Biofuel production

Introductory:

Biofuels are fuels produced directly or indirectly from organic material – biomass – including plant materials and animal waste. Biomass is an industry term for producing energy from burning wood, and some other organic matters. Burning biomass releases carbon emissions, much lower than burning coal, has yet been recognized as a "renewable" source in the legal frameworks of the United States, since the plant could be regenerated. [6]

For this paper, I am primarily talking about the general ideas of biofuel, the development of biofuel, the types of biofuel, biochemical conversion technologies and challenges, etc.

(1) The timeline of the biofuel development

Humans began to use solid biofuels to make fire, dating back to at least 120,000 years ago. The solid biofuels include dung, charcoal, wood in the past. There are four interesting facts during the biofuels development throughout time.

The first is that the liquid biofuels like whale oil and olive oil was produced in the mid 1700s and early 1800s. During that time, the whale oil was widely used for lighting houses. However, with the increasing requirement of the whales, whaling became a serious problem and the population of whale was decling severely within that period. Around the mid 1800s, people transferred to the cheaper kerosene generated from fossil fuels, since the whale oil is too expensive. During the twentieth century, the wood fuels are also replaced by the fossil fuels, since wood resource is a type of unsustainable timer source.

The second fact is Henry Ford built the original Model T, which is running on ethanol. The first internal combustion engine was produced to run on a blend of ethanol and turpentine which was derived from pine trees in the United States in 1826. Then Henry Ford designed his original 1908 Model T to run on ethanol. After that, Rudolph Diesel modified the combustion engine with vegetable oils. All these designs were based on the oils, the biofuels, instead of the fossil fuels. Ford even stated that "*The fuel of the future is going to come from fruit like that sumac out by the road, or from apples, weeds, sawdust – almost anything. There is fuel in every bit of vegetable matter that can be fermented*" (Ford Predicts Fuel from Vegetation, N.Y. TIMES, Sept. 20, 1925, p 24)

The third fact is the commercialization of fossil fuels in the mid nineteenth century, which is almost deadly damage to the biofuels development. From the mid nineteenth century, the coal resources became available; the America's first oil company, Pennsylvania Rock Oil Company, drilled the historic first commercial U.S. oil well in New York in 1854, which means the petroleum could be commercially available in the world. At the same year 1854, the Canadian geologist Abraham Gesner extracted the kerosene from coal successfully, which is a combustible hydrocarbon liquid energy widely used as a fuel in industry as well as households even in some developing countries today. All these facts favored the development of fossil fuels, but prohibited the development of biofuels.

The last fact is the crises of fossil fuels during World War I, which is severely short of ethanol. Since ethanol could be used as a motor fuel when blended with gasoline. In fact, there came several fossil fuels crises after the World War I. Even in the late twentieth century, there are three crises happened because of different reasons. All these crises led the biofuels coming back in the life. Many countries like Brazil and the US are making efforts to generate biofuels in large scale. People figure out that biofuels have so many advantages over the fossil fuels, for example, large supply, renewable resources, less emission, high interest, and so on….

(2) The types of biofuel, technologies of different biofuel conversion today

In fact, biofuel is difficult to be classified. Biofuel, itself, could be recognized as a form of transformed solar energy, so it is definitely a type of renewable resource. Biofuels are energy carriers that store the energy derived from biomass. [For a review of terminology relating to biofuels, see FAO (2004a) UBET – Unified Bioenergy Terminology. Rome. At the same time, there is an extensive range of biomass resources that could be utilized to generate biofuel, even in different forms. According to source and type, biofuels could be classified to primary biofuels and secondary biofuels. Primary biofuels, could be known as the form the organic material essentially in its natural form, such as, firewood, wood chips and pellets. Secondary biofuels can be used for a wider range of applications, including transport and high-temperature industrial processes, such as charcoal, ethanol and biodiesel, and even hydrogen.

Biofuels can be obtained from plants, or agricultural, commercial, domestic, and/or industrial wastes.[9] Since biofuels have been classified as a type of renewable source, the generation of renewable biofuels primarily involve the process of photosynthesis in microalgae or plants, as well as the conversion of biomass, which could convert biomass into energy substances in liquid, gas, or solid form. The biomass conversion can be divided into three directions, including thermal conversion, chemical conversion, and biochemical conversion.

Thermal conversion is to convert biomass materials into other forms of energy through heat, with or without the presence of oxygen. Technologies of thermal conversion are including Combustion, pyrolysis, torrefaction, and gasification. Combustion is the firing of biomass in the presence of oxygen. Furnaces are used to produce steam for use in the form of heat, while boilers are used to drive turbines to produce electricity. Biomass could also be converted in both heat and power(CHP) form at the same time, which is also called co-generation. In CHP processes, the power is the generation of electricity as a by-product. In the meanwhile, some of the “waste heat” could also be recovered as heating energy. Thus, this type of co-generation CHP can covert about 85% of biomass potential energy into energy in practice. Technologies of pyrolysis and torrefaction are both not directly generating energy in practice. They are modifying the conditions, like temperature, pressure, or oxygen, to obtain the biomass feedstocks in some other forms. Through the pyrolysis and torrefaction operation, the biomass energy could convert into much higher density forms, such as charcoal or oil. Pyrolysis is subjecting biomass to high temperatures, under a high pressurized but low oxygen environment. Pyrolysis convert the into liquid fuels and a solid residue called char, or biochar. Torrefaction is also the conversion of biomass through heating, but at lower temperatures than those typically used in pyrolysis. The final product of torrefaction is a dense solid fuel called “bio-coal”. During the torrefaction process, water is removed and cellulose, hemicellulose and lignins from the biomass are partially decomposed.

Chemical conversion could also be recognized as thermochemical technology, which is converting biomass into fuel gases and chemicals. In fact, chemical conversion of biomass involves several stages. In general, the first stage is converting solid biomass into gases. Then the gases may be condensed into oils in the following step. In the last stage the oils may be conditioned and synthesized to produce syngas. Syngas could be separated to produce ammonia, lubricants, and even biodiesel. Gasification is converting the biomass being into gas in a high temperature condition. Gasification requires the temperatures around 800°C. It involves primarily two processes: the first is partial combustion to form gas and charcoal, the second chemical reduction. In the future, gasification technology may combine gas turbines product electricity from biomass plantations and agricultural residues in large scale, which is scientists and engineers are making efforts towards.

Biochemical conversion is playing significant role in the generation of biofuels like bio-ethanol, and some other bioproducts. Biochemical conversion is producing biofuels from lignocellulosic biomass. The biomass-to-ethanol conversion process include hydrolyzing the biomass to fermentable sugars to produce ethanol. At the same time, the intermediate sugars could also be used to produce other high interest chemicals and fuels.

(3) The development of biochemical conversion technologies and challenges

Biofuels have crucial advantages over fossil fuels: environment friendly, low cost, resource availability, economic security, and so on. Therefore, the biofuels are playing a more and more significant role in the world. The US national program has identified bio-fuels & biomass utilization as renewable energy sources. The program states a target of commercial production of ethanol from lignocellulosic biomass by 2012. The program also plans to replace 30% of current motor gasoline consumption with ethanol derived from lignocellulosic biomass by the year 2030, which is called 'Vision 30 x 30'. All these statements indicate the biofuels could be an efficient replacement of the fossil fuels. Therefore, more and more scientists commit themselves to developing technologies of converting biomass to biofuels.

Biomass typically consists of cellulose (~ 38-50%), hemicellulose (~ 23-32%), and lignin (~ 15-25%). Cellulose could be decomposed by the specific enzyme and be able to metabolize. Hemicellulose primarily contains C5 sugar, which is difficult to metabolize. Lignin is also hard to convert because of the presence of aromatic compounds. The biochemical conversion includes several steps. The first step is effective pretreatment, hemicellulose, and lignin. The second is the production of saccharolytic enzymes such as cellulase, hemicellulose. The third step is the fermentation of C5 and C6 sugars and converting into ethanol. Some of them are facing difficulties and holding back the development of biofuel production in large scale.

The purpose of pretreatment is to break down fibrous material and reduce the biomass volume, which is a vital step of biochemical conversion. The efficiency of pretreatment can effectively lead the lignin to breaking into small simple sugars, improving the biochemical conversion process. The current technologies of pretreatment are including hot water treatment, steam explosion treatment, chemical pretreatment like organic solvent, sulfur dioxide, dilute acid, alkaline pretreatment, combination of chemical pretreatment and hot water, ammonia explosion, etc. However, the pretreatment also brought into the inhibitors that are toxic to fermentation or enzyme process. Detoxification of inhibitors is also a fundamental problem needed to seriously considered.

Cellulase and hemicellulose are able to combine microorganisms for fermentation to generate sugars and then convert sugars to ethanol. Enzyme could not catalyst the biomass conversion in the harsh condition due to the pretreatment and the presence of inhibitors. At the same time, these enzymes are from natural origin, which have low specific activities. All these problems are challenging the scientists. The main solution is to discover high efficient and low cost enzyme, and production in large scale. Scientists are focusing on production of enzymes, expanding its range and effectiveness for conversion of sugar to ethanol.

The commercial biochemical conversion of lignocellulosic is developing microorganisms to effectively ferment hemicellulose and cellulose sugars to ethanol. The microorganisms include bacteria, yeast and fungi. Some thermophilic anaerobic bacteria, yeast and fungi could convert hemicellulose into ethanol effectively, while the strains like Saccharomyces cerevisiae could convert hexoses to ethanol in a high yield.

Conclusion

Comparing with the other renewable energy like wind, water, and solar energy available for electric power, only biofuels are well suited for transportation. Although the development of biofuels is prevented by the development of fossil fuel, humans have recognized the advantages and efficiency of biofuels. Despite the challenges of developing biofuels, bioenergy will play more and more roles in the future.

Resource

1. https://www.iea.org/publications/freepublications/publication/essentials2.pdf
2. http://www.intechopen.com/books/biofuel-production-recent-developments-and-prospects
3. http://www.intechopen.com/books/biofuel-production-recent-developments-and-prospects/bioethanol-what-has-brazil-learned-about-yeasts-inhabiting-the-ethanol-production-processes-from-sug
4. http://www.greenfacts.org/en/biofuels/l-2/1-definition.htm
5. https://en.wikipedia.org/wiki/Biomass
[6] See M Le Page, 'The Great Carbon Scam' (21 September 2016) 231 *New Scientist* 20–21
7. http://www.biofuelnet.ca/2014/05/23/interactive-timeline-history-of-biofuels/
8. http://www.biofuelnet.ca/2013/07/31/a-brief-history-of-biofuels-from-ancient-history-to-today/
[9] "What is biofuel? definition and meaning". *BusinessDictionary.com*. Retrieved 30 May 2015.
10. https://en.wikipedia.org/wiki/Biofuel
11. http://www.wgbn.wisc.edu/conversion/bioenergy-conversion-technologies
12. http://tifac.org.in/index.php?option=com_content&view=article&id=774:biochemical-conversion-of-biomass-challenges-a-opportunities&catid=120:publication-bioprocess-a-bioroducts&Itemid=1380
13. http://www.nrel.gov/docs/fy06osti/39436.pdf

14. http://www.conserve-energy-future.com/advantages-and-disadvantages-of-biofuels.php
15. https://passel.unl.edu/pages/informationmodule.php?idinformationmodule=1130447258&topicorder=3&maxto=6&minto=1