Advanced Biofuels USA Paper on General Knowledge and Barriers to

Advanced Biofuels Industry and Our Goals

The Future of Transportation Fuels and Improved Ecological Plans Lies in Advanced Biofuels

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Almost all of us have personal experiences with the consequences of volatile transportation fuel prices. If the price of fuel increases, then it is necessary to pay more per gallon of a certain fuel. On the other hand, if the cost of fuel decreases, then everybody races to nearby gas stations with smiles on their faces. Decreases in the price of transportation fuels are as enjoyable as holidays, but people don't think so much about the consequences of fuel consumption.

The burning of transportation fossil fuels (oil/petroleum) has a large impact on the environment due to emissions of green house gasses (GHG) in the atmosphere. Furthermore, the price of petroleum will probably keep increasing as it has in the past so people will prefer new alternative fuels at lower costs. Consumers will become more interested in investing in and development of biofuels and advanced biofuels in hopes that those fuels will be price competitive with petroleum. If the prices of advanced biofuels drop below petroleum fuel prices, people will switch, especially if they can get the same or better mileage.

However, the present speaks for itself. America has to face the new challenges. The nation is deeply dependent on foreign oil and transportation fuels significantly contribute to accumulation of carbon emissions and the climate change.

Advanced Biofuels: Need for a Technological Revolution

A new technological revolution is about to start. Advanced biofuels will be fueling our cars, trains, and planes. It is time to stop talking about a sustainable energy future, and start working on it. This is an important step leading to mitigation of the considerable risks of climate change. Of course, this journey is challenging; it might be nothing less than a new industrial revolution. However, if that is going to lead to a better perspective for future generations and an improved environmental situation, then it is worth it. "America's future prosperity may well depend on whether American people decide to lead or follow in the new industrial revolution."[1] (President Obama)

[1] The Washington Post. *Earth Day*. Environmental movement 40 years later, Obama administration message,

Fossil fuels and biofuels are distinguished from each other based on many aspects. Oil as a fossil fuel is a non–renewable fuel. Once it is burned there is no way to get it back. It takes millions of years for fossil fuels (coal, natural gas, and oil) to form and the reserves are used much faster than they are formed. Still, gasoline is the major transportation fuel and people enjoy filling their tanks with it. Sadly enough, what is almost forgotten and what scientists and environmentalists try to address is that the planet Earth doesn't contain an infinite supply of liquid gold. Sooner or later there will be a shortage of fossil fuels and when this happens people should be ready and have alternative, renewable and environmentally friendly transportation fuels.

In fact, carbon emissions are higher than they've ever been. Carbon dioxide accumulation in the atmosphere is a serious environmental issue and must be addressed. Figures 1[2] and 2[3] (page 3) show the amount of carbon dioxide present in the atmosphere and indicate global fossil carbon emissions. As can be seen from the Keeling curve in Figure 1, the concentration of atmospheric carbon dioxide has been increasing since 1958 reaching about 390 parts per million by volume (ppmv), where 1 ppm equals 1 mg of substance per kg of solid. By 1960 it was established that the increases of atmospheric carbon dioxide per year are probably matched to the amount of the fossil fuels burned per year.

Figure 2 indicates carbon emissions from burning fossil fuels. The total carbon emissions are close to 8000 million metric tons per year from all fossil fuels and oil contributes the greatest amount, more than 3000 million metric tons per year.

Major issues that should be priorities of the United States include decreasing burning of fossil fuels which harm the environment and the increased difficulty of extracting fossil fuels.

Methods of cheap advanced biofuel production should be developed so that the alternative fuels satisfy our desire for affordable prices and meet the world's supply needs for transportation fuels. The sooner the

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saving the planet. April 22, 2010. http://www.washingtonpost.com (accessed on April25,2010)

[2] This figure was created by Robert A. Rohde from published data and is incorporated into the Global Warming Art project. http://en.wikipedia.org (accessed on April 24, 2010).

[3] United States Department of Energy. *A Compendium of Data on Global Change*. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, Tenn., U.S.A.

American people realize that advanced biofuels will provide an economically, environmentally, and socially sustainable resource, the faster we will move forward to a cleaner and sustainable future.[4] This futuristic resource might enable the U.S. to create or sustain a successful transportation sector which is exactly what is needed for a flourishing economy and mobile society.

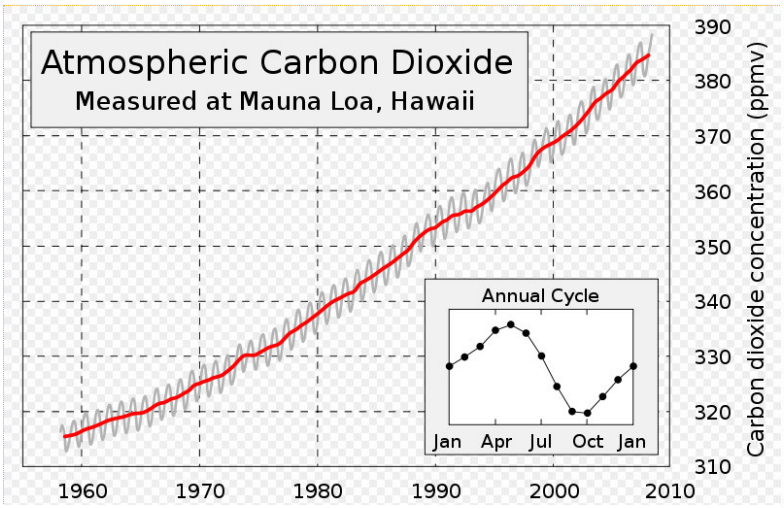

Figure 1. Carbon dioxide concentration measured at Mauna Loa, Hawaii.

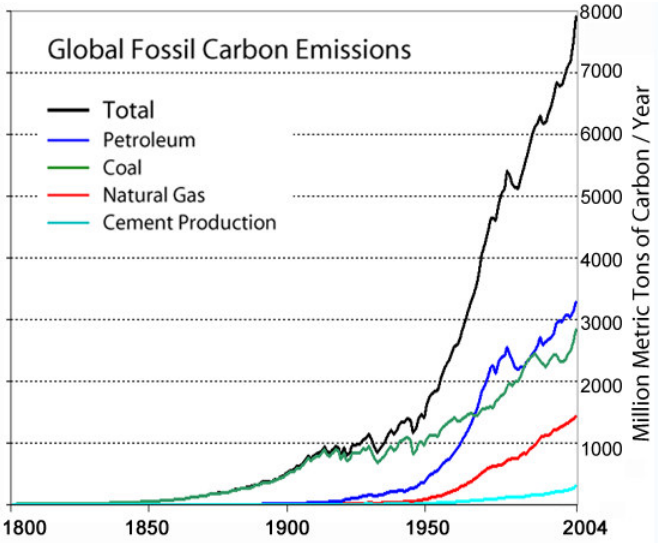

Figure 2. Carbon emission measured in million metric tons per year

If a large portion of transportation fuels gets replaced with advanced biofuels, then there will be noticeable environmental improvements. What makes advanced biofuels very distinctive from other types of fuels is the fact that they are environmentally sustainable and can be used with minimal long-term effects on the environment. They are "high-energy liquid transportation fuels derived from: low nutrient input/high per acre yield crops; agricultural or forestry waste; or other sustainable biomass feedstock."[5]

Advanced Biofuels: What Are They?

[4] Advanced Biofuels USA. About us. http://advancedbiofuelsusa.info (accessed on April 23, 2010).
[5,6] Ivancic, M. Joanne. Advanced Biofuels USA. Truly Sustainable and Renewable Future. http://advancedbiofuelsusa.info (accessed on April 23, 2010).

Many different resources are considered as feedstocks for the production of advanced biofuels; but more important, these types of fuels can be produced from non-food, non-feed, sustainably grown feedstock and agricultural wastes.[6] Biofuels derived from food crops using easily accessible technologies (fermentation and transesterification, for example) are classified as first generation biofuels. The classification of biofuels is based on the type of feedstocks and technologies used to produce them.

The following three generations of biofuels fit into the category of advanced biofuels.

Second generation fuels include cellulosic fuels made from non-food plants, trees, and agricultural residues. This generation of biofuels is more environmentally friendly and more economically sustainable when compared to first generation biofuels.

Third generation fuels are possibly produced from algae. These will include jet fuel and sophisticated biodiesel.[7]

Finally, fourth generation biofuels are fuels derived out of a thin air.[8] However, this generation of biofuels is in its early stages of development; hence will not be discussed in this paper.

Advanced Biofuels: Role in Energy Policy

The Energy Independence and Security Act of 2007 states that the goal by 2022 is to produce 36 billion gallons of renewable fuels which will be available in the U.S. for domestic consumption.[9] Out of 36 billion gallons of renewable fuel 21 billion gallons is expected to come from advanced biofuels, which is more than 58%. Sixteen billion gallons is expected to come from advanced cellulosic biofuel, one billion is expected to come from biomass-based diesel, and the rest from other sources.[10] Until last year

[7] Scientific American. *Energy and Sustainability*. Jet Biofuel Ready for Take off. 29 May 2009. http://www.scientificamerican.com (accessed on April 22, 2010).

[8] Ivancic, M. Joanne. Advanced Biofuels USA. *Advanced Biofuels.* Fulfiling The Promise of Advanced Biofuels. 31 March 2010; pg 5.Printed source. http://advancedbiofuelsusa.info (accessed on April 23, 2010).

[9] The Energy Independence and Security act of 2007. The Effect of Private Wire Laws on Development of Combined Heat and Power Faciities. http://www.oe.energy.gov (accessed on April 20, 2010).

[10] United States Department of Energy. *Office of Science.* Production of Biofuels from Biomass. http://www.science.energy.gov (accessed on April 19, 2010).

11.1 billion gallons of renewable biofuels was produced.[11] One of the reasons why achievement of this goal is so important is because once the renewable fuels are fully developed (as expected by 2022) the green house gas emissions should be reduced by more than 138 million metric tons a year in the U.S.[12] Moreover, this strategy is going to reduce dependence on foreign oil and enhance America's energy independence. Imports of foreign oil would be reduced by more than 328 million barrels a year.[13] These projects are the basis for improved ecological plans and renewable and sustainable transportation fuels.

The investments in advanced biofuels are still way below the amount for their "emergence" and the U.S. Department of Energy (DOE) keeps investing in this alternative. DOE announced $1 billion for multi-year biofuels research and development (R&D) projects with a main goal to enhance the nation's energy supply through increased energy efficiency and clean energy sources. The department's announcement, made in January 2008, includes four projects that will receive up to $114 million in DOE funding to build small-scale biorefinery projects located in Commerce City, Colorado; St. Joseph, Missouri; Boardman, Oregon; and Wisconsin Rapids, Wisconsin. Moreover, DOE expects to fund up to $385 million over four years for the development of six commercial-scale biorefineries in order to approach a cleaner and sustainable future.[14]

The future of transportation fuels is one of the greatest concerns and scientists are doing their best to create promising technologies that will lead to enhanced production of alternative fuels. Likewise, it is necessary to find the right feedstocks for their production. Renewable and environmentally friendly fuels are some of the most promising alternatives since the raw materials for their production are easy to find. Some of the energy crops that are classified as resources of advanced biofuels are perennial grasses (switchgrass, miscanthus), jatoropha, camelina, and poplar.[15] In addition, advanced biofuels can be made from agricultural or food processing waste such as corn cobs, sugar beet pulp, nut shells, meat processing

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[11,12,13] United States Department of Energy. Obama Announces Steps to Boost Biofuels,Clean Coal.3 February 2010. http://www.energy.gov (accessed on April 19, 2010).

[14] United States Department of Energy. DOE to Invest up to $33.8 Million to Further Development of Commercially Viable Renewable Fuels. 26 February 2010. http://www.energy.gov (accessed on April 19, 2010).

[15,16,17,21] Ivancic, M. Joanne. Advanced Biofuels USA. *Advanced Biofuels.* Making Advanced Biofuels. 31 March 2010; pg 4. Printed source. http://advancedbiofuelsusa.info (accessed on April 20, 2010).

residues, used fats and many other sources of waste. [16] Also, the new technologies are looking into municipal solid waste where, for example, vehicle tires and plastics could be used as resources for advanced biofuel production.[17]

In contrast to such a variety of resources, the important reserves of oil and gas are located under the sea and ocean floor where drilling, prospecting, and transport are not just expensive, but also seriously damage sensitive marine areas and disturb marine species.[18] For instance, a sunken oil rig in the Gulf of Mexico about 100 kilometers off the coast of Lousiana was leaking petroleum at the rate of about 1000 barrels per day. There are 113 miles of Louisiana coastline under active cleanup from oil leak, with another 55 miles awaiting approval to start the cleanup process, according to SCAT statistics.[19]

Advanced Biofuels and the Carbon Cycle

Advanced biofuels are carbon neutral. This doesn't mean that carbon dioxide (CO_2) doesn't get released during the combustion of advanced biofuels, but what it means is that all of the CO_2 released was in the atmosphere before and got stored in plants during the photosynthesis. For every gram of CO_2 released during combustion there was a gram removed from the atmosphere by photosynthesis before the plants were burned. This is what keeps a perfect balance and makes advanced biofuels carbon neutral. Some of the most promising types of advanced biofuels include ethanol derived from structural polysaccharides found in plant material, biomass- based diesel, butanol, and fuels derived from algae.

Advanced Biofuels Commercialization

[18] United States Department of Commerce. *National Oceanic and Atmospheric Administration.* Oil and Chemical Spills. http://oceanservice.noaa.gov (accessed on April 18, 2010).

[19] Nola News. *Gulf of Mexico oil spill continues to foul 168 miles of Louisiana coastline.* (accessed on January 4, 2011). http://www.nola.com/news/gulf-oil-spill/index.ssf/2010/12/gulf_of_mexico_oil_spill_conti.html

It's obvious that there are many sources for production of advanced biofuels but one of the greatest challenges is their industrial-scale production. Most of the technologies for the production of advanced biofuels already exist, while some of them are in the early phase of development. The technologies such as fermentation, acid hydrolysis, enzymatic hydrolysis, gasification, thermochemical reactions, catalysis, and algae process are all ways to convert different resources to transportation fuels.[20] All of these technologies work on lowering the cost of advanced biofuels production, and on lowering the carbon emissions. The three concepts that will be discussed in this paper include the concept of ethanol derived from structural polysaccharides found in plant material, the concept of butanol, and finally the concept of fuels derived from algae.

Ethanol from cellulosic material

Ethanol is a 2-carbon alcohol that's showing great promise in production of advanced biofuels. In particular, cellulosic ethanol is a renewable fuel that can be made from a wide variety of non-food materials such as agricultural wastes (sugar beet pulp, corn stover, and cereal straws), industrial plant waste (sawdust, paper pulp), and different energy crops such as switchgrass.[21] By relying on a variety of feedstocks, cellulosic ethanol can be produced in nearly every region of the country, and all over the world using material grown locally. The main obstacle to realizing the promise of cellulosic biofuels is biomass recalcitrance, the difficulty of effectively and efficiently breaking down the plant cell walls into sugars that can be converted into advanced biofuels.

On one hand, ethanol as an advanced biofuel can be derived from cellulose. Cellulose is a linear polysaccharide polymer with many glucose (a six carbon sugar) monosaccharide units. It is often found as

[20] Advanced Biofuels USA. *Advanced Biofuels.* The next Technology Revolution will Fuel the Future. 31 March 2010; pg 2. Printed source. http://advancedbiofuelsusa.info (accessed on April 20, 2010).
[22] Elmhurst College. *Chemistry Department*. Cellulose. http://www.elmhurst.edu (accessed on April 20, 2010).

crystalline, strong, and resistant to hydrolysis. [22] In general, the process of converting cellulose into ethanol is composed of the three main steps which can be seen in the figure below.

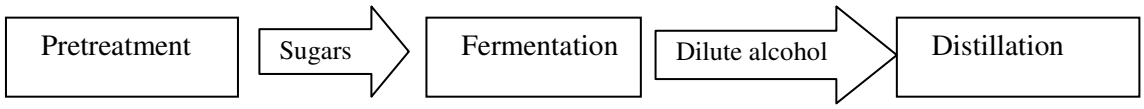
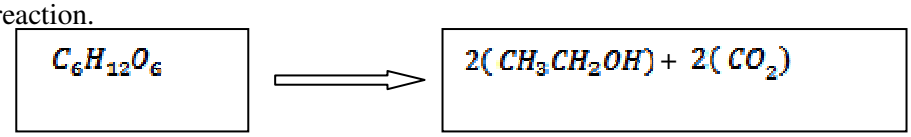


Figure 3.[23] The production of advanced biofuels from cellulosic material.

In the pretreatment (saccharification) step the cell walls are broken down to six carbon sugar (glucose) using different technologies such as pre-hydrolysis, enzymatic hydrolysis, and different thermochemical conversions. Once the glucose is formed, there are two different options; to ferment it, or to send it to a biorefinery as bio-crude where it can be used in catalytic processes and be synthesized into fuels.[24]

Assuming that fermentation is to be performed, glucose gets fermented into ethanol using yeast. Finally, distillation is performed in order to increase the alcohol content. This step is very expensive and benefits from higher initial concentrations of alcohol in order to reduce its costs.[25] Commonly available yeast ferment six carbon sugars, while those that can convert five carbon sugars are not so abundant. The reaction of the glucose with yeast is very complex, but the overall process can be described with the following reaction.



On the other hand, early advanced biofuels technologies search for different ways to derive ethanol from hemicelluloses. One of the reasons for doing so is that hemicelluloses have a random, amorphous

[23,24] United States Department of Energy. *Energy Eficienty and Renewable Energy*. Biomass Program 2007; Growing America's Energy Future. Technology Pathways. Convert in Integrated Biorefineries. Page 9. www.eere.energy.gov (accessed on April 22, 2010).

[25] Ethanol. Ethanol distillation. http://ethanol4car.com (accessed on April 23, 2010).

structure that is not as strong as cellulose.[26] Additionally, hemicelluloses are more accessible to degradative enzymes. They contain five carbon sugars (pentose) but the structure varies depending on the type of plant. The key part is that the five carbon sugars make a great percentage of the available sugars hence it is very important to know how to recover them and ferment into ethanol.

One of the technologies used to get ethanol from cellulosic material is acid hydrolysis where a diluted or concentrated acid is used with many different variations. These variations consider different reaction conditions such as temperature and pressure. One of the examples for hydrolysis of cellulosic materials to ethanol would be use of sulfuric acid since it is one the least expensive acids.[27] In consequence, the issue of acidic wastes comes along. Acidic hydrolysis is sometimes so harsh that toxic degradation products are produced and can interfere with subsequent fermentation.[28]

Another way to break down the polymers to simple sugars is enzymatic hydrolysis. Enzymes are naturally occurring plant proteins that are necessary for certain chemical reactions to occur. Moreover, enzymes from microbes, as plant pathogens, can be used in enzymatic hydrolysis. The pathogens break down the cell plant walls as part of the infectious process. However, a condition for different enzymes to work is that they first must access the molecules that are to be hydrolyzed. Lignin doesn't contain sugar molecules and it encloses cellulose and hemicelluloses, hence making it hard to approach the material for production of ethanol. For this reason, depending on the biomass material used, different physical or chemical pretreatment methods are used in order to break the crystalline structure of lignocelluloses, remove the lignin, and expose cellulose and hemicellulose molecules.[29]

In order to work on complications like these, DOE has invested $33.8 million on enzymatic hydrolysis which includes four projects over four years that will have a major focus on developing the improved enzyme systems that will convert cellulosic material into sugars suitable for the production of

[26] Rensselaer Polytechnic institute. *Department of Chemistry*. Hemicellulose. http://www.rpi.edu (accessed on April 20, 2010).

[27,29] J. Janick, A. Whipkey. *Trends in New Crops and New Uses.* Ethanol From Cellulose: A General Review. 2002, pg. 17-0.http://www.hort.purdue.edu (accessed on April 20, 2010).

[28] Blue Fire Ethanol. Technology; The Process. http://bluefireethanol.com/technology (accessed on April 24, 2010).

biofuels.[30] If the production of cellulosic ethanol becomes cost competitive by 2012, the expected investment would be up to $70 million with a minimum 50% cost share from industry.[31]

Likewise, Atlantic Biomass Conversions Inc., at Hood College in Frederick MD, is trying to direct the evolution of enzymes that break down plant polymers, such as those found in sugar beet pulp, in a more efficient way. In this way the cellulose, hemicelluloses, and pectin can be unwrapped and released from the tangle. The sugar beet pulp residues can be fermented into ethanol, or they can be transported to a refinery as bio-crude where they can be synthesized into fuels.

Finally, some thermochemical processes are also used for ethanol production. In one of these processes the biomass materials are first thermochemically gasified and the synthesis gas (a mixture of hydrogen and carbon dioxide) is bubbled through specially designed fermenters where different microorganisms are used to convert synthesis gas and result in synthesis of ethanol. This process must follow very specific reaction conditions.[32] In this way, ethanol production can be achieved without using microorganisms, but using the specific catalysts (substances that speed up the chemical reactions but are not consumed by the same reactions) which cause gas in the reactor to be converted into ethanol.

The advantages of cellulosic resources are their abundance and widespread volume. Forests hold about 80% of the world's surface biomass hence these cellulosic resources are affordable and represent inexpensive feedstock for fuel production.[33]

Even though, cellulosic ethanol requires a complex refining process, it provides more net energy and it results in lower GHG emissions when compared to non advanced biofuel corn-based ethanol. [34] This is because the production of corn-based ethanol often uses natural gas as a fossil input to provide energy for the process, hence results with greater carbon emissions.

[30,31,34] United States Department of Energy. DOE to Invest up to $33.8 Million to Further Development of Commercially Viable Renewable Fuels. 26 February 2010. http://www.energy.gov (accessed on April 19, 2010).

[32] Ben A. Thorp. *Advances, Developments, Applications in the Field of Cellulosic Biomass.* Key Metric Comparison of Five Cellulosic Biofuel Pathyways. Pg 25. www.tappi.og/bioenergy (accessed on April 23, 2010).

[33] State Energy Conservation Office. Cellulosic ethanol. http://www.seco.cpa.state.tx.us (accessed on April 21, 2010).

[35] Klinke HB, Thomsen AB, Ahring BK (2004) Inhibition of ethanol-producing yeast and bacteria by degradation products produced during pre-treatment of biomass. Appl Microbiol Biotechnol 66:10–26.

However, there are some implications that have to be considered in the equation. For instance, in the pretreatment step, the hemicelluloses break down into five carbon sugars which are not the natural substrates of the yeast used for the fermentation process. The ability of yeast to convert sugars into alcohols depends on the enzymes used in reactions. During the reaction the product inhibition takes place where yeast are killed and enzymes are destroyed due to high alcohol concentrations.[35] Not all the sugars can be converted with the same type of microorganism so it is necessary to find new microorganisms that could react with different sugars. Commonly available yeasts are able to convert mostly six carbon sugar (glucose), while other sugars don't get converted.

The conversion of cellulosic biomass to sugars is a time consuming process. In order to start mass production of biofuels it is necessary to find the ways to speed up the reactions. Moreover, the produced advanced biofuels must be price competitive with petroleum. For instance, the use of E-85 (85% ethanol) fuel has been limited since its usage results in approximately 25% less mileage when compared to millage obtained with gasoline used in engine designed to run on gasoline.[36]

One of the solutions is to reduce the cost of E-85 by 25% in order to make it competitive with gasoline and increase the demand for it.

On the other hand, automotive engineers can design and build engines that will maximize the performance of both gasoline and alcohols. The answer lies in engine design that will vary the compression ratio based on the amount of ethanol in the fuel. [37]

Equally important, 10% home-grown renewable ethanol can be found in gasoline mixtures today at nearby gas stations. This ethanol has reduced carbon dioxide emissions from three to six percent compared to 100% gasoline. Moreover, it has reduced oil imports by 1.6 million barrels per day. [38] This shows that renewable ethanol can stand even with all its drawbacks and weaknesses.

[36,37] Kozak, Robert; *Advanced Biofuels USA.* New Engine Technologies Could give New Life (and Large Markets) to Ethanol. http://advancedbiofuelsusa.info (accessed on April 18, 2010).

[38] Ivancic, M. Joanne. Advanced Biofuels USA. *Advanced Biofuels.* Grow, Baby, Grow. 31 March 2010; pg 3. Printed source. http://advancedbiofuelsusa.info (accessed on April 20, 2010).

In general, one of the barriers to cellulosic ethanol production is the mix of 5 and 6-carbon sugars formed during the hemicelluloses hydrolysis. Microorganisms that ferment both of these kinds of sugars exist but they have lower production rates and they exhibit less tolerance for the product ethanol. A third barrier is created by the difficulty in "unwrapping" and solubilizing the cellulose and hemicelluloses because they are tangled into a rigid cell-wall structure with lignin. For this reason, the specific thermochemical pretreatments are used but they generate by-products that inhibit enzymes hydrolysis and decrease the productivity of fermentative microbes.[39] Finally, the crystal structure of cellulose makes it more difficult for enzymes to convert cellulose to glucose.[40]

Some properties of ethanol create practical challenges in using it efficiently. Because ethanol mixes with water, it might freeze in existing pipeline systems. [41] This wouldn't be a good thing since transportation fuels should handle low temperatures. Also, water in fuel certainly effects the operation of the engines. Moreover, the end product is about 60 to70% of the energy density of gasoline and it is corrosive for commonly used metals in auto fuel systems.[42]

Butanol

An alternative to ethanol might be butanol. Butanol is a family of 4-carbon alcohols. The most common forms are normal butanol (n-BuOH), and iso-butanol (i-BuOH) and both kinds have good fuel properties. [43] Doubling up the carbon number (from two carbon atoms in ethanol) the energy density is increased much closer to the energy density of the gasoline. Butanol has higher energy content than ethanol and it is less corrosive for commonly used metals in auto systems.[44] It is also more hydrophobic than ethanol meaning that it has a higher tendency to repel water.[45]

For this reason butanol could be blended with gasoline at higher concentrations than ethanol. Scientists are using enzymes rather than yeast for the bioconversion, which may simplify the jump over to

[39,40,41,42,43] Genomic Science Program. Fuel Ethanol Production. http://www.genomicscience.energy.gov (accessed on April 20, 2010).

[40] Gevo. What we do, and Technology. http://www.gevo.com/faqs.php (accessed on April 20, 2010).

[44,45] The light party. Butanol, Advanced Biofuels. http://www.lightparty.com (accessed on April 21, 2010).

feedstocks. The proposed procedures result with butanol that is 90 to 95% of the energy density of gasoline. Consequently, butanol can be blended into gasoline engines at higher ratios than ethanol before needing to make modifications. Furthermore, it can be pipelined in existing systems today and be one of the major competitors for gasoline.[46] In general, butanol reduces blend vapor pressure and in that way can reduce the emission of volatile organic compounds (VOCs). In this way smog will be reduced and there will be a great improvement in air quality. [47]

Many large companies are showing interest in making butanol. British petroleum and DuPont are working together in order to develop the sustainable future.[48] Chevron is also looking into biobutanol with Georgia Tech and Weyerhaeuser using forestry products for feedstock.[49] Honda and Research Institute of Innovative Technology (RITE) developed the technology to produce butanol using bacteria.[50] After multiple tests, RITE and Honda R&D Co. confirmed negligible effects on diesel vehicle performance when the RITE biobutanol was used in the mixture with diesel fuel. The technologies of butanol production already exist and tend to minimize the production cost and enable the mass production. Gevo's first commercial facility, located in Minnesota, expects to produce 18 million gallons of isobutanol per year by 2012.[69]

Fuels from algae

Algae are promising sources for transportation fuels production because the yields of oil they give are much higher than the yields for tradition oilseeds such as sunflower, soybean, and corn. Furthermore, growing of algae doesn't require arable lands and potable water. Algae can grow in places far away from forests and farmlands. The experimental production of fuels from algae has been done in the laboratories,

[46] K. Brekke. *Ethanol Org.* Butanol, An Energy Alternative. http://www.ethanol.org (accessed on April 21, 2010).
[47] Laux, Ben; *All Business Company*. Low-vapor-pressure solvents can reduce VOC emissions. emissionshttp://www.allbusiness.com (accessed on April 22, 2010).
[48] Dupont. Dupont and BP Disclose Advanced Biofuels Partnership Targeting Multiple Butanol Molecules. 14 February 2008. http://www2.dupont.com(accessed on April 22, 2010).
[49] Greentechmedia. EPA Issues Renewable Fuel Standards: What It Means for 1st and 2nd Generation Biofuels. 5 February 2010. http://www.greentechmedia.com (accessed on April 22, 2010).
[50] Green Car Congress. RITE Develops Biobutanol for Blending in Diesel Fuels. 13 August 2007. http://www.greencarcongress.com (accessed on April 23, 2010

but practical demonstrations need yet to be developed. One of the issues is that meaningful quantities of fuels from algae have not been produced yet due to a very challenging and expensive step of algal-oil-extraction.[51]

Methods considered to be used for extraction of oil from algae are expeller/press, hexane solvent oil extraction, and supercritical fluid extraction.[52] However, all three methods have drawbacks. Extracting oil from algae using expeller/press methods is energy intensive since it requires drying of algae. Hexane solvent oil extraction presents safety and health issues since it is extremely flammable and harmful if inhaled. The third method of supercritical fluid extraction requires expensive and energy intensive high pressure equipment.[53] Research continues into refining the existing methods and also continues to develop new methods of separation and extraction.

Algae and cyanobacteria (also known as blue-green algae) have evolved complicated but very effective ways to store packages of oil, paraffins, and other compounds they produce inside the cell walls making it difficult to access the valuable oil storages.[54] The only way to get to oils from algae is to somehow pass their cell walls. The easiest way would be to harvest the algae, dry it out and collect the oils and other hydrocarbons. However, during the drying process all the organisms are killed, meaning that algae that undergo such a process usually can't continue to produce oil and new algae must be grown which leads to additional expense.[55]

Another way to get the precious oils from algae includes electro-shock principles where, for a short period of time, algae receive electric impulses which open the pores in the cell walls allowing the oil packages to flow out. This is exactly what Phycal company located in Cleveland does. Solix is about to do a similar thing by using a system developed by Los Alamos National Laboratory.[56]

[51,52,53] National Renewable Energy Laboratory.*A Look back at the U.S. Department of Energy's Aquatic Species Program*: Biodiesel from Algae. http://www.nrel.gov/docs/legosti/fy98/24190.pdf (accessed on April 20, 2010).

[54,55,56] Ivancic, M. Joanne. Advanced Biofuels USA. *Advanced Biofuels.* Algae And Company. 31 March 2010; pg 6. Printed source. http://advancedbiofuelsusa.info (accessed on April 20, 2010).

[57] Algenol Biofuels. http://www.algenolbiofuels.com (accessed on April 25, 2010

[58] Biofuel Digest. *Shock wave:* Camelina Biofuels Break Sound Barrier in Navy F-18 Trial. 23 April 2010. http://biofuelsdigest.com (accessed on April 20, 2010).

Algenol Biofuels[57], located at Bonita Springs in Florida, discovered that some cyanobacteria can produce alcohols (ethanol, butanol) and at the same time can diffuse the alcohols from the cell walls without any assistance. So they are hoping to produce alcohols using genetically enhanced strains.

Biological capture of carbon dioxide is considered a method to recycle carbon from power plants to a certain extent. Carbon dioxide emitted from power plants would be consumed during the algae growth, and algae would be used for transportation fuels production. In this way the CO_2 greenhouse emissions will be reduced. However, this concept has some drawbacks. For example, if CO_2 from coal-fired plants is used for biological capture it might encourage continuation of bringing stored carbon into the atmosphere, rather than recycling what is already there.

Looking to the Future

Advanced biofuels such as ethanol derived from structural polysaccharides found in plant material, butanol, and fuels derived from algae all show a promising future for transportation needs and improved ecological aspects. The abundance of resources and the large number of technologies that can be used in advanced biofuel production clearly show potential for a great sustainable future.

On April 22 the Navy celebrated Earth Day by testing their new "F/A-18 Super Hornet multirole fighter jet" fueled with a 50/50 mixture of green jet fuel made from camelina oil and petroleum-derived military jet fuel.[58] This is a first flight of a supersonic jet flying on a biofuel mixture and it symbolizes a giant leap into the sustainable future of advanced biofuels. Many commercial airlines are also working on getting bio-jetfuels. For example Continental, British and other airways already tested different biofuel mixtures.[59]

[59] Ivancic, M. Joanne. Advanced Biofuels USA. *Advanced Biofuels.* The Advancement of Bio-Jetfuels. 31 March 2010; pg 7. Printed source. http://advancedbiofuelsusa.info (accessed on April 20, 2010)

However, before any of the advanced biofuels are commercially produced, it is important to evaluate the costs and benefits. First, it is important to establish the appropriate technology and the feedstock which is being utilized by that technology. Second, it is necessary to understand the characteristics of products obtained from the process.[60] After these challenges are accomplished, the idea of commercial fuel production is possible.

Even more challenging, there are a few steps that have to be accomplished before Americans see commercially available transportation advanced biofuels. Industries must be able to produce large volumes of advanced biofuels in order to satisfy transportation needs. In addition, the appropriate infrastructure to transport, to deliver, and to use biofuels must be developed.[61] Some drop-in fuels can use existing infrastructure. Ethanol, whether cellulosic or first generation, requires special handling. For example, analysis of existing pipelines and fuel stations may be needed in order to know whether they meet required adaptations or if certain modifications have to be performed.[62]

Many challenges are ahead of us, but the nation has to start moving toward alternative renewable fuels. The lawmakers have to create new policies that would help develop the advanced biofuels industry.

Most of the new technologies and reactions for production of advanced biofuels are created in small research labs, usually at universities and colleges, but there is no large network that works on sustainable and renewable fuels. The national advanced biofuels network is what this nations needs, and American people have to stop waiting. No one wants the price of oil to increase as it did a few years ago.

Because the return on investment may have long time horizons, it is difficult for private investments alone to provide adequate funding for Research and Development. But somebody has to break the ice, and that somebody is the government. In order to move from small research college laboratories to the new plants is expensive and money has to come from somewhere. Once the people of the U.S. see what kind of alternative future is right in front of them, private investments from all over the country will compete in refining the possible approaches to advanced biofuels production.

[60,61,62,63,64] Advanced Biofuels USA. *Advanced Biofuels.* The next Technology Revolution will Fuel the Future. 31 March 2010; pg 2. Printed source. http://advancedbiofuelsusa.info (accessed on April 20, 2010)

For instance, policies that would encourage competition in production of advanced biofuels should be created. All companies should be allowed to compete in a technology neutral manner, and enter the market without barriers.[63] Subsidies and tax credits are essential for all potential competitors to race for the best alternatives and to maximize benefits for consumers.[64] In this way, the companies that work on production of advanced biofuels can compete, and as we all know, if there is a competition then consumers can choose between different advanced fuels, considering that their prices will be lower than the ones of petroleum. In this way prices of production will be minimized and drivers will be happy to go shopping for their favorite fuel.

The land use issue is also one of the essential barriers to advanced biofuel production. Feedstocks have to be grown somewhere and the government should work on the issue by assigning the promising lands for feedstock to be grown. The resources needed for feedstock cultivation and land distribution are also essential challenges and should be considered. For instance, Pine plantations in the Kaipara (New Zealand) are potential source of biofuels which will save the economy billions of dollars, as confirmed by a three years research report by Scion, Landcare Research, MOTU, NIVA and Infometrics. Scion have proposed to government officials that more than "1 million hectares of marginal land throughout New Zealand should be planted in exotic trees, a renewable resource that can be processed to provide fuel." The country could reduce dependence on foreign oil by 65 percent with $ 4.8 billion in a return to economy instead of importing 90 percent of oil at a cost of $ 5.8 billion per year. Biomass plantation forests on low productivity land would allow production of renewable transport fuels without significantly impacting of food or feed industry.[67]

It is important to decrease the consumption of fossil fuels particularly because oil should get more expensive in coming decades reaching over $90 which is its price a barrel today.[66] The increasing price

[65] National Geographic, Daily News. *Has the World Alreade Passed "Peak Oil*
http://news.nationalgeographic.com/news/energy (accessed on January 10, 2011).
[66] http://www.oil-price.net/
[67] Dargaville News. Stirling, Rose, Fill Her Up With Super Pine. http://www.stuff.co.nz (accessed on January 10th 2011)

level might bring to global economic collapse as in 2006 when the crude oil production reached its peak.[65] It is harder to extract oil and fewer resources are available in the Earth's crust, so the transition to cleaner alternative fuels is almost inevitable.

Generally, the goal is to a shift away from fossil fuels that result in GHG emissions, and switch to new alternatives and cleaner sources of energy such as the advanced biofuels. According to the U.S. Energy Information Administration (EIA), the U.S. imports 51 percent of its petroleum, which includes crude oil and refined petroleum products.[68] By switching to advanced biofuels the dependence on foreign oil can be broken. It would be better to produce at home rather than to import billions of dollars worth of fuel.

At the end, everything comes down to American people have to convince their government to step into a new industrial revolution. In order to accomplish this goal, it is essential to educate people and make them understand that the future of transportation fuels and improved ecological plans indeed lies in advanced biofuels. Future generations will enjoy lower carbon emissions and will be privileged to know that they can grow advanced biofuels "in their own backyard."

If people are knowledgeable and ready to vote for a sustainable future and renewable advanced biofuels, then U.S. lawmakers will be encouraged to create long-term policies that meet necessary standards for commercial production of advanced biofuels. This transition has to start somewhere and today it will start here. Consumers want to switch to sustainable, reliable, and renewable carbon neutral transportation fuels that will mitigate climate change and decrease the U.S. dependence on foreign oil. Finally, what this nation also needs is an advanced biofuels information network which would have as a main goal educating people in this country by advertising advanced biofuels through public activities, radio, and television programs. Furthermore, posters on sustainable and renewable advanced biofuels should be on each corner of every rural and urban area. Organizations such as Advanced Biofuels USA,

[68] U.S. Energy Information Administration. *How dependent are we on foreign oil?* http://www.eia.doe.gov (accessed on January 10th 2011)

[69] http://www.gevo.com/what.php (accessed on January 11th 2011)

located in Frederick MD, readily meet the public and show people that the future alternatives are around the next corner. A day when the nation will understand and implement these alternatives is about to knock on our doors. All the nation has to do is to keep walking forward towards the new technology revolution that will fuel the future.

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