Chapter 16

Advancing Energy Security and Economic Growth with Biofuels

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THE NEED FOR FUEL DIVERSIFICATION

The continuing instability in the Middle East and other parts of the world is a strong reminder of the urgent need to diversify our energy portfolio, while protecting our air, water, and soil for future generations. Unfortunately, the United States has never had an energy policy that would provide a consistent long-term vision for the nation's energy future. Although energy demand is expected to grow along with economic expansion over the next decades, how such demand will be met remains largely undetermined. In the absence of a long-term policy, the United States usually resorts to energy-related measures simply in reaction to geopolitical events, such as rising oil prices. Individual states have taken some legislative action of their own to promote energy diversification, but there is a lack of coordination and harmonization nationwide.

This situation leaves the United States vulnerable to political pressure by often hostile countries possessing oil reserves. Trying to contain political instability overseas instead of addressing dependency on foreign oil is no cure for our long-term energy security.[1] As a result, the country frequently has to spend huge amounts of money and endanger the lives of its service men and women to protect overseas oil fields and preserve oil flow. The chronic underdevelopment of domestic energy resources has to change right away. The United States is rich in biomass, wind, solar and geothermal resources, and natural gas. With its technological leadership, the country is in a position to efficiently explore all these domestic energy options and hence spur sustainable economic growth, while at the same time reducing the carbon footprint of its economy.[2]

Vehicle fuel efficiency in the United States has lagged behind than in other parts of the world, such as Europe, where heavy state taxation of fuel has

naturally encouraged conservation. This does not mean that the United States should increase fuel taxes, as such a measure will surely dampen economic activity. Instead, the country should demand from its automotive industry more fuel-efficient vehicles and, at the same time, promote fuel diversification and multi-fuel vehicle production. By encouraging the production and use of domestic transportation fuels at the expense of foreign oil, petrodollars currently ballooning the country's trade deficit will stay in the country and greatly benefit the U.S. economy. Biofuels, such as ethanol, butanol, biodiesel, and green hydrocarbons, along with other transportation options such as electric cars, will attract investment, create jobs, generate tax revenues, and offer the U.S. consumer an unprecedented choice of fuels that will lead to healthy competition at the pump.

CURRENT STATUS

In 2013, the United States consumed 135 billion gallons of gasoline and 59 billion gallons of diesel, both derived from oil, 40 percent of which was imported.[3] Unlike power generation, where domestic energy sources (albeit highly polluting, such as coal) are utilized, the U.S. transportation sector depends heavily on oil imported from a number of countries, including members of the Organization of Petroleum Exporting Countries (OPEC), some of which are often hostile to U.S. interests.

As past oil crises have shown, even speculation about political unrest or military action in or around the Middle East may lead to skyrocketing oil prices. Given that oil is an international commodity, the fact that Canada, a reliable U.S. ally, is our top supplier of imported oil[3] does not insulate us from such future oil price hikes, which can cripple the U.S. economy in a matter of months, if not weeks.

Clearly the current status quo makes no political or economic sense. Yet, there is no federal policy to reduce dependence on oil, since alternatives to oil products, such as biofuels, have been long ignored and only in the last few years have received some attention. To be successful in advancing energy security we need an energy policy with long-term commitment to sustainable domestic fuels, public investment in research and development (R&D), and private investment in technology integration and commercialization.

THE CASE FOR BIOFUELS

Key components of fuel diversification are advanced biofuels (although by no means the only ones), such as:

- Ethanol and butanol for light vehicles
- Biodiesel for trucks and heavy vehicles
- Green (renewable) fuels for aviation and military use

These are fuels that can be produced sustainably from domestic biomass and algae—which means from inedible raw materials with no impact on food resources and land use. Biomass includes agricultural residues from the corn, sugarcane, and other industries, forestry residues, and yard waste, all inedible and abundant. Thanks to year-round favorable climate, some areas of the country, such as Florida, have tremendous potential for both biomass production and algae cultivation.

Advanced biofuels can enhance U.S. energy security and economic growth because of a number of strong attributes:

Energy and National Security

Biofuels have the potential to drastically reduce dependence on imported oil, especially when used in conjunction with other domestic energy sources. The United States still imports from foreign countries 40 percent of the oil it refines to transportation fuels,[3] such as gasoline, diesel, and jet fuel. This heavy dependence weakens the country's foreign policy, as it renders it hostage to geopolitical events even in remote parts of the world, simply because any disruption in oil supplies could destabilize the U.S. economy. Domestic biofuels, as well as complementary technologies like electric vehicles and natural gas-powered vehicles, will reduce dependence on foreign oil and thus strengthen energy and hence national security.

Thanks primarily to state mandates, ethanol today represents 10 percent of the transportation fuel used in the United States.[4] The 13 billion gallons of ethanol consumed annually by U.S. motorists come from corn produced in Midwestern states, a situation that is not sustainable in the long-term as it creates a food vs. fuel competition, which eventually will impact consumer prices. The U.S. government has set an ambitious annual production goal of 36 billion gallons per year of biofuels by 2022, as outlined in the Renewable Fuel Standards (RFS).[4] Out of this amount, the RFS calls for 21 billion gallons to be advanced biofuels.

The goal is to supplement corn ethanol and replace gasoline with advanced biofuels produced from inedible biomass resources available throughout the country, including bagasse from sugarcane fields, stover from corn fields, straw from wheat fields, and woody biomass from forestry throughout the country. The recent elimination of the corn ethanol subsidy, costing U.S. taxpayers over $6 billion a year,[5] is a positive step in the direction of encouraging the development of advanced biofuels.

Diversified Agriculture

Biofuels can strengthen U.S. agriculture, as farmers will produce not only food, but also feedstocks for fuel and power. To date, farmers focus their efforts and are compensated just for the crop they grow, as there is little or no value to the fiber that is co-produced along with the crop. Biofuels change that reality and enable farmers to enter into additional markets by producing biomass or algae for energy generation.

The large biorefineries of the future, where biomass and algae will be converted to fuels and products currently derived from oil, will be located in rural areas close to their source of feedstock for logistical and economic reasons. Individual farmers and farm cooperatives will be able to enter into long-term contracts with biofuel and bioenergy producers, who need biomass in large and consistent quantities as feedstock. Such additional revenue will strengthen U.S. agriculture, attract investment to rural areas, and create much-needed jobs in poor areas of the country.

Technical Innovation

The development of biofuels requires multidisciplinary research that stimulates ingenuity in academia, national labs, and private research. The result is valuable intellectual property that spurs entrepreneurship. The United States has been the world leader in R&D of biomass and algae technologies. The conversion of biomass to biofuels has been the subject of intense R&D work funded by public and private sources in the last 10 years. Companies, mostly financed by venture capital and private equity, have developed diverse biochemical, thermochemical, and aqueous processes to convert biomass and

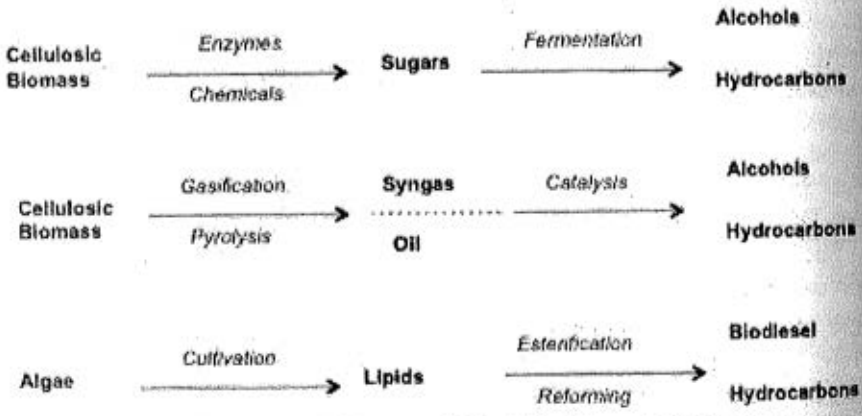

Figure 16.1 Simplified Process Diagrams of the Main Advanced Biofuel Technologies.
Source: **Created by author.**

algae to a variety of liquid fuels, such as ethanol, butanol, diesel, and other hydrocarbons, as shown in Figure 16.1. Biomass technologies are currently going through a demonstration phase and some have advanced to commercial scale. Algae technologies are following a similar path of commercial development. These technologies are briefly described next.

The biochemical technology, shown at the top of Figure 16.1, aims at first breaking down the fiber of biomass into simple sugars through a two-step process: (a) By using steam and small amounts of chemicals (usually an acid or alkali), it opens up the fiber structure; and (b) by adding natural enzymes it breaks down the natural polymers of fiber down to simple fermentable sugars. Subsequently, microorganisms are employed to ferment the sugars to the desired biofuel (e.g., ethanol, butanol, or even a hydrocarbon fuel) or bioproduct (e.g., lactic acid for production of biodegradable plastics).

The thermochemical technology takes a different route, as shown in the middle of Figure 16.1. Using high temperatures it turns biomass into a gas mix of primarily carbon monoxide and hydrogen (called syngas), which subsequently passes over a metal catalyst that helps convert the gases to hydrocarbons or alcohols. Each technology has its advantages and challenges, and we may have multiple market winners, meaning different technologies may work best in different parts of the country, depending on the type of biomass available.

In the last 5 years, intensive R&D in algae has led to the creation of a new industry that promises to produce fuels from yet another abundant source, photosynthetic algae. Using sunlight, carbon dioxide from industrial smoke stacks, and brackish water, companies have developed technologies that produce lipid-bearing algae, as shown at the bottom of Figure 16.1. The lipids are recovered and then thermochemically converted to crude bio-oil, which is refined to renewable aviation and military fuels.

The establishment of a biofuels industry will boost demand in STEM (Science, Technology, Engineering, and Mathematics) education, as technical cross-disciplinary jobs will be in high demand. Employers will be seeking staff with basic and advanced degrees in various fields, including agricultural, chemical, mechanical, electrical, and industrial engineering, chemistry, biology, biochemistry, marine biology, business, agronomy, and forestry. As a result, the technological competitiveness and innovation of the United States will receive a major boost.

Investment and Economic Growth

Biofuels are good for the economy because they create jobs, generate tax revenues, and bring into the economy much-needed private investment. The

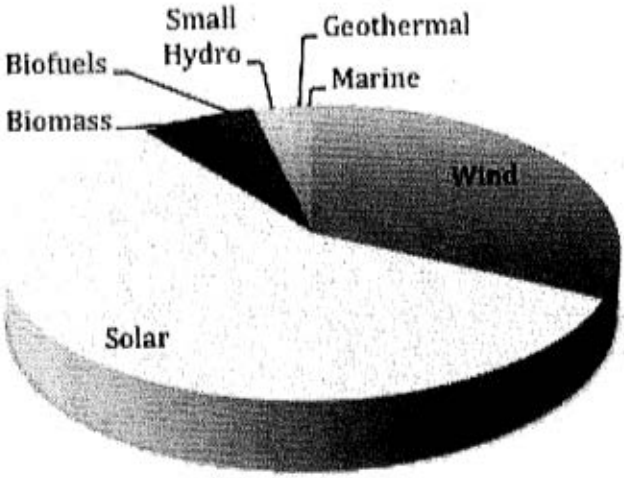

Figure 16.2 Global New Investment in Renewable Energy in 2011. *Source:* Constructed with data from Global Trends in Renewable Energy Investment, Bloomberg New Energy Finance, 2012.

commercialization of advanced biofuels will bring significant private investment to the U.S. economy both for R&D and for commercial deployment. Globally, new investment in biofuels grew at a compounded annual growth rate of 10 percent from 2004 to 2011, despite the difficult economic times of the last few years, and, as shown in Figure 16.2, totaled $6.8 billion in 2011 as part of a considerable total investment of $258 billion into renewable energy production.[6]

Current projections indicate that the capital requirement of each large-size biorefinery will be hundreds of millions of dollars.[7] At the same time thousands of jobs, both direct and indirect, are projected along the value chain of the biomass-to-biofuels and algae-to-biofuels operations that span from agriculture to manufacturing to logistics and sales. Those jobs include permanent ones, such as managers, engineers, scientists, technicians, operators, administrators, machinists, farmers, maintenance technicians, and drivers, as well as temporary ones associated with the construction of the biorefineries and the surrounding infrastructure.

Once biorefineries start operating, local communities will benefit from tax revenues in addition to increased employment. At difficult economic times, such as the present ones, new sources of revenue will help enhance the quality of life and standard of living. Moreover, with advanced biofuels becoming an integral part of American life, the resulting diversification to rural economies

(beyond just agriculture) will provide a cushion during future economic recessions.

Consumer Options

Biofuels will benefit the consumers, since they will provide them with fuel options and will therefore lead to market competition among fuels at the pump. Breaking the monopoly of oil-derived gasoline and diesel will naturally lead to price competition, as motorists in Brazil have enjoyed for years having options that include gasoline, ethanol, blends of the two, as well as compressed natural gas. A recent report has documented the cost and performance advantages of biofuels in the U.S., as gasoline oxygenates, octane enhancers, and discretionary fuels, even though ethanol was until recently limited to no more than 10 percent in blends.[8] As the government raises this ceiling to 15 percent and beyond, the consumer should see even greater competition and savings.

Key to the success of any type of alternative transportation fuel is its ability to use the existing fuel distribution and retailing infrastructure, as infrastructure changes are costly and time-consuming. Ethanol can be readily blended with gasoline at any proportion and can even be used as straight ethanol in flex-fuel vehicles. Similarly, biodiesel can be blended with diesel or even replace it completely. Green hydrocarbons from algae or biomass constitute so-called "drop in fuels" precisely because they are identical to their fossil counterparts. Hence, there is no real obstacle to the wider use of biofuels once they become available.

For the consumer to enjoy the benefits of multiple fuels there is a key prerequisite: the availability of multi-fuel vehicles. These will be vehicles that can run on a variety of available fuels, such as the ones outlined earlier. Auto manufacturers have been massively producing such flexible fuels in other countries, such as Brazil, for years. There is no reason why they cannot do the same in the U.S., if government policy favoring fuel diversity becomes, along with fuel efficiency, the cornerstone of a long-term energy policy.

Environmental Benefits

Biofuels are good for the environment because they are renewable, sustainable, and reduce greenhouse gas emissions. In addition to their energy security and economic benefits, advanced biofuels are also beneficial to air and water quality. They are renewable as carbon dioxide released during combustion is incorporated photosynthetically into the next growth cycle of biomass. They do not compete with food resources because they are produced from inedible biomass and algae that are mostly treated as waste.

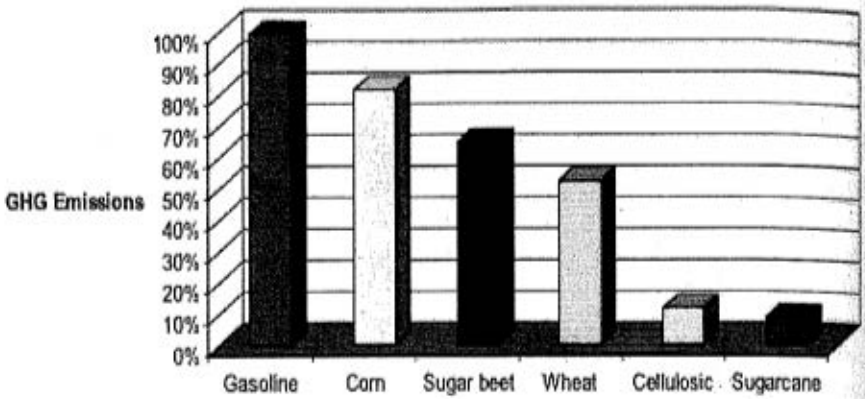

Figure 16.3 Greenhouse Gas Emissions (GEG) of Ethanol Produced from Various Sources, as Compared to the Emissions of Gasoline on a Life-Cycle Basis. *Source*: **Constructed with data from World Energy Outlook, International Monetary Fund, 2007.**

Furthermore, advanced biofuels have a greenhouse gas emission footprint that is significantly lower than that of gasoline on a life-cycle basis. As shown in Figure 16.3 for ethanol, the carbon footprint varies depending on the source of the biofuel.[9] On a life-cycle basis, ethanol produced from sugarcane in Brazil emits only 10 percent of the greenhouse gases when compared to gasoline, a dramatic reduction. Projections indicate a similarly low footprint for advanced ethanol marked as "cellulosic" in Figure 16.3. When all these attributes are pooled together, it becomes obvious that advanced biofuels represent a sustainable fuel option.

BIOFUEL DEPLOYMENT

Realistically speaking, replacing a significant portion of gasoline and diesel with biofuels will take decades and billions of dollars. However, the issue of energy and national security is too urgent to wait for the normal market penetration of biofuels even under the most favorable policy and market conditions. Each biorefinery capable of producing several millions of gallons annually represents a multi-million dollar investment that will take 2–3 years to complete and reach full production potential.[8] As a result, to build a national biofuels capacity in the billions of gallons will require several years.

At the present time the projected cost of advanced biofuels is still higher than that of gasoline. However, there is good reason for optimism. Operating experience from the existing demonstration facilities and the first commercial plants will help enhance productivity, reduce down time, and hence curtail

costs over time. Economies of scale will make a big difference, as biofuels will be produced at the level of tens of millions of gallons per biorefinery and tens of billions of gallons nationwide. Actually, wind power has already set a successful precedent for the tremendous benefits of economies of scale and operating experience in the renewable energy arena, as the cost of wind power is now competitive with power from depletable sources, such as coal and nuclear plants. This did not happen overnight, but rather over a period of several years during which scale increased as wind energy supply and demand did. The same will happen with biofuels.

A faster market penetration for biofuels can be achieved by combining their benefits with those of other transportation alternatives that are already commercial, such as electric vehicles. Both hybrid and plug-in automobiles represent a great opportunity for fuel and fleet diversification, when coupled with biofuels. As car batteries progressively become more cost-effective thanks to higher charge capacity, faster charging, and longer operating life, electric vehicles will become increasingly more affordable. The electrification of the transportation sector can displace significant amounts of gasoline and diesel, particularly for city driving, where distances are rather short. For longer trips, advanced biofuels from biomass and algae can be the fuel of choice thus complementing the use of electricity.

Wide use of electricity in the transportation sector certainly raises the question of how such an increased demand for power generation will be met. This is where the large natural gas reserves—made accessible in the United States in the last few years thanks to hydraulic fracturing—can play a catalytic role. Abundant domestic natural gas at low prices can become the fuel of choice for power generation over the next several years, provided that fracturing is practiced in ways that minimize its impact on the environment. Some utility companies have already reportedly started replacing aging coal plants with natural gas-powered facilities.

BIOFUEL CHALLENGES

A major challenge for the success of biofuels is the expectations we set. They must be realistic. We use huge quantities of oil products, over 6,000 gallons of gasoline and diesel every single second.[3] If we add aviation and military fuels, this figure is even higher. Biofuels, as an alternative to petroleum fuels, still represent just 10 percent of this volume. Scaling up biofuel technologies, reducing the costs, building plants to generate large quantities, producing significant numbers of flex-fuel vehicles, and educating the population are essential and will take time. We need to make sure that policy-makers, technology developers, biofuel producers, fuel distribution companies, and car manufacturers work collectively to meet the challenge.

Biofuels are no silver bullet for energy security, but they can certainly be, along with the electrification of transportation and natural gas, a critical component of a more sustainable and more self-sufficient U.S. economy. Energy has always been a public-private partnership, whether it is electricity or liquid fuels. The same is true for biofuels. Private investment trails public policy and will become reality only if there is an unequivocal commitment by the U.S., in the form of an energy policy, to do whatever it takes to break our heavy dependence on a single source of fuel. To be successful we need a "Manhattan project" mentality that recognizes the urgency of the situation and pools together critical resources across the economy and society to achieve the objective. Given our impressive history in research innovation and entrepreneurship, there is strong reason to believe that the United States can succeed in this crucial endeavor.

CONCLUSION

There are tremendous opportunities in the United States to advance economic growth by investing in domestically produced advanced biofuels, which will spur job creation, generate tax revenues, and reduce the country's carbon footprint, while placing the entire U.S. economy on a more sustainable basis. Biofuels from biomass and algae can enhance U.S. energy security by reducing oil imports. Electric cars, particularly in combination with cleaner electricity produced from natural gas, can complement biofuels to truly diversify the U.S. energy portfolio.

At the federal level, the U.S. government needs to develop a long-term bipartisan roadmap toward energy security by committing to a variety of domestic clean resources of energy. The private sector eagerly awaits such a policy, so it can invest with confidence in the country's future. To develop new low-carbon energy sources, there is no need for wasteful subsidies and import tariffs. Instead, government support should help the private sector as it strives to commercialize new technologies and build the solar, wind, geothermal, biomass, biofuels, and natural gas facilities needed to break this country's oil and coal energy dependence. Public-private partnerships will benefit the U.S. consumer and will secure the country's energy future in a sustainable way.

The United States needs truly flex-fuel vehicles (able to operate on multiple fuels and blends) coming off the assembly lines of automobile manufacturers, as is already practiced in Brazil, where drivers can utilize biofuels or gasoline or blends of the two or natural gas depending on the daily price of each fuel. With an energy policy supporting the development of sustainable fuels and alternative transportation technologies, U.S. consumers will finally

have the choice (many fuels) and means (flex vehicles) to enhance the country's energy security, while at the same time promoting sustainable economic growth and reducing their carbon footprint.

NOTES

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