 2% in 2004 in only three countries- Brazil, Cuba and Sweden

(IEA 2006). Moreover, global output accounted for only some 1% of total transportation fuel consumption in 2005 (Doornbosch and Streenblik 2007). In 2007, production of ethanol was still only about 4% of the global gasoline consumption of 1,300 billion liters (REN21 2008). Considering total global trade trends, biofuels available relative to production output remains modest; only about one tenth of total biofuel production by volume is traded internationally (Masami, Donald and William 2007). Global trade for ethanol fuel was approximately 3 billion liters per year in 2006 and 2007, compared to less than one billion liters in 2000 (Licht FO 2006i). Some 12%, or 1.3 billion liters, of total biodiesel production in 2007 was internationally traded (Masami, Donald and William 2007). Based on this fact, some major players, such as the U.S. and the EU, have targeted biofuel production for domestic consumption, as few countries (Brazil being a major exception) have the ability to be great exporters of ethanol or other biofuels (Timilsina and Shrestha 2010). Moreover, the current situation is harsh for farmers in developing countries since developed countries' policies of tariffs, quotas and subsidies leave developing markets at a disadvantage (IIASA, et al. 2009, 81). On the other hand, global trade in biofuels has seemed to expand due to the comparative advantage of some countries to produce biofuels, such as a favourable climate, lower labour costs, and a greater availability of land (Timilsina and Shrestha 2010). For instance, tropical countries have two or three times higher productivity when water scarcity is not a factor (Philippe and Abigail 2006). Conversely, many countries may not be able to accomplish their biofuel targets and mandates with domestic production alone (Timilsina and Shrestha 2010).

2.3.2. Social Aspects

Essential social factors in biofuel production include the need to share benefits with and ensure involvement in decision making by local communities. Land tenure and the provision of health and educational services are crucial issues (IIASA, et al. 2009, 81). For instance, farmers need to be educated and given the proper resources and incentives to select crops appropriately and to manage them in the most sustainable ways possible such that wildlife habitat is maintained or improved and the use and impacts of chemical inputs are minimized (Worldwatch 2007, 213). In addition, biofuel programs can possibly result in the concentration of land among large commercial farmers to the omission of small farmers

(Ziegler 2010). Furthermore, the dispersion of biofuel production in some parts of the world has resulted in violations of land rights and forced evictions. Among those who are particularly affected are indigenous peoples, small landholders, and forest dwellers. Furthermore, when discussing land rights, it is essential to take gender into account. Land tenure systems throughout the world are systematically discriminating against women, very often making land rights dependent on marital status (Ziegler 2010).

Moreover, since in rural areas many people depend on traditional biomass fuels and their cooking environments are often extremely confined with notable risks of respiratory diseases, biofuels can possibly contribute to reduction of the risks associated with traditional household fuels such as charcoal and fuel wood (IIASA, et al. 2009, 81).Above all, the development of biofuel production potentially has an important role to play in poverty reduction, and hence in realizing the rights of everyone to an adequate standard of living, including food security. Since food and fuel competition in biofuel production is a major concern, food security issues will be discussed in detail below.

2.3.2.1. Food Security

The largest part of poor households' income is allocated to food expenditures. Therefore, rising food prices is a real threat for them and for food security generally, which is defined as a lack of secure access to enough safe and nutritious food for normal growth and development and for an active, healthy life (T. FAO 2008). There is a serious concern that biofuel production works in opposition to food security. In 1970, about 900 million people in developing countries, or one third of the total world population, was consistently undernourished. This figure reached about one billion in 2008. Africa and South Asia were the most effected regions in the world (IIASA, et al. 2009, 22).

The concerns arise because biofuel production forces upward pressure on world food prices. Over the period of 1970-1990, world food prices constantly declined to nearly half, then stagnated until 2002. Subsequently, from 2002 to 2007, world food prices increased around 140 percent. According to Baier's research, the increase in worldwide biofuels production for two years by the end of June 2008 accounted for almost 17 percent of the rise in corn prices and 14 percent of the rise in soybean prices. Concerning sugar, the growth of the price of sugar-based ethanol production in Brazil accounted for the entire boost of the sugar's price over the same time period (Baier, et al. 2009).

The increase in food prices was as a result of a number of factors, including increased demand for biofuel feedstock and rising fuel and fertilizer prices (IIASA, et al. 2009, 22). It also included other factors like strong income growth and subsequent demand for meat products and feed grains for meat production in emerging economies, like China and India (Schneph 2008); adverse weather conditions, like severe droughts in Australia (T. FAO 2008); growth in foreign exchange holdings by major food-importing countries and protective policies adopted by some exporting and importing countries to suppress domestic food price inflation (Trostle 2008); lower levels of global stocks of grains and oilseeds (Zilberman, et al. 2008); and an increase in oil prices (Schmidhuber 2006).There is other literature that, in addition to an assessment of the impacts of biofuels on the 2007-2008 food crisis, project the impacts on food prices in the future. Some estimates indicate that agricultural prices will rise by 30 percent due to biofuel targets by 2020 (IIASA, et al. 2009, 22). The International Food Policy Research Institute (IFPRI) estimates increases for maize of 23-72%, wheat of 8-30%, oilseeds of 18-76%, and sugar of 11.5-66% considering the changes necessary to implement countries' plans that have been announced for biofuel production levels by 2020 (ODI 2008).

There is another study which models the prices of basic foodstuffs in 2020 and 2030 under several different scenarios for biofuel production. Based on the International Energy Agency's World Energy Outlook 2008 projections, price rises for both cereals and other crops in 2020 are about 10 percent higher in comparison to a reference scenario where biofuel development after 2008 is kept constant at the 2008 level (IIASA, et al. 2009, 23). Moreover, this study examines the impact of expanded biofuel production on food supply as well. The residual of the excess demand for cereals for biofuel production is met by reduced food use mostly in developing countries. However, even in the worst case scenario, the reduction in global cereal food consumption is about 29 million tons: that only represents a 1% decline from global cereal consumption of 2,775 million tons projected in the reference case, where biofuel production is frozen at 2008 levels (IIASA, et al. 2009, 23).

In short, current knowledge of the significance of the impacts of biofuel on food prices is highly sensitive to the models that have been used to assess those impacts. Partial equilibrium models, which model the food and agriculture sectors, regardless of the sectors' interaction with other sectors of the economy, not surprisingly find higher impacts on food prices. On the other hand, general equilibrium models, which take into consideration varied sectors and agents, find the impacts to be relatively small (Timilsina and Shrestha 2010). Competition for agricultural land is one of the main concerns. Currently, some 1.6 billion hectares of land are used for crop production, whereas one billion hectares are under cultivation in developing countries. Over the past 30 years, the global crop area expanded by around 5 million hectares per year. In order to accommodate first-generation biofuels production, an additional 27 million hectares in 2020 and 37 million hectare in 2030 are expected to be cultivated (IIASA, et al. 2009, 23).Food/fuel competition can be observed in the considerable decline of global wheat and maize stocks. The increased demand for these food commodities as biofuel inputs caused a surge in their prices in world markets, which in turn resulted in higher food prices (Ziegler 2010).

2.3.3. Ecological Aspects

The world must not be duped into making a false choice between either economic growth or environmental well-being. Economic growth and environmental well-being are interdependent. We must choose both (Engel and Veglio 2010), for an ecological point of view is really crucial to sustainability, since environmental problems in cultivating feedstock for biofuels can be serious. However, the net environmental impact of land use for feedstock production on habitat, biodiversity, and soil, water, and air quality depends on various factors, such as the selection of feedstock, what crop the feedstock replaces, and how it is managed (Worldwatch 2007, 196). The greatest environmental risks associated with biofuels include the aforementioned impacts on habitat, biodiversity, and soil, air and water equality; and the efficient use of water and subsequent recycling of it for fertilizer or absorbing it for biogas. It is very significant to note that water availability and use are important limits on biofuel production (Worldwatch 2007, 194). Furthermore, there can be air quality problems related to feedstock production, so it is vital to review which countries are able to reduce these adverse effects by shifting from petroleum diesel to biodiesel for farm machinery and to regulate that limit or eliminate practices like field burning (Worldwatch 2007, 211).

In the section to follow, the impact of biofuel production on the atmosphere, land, and water will be discussed individually.

2.3.3.1. Atmosphere

Climate change/Greenhouse gas emission

One significant impact of biofuel is diminishing the threat of global climate change. Transportation is 96% dependent on oil (Worldwatch 2007, 101). Transportation serves economic and social development through the distribution of goods and services and through personal mobility. However, energy use for transportation also leads to the depletion of resources and to air pollution and climate change. Reducing energy intensity in transportation can reduce the environmental impacts of transportation while maintaining economic and social benefits (IAEA, et al. 2005, 67-68). Further, the transportation sector alone is responsible for about one quarter of global energy related greenhouse gas (GHG) emissions, and that share is rising. Therefore, it is necessary to examine the claim that in the near future, biofuel can be an option for effectively reducing the demand for oil and the associated transportation-related warming emissions (Worldwatch 2007, 169).

In practice, it is not that simple. Although, a notable increase in biofuel production and use could have a significant effect on emission reductions for transportation, it is possible that would actually be a threat for warming world. This is because several factors play a role in the overall climate impacts of biofuels: the most important factor is changes in land use, choice of feedstock, and management practices. The greatest potential for reducing GHG emissions lies in the development of next generation biofuel feed stocks and technologies (Worldwatch 2007, xix). Moreover, while the Environmental Protection Agency (EPA) has yet to issue Renewable Standard Fuel (RFS) rules to determine which fuels would meet the greenhouse gas (GHG) reduction and land use restrictions specified in the Energy Independence & Security Act (EISA), it is vital to examine whether biofuel products would all meet the EISA biofuel requirements (U.S Energy Department 2008, 4).

However, there is doubt surrounding the question of the effectiveness of biofuel production in diminishing climate change. Carbon losses as a result of land use changes occur at the time of land conversion, yet greenhouse gas avoidance through the adoption of biofuels as a substitute for fossil oil only accumulates slowly over time. Therefore, net greenhouse gas avoidance resulting from the rapid expansion of first-generation biofuels will only be achieved after several decades. In the short run until 2030, the net greenhouse gas balance will be dominated by carbon debt as a result of direct and indirect land use changes (IIASA, et al. 2009, 22). Furthermore greenhouse gasses are emitted at all stages of the biofuel production chain: first, for the fuel used for the production, harvest, collection and transportation of bioenergy feedstock; then for the energy needed to produce fertilizers and pesticides; subsequently during chemical processing of feedstocks; and ultimately during the distribution of biofuels to end users and its final use (IIASA, et al. 2009, 67).

2.3.3.2. Land

Land requirements for biofuel production competes with traditional demands of agriculture and forestry. Furthermore, the growth of the global population as well as rising per capita consumption in developing countries leads to boosted demands for land to sustain the food supply in the future (Timilsina and Shrestha 2010). It is probable that some of this demand will be met with improved crop yields per unit area, which in recent decades has been increasing at about 1.5% for staple crops; however, this would only boost production by 40% by 2020. Therefore, approximately 500Mha more land is required to be brought into cultivation in order to meet the additional demands for food alone (Bustamante, et al. 2009). Hence, biofuel cultivation will expand to natural forest and pasture land, especially where no land supply response is assumed (Gurgel, Reilly and Paltsev 2007, Article 9). Biofuels feedstock production targets up to 2020 suggest that these may be responsible for the deforestation of over 20 million additional hectares while arable land expansion into forestlands for food production will amount to 50 million hectares by 2020 (IIASA, et al. 2009, 23). On the other hand, forests play a vital role in environment, not only in producing timber, wood, fuel, and other products, but also in conserving biodiversity, wildlife habitats, mitigating global climate change, and protecting watersheds against soil degradation and flood risks (IIASA, et al. 2009, 23).

Biodiversity and Soil Quality

Transformation of natural ecosystems, specifically natural forest and natural grasslands, causes high losses of biodiversity. Using abandoned or degraded agricultural land or low intensity grazing lands are relatively less (IIASA, et al. 2009, 24).

According to the Biofuels and Food Security's research done by IIASA, the effect of biofuel production on biodiversity can be categorized as follows: first in the utilization of land according to the type of feedstock used: :

> *(i.e., feedstock specific characteristics together with typical field management practices such as scale of operation, degree of mono-cropping, tillage methods, fertilization intensity, use of agro chemicals to combat pest and diseases, use of GMOs(Genetically Modified Organism), invasive characteristics of feedstocks etc.)* (IIASA, et al. 2009, 77)

Second, the pre-conversion land use or land cover situation:

> *Generally, conversions from natural areas to cultivation of first-generation feedstocks e.g. soybean and palm oil, have the highest impact in terms of loss of biodiversity. Low or no biodiversity losses occur when only the economic purpose changes, e.g. with rape grown for vegetable oil for human consumption or for bio-diesel. On the other hand, positive biodiversity effects can be achieved when converting intensively managed agricultural land to less intensive uses* (IIASA, et al. 2009, 77).

However, biofuels can affect soils both positively and negatively. Deforestation due to plantation expansion may lead to the loss of soil carbon (Guo and Gifford 2002), (Murty, et al. 2002) though growing perennials, such as oil palm, sugarcane, and switch grass instead of annual crops, would be able to increase soil cover and organic levels. Obviously, the impacts differ with crop type, soil type, nutrient demand, and the overall land preparation necessary (Timilsina and Shrestha 2010). For instance, sugarcane generally has less of an impact on soils than rapeseed, maize and other cereals (IEA 2006, Chapter 14). Although, the diversion of agricultural residues, such as bagasse, as an energy input to biofuel production diminished the amount of crop residues available for recycling that could degrade soil quality, and soil organic matter in particular (Timilsina and Shrestha 2010). Another study explains that soybean production for biodiesel in the U.S. needs much less fertilizer and pesticide per unit of energy produced in comparison with maize production for ethanol, and that both feedstocks fare poorly in comparison to second-generation feedstocks like switchgrass, woody plants or a diverse mixture of prairie grasses and forbs (Hill, et al. 2006). IEA's report claims that perennial lingnocellulosic crops such as eucalyptus, poplar, willow or grasses can be grown on poor quality land; moreover, they can increase soil carbon and quality with less-intensive management and fewer fossil-energy inputs (IEA 2006, Chapter 14).

Generally, due to land conversion from natural cover to intensive annual crop production, the organic body content of soil diminishes over time. The use of chemical fertilizers in order to reintroduce nutrients into the soil and pesticides to cope with weeds, insects and blights decreases soil biodiversity. Moreover, the use of nitrogen fertilizers leads to acidification of soils and surface waters (Worldwatch 2007, 205). Nitrogen fertilizer use without taking biofuels into account predicts a boost of an additional 40 million tons to 125 million tons in the period of 2000 to 2030, up from 85 million tons in 2000. Biofuel targets would lead to an additional use of about 10 million tons of nitrogen fertilizer, i.e. a 25 percent increase of predicted growth without demand for first-generation biofuel feedstocks (IIASA, et al. 2009, 24).

2.3.3.3. Water

Water is a fundamental driver of agricultural production and it can be called as the most precious input (IIASA, et al. 2009, 73). The agricultural sector accounts for approximately 70 percent of global freshwater use and as much as 90 percent of water resources in some developing countries, due to highly inefficient irrigation (Pstel 2006, 52). Estimates indicate agricultural water withdrawals will grow from 2630 km^3 in 2000 to 2924 km^3 in 2030 and to 3090 km^3 in 2050, rises of 11 and 17 percent, respectively, in comparison to 2000. Climate change and related warming might add an additional 5-9 percent in 2030 and 8-10 percent by 2050. Water demand for food production alone will grow substantially in the coming years and is likely to intensify water scarcities in many regions (IIASA, et al. 2009, 24).

Water Use for Irrigation

There are vast differences in water use of varied feedstocks as well as major location-specific differences in the amount of water available from rainfall and irrigated water resources. Therefore, the required irrigation water per liter of bio-ethanol produced might differ broadly across different locations (IIASA, et al. 2009, 75). For instance, cultivation of sugar-cane, especially, is extremely water intensive (Worldwatch 2007, 208).

Dense water use during dry spells intensifies water scarcities and damages river ecosystems, visible in Brazil and many other countries (F.O.Licht 2005k). Moreover, irrigation leads to soil loss and leaching of nutrients and agro-chemical residues from the soil (Durbin 2006).

In 2005, there were 10 million ha used for cultivation of ethanol feedstocks, largely sugar cane in Brazil, India, and South Africa, and maize in the United States of America and China. Bio-ethanol feedstocks are responsible for about 1.4 percent of total evapotranspiration of irrigation water withdrawals (IIASA, et al. 2009, 74).

According to the International Water Management Institute:

> *Globally, there is enough water to produce both food and biofuel. But, in countries where water is already scarce, like India and China, growing biofuel crops will intensify existing problems* (IWMI 2008).

Water Quality

Increasing biofuel production will influence water quality as well as water quantity, both through run-off of agro-chemicals and through harmful substances produced in feedstock processing and conversion (IIASA, et al. 2009, 76). Normally, less than half the nitrogen in fertilizer that is applied to crops is in fact taken up by them; the rest is dissolved in surface water, absorbed into groundwater, or lost to the air (UNEP 2000). Among all food crops, corn requires more pesticides and corn hybrids need more nitrogen fertilizer than any other crop. Therefore, run-off of these chemicals can find their way into groundwater, resulting in contamination and affecting water quality (Worldwatch 2007, 208).

Regardless of the biofuel feedstocks' type, the enhanced competition for agricultural resources as a result of biofuel feedstock production might add to the risk of intense environmental pressure created by the overexploitation of resources, poor farming practices, or the increased cycling of nutrients and pollutants beyond the protective and self-cleaning capacities of biological systems (IIASA, et al. 2009, 76).

3. Sustainable Development

In the next stage, having reliable indicators is essential since any judgment needs to be based on the proper assessment. The indicators should have certain criteria to be reliable and practical at the same time. One of the most important criteria is the validity and reputation of the source of the indicators. It should have such a framework that every country is able to use it. In order to make these indicators practical, they have to be defined in a way that can be easily measured. Moreover, data availability is very crucial in this sense, as an indicator which looks nice but lacks any way to measure it would be useless. They can be good in theory but not in practice. Another important aspect is the selection between a broad range of different issues and indicators. The indicators should of course be simple enough to be understandable and usable.

Based on the aforementioned reasons, two different packages of indicators have been selected. First, the Energy Indicators for Sustainable Development (published, edited, and issued by the International Atomic Energy Agency (IAEA) through cooperation with several international organizations such as the International Energy Agency (IEA), the United Nations Department of Economic and Social Affairs (UNDESA), Eurostat and the European Environment Agency (EEA). The second one is GBEP Sustainable Indicators for Bioenergy, which has recently been issued by the Food and Agriculture Organization of the United Nations (FAO).

In this chapter, the first section will provide a definition of sustainable development. More importantly will be the relation between energy and sustainable development, which will be at the core of this study. These discussions would help us to choose the best indicators. Further, it will include a brief description of each of these packages of indicators. Next, there will be a comparison between these two lists of indicators in the aim of finding the best combination.

3.1. Sustainable Development Definition

Sustainable development is the main aim of any country planning. It is essential to ensure that there is no conflict between the actions of each of the country planning's items and sustainable development in both the short and long run. The best definition for sustainable development is the one in the Brundtland Report:

> *[Sustainbile development is] development that meets the needs of the present without compromising the ability of future generations to meet their own needs* (WCED 1987).

Other definitions of sustainable development exist, though what really matters is having an understanding of the crucial features of sustainable development. The term 'development' expresses the concept of a clean, healthy environment and preferences in terms of social development, along with the satisfaction of economic needs and that the present generation must not, through the destruction of ecological processes essential to life, endanger the ability of future generations to be at least as well off as the current generation. There is broad agreement that sustainable development has three pillars - economic, social and environmental - and each policy must consider all three (APEC Energy Working Group 2002).

3.2. The Importance of Energy in Sustainable Development

It has been almost three decades since the topic of sustainable development emerged on the international agenda though it is only lately that sustainable development and energy have assumed greater eminence in international debates (APEC Energy Working Group 2002).

Energy is critical in sustainable development and poverty reduction determinations. It has impacts on all development's dimensions - social, economic, and environmental - including livelihoods, agricultural productivity, access to water, health, education, population levels, and gender-related issues. None of the Millennium Development Goals (MDGs) can be met without improvement both in the quality and quantity of energy services in developing countries (UNDP 2011).

Nowadays, the permanent increase of the world's population brings up serious concerns. Adequate and affordable energy supplies play a crucial role in economic development and the transition from agricultural economies to modern industrial and service-oriented societies. Energy is also essential for social and economic well-being improvements; moreover, it is indispensible to most forms of industrial and commercial wealth generation. Furthermore, it is a key for relieving poverty, improving human welfare, and raising living standards. However, energy is only a tool for bigger purposes. The main goals are good health, high living standards, a sustainable economy and a clean environment. Any type of energy, whether it be coal, solar, nuclear, wind or any other, is in itself not necessarily good or bad; each is only valued insofar as it can achieve these aims (IAEA, et al. 2005, 1).

However, current energy supply and consumption, based on limited resources of fossil fuels, is considered to be environmentally unsustainable. On the other hand, there is no kind of energy production or conversion technology which is completely without risk or waste. In energy chains, which start with resource extraction and end with the provision of energy services, pollution, emission and disposal often have severe health consequences and evident negative environmental impacts as well. Any technology might not producing harmful substances at the point of use, but emissions and wastes are always associated with its manufacture and other stages of the life cycle. Among all kinds of energy, the burning of fossil fuels is chiefly responsible for urban air pollution, regional acidification, and the risk of human-induced climate change. (IAEA, et al. 2005, 1). The judicious use of resources, technology, appropriate economic incentives and strategic policy planning at the local and national levels are requisites for achieving sustainable economic development on a global scale. Also, it needs regular monitoring of the impacts of selected policies and strategies to observe whether they are furthering sustainable development or should be adjusted. Considering that, the importance of being able to measure a country's state of development and to monitor its progress or lack of progress towards sustainability will be revealed (IAEA, et al. 2005, 1-2).

In its assessment of the main policy challenges facing the movement toward more sustainable energy sources, the UNESC notes that the governments are responsible for such actions; therefore, governments are best placed to remove policy tensions. These tensions exist where a careful balance must be pursued to achieve an optimum outcome in terms of economic and social development in the face of potential negative externalities, such as environmental consequences due to energy production and use (APEC Energy Working Group 2002).

Government action is essential to orient market forces on the path toward environmentally sound solutions. Still, while accepting that the basic responsibility for sustainable energy policy rests with governments, a participating approach including all stakeholders is desirable to facilitate progress (APEC Energy Working Group 2002) The UN Economic and Social Council (UN ESC) summarises that the underlying principles guiding the approach to energy for sustainable development:

> *are embodied in an approach that seeks to promote the efficient production and use of energy, wider-scale use of renewable sources, and transition to the next generation of fossil fuel and nuclear energy technologies. The international community can facilitate the movement from the present energy system to a more sustainable development one by supporting capacity building, technology transfer and investments in developing countries* (UN 2001).

There are seven main challenges that are as follows:

1. Improvement of the accessibility of energy;
2. Improvement of energy efficiency;
3. Increase in the use of renewable energy sources;
4. Introducing advanced fossil-fuel technologies;
5. Improvement of nuclear energy technologies;
6. Improvement of the rural energy situation; and
7. Improvement of energy efficiency and the minimization of emissions in transportation (APEC Energy Working Group 2002).

3.3. Sustainable Development Indicators

Sustainable development basically refers to the common goal of governments, non-governmental organizations, and companies to focus on the well-being of people, the planet, and profits. Government leaders are acknowledging and facilitating the design and application of sustainable development indicators for national governments and the world at large. Some nongovernmental organizations have also independently organized multi-stakeholder collaborative initiatives to create and maintain highly useful metrics methodologies, scientific databases, research reports, and a variety of informative calculator applications. Corporations, as well, are supporting the development of global and national sustainable development indicators and measurement systems, as they too see the need for policymakers and business leaders alike to progress from ignorance to knowledge and to supply their organizations with the macro-level intelligence that will inevitably affect their businesses (Wirtenberg, Russell and Lipsky 2008).

In 1992 the United Nations Conference on Environment and Development acknowledged the indispensable role that indicators could play in helping countries make well-versed decisions concerning sustainable development. The Commission on Sustainable Development (CSD) approved its Work Programme on Indicators of Sustainable Development in 1995 at the international level. Over the period from 1994 till 2001, the first two sets of CSD Indicators of Sustainable Development were developed. These indicators have been tested, applied, and used in many countries around the world as the basic elements of the development of national indicators for sustainable development (United Nations 2007, 3).

The third edition of CSD indicators has been revised in order to respond to the decisions taken by the CSD and the World Summit on Sustainable Development in 2002. This summit was an encouragement for further work on indicators at the country level in line with national conditions and priorities and invited the international community to support efforts of developing countries in this regard (United Nations 2007, 3). This effort works for better facilitation of national policymaking and performance measurements. The revised version has a framework which addresses future risks, correlation between themes, sustainability ends, and basic social needs (UNDESA 2001).

However, at one point, the UN ISD package contained more than 130 indicators. The last version of the package includes 58 indicators categorized into four dimensions, 15 themes and 38 sub-themes. When it became apparent that a vast set of indicators was unmanageable and hard to use effectively, the number of indicators was restricted (IAEA, et al. 2005, 5).

3.3.1. Energy Indicators and Sustainable Development (EISD)

The primitive work on energy indicators undertaken by the International Atomic Energy Agency (IAEA) in with cooperation of UNDESA, the International Energy Agency(IEA) and other international and national organizations was presented at the ninth session of the Commission on Sustainable Development (CSD-9) in 2001 under the title “Indicators for Sustainable Development” (ISED). Energy was a principal theme during this session. The most vital issues identified at CSD9 were improving affordability of and accessibility to modern energy services for the rural and urban poor, along with promoting less wasteful use of energy sources by the rich. The distribution of information on clean and efficient technologies, good practices, and adequate policies was identified as an essential contribution to providing energy for sustainable development. The international community noted that related information could guide decision makers to appropriate policy and energy supply options, and that energy indicators were tools for monitoring the consequences of such choice (IAEA, et al. 2005, 6).

The core set of energy indicators in use today, called Energy Indicators for Sustainable Development (EISD), has been designed to provide information on current energy-related trends in a framework that helps decision-making at the national level. It would give countries the ability to assess effective energy policies for actions promoted at the World Summit on Sustainable Development (WSSD), namely;

1. To integrate energy into socio-economic programmes;
2. To combine more renewable energy, energy efficiency and advanced energy technologies to meet the growing need for energy services;
3. To increase the share of renewable energy options;
4. To reduce the flaring and venting of gas;
5. To establish domestic programmes on energy efficiency;
6. To improve the functioning and transparency of information in energy markets;
7. To reduce market distortions; and
8. To assist developing countries in their domestic efforts to provide energy services to all sectors of their populations.

Moreover, the indicators should make it easier to identify which programmes are required for sustainable development. It requires energy statistics to be collected besides the scope of regional and national databases (IAEA, et al. 2005, 6).

3.3.2. Indicators for Assessing the Sustainable Production and Use of all Forms of Bioenergy (GBEP)

On 24 May 2011, The Global Bioenergy Partnership (GBEP) approved a set of 24 voluntary, science-based indicators for evaluating the sustainable production and use of all forms of bioenergy. This agreement denotes the first global and government-level consensus for such indicators (FAO 2011). . The Global Bioenergy Partnership was launched in January 2007 in response to the July 2005 Gleneagles Plan of Action of the G8 +5 (Brazil, China, India, Mexico and South Africa), which called for "a Global Bioenergy Partnership to support wider, cost effective, biomass and biofuels deployment, particularly in developing countries where biomass use is prevalent." Its partners at the moment consist of 23 national governments and 13 international organizations, as well as 22 governments and nine international organizations as observers (FAO, GBEP Sustainability Indicators for Bioenergy 2011).

The main aim of sustainability indicators for bioenergy is to assist countries in assessing and developing national, sustainable forms of bioenergy production and use, dependant on multilateral trade obligations. These indicators embody all three sustainability pillars (economic, environmental and social)) and explicitly include provisions on: greenhouse gas (GHG) emissions; biological diversity; the price and supply of a national food basket; access to energy; economic development; land tenure; female and child labor; and energy security. In addition, the indicators represent features by which the sustainability of biofuels production and use can be measured, which are not rigid in terms of policy and are not legally mandatory (FAO, GBEP Sustainability Indicators for Bioenergy 2011).

Moreover, the Partnership has approved the launch of a capacity-building initiative to promote the optimum use of modern bioenergy for sustainable development

The table below shows the summary of the 24 indicators for the three pillars:

PILLARS GBEP's work on sustainability indicators was developed under the following three pillars, noting interlinkages between them:		
Environmental	**Social**	**Economic**
THEMES GBEP considers the following themes relevant, and these guided the development of indicators under this pillar:		
Greenhouse gas emissions, Productive capacity of the land and ecosystems, Air quality, Water availability, use efficiency and quality, Biological diversity, Land-use change, including indirect effects.	Price and supply of a national food basket, Access to land, water and other natural resources, Labour conditions, Rural and social development, Access to energy, Human health and safety.	Resource availability and use efficiencies in bioenergy production, conversion, distribution and end-use, Economic development, Economic viability and competitiveness of bioenergy, Access to technology and technological capabilities, Energy security/Diversification of sources and supply, Energy security/Infrastructure and logistics for distribution and use.
INDICATORS		
1. Life-cycle GHG emissions	9. Allocation and tenure of land for new bioenergy production	17. Productivity
2. Soil quality	10. Price and supply of a national food basket	18. Net energy balance
3. Harvest levels of wood resources	11. Change in income	19. Gross value added
4. Emissions of non-GHG air pollutants, including air toxics	12. Jobs in the bioenergy sector	20. Change in consumption of fossil fuels and traditional use of biomass
5. Water use and efficiency	13. Change in unpaid time spent by women and children collecting biomass	21. Training and re-qualification of the workforce
6. Water quality	14. Bioenergy used to expand access to modern energy services	22. Energy diversity
7. Biological diversity in the landscape	15. Change in mortality and burden of disease attributable to indoor smoke	23. Infrastructure and logistics for distribution of bioenergy
8. Land use and land-use change related to bioenergy feedstock production	16. Incidence of occupational injury, illness and fatalities	24. Capacity and flexibility of use of bioenergy

Figure 1, GBEP Sustainability Indicators for Bionenergy. Source: FAO, May 2011

3.3.3. Comparison of Indicators

A comparison has been made between two described indicators' packages, which can be found in appendix 1. The first package of indicators contains general issues related to all kinds of energy. The advantage that the second indicator grouping has is that it is specifically related to bioenergy. Therefore, it is more relevant to this study. However, the two sets contain many of the same indicators, though of them have different ways of calculating it while still referring to the same issues.

The table in appendix 1 has three different sections. The first section provides those indicators that are common to both series. They might have some minor differences in calculation and definition, though the main issues at stake are the same. The second section refers to those indicators that have not been taken into consideration in the Energy Indicators and Sustainable Development set but have been mentioned in the Indicators for Assessing the

Sustainable Production and Use of all Forms of Bioenergy. The third section is those that cannot be found in this set but have been included by the EISD. At the end, there are a few indicators that are not related to the topic of this study but exist in EISD's indicators and will not be discussed in this study.

4. India as a Case Study

4.1. Introduction

In addition to the fact that India is a populous country, its economy has had a growth rate of about 9 percent over the past few years. Due to this high growth rate, energy demand is also growing rapidly to meet this high economic growth rate (Ravindranath, Sita Lakshmi, et al. 2010) . It is expected that the energy demand in India will be twice what it is now by 2030, with transportation energy demands making up the fastest rate of growth (WEO 2007). During 2007, India's crude oil consumption was some 156 million tons, 77 percent of which was imported. This statistic simply indicates the high dependency of India on oil imports (Minisrty of Petroluem and Natural Gas 2007). The imports of oil in India are estimated to rise to 6 million barrels per day by 2030, which would make India the third largest importer of oil (IEA, World Energy Outlook 2007). Half of the demand of oil in India belongs to the transportation sector and the country currently imports around three quarters of the oil it uses for consumption (IIASA, et al. 2009, 53).

Due to volatile oil prices and uncertainty concerning the sustainability of oil supplies, India has been searching for alternatives, petroleum products in particular, in order to promote energy security. Biofuel is one of the most promising options (Ravindranath, Sita Lakshmi, et al. 2010) since biofuels are renewable liquid fuels coming from biological raw material and can be good substitutes for oil in the transportation sector. Moreover, ethanol and biodiesel are promising for solving problems such as environmental degradation, energy security, restricting imports, rural employment and agricultural economy (Planning Commission, Government of India 2003, 1).

According to the Planning commission (Planning Commission, Government of India 2003, 2), the rationale of using biofuels for transportation in India can be described as follows:

- *ethanol and biodiesel being superior fuels from an environmental point of view;*
- *use of biofuels becoming compelling in view of the tightening of automotive vehicle emission standards and court interventions;*
- *the need to provide energy security, especially for rural areas;*

- *the need to create employment, especially for the rural poor living in areas having a high incidence of land degradation;*
- *providing nutrients tothe soil, checking soil erosion, and thus preventing land degradation;*
- *addressing global concerns relating to the containment of Carbon emissions;*
- *reducing dependence on oil imports;*
- *usability of biofuels in present engines without requiring any major modifications;*
- *the production of biofuels utilizing presently under-utilised resources of land and of molasses and, in the process, generating massive employment for the poor;*
- *the use of biofuels not requiring major or time-consuming studies or research; and*
- *the programme of production of biofuels in the country is feasible, is environmentally desirable, and is less injurious to health and would address a variety of concerns.*

India has large areas of arable land as well as good climate conditions (tropical) with a decent amount of rainfall in large parts of the areas in querstion to account for large biomass production annually. Therefore, the country has good potential for biomass production, which can then be processed into biofuels and used as substitutes for transportation fuels (Planning Commission, Government of India 2003, 6).

In India ethanol is produced through the fermentation of molasses, which is one of the by-products of sugar manufacture. India is the fourth biggest ethanol producer. The first three countries are as follows; Brazil, the United States and China (Gonsalves 2006). India is a large producer due to its four million hectares of irrigated, cultivated land. Approximately 1.2-1.8 million tons per year are used for ethanol (IIASA, et al. 2009, 53). As a matter of the fact, India is now the world's largest sugar consumer, which puts added pressure on the ethanol industry (Gonsalves 2006).

Commercial production of biodiesel in India is not significant. Since the prices of vegetable oil are high in the domestic market, it is not economically feasible to produce biodiesel (IIASA, et al. 2009, 54). Based on the fact that the demand for edible oil is higher than its domestic production, therefore, there is no possibility of diverting this oil for production of bio-diesel (Planning Commission, Government of India 2003, 6). However, the strategy of biodiesel production here is based on non-edible oils (mainly jatropha), as this would not compete with food sources (IIASA, et al. 2009, 54). Good incentives for doing so is that there are large areas of degraded forest land and unutilised public land, field boundaries, and fallow lands of farmers where non-edible oil can be grown (Planning Commission, Government of India 2003, 6). Jatrophacarcus, based on certain reasons, has been found to be the most suitable species. It will use those lands that are mainly unproductive and are located in poverty-stricken areas and degraded forests. The plantations would be within farmers' field boundaries, fallow lands, and on public lands such as along railways, roads and irrigation canals (Planning Commission, Government of India 2003, 6).

On the other hand, India is a country with a large growing population, especially in rural areas, which depends on agriculture, grazing land, and water resources for food production and livelihoods. The population density is high, almost 350 persons per sq.km, which is a limitation on land availability for food and fuel production. Therefore, it is essential to assess the potential environmental and socio-economic implications of biofuel production plans especially on net GHG benefits from land conversion, land available for food production, water requirements, and biodiversity (Ravindranath, Sita Lakshmi, et al. 2010).

However, despite the advantages mentioned, it is necessary to be cautious about the adverse impacts of biofuel production on the economy, society and environment. These effects might even be barriers for sustainable development rather than being a path toward it. Some of the main concerns have been discussed in the first chapter. Moreover, the previous chapter tried to present a series of indicators that could contribute to feasible evaluationsTo continue, this study will review India's biofuel production program separately for ethanol and biodiesel. The next stage will be examining the effect of biofuel production in India on sustainable development based on the combination of indicators that have been discussed in the preceding chapter.

4.2. Ethanol

In order to study ethanol production in India, this section is divided into two different parts. The first part will be a review of the planning of the government and the targets they have set. This section will review the expectation of the government from ethanol production in different aspects. Later on, there will be a study on the effects of implementing these policies. It will examine the advantages or disadvantages of ethanol impacts on different economic, environmental and social dimensions based on the indicators that were discussed in the previous chapter.

4.2.1. Policy / targets

As a result of rising oil prices as well as increased imports of oil for transportation, India initiated its bio alcohol transportation fuel blending in 2001. The government launched three pilot projects: two in Maharashtra and one in Uttar Pradesh during 2001. In addition, R and D studies were undertaken at the same time to assess the techno-commercial feasibility and identify vehicle modification requirements, if any. Both the R and D and pilot projects were successful and identified a blending potential of ethanol with petrol at up to 5%, as well as green-lighting the entire practice of using ethanol-laced petrol in vehicles (Gopinathan and Sudhakaran 2009).

The second phase was designed to cover the entire country and the third phase wanted to increase ethanol blending to 10%. The availability of molasses and alcohol was estimated to be sufficient to achieve this requirement after completely meeting the requirements of the chemical industry and potable sectors. Regarding surplus availability of alcohol, the central government has implemented a 5% ethanol-laced petrol supply in nine states (out of 29) and four contiguous union territories (out of six) as its first phase (Gujarat, Andhra Pradesh, Haryana, Karnataka, Maharshtra, Punjab, Tamil Nadu, Uttar Pradesh, Damman and Diu, Goa, Dadra and Nagar Haveli, Chandigrah, Pondicherry) (Gopinathan and Sudhakaran 2009). The demand and supply of ethanol was estimated by the Planning Commission Government of India to take only 5% of the required volume for the potable and chemical industries (Table 1) (Gopinathan and Sudhakaran 2009).

Table 1. Projected Demand and Supply of Ethanol for 5% Blending with Petrol, Source: GOI 2003, Planning Commission Report

Year	Petrol demand (Mt)	Ethanol demand (ML)	Molasses production (Mt)	Ethanol production (ML)			Ethanol utilization (ML)		
				Molasses	Cane	Total	Potable	Industry	Balance
2001–2002	7.07	416.14	8.77	1,775	0	1,775	648	600	527
2006–2007	10.07	592.72	11.36	2,300	1,485	3,785	765	711	2,309
2011–2012	12.85	756.36	11.36	2,300	1,485	3,785	887	844	2,054
2016–2017	16.4	965.30	11.36	2,300	1,485	3,785	1,028	1,003	1,754

The cost estimates of using sugarcane-molasses ethanol route took into consideration prevailing prices of molasses at that time, past trends (Rs. 1,000), and efficiencies of production (220 1/ton). The ethanol costs were less than Rs. 9/1 and quite economical in comparison to the cost of imported gasoline, which was about Rs. 10-12/1 at the time (Planning Commission, Government of India 2003). The committee then estimated the surplus alcohol production in the country by considering the past production and consumption trends of molasses and alcohol (Table 2).

Table 2. Molasses and Alcohol Production Consumption Trends (in million liters); Source: GOI 2003, Planning Commission report

Year	Molasses production	Alcohol production	Industrial use	Potable use	Other uses	Surplus availability
1998–1999	7.00	1,411.8	534.4	5,840.0	55.2	238.2
1999–2000	8.02	1,654.0	518.9	622.7	576	455.8
2000–2001	8.33	1,685.9	529.3	635.1	588.0	462.7
2001–2002	8.77	1,775.2	5,398.0	647.8	59.9	527.7
2002–2003	9.23	1,869.7	550.5	660.7	61.0	597.5
2003–2004	9.73	1,969.2	578.0	693.7	70.0	627.5
2004–2005	10.24	2,074.5	606.9	728.3	73.5	665.8
2005–2006	10.79	2,187.0	619.0	746.5	77.2	742.3
2006–2007	11.36	2,300.4	631.4	765.2	81.0	822.8

Moreover, it was assessed that an area of 4.36 million hectares under sugar cane production may increase to 4.96 million hectares in 2006-2007, yielding an extra cane production surplus of 50 million tons. This would supply a sufficient base for ethanol for 10% blending even in the ten-plan period. Thus, the committee submitted the outcomes in April 2003 including the following recommendations:

- The country must move toward the substitution of ethanol for gasoline;
- Molasses and distillery production’s capacity can be expanded to reach a 5-10% blend of ethanol;
- Ethanol might be manufactured either by using molasses or directly from sugar cane juice when sugarcane reaches a surplus;
- Restrictions on movement of molasses and putting up ethanol manufacturing plants might be removed;
- Ethanol imports should be subjected to proper duties; and
- Buyback arrangements with oil companies would be settled (Gopinathan and Sudhakaran 2009).

Several sugar mills increased the production and supply of ethanol by adding extra capacities. By the end of the 2004, it was projected that around a capacity of approximately 300 million liters would be created for the production of anhydrous alcohol (Ethanol India 2009). However, due to 2003-2004 seasonal droughts, sugarcane crops and sugar production diminished (Figure 2, Figure 3, Figure 4). Consequently, there was a lower availability of molasses and molasses prices subsequently rose. The sugar output dramatically dropped to 13 million tons, normally reaching 21 million tons, and molasses production decreased to 5.9 million tons, which normally reached 9 million tons; as a result, ethanol manufacturing levels shrank to 1,518 million liters, which normally achieved 2,000 million liters (Figure 4). Consequently, ethanol requirements for 5% blending in the nine states where blending was compulsorily set at 363 million liters in 2003-2004 was impossible, as the oil companies could only obtain 196 million liters. Moreover, most of the states have a tangle of rules and regulations such as restrictions on interstate movement, high excise duties, and storage charges in order to control alcohol for the potable liquor industry. As a result of a large number of taxes and levies, ethanol blending turned out to be commercially unviable in most of the states. Consequently, ethanol supplies to oil companies virtually halted in September 2004. Therefore, to supplement the lack of supplies in the year 2004, India imported 447 million liters of ethanol from Brazil (Gopinathan and Sudhakaran 2009).

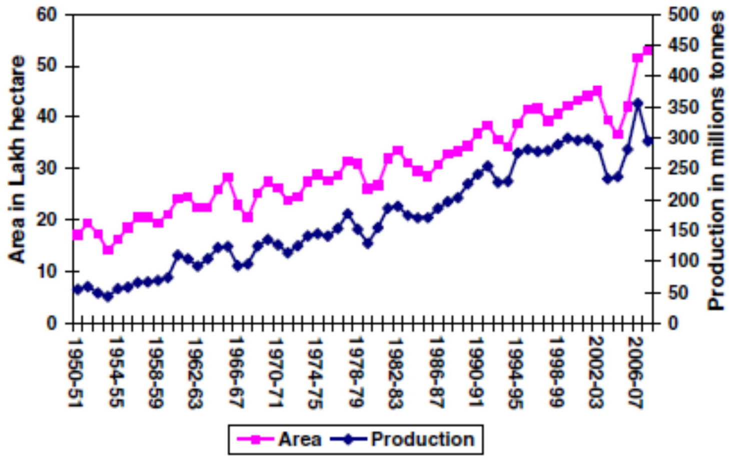

Figure 2, Indian Sugarcane Area and Production- a Cyclical Trend - Source: Cooperative Sugar 40 (5), January 2009, NFCSF Ltd., New Delhi.

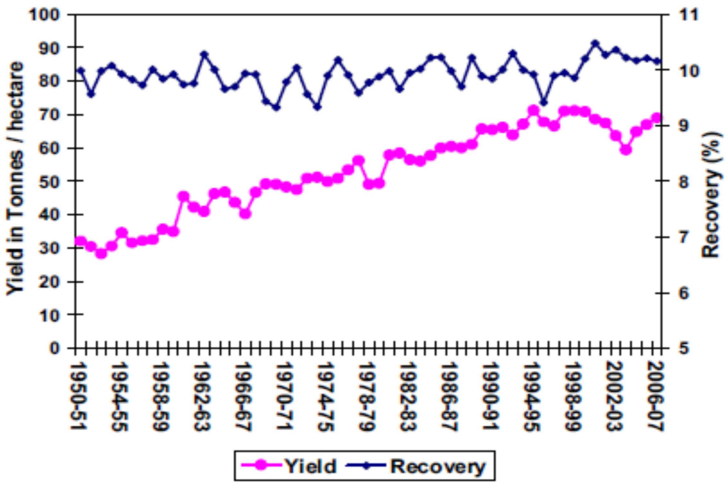

Figure 3, Indian Cane Yields and Sugar Recovery Percentages - Source: Cooperative Sugar 40 (5), January 2009, NFCSF Ltd., New Delhi.

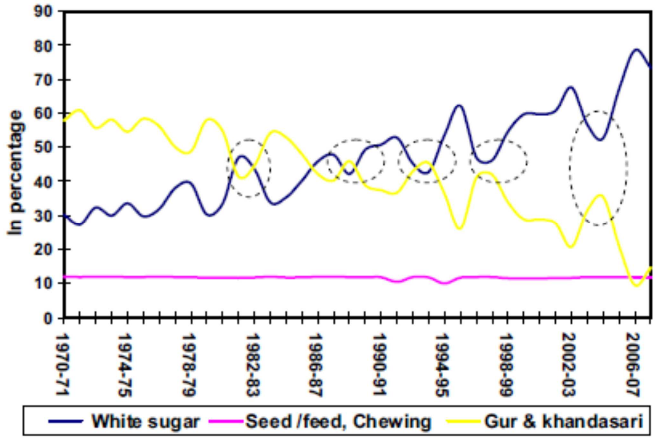

Figure 4. Sugarcane Utilization Trends for Various Purposes in Percentage - Source: Cooperative Sugar 40 (5), January 2009, NFCSF Ltd. New Delhi.

High ethanol prices and low availability brought up difficulties, so the government of India revised its 5% blending mandate with the announcement that 5% ethanol blended petrol would be supplied in identified areas under the following conditions, according to the ministry of petroleum and natural gas (Ministry of Petroluem and Natural Gas 2004):

- *The indigenous price of ethanol offered for the ethanol blend program is comparable to that offered by the indigenous ethanol industry for alternative uses;*

- *The indigenous delivery price of ethanol offered for the ethanol-blended petrol program at a particular location is comparable to the import parity price of petrol at that location; and*
- *There is an adequate supply of ethanol*

In order to develop an integrated energy policy to deal with all aspects and forms of energy, a new government expert committee was commissioned. The new reporting on molasses scarcity differed from the previous committee on the potential of sugarcane ethanol for India. The relative virtues of sugarcane ethanol and alternative technologies for ethanol development are still under debate. Furthermore, it raised some other issues such as water scarcity, the lack of sufficient arable areas for sugarcane, and a discussion about the availability of molasses-based alcohols from the sugar industry, which is not expected to grow notably in the coming years (Gopinathan and Sudhakaran 2009). Therefore, the committee made the some major recommendations which are as follows (Government of India, Planning Commission 2006):

- *Set import tariffs on alcohol independent of use and at a level no greater than that for petroleum products.*
- *Do not mandate blending of ethanol with petrol and prices of ethanol at its economic value vis-à-vis petrol.*
- *To encourage alternate routes to ethanol, such production may be procured at the full trade parity price of petrol for 5-7 years instead of being purchased at its true economic value based on calorific content duly adjusted for improved efficiency; and*
- *Create incentives for cellulosic ethanol with investment credits.*

The powerful monsoon in the year 2005-2006 increased sugarcane production, the viability of molasses, and also led to rising prices of petroleum, creating renewed interest in the ethanol program. In August 2005, due to government negotiations and agreements between the sugar industry and oil marketing companies, the ethanol program restarted in a limited number of designated states and union territories. In September 2006, the government of India announced the second phase of the Ethanol Blending Program (EBP) as a result of the strength of sugar production in that period. This program mandates 5% blending of ethanol with petrol and gasoline, subject to commercial feasibility in the 20 states and 8 union territories that took effect in November 2006. Oil marketing companies then lifted open offers for ethanol from domestic producers. Afterward, tenders were finalized and the EBP was initiated in almost ten states (Gopinathan and Sudhakaran 2009).

However, due to the high state taxes, excise duties, and levies, which collectively made ethanol blending commercially unviable, the EBP was not implemented in other states. Subsequently, in the Indian sugar year 2006-2007 (October- September) ethanol production for blending with petrol only reached approximately 250 million liters despite the target of 550 million liters (Gopinathan and Sudhakaran 2009).

In addition, the sugar industry proposed that it could provide ethanol at Rs. 19/1 ($0.38/1), which is lower than the product it substitutes (methyl tertiary butyl ether (MTBE)), which cost Rs. 24-26/1 (40.49-0.53/liter) at the time. During 2006-2007, petroleum companies procured fuel grade ethanol from sugar companies at rates ranging between Rs. 19.0 to 21.5 (47-53 cents)/l. Ethanol production's cost depends on the price of molasses, which is widely vulnerable during the season. According to the industry sources' estimation, the average cost of production of ethanol ranges from Rs. 16 to 18 (40-44 cents)/l at 2006 prices of molasses (Rs. 2,000-3,000). The eleventh planning commission report also indicates that the economics of sugar production are essentially dependent on the production of by-product ethanol. After a steady 5% of ethanol-blended petrol sales extended to the country as a whole, the content of ethanol in petrol was to be considered for boosting to 10% by the middle of the eleventh plan, subject to ethanol availability and commercial viability blending (Gopinathan and Sudhakaran 2009). In October 2008, the government made a plan for an E-10 mandate (F.O.Licht 2008).

4.2.2. Impacts

One of the very vital points in reviewing the impacts of ethanol production is bearing in mind that ethanol is produced from molasses in India, which is a by-product of the sugar industry. Therefore, the most important issue is the threat of competition of ethanol production with food, as there has not yet been cultivation of a new crop for ethanol production. All of the other possible adverse impacts of biofuel production are mostly felt in the environment in reducing soil quality, increasing water use and efficiency, reducing water quality and biological diversity, land use, and land-use changes to accommodate bioenergy feedstock; though extremely important, these issues are not going to form a part of this study as they are significant and require more space than this study can allow.

Ethanol can be produced from sugarcane, molasses, sweet sorghum, wheat, corn, sugar beet, rice, cassava, and potato. In India ethanol is produced from molasses which is a by-product of sugar manufacturing. Moreover, alcohol is a raw material for industrial use in the production of potable alcohol and chemicals. Therefore, production of ethanol in India is integrated and dependent on the industry structure, government policies, and controls in the sugar and other related industries (Gopinathan and Sudhakaran 2009).

The sugarcane growing areas of India can be broadly categorized into three regions based on climate conditions, yield of cane, and sugar content; (a) the subtropical northern belts: Uttar Pradesh, Uttaranchal, Bihar, Punjab, and Haryana; (b) the subtropical peninsular region: Maharashtra, Gujarat, and Karnataka; and (c) the tropical: Tamil Nadu, Andhra Pradesh, and Orissa (Gopinathan and Sudhakaran 2009) (Table 3).

Table 3. Classification of Sugarcane Belts of India

Region	State	Average yield tones/ha	Average recovery (%)	Average crushing days	Temperature	
					Min (°C)	Max (°C)
Subtropical—north	Bihar	42.91	9.13	93.00	7.7	41.5
	Uttar Pradesh	57.57	9.62	134.42	3.6	42.6
	Uttaranchal	57.95	9.54	131.00	2.1	42.1
	Punjab	60.21	9.60	107.85	4.6	43.6
	Haryana	60.54	10.00	136.28	4.1	43.3
Subtropical—central	Gujarat	72.08	10.70	154.14	11.1	40.9
	Maharashtra	72.77	11.46	116.71	10.9	42.8
	Karnataka	83.74	10.56	141.85	14.4	41.5
Tropical—south	Orissa	59.01	9.33	72.42	11.5	41.2
	Andhra Pradesh	76.64	10.16	123.85	13.6	41.0
	Tamil Nadu	100.25	9.59	185.85	18.5	37.5

Source: Sugar data from Cooperative Sugar Journal, published by Indian Sugar Mills Association. Temperature data from www.indiawaterportal.org. Values are average of 2001–2002 to 2006–2007.

4.2.2.1. Economic

Productivity (EISD: ECO_2, GBEP: 17)

The supply of sugarcane to mills is dependent on cane production from a vast number of small farmers, as the mills cannot own land themselves according to the Indian land ceiling act. Therefore, the average size of farm prosperities are less than one ha and only one fourth are more than four ha (Gopinathan and Sudhakaran 2009). This fact implies that a mill of 3,000 tons crushes/d must procure cane from 18,000 farmers (KPMG 2007). Another issue to be taken into consideration is the crop cycle, which is limited to two to three years due to extreme climate conditions in most parts of India, in comparison to six- to seven-year cycles in other countries. Hence, there must be flexibility among farmers to convert to other crops in case of profit losses (Gopinathan and Sudhakaran 2009). In addition, the value chain of the sugar industry has noteworthy variations from region to region regarding the profitability of cane, cost structures, sugar recovery, and complex taxes and levies on sugar and its by-products (KPMG 2007) (ISMA 2008).

The land areas under cane cultivation, cane production, productivity, and sugar production have increased intensely since independence (Gopinathan and Sudhakaran 2009) (Figure 2, Figure 3).

The economics of ethanol production from molasses is highly dependent on the cost of molasses in India. The cost of molasses varies across different states in India. A decent amount of the cost goes to central excise duties, sale taxes, transportation costs, and the statutory-controlled sugarcane and sugar prices (Gonsalves 2006). Moreover, the Indian sugar and ethanol industries are not competitive in international markets in comparison with Brazil and the United States, which are the major producers and exporters. Despite the fact that India is the second largest sugar producer in the world after Brazil, the following causes can be attributed (Gonsalves 2006):

(i) Low cane yield per acre as a result of archaic farming practices and a lack of irrigation and fertilizers;
(ii) Depletion of ground water resources;
(iii) Extreme dependence on monsoons, which can be inconsistent and unreliable; and
(iv) Absence of utilization of advanced technologies in ethanol production.

4.2.2.2. Social

Price and Supply of a National Food Basket (GBEP: 10)

Biofuel production is expected to have direct and indirect impacts on food security, with more land in developing countries being converted to biofuel production as a result of the lower costs of production, especially for labor (Worldwatch 2007). Several studies argue that the growing demand for biofuels feedstock has already contributed to increasing worldwide food prices (FAO, FAOSTAT 2008) (Pena 2008) (Bates, et al. 2008). The rise in demand of biofuel from 2000-2007 accounted for 30% of the rise in weighted average grain prices. The largest influence was on maize prices, with the increased biofuel demand accounting for 39% of the rise in prices. India could face a similar situation in the future concerning food prices related to the growing demand for biofuels as a central target of the Indian government (Ravindranath, Sita Lakshmi, et al. 2010). Figure 5 shows this trend. The area under food cultivation in India has stabilized over the past two to three decades, despite constant population growth (of 1.8% since the 1990s). Moreover, the area projected to be under food production in 2020 is expected to be 130 to 10 Mha (Ravindranath, Sita Lakshmi, et al. 2010).

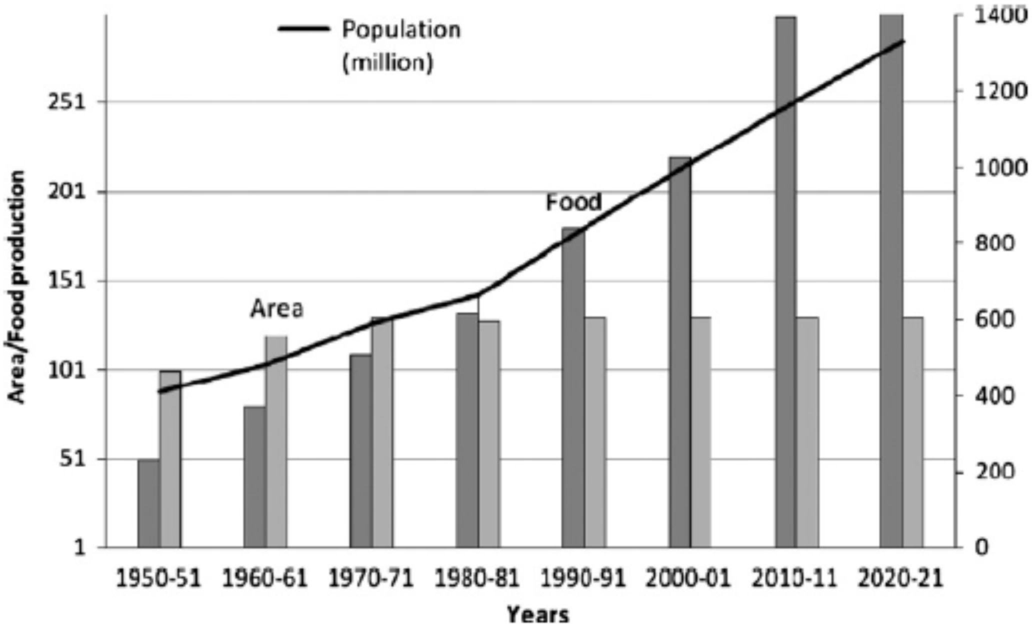

Figure 5. Trends in Area under Food Production (in million hectares) and the Food Grain Production and Demand (in million tons) along with Population Growth for the Period 1950-1951 to 2020-2021. Source: TERI (2008)

Since biofuel production has been accused of raising the food prices specifically with regard to sugar prices, it is worthwhile to consider the causes of sugar price fluctuations. The production of sugarcane and sugar fluctuations have been notable over the past few years

(Gopinathan and Sudhakaran 2009) (Figure 2). Multiple natural factors including the distribution of rainfall, flood and drought conditions, pests and diseases, fluctuations in prices of gur and khandasari (traditional Indian sugar products), and changes in returns from competing crops can be asserted. Moreover, man-made factors include government policies concerning sugarcane prices, release mechanisms, taxes, and export and import controls. Sugarcane prices are determined independently from sugar market prices and have been rising each year (Gopinathan and Sudhakaran 2009).

The constant rising trends in the sugar cycle start with timely cane payments by millers, which come from the increased profits for sugar produced and sold on the markets. This leads to greater cane planting by farmers, boosts in cane production and factories to crush it, increased sugar production, subsequent decline in profitability for mills, and delayed payments to farmers. Wide disparities occur as a result of high sugarcane prices and low sugar prices in markets. When millers are then unable to make payments on time, debts to farmers start rising. Thus, the farmers are forced to cultivate other crops, which results in the fall of sugar production. This cycle is intensified in a deficit situation, leading to an increased diversion of cane production to gur and khandsari, resulting in less availability of cane for white sugar manufacturing (Figure 4). All these factors feed again into the reduction of sugar production, higher sugar prices, a faster turnaround of industry and timely cane payments, and thus the vicious cycle continues (Gopinathan and Sudhakaran 2009).

Formerly, these cycles rose every four to five years (Figure 6). Recently, these deficit/surplus gaps are becoming wider regardless of stock positions, various control regimes, and policy interventions.

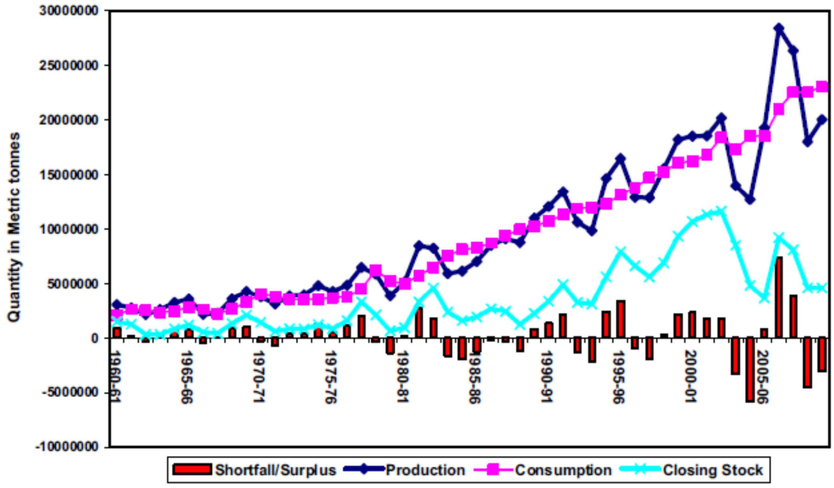

Figure 6.Indian Sugar Production and Consumption - Vicious Cycle. Source: ISMA 2008 and incorporating 2008-2009 .data

However, sugar consumption in India has been growing at a constant rate of 3% at 23.1 million tons, with per capita consumption at 18 kg, which is lower than the world average of 22 kg (Figure 6). There is a continuous shift in consumption trends from household to industrial consumers. According to a nationwide survey in 2007, 61% of sugar sold in the free market accounted for industrial and small business operations (KPMG 2007). Therefore, regarding the competition between food and fuel, caution is needed.

Jobs in the Bioenergy Sector (GBRP: 12)

After cotton textiles, the sugar industry is the second largest agricultural industry in India, which is primarily located in rural India. With more than 516 sugar mills operating in more than 18 states of the country, the sugar industry in India has been a pivotal driver of socioeconomic development in rural areas. Around 50 million sugarcane farmers and a large number of agricultural labours are involved in sugarcane cultivation and subsidiary activities, which includes 12% of the whole rural population. Moreover, the sugar industry provides employment to some two million skilled or semiskilled workers (primarily) and others from the rural areas (Gopinathan and Sudhakaran 2009).

4.2.2.3. Environmental

Land Use and Land-Use Changes related to Bioenergy Feedstock Production (GBEP: 8)

Land demands for food, animal husbandry, and biofuel is increasing, which leads to additional pressures on land and other resources. In a study by Ravindranath and Sital Lakshmi, the calculation of the required land for first generation biofuels for 2020 is projected by the taking the biofuel demand estimated for two scenarios and dividing them by indicative biofuel crop yields per hectare (Ravindranath, Sita Lakshmi, et al. 2010). It is essential to bear in mind that sugarcane in India is a vital food crop; this fact should demonstrate the limited potential for meeting biofuel demands. At the moment, ethanol production in India is largely based on sugar molasses. Another feasible option would be growing sweet sorghum in marginal lands, although the yields are likely to be low (Ravindranath, Sita Lakshmi, et al. 2010). The projected land area required for bioethanol and biodiesel production for different crop types are demonstrated in the table below. If sugarcane is selected for producing ethanol, then land areas required could be as low as 0.70 Mha and as high as 4.01 Mha for a 2020. If sweet sorghum is adopted, the projections would be 4.56 and 26.28 for the low and high scenarios for 2020 (Ravindranath, Sita Lakshmi, et al. 2010).

Table 4.Land Required (Mha) for Meeting the Projected Biofuel Demand for 2020. Source: FAO (2008). Mielke (2007), Jongschapp et al. (2007), Fresco (2006), Thow and Warhurst (2007).

Projected demand	2020-low	2020-high
Gasoline	12.9	74.0
20% of gasoline	2.6	14.8
Ethanol	4.0	23.1
Diesel	54.7	144.0
20% diesel	10.9	28.8
Biodiesel	12.7	33.5

Water Use and Efficiency (GBEP: 5)

In many tropical regions, particularly in India, food production is subjected to water stress and decreasing groundwater levels. More importantly, food scarcity is highly linked to water scarcity in most parts of developing countries (Ravindranath, Sita Lakshmi, et al. 2010). Scarcity of water, rather than land, may prove to be a dominant limiting factor for biofuel production in many regions. Many of the current first generation biofuel crops such as sugarcane, palm oil, and maize have relatively higher water requirements (FAO, FAOSTAT 2008) (Table 5). Therefore, these crops only can be cultivated under irrigated conditions or in regions with high rainfall to achieve high yields. Extensive cultivation of biofuel crops for commercial purposes might end in competition for water between biofuel production and survival food production (Pena 2008). However, in India, crops such as sweet sorghum or maize can be grown under rain-fed conditions. Presently, sugarcane is cultivated mainly for sugar production and it is only the molasses which is used in ethanol production. Therefore, it does not seem that in India, competition for water for food or fuel production would be a serious issue (Ravindranath, Sita Lakshmi, et al. 2010).

Table 5.Water Requirements for Different Biofuel Crops. Source: Wetland International Annual Review (2008).

Crop	Water (1000 l/ha)	Ethanol yield (l/ha)	Water per liter of ethanol (l)
Sugarcane	36,000	8924	4000
Maize	8000	3216	2500
Sweet sorghum	4000	3160	1300
Jatropha	Rain-fed crop		

Water Quality (EISD: ENV4; GBEP: 6)

Biofuel production on a commercial scale would require the use of nitrogenous fertilizers, pesticides, and even herbicides, all of which result in pollution of the soil and down-stream water bodies. Run-off nutrients, especially nitrogen and phosphorus, cause eutrophication of water bodies, negatively influencing aquatic biodiversity. In India, however, sweet sorghum will be grown mainly in rain-fed crop lands which are not suitable for irrigation. Therefore, the pollution of water bodies is unlikely (Ravindranath, Sita Lakshmi, et al. 2010).

4.3. Biodiesel

4.3.1. Policy/ Targets

India has a massive untouched potential of nonedible oil-bearing plant species distributed throughout the country; 300 species of trees have been reported to produce oil-bearing seeds (Subramanian, et al. 2005). However, in April 2003, the government of India's biofuels committee submitted a report on biofuels, which found that Jatrophacurcas is the most suitable for biodiesel production in India based on the following advantages (Gopinathan and Sudhakaran 2009):

(i) The estimation of oil yield per hectare for Jatropha is the highest among tree-borne oil seeds. The average seed production is 3.75 tons/ha, with an oil content of 30-35% and oil yield of 1,200 kg/ha estimated in comparison with 375 kg/ha per for soybeans in the USA and 1,000 kg/ha for rapeseed in Europe;

(ii) Possibility of cultivation in area of low rainfall (200 mm/yr), low fertility, and marginal, degraded, or fallow wastelands;

(iii) The collection, planting and growing of these trees are relatively easy, without specific requirements;

(iv) Possible use of by-products for manure and biogas generation;

(v) Opportunity to intercrop and incorporate into existing social forestry and poverty mitigation programs that deal with land improvement;

(vi) Conformation with clean energy fuel requirements from experimental studies for automotives in India and other parts of world.

The estimates show that a plant density of 2,500 trees/ha and average seed yield of 1.5 kg/tree is perfectly feasible A 1-ha plantation is capable of an average of 3.75 toms/ha of seed production, with a corresponding yield of 1.2 tons of oil/ha and 2.5 tons of cake. It is projected that by the end of the 11th plan (2011-2012) period, 13.38 million tons of biodiesel for 20% blending will be required, which corresponds to about 11.2 million hectares of land for jatropha. Cultivation of jatrohpa is expected to create employment for the rural population (Gopinathan and Sudhakaran 2009).

Many states have launched biodiesel programs based on central of self-designed policy instructions. 200 districts in 19 potential states have been recognized as suitable for jatropha cultivation over a period of three years on the basis of availability of wasteland, rural poverty ratio, census analysis of peoples below the poverty line, and agro-climatic conditions. For every district, there is a plan to divide the area into blocks, with each block hosting a 15,000-ha jatropha plantation (Planning Commission, Government of India 2003). Detailed information on the progress of each district has been summarized in Table 6.

Massive amounts of small and medium private enterprises also invested in cultivated as well as commercial production of biodiesel, though the market for biodiesel has not yet developed on a commercial scale. The current status of their performances is summarized in Table 7 (Gopinathan and Sudhakaran 2009). In October 2005, the Ministry of Petroleum and Natural Gas launched a biodiesel purchase policy to take effect from January 2006. Thanks to this policy, oil marketing companies purchased biodiesel from 20 purchase centers in 12 states (altenburg, et al. 2008). According to government missives, biodiesel has been completely exempted from excise duties (Gopinathan and Sudhakaran 2009).

No.	Name of state	Status of activities
1	Andhra Pradesh	Promotion of pongamia and simaruba with an objective to achieve 100,000 acres of biodiesel plantations in 13 districts was initiated in order to make productive use of degraded land. Forest department is planning to enter into a public private partnership with private company for ensuring buy back agreements. For example, a formal agreement was entered with Reliance Industries for jatropha planting. The company has selected 200 acres of land at Kakinada to grow jatropha. Government has reduced the value added tax for biodiesel to 4% and state road transport corporation was planned to run 10% of its fleet on 5% blending of biodiesel (APGO 2006)
2	Bihar	Plantations have been initiated in districts namely, Araria, Aurangabad, Banka, Betiah (West Champaran), Bhagalpur, Gaya, Jahanabad, Jamui, Kaimur, Latehar, Muzzaffarpur, Munger, and Nawada
3	Chhattisgarh	Chhattisgarh Biofuel Development Authority has been set up for promotion of biofuel. 210 million jatropha saplings were raised for planting in the year 2005 and 2006 and planted on 84,000 ha of farmer's and government fallow land. Pilot demonstration plantation was established on 100 ha in government fallow land in each district. A small transesterification plant was installed for biodiesel production at Raipur. Biodiesel-based power generators for rural electrification in a cluster of 50 remote villages were also installed. As a part of the government plan to electrify all villages by 2012, 400 villages are planned to electrify through jatropha based biodiesel funded by Village Energy Security Program of MNRE. State-of-art laboratory was set up in association with a local NGO, for testing of oils and biodiesel, etc. As a demonstration, chief minister continued to use biodiesel-blended fuel in his official vehicle. Government notification issued for allotting government revenue fallow land on lease to private investors to undertake Jatropha/Karanj plantation and also to setup biodiesel plant
4	Jharkhand	Plantations have been initiated in 19 districts namely Bokaro, Chatra, Daltenganj, Devgarh, Dhanbad, Dumka, Garhwa, Godda, Giridih, Gumla, Hazaribag, Jamshedpur, Koderma, Pakur, Palamu, Ranchi, Sahibganj, Singhbhum (east and west)
5	Gujarat	Plantations have initiated in 10 districts. Ahmednagar district more than 1,000 farmers are working with Govind Gramin Vikas Pratishthan for jatropha planting an area of 2,500 acres. To date, more than 2 million jatropha plants have been planted in the target area of the five villages of Vankute, Dhoki, Dhotre, Dhavalpuri, and Gajdipoor
6	Goa	Plantations have been initiated in Panaji, Padi, Ponda, and Sanguelim districts
7	Himachal Pradesh	Plantations have been initiated in Bilaspur, Nahan, Parvanu, Solan, and Unna districts
8	Haryana	Plantations have been initiated in 11 districts namely, Ambala, Bhiwani, Faridabad, Gurgaon, Hisar, Jind, Jhajjar, Mohindergarh, Punchkula, Rewari, and Rohtak
9	Karnataka	A biofuel policy has been drafted by state government. Plantation has been initiated in 15 districts. Farmers in semiarid regions of Karnataka are also planting jatropha. Since 2002, Labland Biodiesel, a Mysore-based private limited company, is active in biodiesel and jatropha development
10	Kerala	Plantations have been initiated in Kottayam, Quilon, Trichur, and Thiruvananthapuram districts
11	Madhya Pradesh	Plantations have been initiated in 20 districts, namely Betul, Chhindwara, Guna, Hoshingabad, Jabalpur, Khandwa, Mand Saur, Mandla, Nimar, Ratlam, Raisena, Rewa, Shahdol, Shajapur, Shivpuri, Sagar, Satna, Shahdol, Tikamgarh, Ujjain, and Vidisha
12	Maharashtra	200 ha plantations were raised in Nasik and Aurangabad districts. In July 2006, Pune Municipal Corporation demonstrated biodiesel blended fuel in over 100 public buses. In September 2007, the Hindustan Petroleum Corporation Limited partnership with the Maharashtra State Farming Corporation Ltd. for a jatropha-based biodiesel venture
13	Orissa	Plantations have been initiated in 13 districts namely Bolangir, Cuttack, Dhenkanal, Ganiam, Gajapati, Jajapur, Koraput, Keonjhar, Kalahandi, Nowrangpur, Nawapra, Phulbani, and Puri
14	Punjab	Plantations have been initiated in 5 districts namely, Ferozpur, Gurdaspur, Hoshiarpur, Patiala, and Sangrur
15	Rajasthan	Plantations have been initiated in Udaipur, Kota, Sikar, Banswara, Chittor, and Churu districts
16	Tamil Nadu	The government has been promoting development of jatropha through large scale entrepreneurs. To support contract farming of jatropha in 20,000 ha, government allocated Rs. 400 million through primary Agriculture Cooperative Banks. The government has abolished purchase tax on Jatropha. Currently entrepreneurs established 1,000 acres area under jatropha against the target of 20,000 ha
17	Uttarakhand	A biodiesel board has been established to coordinate jatropha cultivation. Board also coordinate seed procurement, extraction, and transesterification. Along with MNRE government planned to electrify 500 villages with biodiesel

Table 6.Details of Progress on Biofuel Initiatives in Various States of India. Source: (Gopinathan and Sudhakaran 2009)

Table 7.Current Status of Commercial Biodiesel Production in India. Source: (Gopinathan and Sudhakaran 2009)

No.	Organization/institution	Technology/raw material	Capacity
1	Southern Online Biotechnologies (P) Ltd.,[z] in Andhra Pradesh with Chemical Construction International Ltd., New Delhi[y]	The technology for the unit will be provided by Lurgi Life Science Engineering, Germany, along with their local partner, Chemical Constructions national Private Limited, New Delhi. Both oil expelling and transesterification units. Raw material supply—*Pongamia*, *Jatropha* and other raw materials like acid oils, distilled fatty acids, animal fatty acids and nonedible vegetable oils	Initial capacity of 30 tonnes of biodiesel/d, which is expandable to 100 tonnes/d. Current availability of seeds in the state is less than 4,000 tons
2	Maharashtra Energy Development Agency and Mint Biofuels, Pune[x]	Karanja oil-based biofuel	Initially had a capacity of 100 l/d, scaled up to 400 l/d
3	Gujarat Oelo Chem Limited (GOCL)[w]	From vegetable-based feedstock	Supplying to Indian Oil Corporation
4	Kochi Refineries Ltd. (KRL)[v]	From rubber seed oil	Capacity of 100 l/d
5	TeamSustain Ltd., Kochi, a division of US-based Dewcon Instruments Inc.[u]	Discussion in progress	
6	Shirke Biohealthcare Pvt. Ltd, Hinjewadi, Pune[t]	From *Jatropha* plant	To process 5,000 l
7	Jain Irrigation System Ltd[s]	Large-scale transesterification biodiesel plant with *Jatropha*	Capacity of 150,000 tons/d in Chattisgarh by 2008
8	Nova Bio Fuels Pvt. Ltd[r]	Transesterification biodiesel plant with *Jatropha* of Rs. 200 million	Capacity of 30 tons/d in Panipat in 2006
9	Naturol Bioenergy Limited, Andhra Pradesh[q]—a joint venture with Energea Gmbh (Austria) and Fe Clean Energy (United States), Kakinada	100% export-oriented unit to blend of palm oil, rapeseed, jatropha, pongamia, and vegetable oil. Shipping biodiesel to the EU for blending the alternative fuel into gasoline and diesel	100,000 tonnes of biodiesel annually. 120,000 ha for *Jatropha* cultivation
10	Savoia Biodiesel plant, Ganapathipalayam, Tamil Nadu[p]	Transesterification biodiesel plant with *Jatropha*	
11	KTK German Bio Energies India[o]	Rubber seeds	Commercial production of biofuel in 2006
12	Mint Biofuels, Pune[n]	Pongamia seed based	400 l/d and 5,000 tonne of fuel/d
13	Sagar Jatropha Oil Extractions Private Limited, Vijayawada[m]	Jatropha oil extraction unit of Rs. 100 million	Jatropha oil is mixed with diesel to produce biodiesel
14	D1-Mohan Bio Oils Limited[l] (a joint venture of Mohan Breweries and Distilleries and U.K.based D1 Oils Plc)	One lakh hectares under jatropha cultivation in Tamil Nadu	24 tonnes/d capacity
15	Classic Jatropha Oil (India) Ltd., Coimbatore[k]	Promoting cultivation of *Jatropha* in Tamil Nadu	
16	Bharat Renewable Energy and the government-owned Hindustan Petroleum[j]	40,000 ha of *Jatropha* cultivation	Million metric tons of biodiesel by 2015
17	Cleancities Biodiesel, Visakhapatnam[i]	Blend of palm oil, jatropha oil and soya oil	Capacity of 250,000 tonnes
18	Emami Group, Kolkata[h]	Blending of waste cooking oil of Rs. 150 crores	
19	Alagarh Industries in Sivakasi (Tamil Nadu)[g]		5 tonnes/d capacity
20	D1-BP Fuel Crops, based in the UK, is a 50:50 Joint Venture between BP and D1 Oils[f]	Feedstock *Jatropha* and other nonedible oil seeds	
21	Newcastle-based D1 Oil Plc, along with Labland Biotech[e]	Developed 10,000 ha of jatropha in India	
22	Aatmiya Biofuels Pvt Ltd, Gujarat[d]		Commercialized by March 2005 and now producing 1,000 l/d

[z] http://www.sol.net.in/bio_index.php cited 10 Nov 2008.
[y] http://cdm.unfccc.int/UserManagement/FileStorage/FS_686206579 cited 12 Dec 2008.
[x] http://www.mahaurja.com/ cited 10 Nov 2008.
[w] http://www.gujaratoleochem.com/product1.htm cited 12 Dec 2008.
[v] http://www.bharatpetroleum.com/refineries/refinerykochi_overview.asp?from=ref cited 12 Dec 2008.
[u] http://www.teamsustain.com/g_home.html cited 10 Nov 2008.
[t] http://www.shirkebiofuels.com/biodiesel.htm cited on 10 Feb 2009.
[s] http://www.jains.com/jatropha/Jatropha%20cultivation.htm cited 12 Dec 2008.
[r] http://novabiofuels.com/knowbiofuel.html cited 10 Nov 2008.
[q] http://www.naturol-bio.com/ cited 10 Feb 2009.
[p] http://www.savoiapower.com/biodiesel.html cited 10 Feb 2009.
[o] http://ecoworld.com/features/2006/04/06/indias-biodiesel-scene/ cited 12 Dec 2008.
[n] http://www.mintbiofuels.com/expanse.html cited 10 Feb 2009.
[m] http://www.tech2transfer.com/pdf/Article.pdf cited 10 Feb 2009.
[l] http://www.d1plc.com/globalIndia.php cited 12 Dec 2008.
[k] http://www.svlele.com/biodiesel_in_india.htm cited 10 Feb 2009.
[j] www.cleantech.com cited 12 Dec 2008.
[i] http://www.cleancities.in/ cited 09 Jan 2009.
[h] http://www.emamigroup.com/index.php cited 10 Feb 2009.
[g] http://www.unctad.org/en/docs/ditcted20066_en.pdf cited 09 Jan 2009.
[f] http://www.d1bpfuelcrops.com/ cited 10 Feb 2009.
[e] http://resourceguide.biospectrumasia.com/CompanyDetails.aspx?id=26 cited 10 Feb 2009.
[d] http://ecoworld.com/features/2006/04/06/indias-biodiesel-scene/ cited 09 Jan 2009.

4.3.2. Impacts

4.3.2.1. Economic

Productivity (EISD: ECO_2, GBEP: 17)

Even though jatropha has some advantages, such as high yields even on marginal and dry lands without inputs like irrigation, fertilizers, and pesticide, the cultivation of this non-native plant has yet materialized. Lack of research data concerning the amenability of jatropha for large scale commercial plantation and its consistent yield are among the main reasons. Therefore, the productivity and economic feasibility of this crop in India is still under debate and most farmers do not consider jatropha cultivation rewarding unless they are supported by government subsidies. What's more, since the focus and incentives have centered mostly on jatropha, the potential oil of other native, seed-bearing trees has been neglected both for research purposes and commercial exploitation (Gopinathan and Sudhakaran 2009).

The delicate point in jatropha plantation is wastelands. While wastelands represents a vast untouched land resource, there is little reason to believe that more than 10% of the total wasteland resources (about one third of the land designated degraded pastures/grazing land; underutilised/degraded notified forest land; or degraded land under plantation crops) could be commercially feasible as jatropha plantations. Moreover, as a result of poor soil quality, marginal lands cannot bear high plantation density without adversely affecting output per plant. Hence, yield per hectares from such lands is likely to be lower in comparison to yield from lands of higher quality (Rajagopal 2007). Furthermore, high plantation densities of 2,500 plants per hectare are possible only under good soil and water quality conditions, whereas on the available rain-fed plantations on marginal soils, the optimum density is only approximately 1,600 plants per hectares. The production per hectare is expected to be lower on wastelands (Rajagopal 2007).

More importantly, the current price of biodiesel produced from jatropha is not competitive with conventional diesel at present market prices. Conventional diesel is largely subsidized and the present production costs of jatropha oil are higher than the market price. Moreover, committed subsidies, minimum support prices, and exemptions from taxes are yet to be applied (Gopinathan and Sudhakaran 2009). There is furthermore a wide variation in key economic parameters and a lack of standardized seed materials or cultivation practices. This requires more attention and research to be focused on large-scale planting in the future (Rajagopal 2007).

4.3.2.2. Social

Allocation and Tenure of Land for New Bioenergy Production (GBEP: 9)

The Global Exchange for Social Investment (GEXI 2008) published a detailed survey on the status of Indian jatropha plantations. According to their report, jatropha plantations can be categorized into three types of ownership trends: private, public, and public-private partnerships with 31%, 31% and 38% respectively. In total, the area under plantation is estimated to be 497,881 ha, of which 84,000 ha is in Chhattisgarh, 33,000 ha is in Rajasthan, 20,277 ha is in Uttaranchal, and 328 ha is in Haryana. Large amounts of these crops are grown in non-irrigated lands and 60% are planted in wastelands.

11.2 million hectares of land with specific categories for plantation have been identified in the project document, though the quality and ownership of the land projected for cultivation continues to be debated. Many of the lands described in the plan are held by state governments and managed by collaborative groups or owned by selective communities, such as *panchayats*. However, Indian's experience suggests that collective ownership has been very difficult to manage for large-scale commercial production. Even on private lands, the present land-holding and tenancy laws act as stumbling blocks for large-scale plantations (Gopinathan and Sudhakaran 2009).

Moreover, there is a concern that large-scale commercial biofuel production may adversely influence access by the poor to the wastelands, which are used for cattle grazing and fuel-wood collection (Ravindranath, Sita Lakshmi, et al. 2010). A majority of wastelands allocated to the jatropha plantations are classified as common property resources (CPR). This means that a group such as a village collectively owns such resources and membership in the group confers upon an individual the right to access the resource. Such resources can play an important role in the lives of its users by supplying a wide variety of commodities like food, fuel wood, fodder, timber, thatching materials for home roofing, etc. (Gundimeda 2005) (Ravindranath and Hall, Energy and Environemnt-a Developing Country Perspective from

India 1995). In a study of Gundimeda, evidence (Beck and Ghosh n.d.) (Iyengar and Shukla 2002) (Jodha 2005) from CPRs in arid and semi-arid regions of India shows that: (i) CPRs contribute between 12 percent and 25 percent of poor household income; (ii) the poorer the household, the more vital the influence of CPRs; (iii) CPRs contribute to rural equity since they are accessed more by the poor than the rich. Hence, the composition of tree species cultivated on wastelands is essential, as disrespect for rural needs by building up wastelands can cause adversity for the poor and conflicts with growers of biodiesel or other plantations on such lands (Rajagopal 2007).

Jatropha has several disadvantages in this sense. First, jatropha's leaves are not proper for livestock or for fodder, which can be considered another food crisis (Narain 2005). In this context, cultivation of jatropha on common lands, which are often grazing lands, could possibly make the food crisis worse. Second, jatropha yields minor amounts of wood per tree. A case study in Gujarat village demonstrates that the poor collect 70 percent of their fuel and 55 percent of their food requirements from CPRs (Chen 1991). Building up these resources for biofuel, then, could be seriously detrimental to rural livelihoods, as wood is used for cooking, cleaning, certain jobs, construction, and other daily needs.

Change in Income (GBEP: 11)

There are some major barriers for adoption of jatropha, especially for small farmers. One such issue is that as a long perennial, jatropha needs up to 4 years to grow, having a long maturation phase. There are also various uncertainties concerning cultivation and marketing. A study conducted by the Employment Gaurantee Scheme in Maharashtra indicated that subsidies primarily benefiting the large farmers who adopt this crop (PRAYAS n.d.) Moreover, this study claimed that the total subsidies exceeded the costs of cultivation. However, small and marginal farmers might indirectly benefit if e they could access new employment opportunities in plantations or if there were an increase in the price of crops displaced by jatropha. In addition, it is expected that small farmers are more sceptical of buy-back contracts being offered by biodiesel companies with scant track records from farmers in given regions (Rajagopal 2007).

Jobs in the Bioenergy Sector (GBEP: 12)

Biofuel production in India is viewed as an option for generating rural employment and improving rural development. Biofuel production has high potential for creating of large number of jobs at multiple stages of the supply-chain, such as production (cultivation practices), harvesting, transportation, processing, and marketing (Worldwatch 2007); still, this generation of employment depends on the chosen biofuel crop and the former use of the land cultivating it. Under some conditions, biofuel production using mechanization that displaces traditional agriculture can lead to loss of employment. Therefore, employment creation can be expected only when more labor-intensive production techniques are used for biofuel production in comparison to the production practices of other land use. Since, in India, biofuel production will be mostly in wastelands, new jobs would be created in biofuel production, transportation and processing (Global Subsidies Initiative 2008). The planning commission is aiming to develop biofuel production in wastelands as an employment generation tactic in rural areas (Planning Commission, Government of India 2003).

4.3.2.3. Environmental

Life-Cycle GHG Emissions (EISD: ENV 1; GBEP: 1)

One of the combative issues in biofuel production is the estimates of GHG emissions from biofuel crops and thus the effectiveness of using biofuels for mitigation of climate change. There is a decent amount of available literature focused on the potential emissions from biofuels in developed countries, though very few studies are available for developing countries. Most studies concluded that the first generation biofuel production could result in a net GHG emission reduction in the range of 20-60% in comparison with fossil fuels, excluding GHG emissions from land-use conversion (Ravindranath, et al. 2009) Most studies do not include GHG emissions from land conversion, the chief source of CO_2 emissions in biofuel production. The constant rising demand for biofuel production and extensive policies adopted by nations to meet them will further require new land cropping technologies involving direct and indirect land-use changes (LUC), which will have significant impacts on the net climate benefits of biofuel production (Fargione, et al. 2008) (Gibbs, et al. 2008) (Leemans, et al. 1996) (schlamadinger, et al. 2001) (Searchinger, et al. 2008). The concept of a "*Carbon Debt*" from biofuel production indicates how many tons of CO_2 resulting from land conversion can be offset by biofuel-substituting fossil fuels. Carbon debt can also be used to determine the number of years of biofuel production needed to offset total CO_2 emissions resulting from land conversion. Land-use conversion from native land uses to biofuel crops constantly results in noteworthy CO_2 emissions and carbon debts ranging from one to several hundred years (Fargione, et al. 2008). Other studies have highlighted that land-use conversion and cultivation of biofuel crops could have notable, both positive and negative, consequences for food security, biodiversity and water (IEA, The outlook for biofuels 2006) (IPCC 2007) (RFA 2008) (Thow and Warhurst 2007). Moreover, a better understanding of the life-cycle of GHG emissions, particularly including land-use and land conversion actions, has been recommended by the United Nations (UN, Sustainable Bioenergy: A Framework for Decision Makers 2008).

In India, the conversion of forest land into cropland is prohibited under the National Forest Policy. Moreover, cropland utilization has stabilized for over 20 years, since the Indian government supports biodiesel crops only on wastelands. Hence, meeting land demands for biofuel production is expected to be provided from degraded grassland or wastelands, which have become degraded as a result of overgrazing, fire, and soil erosion. These facts mean a reduction in carbon emissions from biofuel production to a relatively low level in comparison with global scenarios that would include a conversion of forest and productive grasslands (Ravindranath, Sita Lakshmi, et al. 2010). One study in India shows that if the yield of biofuel crops decreases by 50%, emissions will automatically rise as a result of higher transportation distances to collect the requisite raw materials to produce the same amount of biofuel. In better words, there are other vital factors determining the quantity of emissions associated with biofuel, such as the yield of biofuel crops, the distance of biofuel manufacturing units from the source of biomass, and the mode of transportation used to move raw materials (Leduc, et al. 2009).

Ravindranath et. al. estimated CO_2 emissions in 2010 from land conversion by considering eight types of land conversions and using the total area needed for each biofuel crop (Table 8).

Table 8.Mean Annual CO_2 Emission (Mt) under Different Scenarios[2]. Source: (Ravindranath, Sita Lakshmi, et al. 2010)

India (Mt/ha/yr)	2020-low	2020-high
Jatropha (low yield)+sugarcane	75.92	211.85
Jatropha (med yield)+sugarcane	27.86	85.34
Jatropha (high yield)+sugarcane	15.85	53.71
Palm oil+sugarcane	11.01	40.96
Jatropha (low yield)+sweet sorghum	97.18	334.30
Jatropha (medium yield)+sweet sorghum	49.13	207.79
Jatropha (high yield)+sweet sorghum	37.11	176.16
Palm oil+sweet sorghum	32.27	163.41

In addition, the study assumes that CO_2 emissions from land conversion would take place over a 30 year period. The mean annual CO_2 emission projection for the 2020-low scenario range is 11 Mt CO_2, if abandoned land is converted to oil palm cultivation and grasslands to sugarcanes,, with an upper limit of 97 Mt CO_2 if grasslands are converted to low-yielding jatropha and sweet sorghum (Table 9). The same range for the 2020-high scenario is 41-334 Mt CO_2. The emission factors which have been used for estimates of CO_2 emissions are demonstrated in Table 9.

Table 9.CO_2Emission Factors Used. Source: Fargione et al. (2008)

Land conversion		Net CO_2 debt over 30 years (tons/ha)	Mean annual net emissions (in tons/ha/yr)
From	To		
Abandoned	Oil palm	69	2.3
Grassland	Jatropha	85	2.8
Grassland	Sugarcane	165	5.5
Grassland	Sweet sorghum	165	5.5

The total CO_2 emissions from diesel and gasoline consumption for transportation in the Alternative Policy Scenario for 2030 is projected to be 320 Mt CO_2 for India (IEA, World Energy Outlook 2007), while the annual CO_2 emission from land conversion is only estimated to be in the range 41-334 Mt CO_2 for the 2020-high scenario (Table 8). However, this does not take into consideration the emissions released in growing, transporting, and processing biofuel. Therefore, the potential emissions from land conversion to biofuel crops

[2] Mean annual CO2 emission = (area of native/original land use converted to the selected biofuel crop under each scenario) × (CO2 emission factors associated with the conversion from native/original land use to the selected biofuel crop).

by cultivating first generation biofuel crops are considerable (Ravindranath, Sita Lakshmi, et al. 2010).

Moreover, the GHG emission estimates mentioned above do not include the following factors, which could increase or decrease the total GHG emissions from biofuel production:

(i) Indirect emissions as a result of land conversion and use for biofuel crops leading to additional land conversion to substitute any loss of biomass (e.g. food grains, grass or fuel wood) from the land used for biofuel production. However, this is unlikely in India since wastelands are used and not crop lands; moreover, there are regulations on conversion of forest lands for non-forest purposes.

(ii) Net carbon increase as a result of by-products (e.g. electricity production from sugarcane-bagasse in an ethanol plant).

(iii) Carbon sequestration in the degraded land considered to be unimportant in the baseline scenarios due to the lack of biofuel production., Perennial crops, such as palm oil, have the advantage that they would sequester carbon while they are growing, as well as providing oil to produce fuel (Ravindranath, Sita Lakshmi, et al. 2010).

Water Use and Efficiency (GBEP: 5)

In India the chief biodiesel crop (jatropha) is likely to be grown in marginal lands with no need for (Ravindranath, Sita Lakshmi, et al. 2010). Therefore, water use in the biodiesel production would not seem to be an issue.

Water Quality (EISD: ENV4; GBEP: 6)

The chief biofuel crop in India is jatropha and it is mostly grown without any irrigation and only marginal fertilizer application. Thus, the pollution of water bodies is unlikely. Moreover, the wastelands are not suitable for irrigation anyway (Ravindranath, Sita Lakshmi, et al. 2010).

Biological Diversity (GBEP: 7)

As discussed in the preceding chapter, the implications of biofuel production for biodiversity are one of the most important environmental concerns. Biofuel production on a large scale could have negative as well as positive implications for biodiversity. Which type it has depends on the land category converted for biofuel production, biodiversity status of the land before conversion, the biofuel crop, and the cultivation practices. Expanded biofuel production would have large consequences for biodiversity, with biodiversity is defined as species richness and is estimated as the number of species of plants, animals and microorganisms per unit area (Ravindranath, Sita Lakshmi, et al. 2010). Negative impacts on biodiversity caused by increased biofuel production are as follows: (i) habitat conversion and loss; (ii) agricultural intensification; (iii) introduction of invasive species; and (iv) pollution (Sala, Sax and Lesloe 2009) (FAO, FAOSTAT 2008).At the moment, a sufficient understanding of the consequences of biofuel production from first generation and next generation crops is lacking and needs further research.

In India, biofuel crop production is mainly intended for marginal areas or wastelands. Due to overgrazing, soil erosion, and lack of vegetation cover, these land categories are subject to degradation. Therefore, the threat of biodiversity loss caused by biofuel production is doubtful in the India scenario. Sustainable biofuel production conducted in marginal lands could, in contrast, possibly lead to biodiversity conservation (Ravindranath, Sita Lakshmi, et al. 2010).

Harvest Levels of Wood Resources (EISD: ENV6; GBEP: 3)

In India, there is a legal ban on conversion of forest land to non-forest purposes, which includes biofuel production. Figure 7 shows that the forested area in India has stabilized since 1990 (Ravindranath, Sita Lakshmi, et al. 2010).

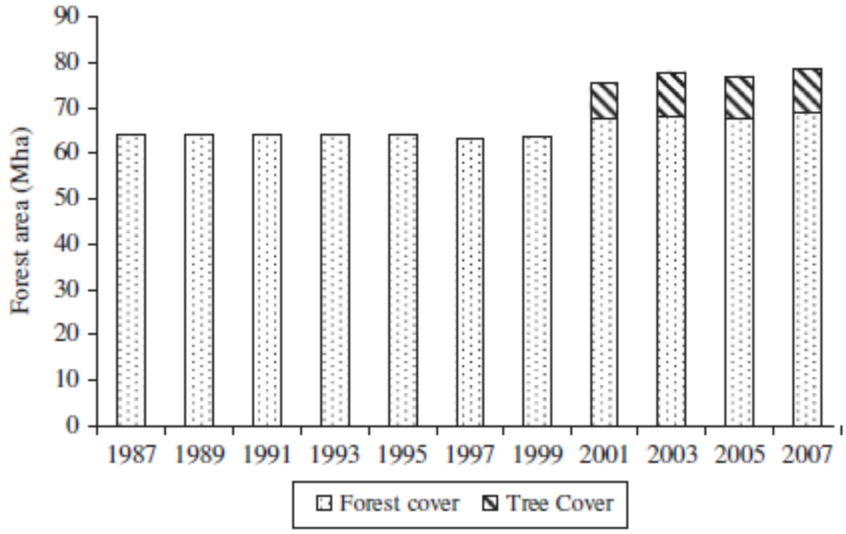

Figure 7. Trends in Areas under Forest and Tree Cover in India (million hectares). Source: (State of Forest Report 2007).

Soil Quality (EISD: ENV5; GBEP: 2)

Land degradation is a one of the chief environmental concerns in arid and semi-arid regions. As previously discussed, land degradation comes as a result of deforestation, non-sustainable forest extraction, overgrazing by livestock, fire, inappropriate agronomic practices in crop production leading to soil erosion, and the introduction of invasive species. Moreover, degraded or marginal lands need vegetation cover, and soil and water sources. In semi-arid regions, marginal lands are being targeted for biofuel production. Jatropha is the main crops being used in marginal lands in India (Ravindranath, Sita Lakshmi, et al. 2010). There is an argument that on a modest scale, jatropha cultivation can help to improve soil-water conservation, soil reclamation, and erosion control, and be used for living fences, firewood, green manure, lighting fuel, local soap production, insecticides, and medicinal applications. Nevertheless, this study concluded that high oil yields in combination with low nutrient requirements (soil fertility), lower water use, low labor inputs, the non-existence of competition with food production, and tolerance to pests and disease have not been supported by scientific evidence. Jatropha has not yet been observed on a large scale as a crop with consistent performance (Jongschaap, et al. 2007).

5. Conclusion

Due to the constantly growing population, climate change issues, and depletion of finite resources, there is an inevitable need to search for alternative energy sources. Therefore, countries are experimenting with different kinds of renewable energies. Among these renewable energies, biofuel is one that is generating global interest in expanding its production. This study focuses on the biofuel production in a developing country based on the fact that most of the share of current and future population growth belongs to developing countries. Hence, providing safe, adequate, and accessible energy for the current population and future generations is one of the critical policy issues in developing countries. This research attempts to evaluate biofuel production based on a proper index of sustainable development. It aims to find an answer for whether biofuel production would be able to fulfil sustainable development goals.

In order to reach the aim of the study, the first chapter was allocated to the introduction of biofuel and more importantly to observe the advantages and disadvantages of the biofuel production. Further, there was a discussion of sustainable development to clarify its definition and identifying its most important factors The evaluation section needed to be done based on reliable indicators. Therefore, the subsequent discussion was devoted to describing the two most relevant packages of indicators (EISD and GBEP). The comparison between them and combination of them formed a set of indicators which have been used in the final chapters.

India was selected as a case study in this research since it has a concrete plan for biofuel production. Moreover, because India has both a high economic growth rate and population growth, it makes an interesting case study. Besides, one of the main critiques of biofuel production is the competition between food and fuel, and this country is tangibly dealing with food security issues.

Among the long list of indicators that have been explored in the third chapter, the following indicators within the three economic, environmental and social dimensions were the subject of the study in India, based on their relevance and importance:

productivity, jobs in the bioenergy sector, changes in income, allocation and tenure of land for new bioenergy production, price and supply of national food basket, soil quality, biological diversity in the landscape, water use and efficiency, life-cycle of GHG emissions, water quality, and land use and land-use changes related to bioenergy feedstock production.The analysis was divided into two different sections, ethanol and biodiesel. The result of the examination of biofuel production in India based on the aforementioned indicators can be summarized as follows:

India's selection of feedstock for biofuel differs from the rest of the world. Sugarcane-molasses-based biofuel and nonedible oil seed-based biodiesel provide suitable conditions for economic development, poverty alleviation, and carbon dioxide mitigation with lesser impacts on food supply. Since the sugarcane industry is one of the largest rural industries, the bioethanol program is likely to improve rural agricultural income and create extra employment for people collaborating directly or indirectly with the sugar industry. There is also an opportunity to overcome the cyclicality of sugarcane, sugar, molasses, and alcohol production. Sustainable production supports market prices of sugar, molasses, and ethanol to steady and even decrease drastic instability experienced in past. In addition, the wide volatility in molasses prices, the chief determining element in the cost of ethanol, can be brought under control. In case sugar prices are occasionally depressed, factories can divert some of the sugarcane juice to ethanol production, thus bringing in extra income and ensuring better and appropriate payments to farmers (Gopinathan and Sudhakaran 2009).

It seems that the land required can be feasibly attained, assuming the extent of available wasteland was correctly estimated for India. The annual GHG emissions from land conversion, the likely source of GHG emissions, are predicted to range from 11 to 334 Mt CO_2 once more depending on the type of scenarios selected and the crop types used. The area under food production is likely to be stabilized in India, thus the expansion of biofuel crops in wastelands would not be likely to have a notable impact on food production. Moreover, biofuel policies encourages production solely on wastelands or marginal lands. Likewise, the application of degraded land is subjected to continuous degradation is not projected to have any significant adverse influence on biodiversity. More importantly, there is an actual ban in India on conversion of forest land to non-forest purposes, including for biofuel production. Perhaps most importantly, biofuel production in India through the cultivation of jatropha on wastelands under rain-fed conditions does not seem to have any negative consequences on availability of water for food production. However, interpretation of the environmental and socio-economic consequences demands caution, due to the limited field experience of analysts along with the absence of evidence from field studies on the adverse influences of biofuel production (Ravindranath, Sita Lakshmi, et al. 2010).

However, there are some concerns that undeniably require constraint. The reliance on only one or two crops presents a higher risk of scarcity in the biofuel supply as a result of drought or pest attacks that might result in crop failure, particularly where cultivation has to be undertaken on marginal lands with little or no adjustable inputs. More research is needed on the development of a wide variety of crops and technologies that are appropriate for diverse socio-economic and environmental conditions in rural areas in India. Further research should be able to answer these questions: (i) would focusing on private farmlands deliver higher net benefits than common property lands? And (ii) whether recreation of common lands or rural development is the aim, are there any alternative single-purpose crops besides jatropha that can supply modern biofuel along with food, fodder, and fuel wood for cooking and/or electricity production (Rajagopal 2007)?Additionally, inconsistent government policies, accessibility of land, choice of crops, yields, and market prices are critical barriers that will be encountered during the implementation of this program (Gopinathan and Sudhakaran 2009).

Suggestions:

Ethanol supply and price vulnerability can be reduced if the government, the private sector and other stakeholders utilize alternative feedstock sources, such as sweet sorghum and tropical sugar beet. Applying energy-efficient methods for anhydrous alcohol, like pressure-swing absorption or membrane separation, can greatly reduce the manufacturing costs of ethanol. Distilleries closed as a result of the low demand for alcohol-based chemicals should be revitalized. Cross-state movements of molasses and ethanol manufacturing from sugar juices (at least secondary juice) instead of molasses alone would also help the reduction of ethanol cost production. Above all, a consistent policy in which the central and state governments work toward common goals should be taken into consideration for successful implementation of the program (Rajagopal 2007).

The study will conclude with a well-worded sentence from Righelato and Sparcklen that both suggests additional research and implies the issues that countries face in the future (Righelato and Sparcklen 2007)*:*

> *Sustainable biofuel production systems could play a highly positive role in mitigating climate change, enhancing environmental quality and strengthening global economy but it will take sound, science-based policy and additional research.*

Appendix 1

Comparison of Indicators

In common	IAEA		FAO	
Aspect	Indicator	Definition	Indicator	Definition
Economic	**1.Use and Production Patterns** **Productivity:** Energy use per unit of GDP ECO2	Ratio of total primary energy supply (TPES), total final consumption (TFC), and electricity use to gross domestic product (GDP)	**1.Gross Value Added** **19**	Gross value added per unit of bioenergy produced and as a percentage of gross domestic product
	2. Use and Production Patterns **Diversificatio n** (fuel mix) 2.1.Non-carbon energy share in energy and electricity 2.2.Fuel shares in energy and electricity 2.3.Renewable energy share in energy and electricity ECO11,12,13	2.1.The share of non-carbon energy sources in primary energy supply (TPES) and in electricity generation and generation capacity 2.2.The structure of energy supply in terms of shares of energy fuels in the total primary energy supply (TPES), total final consumption (TFC) and electricity generation and generating capacity 2.3.The share of renewable energy in the total primary energy supply (TPES), total final consumption (TFC) and electricity generation and generating capacity (excluding non-commercial energy)	**2.Change in the Consumpti on of Fossil Fuels and Traditional Uses of Biomass** **20** **Energy Diversity** **22**	20.1-Substitution of fossil fuels with domestic bioenergy measured by energy content and in annual savings of convertible currency from reduced purchases of fossil fuels 20.2-Substitution of traditional uses of biomass with modern domestic bioenergy measured by energy content 22.Change in diversity of total primary energy supply due to bioenergy
	2. Use and Producti on Patterns and Prices	Actual prices paid by final consumer for energy with and without taxes and subsidies	**Net Energy Balance** **18**	Energy ratio of the bioenergy value chain in comparison with other energy sources, including energy ratios of feedstock production; processing of feedstock into bioenergy; bioenergy use; and/ or lifecycle analysis

	ECO14			
	1.Productivity : Energy use per unit of GDP ECO2	Ratio of total primary energy supply (TPES), total final consumption (TFC) and electricity use to gross domestic product (GDP)	**1.Productivity:** **17**	• Productivity of bioenergy feedstock by feedstock or by farm/plantation • Processing efficiencies by technology and feedstock • Amount of bioenergy end product by mass, volume or energy content per hectare per year • Production cost per unit of bioenergy
Social	**1.Equity** **Affordability** Share of household income spent on fuel and electricity SOC2	Share of household disposable income (or private consumption) spent on fuel and electricity (on average and for 20% of the population with the lowest income)	Change in Income 11	Contribution of the following to change in income due to bioenergy production: -Wages paid for employment in the bioenergy sector in relation to comparable sectors -Net income from the sale, barter and/or own-consumption of bioenergy products, including feedstock, by self-employed households/individuals
	2.equity **Accessibility** Share of households (or population) without electricity or commercial energy, or heavily dependent on non-commercial energy SOC1	Share of households or population with no access to commercial energy services including electricity, or heavily dependent on "traditional" non-commercial energy options, such as fuel wood, crop wastes and animal dung	Bioenergy used to expand access to modern energy services 14	-Total amount and percentage of increased access to modern energy services gained through modern bioenergy (disaggregated by bioenergy type), measured in terms of energy and numbers of households and businesses -Total number and percentage of households and businesses using bioenergy, disaggregated into modern bioenergy and traditional use of biomass

	3.Health **Safety** Accident fatalities per energy produced by fuel chain SOC4	Number of annual fatalities per energy produced by fuel chain	3.1.Changes in mortality and burden of disease attributable to indoor smoke 15 3.2.Indicence of occupational injury, illness and fatalities 16	3.1.Changes in mortality and burden of disease attributed to indoor smoke from solid fuel use, and changes in these as a result of the increased deployment of modern bioenergy services, including improved biomass-based stoves 3.2.Incidences of occupational injury, illness and fatalities in the production of bioenergy in relation to comparable sectors
Environmental	1.Atmosphere Climate Change GHG emissions from energy production and use per capita and per unit of GDP ENV1	Emissions of greenhouse gases (GHGs) from energy production and use, per capita and per unit of gross domestic product (GDP), including carbon dioxide (CO_2), methane (CH4) and nitrous oxide (N2O)	Lifecycle GHG emissions 1	Lifecycle greenhouse gas emissions from bioenergy production and use, as per the methodology chosen nationally or at community level, and reported using the GBEP Common Methodological Framework for GHG Lifecycle Analysis of Bioenergy “Version One”
	2.Land Soil Quality Soil Area where Acidification Exceeds Critical :oad ENV 5	Soil area where damage could occur due to acidification levels that exceed critical loads	Soil Quality 2	Percentage of land for which soil quality, in particular in terms of organic carbon, is maintained or improved out of total land on which bioenergy feedstock is cultivated or harvested
	3.Land	Annual change in the amount of natural and plantation forest area	Harvest levels of wood	Annual harvest of wood resources by volume and as a percentage of net growth or

	Forest Rate of Deforestation Attributed to Energy Use ENV6	tracked over time that could be attributed to using wood as a fuel for energy purposes	resources 3	sustained yield, and the percentage of the annual harvest used for bioenergy
	4.Atmosphere Air Quality 4.1.Ambient Concentrations of Air Pollutants in Urban Areas ENV2 4.2.Air Pollutant Emissions from Energy Systems ENV3	4.1.Ambient concentrations of air pollutants such as ozone, carbon monoxide, particulate matter(PM10, PM2.5, total suspended particulate[TSP], black smoke), sulphur dioxide, nitrogen dioxide, benzene and lead 4.2. Emissions of air pollutants from all energy-related activities including electricity production and transportation. Main causes of growing concern are emissions of acidifying substances, such as sulphur oxide (SOx) and nitrogen oxides (NOx); ozone-forming gases (ozone precursors), such as volatile organic compounds (VOCs), NOx and carbon monoxide (CO); and fine particulates	Emissions of Non-GHG Air Pollutants, Including Air Toxins 4	Emission of non-GHG air pollutants, including air toxins from bioenergy feedstock production, processing, transport of feedstocks, intermediate products and end products, and use; and in comparison with other energy sources
	5.Water Water Quality ENV4	-Contaminant discharges in liquid effluents from all energy-related activities, including the discharge of cooling waters, which can raise the temperature of the watercourse -Total accidental, licensed and illegal disposal of mineral oil into the coastal and marine environment	Water Quality 6	-Pollutant leaching to waterways and bodies of water attributable to fertilizer and pesticide application for bioenergy feedstock cultivation, and expressed as a percentage of pollutant leaching from total agricultural production in the watershed -Pollutant leaching to waterways and bodies of water attributable to bioenergy

				processing effluents, and expressed as a percentage of pollutant loadings from total agricultural processing effluents in the watershed
	6.Land Solid Waste Generation and Management 6.1.Ratio of Solid Waste Generation to Units of Energy Produced ENV7 6.2.Ratio of Solid Properly Disposed-of Waste to Total Generated Solid Waste ENV8	6.1.Amount of solid waste(excluding radioactive waste) produced manually from activities related to the extraction and conditioning of primary fuels, and waste produced in thermal power plants, expressed as weight of waste per unit of energy produced 6.2.Amount of waste generated by the energy sector that has been properly disposed of, expressed as a percentage of the volume of total solid waste produced by the energy sector	Land Use and Land-Use Changes Related to Bioenergy Feedstock Production 8	-Total area of land for bioenergy feedstock production, as compared to total national surface and agricultural and managed forest land area -Percentages of bioenergy from yield increases, residues, wastes and degraded or contaminated land -net annual rates conversation between land-use types caused directly by bioenergy feedstock production, including the following(amongst others): -Arable land and permanent crops, permanent meadows and pastures, and managed forests; -Natural forests and grasslands(including savannah, excluding natural permanent meadow and pastures), peat lands, and wetlands

2-

New items in FAO	indicators	Definition
Economic	Training and Requalification of the Workforce 21	Percentage of trained workers in the bioenergy sector out of total bioenergy workforce, and percentage of re-qualified workers out of the total number of jobs lost in the bioenergy sector
	Infrastructure and Logistics for the Distribution of Bioenergy 23	Number and capacity of routes for critical distribution systems, along with an assessment of the proportion of the bioenergy associated with each
	Capacity and Flexibility of the Use of Bioenergy 24	-Ratio of capacity for using bioenergy compared with actual use for each significant utilization route

		-ratio of flexible capacity which can use either bioenergy or other fuel sources to reach total capacity
Social	Allocation and Tenure of Land for New Bioenergy Production 9	Percentage of land-total and by land-use type-used for new bioenergy production where: -a legal instrument or domestic authority establishes titles and procedures for change of title; and -the current domestic legal system and/or socially accepted practices provide due process and the established procedures are followed for determining legal title
	Price and Supply of a National Food Basket 10	Effects of bioenergy use and domestic production on the price and supply of a food basket, which is a nationally defined collection of representative foodstuffs, including main staple crops, measured at the national, regional, and/or household level, taking into consideration: -changes in demand for foodstuffs for food, feed, and fibre; -changes in the import and export of foodstuffs; -changes in agricultural production due to weather conditions; -changes in agricultural costs from petroleum and other energy prices; and -the impact of price volatility and price inflation of foodstuffs on the national, regional, and/or household welfare level, as nationally determined
	Jobs in the Bioenergy Sector 12	• Net job creation as a result of bioenergy production and use, total and disaggregated (if possible) as follows: -skilled/unskilled -temporary/indefinite • Total number of jobs in the bioenergy sector and percentage adhering to nationally recognized labour standards, consistent with the principles enumerated in the ILO Declaration on the Fundamental Principles and Rights at Work, in relation to comparable sectors

	Changes in Unpaid Time Spent by Women and Children Collecting Biomass 13	Change in the average unpaid time spent by women and children to collect biomass as a result of switching from traditional uses of biomass to modern bioenergy services
Environmental	Water Use and Efficiency 5	-Water withdrawal from nationally-determined watershed(s) for the production and processing of bioenergy feedstocks, expressed as the percentage of total actual renewable water resources (TARWR) and as the percentage of total annual water withdrawals (TAWW), disaggregated into renewable and non-renewable water sources -Volume of water withdrawn from nationally-determined watershed(s) used for the production and processing of bioenergy feedstocks per unit of useful bioenergy output, disaggregated into renewable and non-renewable water sources
	Biological Diversity 7	-Area and percentage of natonally recognized areas of high biodiversity value or critical ecosystems converted to bioenergy production -Area and percentage of the land used for bioenergy production where nationally recognized invasive species, by risk category, are cultivated -Area and percentage of the land used for bioenergy production where nationally recognized conservation methods are used

3-

Items that have not been considered in FAO but exist in IAEA	Indicators	Definition
Social	1-Disparities Household Energy Use for each Income Group and Corresponding Fuel Mix	Energy use of representative households for each income group and the corresponding fuel mix of household incomes divided into quintiles (20%)

	SOC3	
Economic	1-Use and Production Patterns Overall Use ECO1	Energy use in terms of total primary energy supply (TPES), total final consumption (TFC) and final electricity use per capita
	2- Use and Production Patterns Efficiency of Energy Conversion and Distribution ECO3	Efficiency of energy conversion and distribution, including fossil fuel efficiency for electricity generation, efficiency of oil refining and losses occurring during electricity transmission and distribution, and gas transportation and distribution
	3- Use and Production Patterns Production 3.1. Reserve to Production ratio ECO4 3.2. Resources to Production Ratio ECO5	3.1. Ratio of energy reserves remaining at the end of a year to the production of energy in that year. Also, lifetime of proven energy reserve or the production life index 3.2.Ratio of the energy resources remaining at the end of a year to the production of energy in that year, lifetime of proven energy resources
	4- Use and Production Patterns End Use 4.1. Industrial Energy Intensities ECO6 4.2. Agricultural Energy Intensities ECO7 4.3. Service/Commercial Energy Intensities ECO8 4.4. Household Energy Intensities ECO9 4.5. Transport Energy Intensities ECO10	4.1.Energy use per unit of value added in the industrial sector and by selected energy-intensive industries 4.2. Final energy use per unit of agricultural value added 4.3. Final energy use per unit of service and commercial value added per floor area 4.4. Amount of total residential energy used per person or household or unit of floor area. Amount of energy used by residential and per person, household, or unit of floor area, or per electric appliance 4.5. Energy use per unit of freight-kilometer (km) hauled and per unit of passenger-km travelled by mode

	3. Security 4. Imports Net energy import dependency ECO15	The ratio of net import to total primary energy supply (TPES) in a given year in total and by fuel type such as oil and petroleum products, gas, coal and electricity
	5. Strategic fuel stocks Stocks of critical fuel per corresponding fuel consumption ECO16	Ratio of the stocks of critical energy fuels to the daily, monthly or annual use of the corresponding fuel. Critical fuel is usually oil. Some countries might consider other fuels critical (e.g. natural gas, ethanol, etc.)

Deleted items IAEA (not relevant)	**Indicators**
Environmental	1.Solid Waste generation and management 1.1.Ratio of solid radioactive waste to units of energy produced ENV9 1.2.Ratio of solid radioactive waste awaiting disposal to total generated solid radioactive ENV10

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PERSONAL INFORMATION

Name	**Shadi Mohebinejad**
Address (House number, street name, postcode, city, country)	Helblinggasse 1-3/28 Vienna 1170 Austria
Telephone	+436604834284
E-mail	s.mohebinejad@iaea.org/shadimn@gmail.com
Nationality	Iranian
Date of birth (Day, month, year)	23/08/1982

EDUCATION

• Date	2009-2011
• Name and type of organization	Erasmus Mundus Master Program of Global Studies-offered by a consortium of five European universities: Roskilde Universitet, London School of Economics and Political Science, Universität Leipzig, Universität Wien, Uniwersytet Wrocławski
• Principal subjects	Interdisciplinary research-based Master, includes: History, Political science, Economics, Social Science
• Research Projects	Title of Master Thesis:" Biofuel Production on Developing country: A Key to Sustainable Development? Case Study: India "
• Level in national classification	M.A
• Date	2004-2007
• Name and type of organization	University of Tehran-Iran
• Principal subjects	Energy Economics and Marketing
• Research Projects	Thesis topic: "The effect of Macroeconomics Conditions on Banks' Credit risk" which the article with the same title was published in "Economic Research and Reviews".
• Level in national classification	M.A
• Date	2000-2004
• Name and type of organization	University of Tehran
• Principal subjects	Theoretical Economics
• Level in national classification	B.A

Training and Certification

• Dates	2008
• Name and type of organization	Central Bank of Iran
• Principal subjects	Risk Management
• Title of qualification awarded	Credit Risk Management
• Dates	2008
• Name and type of organization	Institute for Development & Economic Research
• Principal subjects	Finance
• Title of qualification awarded	Advanced Financial Management
• Dates	2008
• Name and type of organization	Institute for Development & Economic Research
• Principal subjects	Finance
• Title of qualification awarded	Investment Management
• Dates	2007-2008
• Name and type of organization	Export Development Bank of Iran
• Principal subjects	Banking
• Title of qualification awarded	International Banking

• Dates	2007
• Name and type of organization	Export Development Bank of Iran
• Principal subjects	Banking
• Title of qualification awarded	Islamic Banking

Work experience

• Dates	July 2011- Present
• Name and address of employer	International Atomic Energy Agency (IAEA)
• Occupation or position held	Project Assistant
• Main activities and responsibilities	1. Working on a project about the renewable energies and sustainable development. Combine the IAEA "Energy indicators for sustainable development (EISD)" with the FAO indicators for agriculture and forestry using as guiding principle their relevance for analyzing bio-fuel production in the context of sustainable development 2. Develop brief description of data requirements, application and pitfalls in using any new indicators (template: EISD) 3. Collect and evaluate data for three distinct regions, identify gaps and develop strategies to cope with data gaps

• Dates	April 2011- July 2011
• Name and address of employer	United Nations Office on Drugs and Crimes (UNODC)
• Occupation or position held	Project Assistant
• Main activities and responsibilities	Collecting the data from different countries to analyze the result of treatment programs which have been done by UNODC training package, Assistant in event organizing, designing and preparing poster.

• Dates	2006-2009
• Name and address of employer	Risk Management Department - Export Development Bank of Iran
• Position held	Expert
• Main activities and responsibilities	Working on identifying and measuring operational risk- Identifying and measuring Credit Risk- Rating customers and their credit's limits- Banks' Rating- Evaluating different banks' risk and companies' risk- Evaluating the countries' risk- Monitoring and adjusting bank's financial statement items to Basel II standards- Preparing the reports for international bank rating agency(Fitch)-Editing the bank's annual report- Regular reporting on portfolio analysis- Updating the in used models of risk evaluating

• Dates	2004-2006
• Name and address of employer	Developing & Planning Department - Export Development Bank of Iran
• Occupation or position held	Expert
• Main activities and responsibilities	Writing and editing different structures for different department of bank- Developing the ways of supplying facilities for customers -

Publication and Awards

Article	"The Effect of Macroeconomics Conditions on Banks' Credit risk" in "Economic Research and Reviews"/Iran "Women's rights in Iran" INTERFER (International Reportage Festival/Serbia)
Grant	Tuition Fee waiver grant from Erasmus Mundus Consortium ,due to the excellent result of the first year of study

Personal skills

Personality	communicative, high skilled in group working, strong analytical, independent, determined, good time manager, curious and enthusiasm, energetic and hardworking
Mother tongue	Persian
Other languages	English(Excellent) – Germany (Intermediate)_ Spanish(Basic)_Arabic(Basic)
Technical skills	Microsoft Office(Word, excel, Power point, Access) Eviews , SPSS, MATLAB