# Biofuel Second Generation and Energy Security: An Overview

Prof. Akram A. Khan[1] & Talha Akbar Kamal[2]

**Abstract:** The total primary energy consumption of the world is increasing at a very fast pace and the major component of this energy consumption consist of oil, coal and natural gas, constituting around 85% of the total energy required. This increase in the total energy consumption leads to problem of increase in the CO2 emission and excessive burden on the limited available fossil fuel. The increasing demand of energy with such an alarming rate, calls for the search of a sustainable energy source which can meet the energy requirement of the world without degrading the environment at a regular basis. In order to substitute the fossil fuel and meet the global energy need without affecting the environment, biofuel come into existence and the growth of biofuel in the last 10 year shows that biofuels have the capability and potential to act as a sustainable energy resource for the future generation. The feedstock requirement for the production of first generation biofuel is also facing a sustainability issue as they require food crops such as corn, sugarcane etc for its production; this diversion of the agricultural resources to energy production has created a question mark on the future food safety of the developing nation. To tackle this problem a new source of the renewable energy was emerged i.e. second generation biofuels. Second generation biofuels offer opportunity for reducing reliance on the fossil fuel and climate change mitigation, along with problem of food security arises from the diversion of agricultural resources to energy production. Second generation biofuels would be generally made from non-edible lignocellulosic biomass, including residues of crops or forestry production and whole plant biomass. Although production of second generation biofuel is not started on the commercial level but its ability to substitute the fossil fuel without harming the environment has attract the interest of the many developed countries.

**Keywords:** biofuels, second generation biofuels, energy security, biomass, CO2 emission.



## 1. Introduction

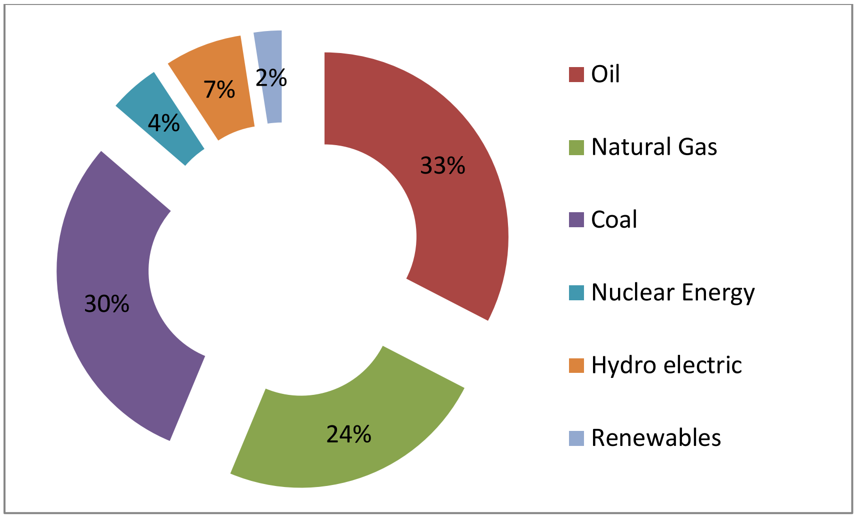
For the economic development of a nation availability of continuous energy at an affordable price is very important. Therefore energy security is the prerequisite for the economic development. Therefore, IEA defines energy security as “the uninterrupted availability of energy sources at an affordable price” (IEA, 2014). Keeping in mind the sustainable approach, in the long run energy security has also included economic developments and environmental friendliness along with continuous supply of energy at affordable price. Thus energy security consists of 4 major dimensions 1) availability, 2) affordability, 3) economic development, and 4) environment friendly. In 2014, the total primary energy consumption of the world by fuel was 12928.4 MTOE, which is 0.95% more than the previous year. The major component of this fuel energy mix is oil, coal and natural gas constituting 87% of the total energy required. Hydro electricity (7%), nuclear energy

[1] Chairman, Dept of Agricultural Economics & Business Management, Aligarh Muslim University, Aligarh, akramakhan1@gmail.com, 07417745269

[2] Research Scholar, Dept of Agricultural Economics & Business Management, Aligarh Muslim University, Aligarh, talhakamal23@gmail.com, 09411697538

(4%) and renewable accounts just 13% of the energy requirements of the fuel. The following figure 1 shows the same.

**Figure1: World Primary Energy Consumption by Fuel, 2014**




(Source: BP (2015))



From figure 1 it is clearly visible that the fossil fuels have extensive pressure to meet the energy requirement of the world. The total demand for energy is increasing with good pace; from 2001 the average annual increase in the total primary energy consumption has been around 2.33% (BP, 2015). With increasing demand of energy, the $CO_2$ emission by burning the fuel is also increasing and the speed by which it is increasing is faster than the energy consumption, from 2000 the average annual increase in the $CO_2$ emission by primary energy sources is 2.51% and the extensive use of fossil fuel is one of the most important factor (BP, 2015). The increase of the $CO_2$ emission with such an alarming rate, calls for the search of a sustainable energy source which can meet the energy requirement of the world without degrading the environment. In order to substitute the fossil fuel and meet the global energy need without affecting the environment, biofuel come into existence and the growth of biofuel in the last 10 years shows that biofuels have the capability and potential to act as a sustainable energy resource for the future generation.

The potential of biofuel to substitute the fossil fuels has dramatically attracted the interest of the high petroleum importing countries (Alston, Beddow, & Pardey, 2009). Ability of the biofuels to reduce the GHG emission, which helps in stabilizing the climate, also stimulated the growth of biofuel industry (Farrell, Plevin, Turner, Jones, O'Hare, & Kammen, 2006). But in developing countries, this diversion of the agricultural resources to energy production has created a question mark on the future food safety of the nation.

The emergence of the new source of the renewable energy i.e. second generation biofuels, offer opportunity for reducing reliance on the fossil fuel and climate change mitigation, along with problem of food security arises from the diversion of agricultural resources to energy production. Second generation biofuels would be generally made from non-edible lignocellulosic biomass, including residues of crops or forestry production (corn cobs, rice husks, forest thinning, sawdust, etc.), and whole plant biomass (e.g., energy crops such as switchgrass, poplar and other fast-growing trees and grasses). Biofuels obtained from vegetable oils produced from sources that do not directly compete with crops for high-quality land (e.g., jatropha and microalgae) can also be labeled as second generation biofuels (Carriquiry, Du, & Timilsina, 2011). As both food and energy both are essential to human well-being so, second generation biofuel is the middle path for energy security as well as of food security.

## 2. Objective of the Study

The objective of this study is to provide the conceptual understanding of biofuels i.e. first generation and second generation and access the energy security by second generation biofuels by evaluating them on all the four dimensions i.e. availability, affordability, economic development, and environment friendliness.

## 3. Biofuels

"Biofuels are fuels derived from biomass or waste feedstock and include ethanol and biodiesel. They can be classified as conventional and advanced biofuel according to the technologies used to produce them and their respective maturity" (IEA, 2011). Biofuels are mainly produced from renewable resources, especially plant biomass, vegetable oils & treated municipal & industrial waste. Biofuels are considered neutral with respect to the emission of $CO_2$ because $CO_2$ given off by burning them is balanced by the $CO_2$ absorbed by the plants that are grown to produce. The use of biofuels as an additive to petroleum-based fuel can also result in cleaner burning with less emission of $CO_2$ and particulars. There is a lot of discussion on the terminology and definitions used to classify biofuel. They are commonly referred to as "first-generation biofuel" or "second-generation biofuel", but the distinction is unclear. The reason is that the same fuel might be classified as first- or as second-generation, depending on whether the determining criterion is the maturity of the technology, the greenhouse-gas emissions balance or the applied feedstock. In World Energy Outlook 2011, Biofuels were also classified as “conventional” and “advanced” according to the technologies used to produce them and their respective maturity.

***Conventional biofuel*** include well-established technologies that are producing biofuel on a commercial scale today. These biofuel are commonly referred to as first-generation and include sugar cane ethanol, starch-based ethanol, biodiesel, Fatty Acid Methyl Esther (FAME) and Straight Vegetable Oil (SVO). Typical feedstock used in these mature processes include sugar cane and sugar beet, starch-bearing grains, like corn and wheat, and oil crops, like canola and palm, and in some cases animal fats.

***Advanced biofuel*** sometimes referred to as second or third-generation biofuels comprise different conversion technologies that are currently in the research and development, pilot or demonstration phase. More specifically, this category includes emerging biofuel technologies, such as hydrogenated biodiesel, which is based on vegetable oil, as well as all those based on ligno-cellulosic biomass, such as cellulosic-ethanol, biomass-to-liquids (BTL) diesel and bio-derived synthetic natural gas (bio-SNG), among others. The category also includes novel biofuel technologies that are mostly in the research and development and pilot stage, such as algae-based biodiesel or butanol, as well as the conversion of sugar into diesel-type biofuel using micro-organisms (such as yeast). This definition differs from the one used for “Advanced Biofuels” in the US legislation, which is based on a minimum 50% life-cycle greenhouse-gas reduction and which, therefore, includes sugar cane ethanol.

Production of biofuels has been increasing with a very rapid pace in the past few years, particularly in US and Brazil, the major producer of biofuels in the world. Total production of fuel ethanol has increased from 13,123 million Gallon in 2007 to 24570 millions of Gallon in 2014 (Licht). This increase in the biofuel production is not free from controversies; the story of biofuels has been described as one of ‘riches to rags’ (Sengers, Raven, & Van Venrooij, 2010). The production of the biofuel is linked with a debate of ‘food vs. fuel’ and other social, environmental, economic and ethical challenges are also emerging especially with respect to so-called ‘first generation’ biofuels produced from food crops. All these factors together stimulated in developing a biofuel produced from non food biomass, which are less water and land intensive or use residue from crops.

## 4. Second Generation Biofuels

The term “second generation biofuel” is defined mainly on the basis of the feedstock and conversion technologies, the feedstock use for the production of second generation biofuel are non edible and the conversion technologies are still in the research and development, pilot or demonstration phase. The raw material use for the production of second generation biofuel can be agricultural residues such as straw and stover, residues from forestry, or dedicated energy crops such as grasses (e.g. switchgrass) and wood from short rotation forestry.

### 4.1. Conversion Process of Second Generation Biofuels

Biomass conversion for the production of $2^{nd}$ generation biofuel is conducted by two ways:

***Thermo chemical decomposition:*** The thermo chemical conversion process includes direct combustion, gasification, liquefaction, and pyrolysis. When biomass is heated under oxygen deficient conditions, it generates synthesis gas, or syngas, which consists primarily of hydrogen and carbon monoxide. This syngas can be directly burned or further processed for other gaseous or liquid products.

***Biological or biochemical processing:*** Biological conversion technologies are based on microbial and enzymatic process for producing sugars from biomass such as lignocellulosic, starch, cellulosic. The sugars later can be converted into alcohol and other solvents of interest to fuel and chemicals.

### 4.2. Potential Feedstock for the Production of Second Generation Biofuels

The potential feedstock required for the production of second generation biofuels are lignocellulosic biomass. In general, lignocellulosic feedstock is divided into three categories:

***Agricultural residues*** mainly consider residue of the crops such as corn, barley, rice, sorghum, wheat and sugarcane. The main benefit of using the residues of these crops for the production of biofuel instead of the food grains or dedicated energy crops is that no additional land is required for the production. As residue based biofuel production avoids competition for land and this will leads to the minimal direct impact on the prices of the food. In addition to this, green house gas emission which is associated with the direct and indirect usage of the land is also avoided and improves the carbon balance of the fuel (Searchinger, et al., 2008).

***Forest residues*** mainly included logging residues produces from the harvest operation, fuel wood extracted from forest lands, primary and secondary wood processing mill residues (Perlack, Wright, Turhollow, Graham, Stokes, & Erbach, 2005).

***Energy crops*** are the non-food crops which provide an additional potential source of feedstock for the production of biofuel. Energy crops are grouped into grassy and woody energy crops.

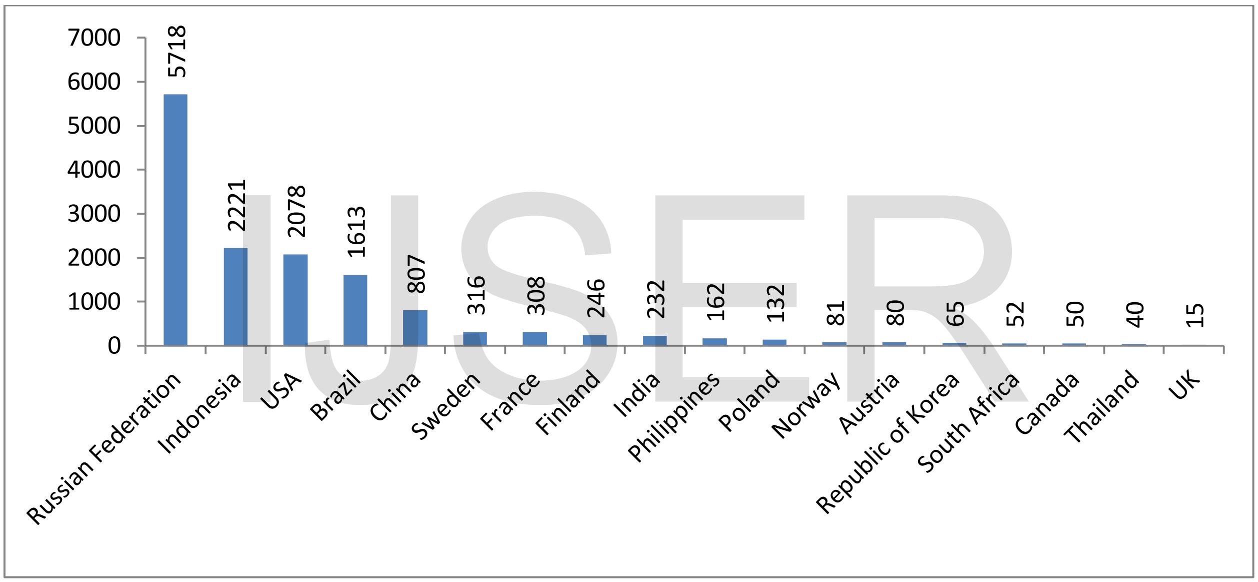
**a) Grassy Energy Crops** or perennial forage crops mainly include switchgrass and miscanthus. These are the promising source of feedstock for second generation biofuels. Switchgrass is the most commonly used feedstock because it requires relatively low water and nutritious input and this makes it less cost effective. In addition to it, switch grass have positive environmental impact and adaptability to low-quality land (Keshwani & Cheng, 2009). Miscanthus is a grass mainly found in Asia and a compelling feedstock for second generation biofuel production in Europe (Lewandowski, Scurlock, Lindvall, & Christou, 2003), because it requires a very low level of nitrogen and it can also tolerate the cold conditions. The major drawback of using this feedstock is that it takes at least 2 to 3 years to start fuel production as it must be established and propagated via rhizome cuttings.

**b) Woody Energy Crops** are mainly consisting of the fast growing tree species like Poplar, willow, and eucalyptus. The most important attributes of these class species are the low level of input required when compared with annual crops (Smeets, Faaij, Lewandowski, & Turkenburg, 2007). In short, dedicated energy crops as feedstock are less demanding in terms of input, helpful in reducing soil erosion and useful in improving soil properties. Moreover, when compared with food crops more energy per unit of land is obtained from these crops, as higher proportion of the biomass can be utilized. On the other hand, in spite of the higher yield, food versus fuel debate does not be entirely escaped by the dedicated energy crops because additional land is needed for their production. So these crops should be planted on the land where neither food crop production nor grazing pastures takes place, or on lands that are not needed for any production activity, by this these crops do not compete for land with food production.

**5. Availability of the Biomass for the Production of Second Generation Biofuels**

For the sustainable production of second generation biofuel it is very important to estimate the availability of the biomass required for its production. According to FAO (2010), total biomass produced from the forest is about 600066 MT but the full amount of forest biomass cannot be used for the production activities. Only 30% of the forested area is used from the production of wood and non-wood production activities. Out of this 30% harvested biomass only 46% is considered as residue and rest is used in the production of roundwood. This is the residue which left in the forest and is used for the domestic purposes or left alone in the forest. Figure 2 provides the information about the availability of the forest residue in the major countries of the world.

**Figure 2: Top Producer of the Forest Residue in the World (in Million Tonnes)**




(Source: Baruya, 2015)

Above figure shows the total potential residue of world's forest that is designated for the production purpose, which is 14216 MT. In addition to this, the total residue generated from forest also consists of the residue generated from the wood processing industry. The biomass supplied to wood processing industry is not utilized fully, so it can also became a part of the total residue generated from forest and the data of the residue generated from the wood processing industry is given below.

**Table 1: Total Residue from Industrial Wood Production in 2013 (in Million Tonnes)**

| Country | Residue from Forest Felling and Cutting | Residue from Saw Mills | Total Residue Potential from Industrial Wood Production in 2013 |
|---|---|---|---|

| | | | |
|---|---|---|---|
| USA | 111.8 | 44.0 | 155.8 |
| Russian Federation | 68.5 | 27.0 | 95.5 |
| Brazil | 59.1 | 23.3 | 82.3 |
| Canada | 56.2 | 22.1 | 78.4 |
| China | 55.4 | 21.8 | 77.2 |
| Indonesia | 25.2 | 9.9 | 35.1 |
| Sweden | 23.8 | 9.4 | 33.2 |
| India | 19.8 | 7.8 | 27.6 |
| Finland | 18.7 | 7.4 | 26.0 |
| Germany | 16.9 | 6.7 | 23.6 |
| Poland | 12.5 | 4.9 | 17.4 |
| France | 9.8 | 3.8 | 13.6 |
| Australia | 9.2 | 3.6 | 12.8 |
| Japan | 7.1 | 2.8 | 10.0 |
| South Africa | 6.4 | 2.5 | 8.9 |
| Austria | 4.7 | 1.9 | 6.6 |
| Norway | 3.4 | 1.3 | 4.8 |
| Philippines | 1.5 | 0.6 | 2.2 |
| Republic of Korea | 1.5 | 0.6 | 2.1 |
| UK | 1.2 | 0.5 | 1.7 |
| Thailand | 0.01 | 0.00 | 0.01 |
| **Total** | **512.71** | **201.9** | **714.81** |

(Source: Baruya, 2015)

Table 1 show that the total residue generated from the industrial wood in 2013 was 714.81 MT from these selected 21 counties and this accounts around 80% of the total residue generated by the industrial wood throughout the world (Baruya, 2015). This shows that forest has a huge potential to generate biomass for the production of second generation biofuel on an annual basis.

In addition to the forest residue, there is also agricultural residue which can also be used as a potential biomass for the production of second generation biofuel. Basically agricultural residues refer to the material that remains in the field after a crop has been harvested, they include straw, stalks and leaves that are left over after harvest. These residues have to serve a number of purposes like retain the soil fertility, some of the residue used as a fodder for livestock etc. Residue generated from the processing units such as sugar beet pulps, cotton mill wastes, and peanut shells are also part of agricultural residue and can contribute in the production of second generation biofuel. The total availability of the agricultural residue of the world from the major crops are given in the following table

**Table 2: World's Total Agricultural Production along with the Total Residue Generated in 2013**

| Crops | Residue | Crop Residue Ratio* | Production (MT)** | Residue(MT) |
|---|---|---|---|---|
| Barley | Straw | 1.35 | 143.6 | 193.86 |
| Cacao | Pods | 1.5 | 4.586 | 6.878 |
| Cassava | Stalk | 0.13 | 263.315 | 34.231 |
| Coconut | Fronds | 0.47 | 62.185 | 29.227 |
| | Husk | 0.49 | 62.185 | 30.471 |
| | Shell | 0.39 | 62.185 | 24.252 |
| Coffee | Husk | 1.32 | 8.921 | 11.776 |
| Groundnut | Husk | 0.47 | 42.846 | 20.138 |
| Maize | Cob | 0.33 | 1017.537 | 335.787 |
| | Husk | 0.22 | 1017.537 | 223.858 |
| | Stover | 1.96 | 1017.537 | 1994.372 |
| Millet | Straw | 2.54 | 24.683 | 62.696 |
| Oat | Straw | 1.42 | 23.881 | 33.911 |
| Oil Palm | Empty Bunches | 0.31 | 55.139 | 17.093 |
| | Fronds | 2.6 | 55.139 | 143.362 |
| | Shell | 0.06 | 55.139 | 3.308 |
| Rice | Straw | 1.33 | 738.064 | 981.625 |
| | Husk | 0.25 | 738.064 | 184.516 |
| Rye | Straw | 1.61 | 16.681 | 26.856 |
| Sorghum | Straw/Stalk | 2.44 | 55.481 | 135.375 |
| Soybean | Straw | 1.53 | 278.093 | 425.482 |
| | Pods | 1.09 | 278.093 | 303.121 |
| Sugarcane | Top/Leaves | 0.2 | 1898.207 | 379.641 |
| | Bagasse | 0.26 | 1898.207 | 493.534 |
| Wheat | Straw | 1.28 | 711.142 | 910.262 |
| Total | | | 10528.448 | 7005.634 |

(Source: * FAO, **FAOSTAT)

Above table provides the total agricultural residue generated by the major crops of the world in 2013 and it is found that overall the total residue is around 66% of the total production which shows that with increase in production, the amount of the total residue generated will also increase in the near future. So, agricultural residue is also proving to an important biomass for the production of second generation biofuel. According to IEA (Baruya, 2015), the world's agricultural economy is among the top suppliers of the biomass for the production of bioenergy and it is expected that in future also the trend is same.

The availability of the biomass for the production of second generation biofuel has one more dimension which includes the production of dedicated energy plant. As discussed above energy crops are of two types grassy energy crops like switchgrass and miscanthus and woody (tree) energy crops, which includes fast growing tree species like poplar, willow and eucalyptus.

In the reviewed studies, it has been found that dedicated energy plants have a great potential to supply potential biomass for the production of second generation biofuel. According to IEA (2010), in the short run to avoid competition with the food, the unused land is the only available option for the plantation of the energy crops but it is assumed that due to sustainable improvement in the agriculture throughout the world, significant amount of land should be made available for the plantation of dedicated energy plants. According to the International Institute for Applied System Analysis (IIASA), 790 Mha of extensive pastures could be made available for the plantation of dedicated energy plants (IEA, 2010). WEO (IEA, 2006) predicts that in 2050 the maximum available land area for the production of dedicated energy plants could be around 5.7 Gha, assuming an availability of 4 Gha of agricultural land and 1.7 Gha of marginal land. On the other hand, it has been also found in the studies that no additional agricultural land could be provided for the production of dedicated energy crops and hence the plantation of the dedicated energy plant could take place only on marginal land and the estimated yield would be around 8 EJ in 2050. In 2010, the total unused area for agriculture is around 1.8 Gha and this land could be used for bioenergy supply in future (Baruya, 2015).

So, from the above provided information about the availability of the biomass for the production of second generation biofuel from all the three sources, it can be easily concluded that world has the huge potential for the production of second generation biofuel and it is expected that in future also there will be no scarcity in the supply of biomass for the production of second generation biofuel.

## 6. Production Cost of Second Generation Biofuel

At present, the commercial production of second generation biofuels is started on a very limited scale. Its production is only confined to demonstration and pilot projects. But large number of estimates is available for its production. Basically, production cost of second generation biofuel depends on various cost associated with feedstock provision, capital investment and the operating and maintenance cost of conversion plants (Purohit & Fischer, 2014).

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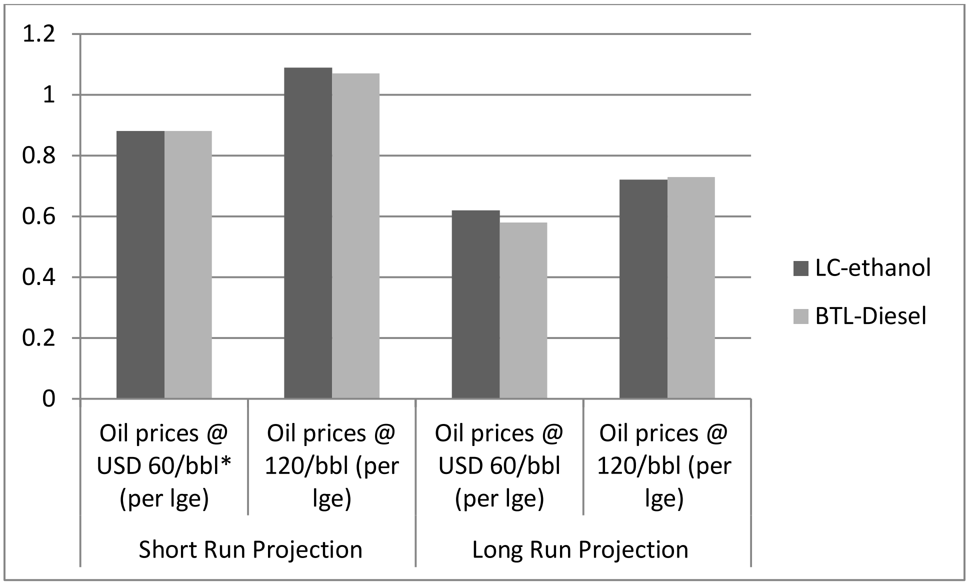
IEA gave a detailed projection for short term and long term production cost of the second generation biofuel under two oil price scenarios and the same is shown in the following figure 3.

**Figure 3: Production Cost of Second Generation Biofuels**




(Source: IEA, 2010)

(*in short run oil prices @ USD 60/bbl, cost of production lies between USD 0.84- 0.91/ lge)



From the above, with oil prices at USD 60/bbl, the production cost of second generation biofuels, i.e. BTL- diesel and lignocellulosic ethanol in short run ranges between USD 0.84 – 0.91/lge ; at this cost, both are not competitive with fossil fuel and most of the first generation biofuels. In the long term, with increased plant capacities and improved conversion efficiencies, they could be produced at approximately USD 0.62/lge for cellulosic ethanol and $0.58/lge for BTL-diesel (IEA, 2009). At this price, they can only competitive with only rapeseed biodiesel but still more expensive than gasoline and other first-generation biofuels. With oil at USD 120/bbl, production costs of cellulosic ethanol and BTL- diesel raises to USD1.09/lge and USD1.07/lge, respectively and in the long term, prices are projected to fall to USD 0.72/lge for lignocellulosic ethanol and USD 0.73/lge for BTL-diesel. Therefore at this cost, both the second generation biofuels could be produced at lower costs than gasoline and rapeseed biodiesel and close to the costs of corn ethanol.

When it comes to the breakup of the different cost associated with production of second generation biofuel, it was found that in short run, feedstock cost is the largest cost factor in the production of cellulosic ethanol which accounted for around 42% in both the oil price scenario and capital cost is around 38% when oil price is USD 60/bbl and 42% with oil prices at USD

120/bbl. But in the case of BTL-diesel it is capital cost which is highest and covered 49% of the total cost with oil prices at USD 60/bbl and 51% at oil prices at USD 120/bbl. Feedstock cost covers around 35% and 33% in both the oil price scenario. In long run for cellulosic ethanol, feedstock costs are expected to remain the largest cost factor in both the oil scenarios, accounting for 55% of total production costs at an oil price of USD 60/bbl and 56% with oil at USD 120/bbl. On the other hand, capital costs account for approximately 31% of total production costs with the oil price at USD 60/bbl and 37% with oil price at USD120/bbl, making it significant for overall production costs. For BTL-diesel also, feedstock cost is the highest as it amount to 49% at oil prices USD 60/bbl and 44% at oil price USD 120/bbl. Capital cost reduced considerable in long run, as it is expected to be 37% and 38% in both the scenario. Co-production gains are also estimated as an important factor for reducing the cost of production of cellulosic ethanol and it is estimated that in short run, co-production gains lies in the range of 9-14 percent but in long run it is estimated to reach between 15 and 25 percent of total production cost (IEA, 2010).

Above provided information about the cost of production of second generation biofuels clearly shows that in the production of second generation biofuel, capital or investment cost and feedstock cost covers more than 80% of the total cost in both the oil price scenario.



## 7. Economic efficiency of second generation biofuel

The production of second generation biofuel is expected to have an overall economic impact, it does not only provide alternative energy source but also expected to contribute in the overall economic development of the nations. It is expected that, once the production of second-generation biofuels become commercially viable, it will lead to the development of a new domestic industry based upon the existing infrastructure and feedstock sources, which ultimately results in the overall deduction in the investment cost. In addition, production of second generation biofuels is expected to generate extra income to the farmers by selling unutilised agricultural residues. With the establishment of the second generation biofuel industry, it is also expected that large number of employment opportunity will be generated. It is believed that this industry will have a great potential to provide a large number of direct and indirect jobs. These jobs may not be in the primary agricultural sector because the proposed feedstock is by-products of agriculture. However, jobs will be generated in the collection and transport of residues, biomass pre-processing, and the generation of bioethanol and related by-products. This shows that production of second generation biofuel not will only provide opportunity to meet the energy requirement of the country but will also help in developing the infrastructure and strengthening the economic condition of the people especially in the rural part of the country.

## 8. Environment stewardship of second generation biofuel

Production of second generation biofuel have an impact on the environment also, it is expected that with the production of biofuels from lignocellulosic biomass the carbon emission in the world could be brought down. Second generation biofuels have the potential to reduce the $CO_2$ emission by replacing the fossil fuels. It has been found from the literature that second generation biofuels have the potential to reduce the GHG emission by 60-120%; this value is even greater than the first generation biofuels (IEA, 2010). The only issue which can affect the production of second generation biofuel is the impact of indirect land use change (iLUC). As for the production of second generation biofuel from dedicated energy crops requires land for planting energy crops, this can cause an impact on the land as well as the bio diversity of the region but if the conditions are to be assessed carefully then the impact of iLUC can be minimized upto a maximum level. Thus the impact of iLUC can be solved with proper planning and policies.

In addition to this, plantation of dedicated energy plants as a biomass for the production of second generation biofuel has some positive effects also as the plantation provide year round coverage of the land which can leads to increase in the water retention capacity of the soil. Problem of soil erosion can also be reduced as the roots of energy crops hold the soil throughout the year and they also increases the carbon content of the soil.

## 9. Conclusion

With the increasing demand of energy consumption and limited availability of the fossil fuels along with the different environmental problems, second generation biofuels seems to be the most appropriate source for the replacement of fossil fuels. Although at present the cost of second generation biofuels are not competitive and the production is also not started on the fully commercial scale but constant research work in this field is carried out in different parts of the world and very soon it is expected that the cost of production will be competitive with other sources of energy. The availability of the biomass in the form of agricultural residue, forest residue and dedicated energy crops is also sufficient enough to produce second generation biofuel throughout the year in considerable amount. Along with the abundance availability of the feedstock for its production, second generation biofuels ensures a sufficient amount of job creation in the different parts of the world especially in the development countries which shows that second generation biofuel not only provide sufficient and clean energy but results in the economic development also. Unlike other sources of energy second generation biofuels promises to provide clean and green energy to the world as it is estimated that second generation biofuels are sufficient enough to reduce the amount of GHG emission upto a great extent. So an alternative source of renewable energy which can provide clean energy supply at regular basis along with economic development can be found in the second generation biofuels.

As the commercial production of second generation biofuels is very limited and constant R&D is going all over the world to bring down its cost, so it will be essential to make proper provisions in all parts of the world to promote the production of second generation biofuels. It is required that different countries in the world should take into consideration that as this is a new technology which is still looking for a major breakthrough so, special concession are required for its production along with the promotional aspects.



**References**

Alston, J., Beddow, J., & Pardey, P. (2009). *Mendel Versus Malthus: Research Productivity and Food Prices in the Long Run.* Minneapolis: Department of Applied Economics, University of Minnesota.

Baruya, P. (2015). *World Forest and Agricultural Arop Residue Resources for Cofiring.* London: IEA Clean Coal Centre.

BP. (2015). *BP Statistical Review of World Energy June 2015.* London: BP stats.

Carriquiry, M. a., Du, X., & Timilsina, G. R. (2011). Second Generation Biofuels: Economics and Policies. *Energy Policy*, *39*(7), 4222–4234. http://doi.org/10.1016/j.enpol.2011.04.036

FAO. (2016, April 14). *Bioenergy and Food Security*. Retrieved May 13, 2016, from Food and Agricultural Organisation of the United Nation: http://www.fao.org/energy/befs/86304@192081/en/

FAO. (2010). FAO Forestry Paper 163. *Global Forest Resources Assessment 2010* (p. 42). Italy: Food and Agricultural Organization of the United Nations.

FAOSTAT. (n.d.). *Download*. Retrieved May 15, 2016, from Food and Agricultural Organisation of the United Nation: http://faostat3.fao.org/download/Q/QC/E

Farrell, A., Plevin, R., Turner, B., Jones, A., O'Hare, M., & Kammen, D. (2006). Ethanol can Contribute to Energy and Environmental Goals. *Science 311* , 506–508.

IEA. (2014). *Energy Supply Security 2014*. Paris: IEA.

IEA. (2010). *Sustainable Production of Second-Generation Biofuels: Potential and Perspectives in Major Economies and Developing Countries*. Paris: IEA.

IEA. (2006). *World Energy Outlook 2006*. Paris: IEA.

IEA. (2011). *World Energy Outlook 2011*. Paris: IEA.

Keshwani, D., & Cheng, J. (2009). Switch Grass for Bioethanol and other Value-Added Applications: a review. *Bioresource Technology100,* , 1515–1523.

Lewandowski, I., Scurlock, J., Lindvall, E., & Christou, M. (2003). The Development and Current Status of Perennial Rhizomatous Grasses a Senergy Crops in the US and Europe. *Biomass and Bioenergy 25* , 335–361.

Licht, F. (n.d.). *Ethanol Industry Outlook 2008-2014 reports*. Retrieved 08 29, 2015, from www.ethanolrfa.org: www.ethanolrfa.org

Perlack, R., Wright, L., Turhollow, A., Graham, R., Stokes, B., & Erbach, D. (2005). Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply. *DepartmentofEnergy* .

Purohit, P., & Fischer, D. (2014). *Promoting Low Carbon Transport in India, Second-Generation Biofuel Potential in India: Sustainability and Cost Considerations*. New Delhi: Magnum Custom Publishing.

Searchinger, T., Heimlich, R., Houghton, R., Dong, F., Elobeid, A., Fabiosa, J., et al. (2008). Use of U.S. crop lands for biofuels increases greenhouse gasesthrough emissions from land use change. *Science 319* , 1157–1268.

Sengers, F., Raven, R., & Van Venrooij, A. (2010). From Riches to Rags: Biofuels, Media Discourses, and Resistance to Sustainable Energy Technologies. *Energy Policy 38,* , 5013–5027.

Smeets, E., Faaij, A., Lewandowski, I., & Turkenburg, W. (2007). A Bottom-Up Assessment and Review of Global Bio-Energy Potentials for 2050. *Progress in Energy and Combustion Science 33* , 56–106.