ETHANOL, BIOMASS, BIOFUELS AND ENERGY: A PROFILE AND OVERVIEW

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PART I. INTRODUCTION

> 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. There's enough alcohol in one year's yield of an acre of potatoes to drive the machinery necessary to cultivate the field for a hundred years.[1]
>
> -- Henry Ford

Expressing his outlook on energy that was widely shared by the automotive industry nearly eighty years ago, the future that Henry Ford predicted remains a future for our generation. Diminishing worldwide petroleum reserves coupled with growing demand from China, India, Brazil and other nations has created a precarious situation in regards to energy procurement. In the United States, 40.1% of total energy consumption comes from petroleum, 22.9% from

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1. *Ford Predicts Fuel from Vegetation*, N.Y. TIMES, Sept. 20, 1925, at 24.

coal, 22.6% from natural gas, 8.1% from nuclear electric power, and 6.1% from renewable energy.[2] The American dependency on petroleum is clearly illustrated by the fact that it constitutes the largest source of energy consumption. With 7.5 billion barrels of oil used by Americans in 2006, petroleum's ability to fuel automobiles and heat homes has placed it in a category of necessary goods joined by food, water, and shelter.[3]

What complicates the energy situation in the United States is two-fold in nature. First, natural resource energy is finite. Second, there is an imbalance of oil stocks and reserves due to geological circumstances beyond control. According to the Energy Information Agency, an estimated 1.32 trillion barrels of oil are left in the world;[4] and only 1.6% of that amount resides in the United States.[5] More significantly, of the 1.32 trillion barrels of oil, 6% is in Venezuela,[6] 8.7% is in Iraq,[7] 10.3% is in Iran,[8] and 19.9% is in Saudi Arabia.[9] This petroleum imbalance has created a world where the use of energy as an overt weapon is no longer a theoretical threat of the future, but happening now. The 2007 State of the Union address by President George W. Bush expressed America's dependence on foreign oil and the fact that it "leaves us [America] more vulnerable to hostile regimes, and to terrorists – who could cause huge disruptions of oil shipments, and raise the price of oil, and do great harm to our economy."[10] This geopolitical situation has allowed regimes such as Iran, Saudi Arabia, and Venezuela to avoid democratic reforms and insulate themselves from international and domestic pressures. Furthermore, as Thomas Friedman states, "it has fostered a counterwave – a [new] wave of authoritarian leaders who are not only able to ensconce themselves in power because of huge oil profits but also to use their oil wealth to poison the global [political and economic] system."[11]

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2. ENERGY INFO. ADMIN., ANNUAL ENERGY REVIEW, U.S. PRIMARY ENERGY CONSUMPTION BY SOURCE AND SECTOR, 2005, http://www.eia.doe.gov/emeu/aer/pdf/pecss_diagram.pdf (renewable energy includes conventional hydroelectric power, wood, alcohol, geothermal, solar, and wind).

3. Robert J. Samuelson, *Blindness on Biofuels*, WASH. POST, Jan. 24, 2007, at A23.

4. ENERGY INFO. ADMIN., WORLD PROVED RESERVES OF OIL AND NATURAL GAS, MOST RECENT ESTIMATES, Jan. 9, 2007, http://www.eia.doe.gov/emeu/international/reserves.html (estimate derived from the Oil & Gas Journal, Jan. 1, 2007).

5. *Id.*

6. *Id.*

7. *Id.*

8. *Id.*

9. *Id.*

10. Pres. George W. Bush, State of the Union Address (Jan. 23, 2007) (transcript available at http://www.whitehouse.gov/stateoftheunion/2007/index.html).

11. Thomas Friedman, *Fill'Er Up With Dictators*, N.Y. TIMES, Sept. 27, 2006, at A5.

The U.S. energy industry has returned to past conditions and has created a need for alternative sources of energy. New data from the polling firm Public Opinion Strategies shows that 78 percent of Americans support increasing the use of ethanol and two-thirds of Americans support the increased use of biofuels in general.[12] "Additional results show that 91 percent of Americans feel the country is facing an energy crisis and 53 percent believe we should diversify our energy supply by utilizing alternative energy sources like ethanol."[13]

The three main constituents of alternative energy in respect to flexible fuels are ethanol, biodiesel, and methanol. Flexible fuels, or fuel blends, are motor fuels produced with "low levels of alternative fuels [blended] with conventional fuels."[14] Ethanol can be simply defined as ethyl alcohol or grain alcohol.[15] Biodiesel (fatty acid alkyl esters) is a cleaner burning diesel replacement fuel made from natural, renewable sources such as new and used vegetable oils and animal fats.[16] Methanol is an alcohol based fuel "produced by a process using natural gas as a feedstock."[17] Different concentrations of alternative fuels within a fuel blend are denoted by a letter[18] and number, which signifies the percent of alternative fuel within the fuel blend. For example, E85 is defined as a fuel blend that contains 85% ethanol and 15% gasoline.[19]

According to Robert J. Samuelson, "production of ethanol from corn has surged from 1.6 billion gallons in 2000 to 5 billion in 2006."[20] This production has come from 101 ethanol bio-refineries nationwide which have the capacity to produce more than 4.8 billion gallons annually.[21] Currently, thirty-nine ethanol refineries and seven expansions are under construction with a potential combined

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12. Press Release, Renewable Fuels Ass'n., Vast Majority of Americans Want More Ethanol (June 1, 2006), http://www.ethanolrfa.org/media/press/rfa/2006/view.php?id=721.

13. *Id.*

14. U.S. Dep't. of Energy, Fuel Blends, http://www.eere.energy.gov/cleancities/blends/ (last visited May 19, 2007).

15. U.S. Dep't. of Energy, What is Ethanol?, http://www.eere.energy.gov/afdc/altfuel/whatis_eth.html (last visited May 19, 2007).

16. U.S. Dep't. of Energy, Biodiesel, http://www.eere.energy.gov/afdc/altfuel/biodiesel.html (last visited May 19, 2007).

17. U.S. Dep't. of Energy, What is Methanol*?*, http://www.eere.energy.gov/afdc/altfuel/whatis_methanol.html (last visited May 19, 2007).

18. As in, "E" denotes ethanol blend, "B" denotes biodiesel blend, and "M" denotes Methanol blend.

19. U.S. Dept. of Energy, E85 Fuel, http://www.eere.energy.gov/afdc/e85toolkit/e85_fuel.html (last visited May 19, 2007).

20. Samuelson, *supra* note 3.

21. Press Release, Renewable Fuels Ass'n., 2005 Energy Bill Sparked Growth in Renewable Fuels (Aug. 6, 2006), *available at* http://www.ethanolrfa.org/media/press/rfa/2006/view.php?id=790.

annual capacity of nearly 2.5 billion gallons.[22] The upward production trend has been further encouraged by government-set ethanol mobile-fuel production benchmarks: 35 billion gallons by 2017 with an ultimate goal of 60 billion gallons by 2030.[23]

While all of these conditions should amount to optimal circumstances for a new age of energy propelled by the farm industry, it should be tempered with careful research, study, and analysis. The following parts and sections will survey three aspects of bio-ethanol in respect to future outlook. The first part will discuss federal and state incentives for ethanol use and production. The second part will outline the ethanol production methodology and examine the net energy balance of bio-ethanol production. Finally, the problems and potential impact of ethanol will be reviewed.

PART II. INCENTIVES

In his 2006 State of the Union Address, President Bush spoke five words that sparked the alternative fuel industry: "America is addicted to oil."[24] The government has recognized the energy dilemma looming over the United States and has taken steps to promote energy independence and security. On August 8, 2005, the Energy Policy Act of 2005 was signed into law.[25] While the Energy Policy Act represents the largest and most comprehensive piece of energy legislation passed by the federal government, other federal and state acts have been passed in order to promote the use and production of ethanol and biofuels.[26] Ranging from federal mandates to state tax credits, the past decade has produced a wealth of incentives for biofuels producers and consumers.

Section I. Federal Incentives

The significance of the Energy Policy Act of 2005 resides within the renewable fuels standard that will double the use of ethanol and biodiesel by

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22. *Id.*

23. Samuelson, *supra* note 3.

24. Pres. George W. Bush, State of the Union Address (Jan. 31, 2006) (transcript available at http://www.whitehouse.gov/stateoftheunion/2006/) [hereinafter *State of the Union*].

25. U.S. Dep't. of Energy, On the Road to Energy Security, *available at* http://www.energy.gov/media/FINAL_8-14_DOE_booklet_copy_sep.pdf (last visited May 19, 2007).

26. *See* U.S. Dept. of Energy, Energy Efficiency and Renewable Energy, State & Federal Incentives & Laws, http://www.eere.energy.gov/afdc/laws/incen_laws.html (providing a database with links detailing various federal and state initiatives meant to promote renewable fuels).

2012.[27] As an amendment to the Clean Air Act[28], the renewable fuels standard calls for a gradual increase in the volume of renewable fuels[29] incorporated into gasoline sold or introduced within U.S. markets. Table 1 details the corresponding calendar year and applicable volume of renewable fuel:

Table 1. Applicable volume of renewable fuel[30]

Calendar Year:	Applicable Volume of Renewable Fuel **(in billions of gallons)**
2006	4.0
2007	4.7
2008	5.4
2009	6.1
2010	6.8
2011	7.4
2012	7.5

Furthermore, beginning in the year 2013, a minimum of 250 million gallons must be derived from cellulose ethanol.[31]

In order to "accelerate deployment and commercialization of biofuels" and ensure rural participation in the development of the biofuels industry, the Energy Policy Act of 2005 permits the Secretary of Energy to implement an incentives program.[32] More specifically, according to section 942 of the Act, a 1 billion gallon reverse auction program to purchase the first 1 billion gallons of cellulosic ethanol from the lowest cost provided will be designed and held.[33] According to Mohanbir Sawhney, "[r]everse auctions are fixed-duration bidding events hosted by a single buyer, in which multiple suppliers compete for business" which can "lower the cost of procuring products and services."[34]

Aside from the reverse auction program, a number of tax credit programs have been created as part of the Energy Policy Act of 2005. One such program has been the Small Agri-Biodiesel Producer Tax Credit, which "is a volumetric

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27. Energy Policy Act of 2005, Pub. L. No. 109-58, § 1501(a)(2)(o)(2)(B)(i), 119 Stat. 594, 1069, (2005) (amending Section 211 of the Clean Air Act (42 U.S.C. 7545)).

28. *Id.* § 1501(a), 119 Stat. at 1067.

29. *See id.* § 1501(a)(2)(o)(1)-(2), 119 Stat. at 1067-69 (defining renewable fuels as cellulosic biomass ethanol, waste derived ethanol, and biodiesel).

30. *Id.* § 1501(a)(2)(o)(2)(B)(i), 119 Stat. at 1069.

31. *Id.* § 1501(a)(2)(o)(2)(B)(iii), 119 Stat. at 1070.

32. *Id.* § 942(a)(1), (c)(1), 119 Stat at 878-79.

33. *Id.* § 942(c)(3)-(4)(A), 119 Stat. at 879.

34. Mohanbir Sawhney, *Forward Thinking About Reserve Auctions*, CIO MAGAZINE (June 1, 2003), http://www.cio.com/archive/060103/gains.html.

based income tax credit for the production of agri-biodiesel."[35] This program gives 10 cents per gallon on the first 15 million gallons of agri-biodiesel produced at facilities with capacity not exceeding 60 million gallons.[36]

Another tax credit program from the Energy Policy Act of 2005 has been the Refueling Infrastructure Tax Credit. This program is designed to extend a 30% tax credit, up to $30,000,[37] for refueling equipment for E85 ethanol, compressed natural gas, liquefied petroleum gas, hydrogen, and biodiesel blends containing at least 20% biodiesel.[38]

Independent of the Energy Policy Act of 2005, other prominent tax incentives have included the Biodiesel Blenders Tax Credit and the Volumetric Ethanol Excise Tax Credit (VEETC) created by the American Jobs Creation Act of 2005 (JOBS Bill).[39] The Biodiesel Blenders Tax Credit issues a $1.00 per gallon tax credit for "agri-biodiesel"[40] and a $.50 per gallon tax credit for petroleum blended biodiesel produced from recycled oils and animal fats.[41] The benefit of the credit is calculated based on the percent of biodiesel blended with petroleum diesel so that 20% of "agri-biodiesel" is worth $.20 per gallon.[42] Similar to the Biodiesel Blenders Tax Credit, the VEETC allows for a tax refund of $.51 per gallon on each gallon of ethanol blended with gasoline to be paid within 20-28 days of blending gasoline with ethanol.[43] For example, E85 receives a credit equal to $.43 per gallon and E10 receives a credit of $.05 per gallon.

National programs such as the Energy Policy Act of 2005, Biodiesel Blenders Tax Credit, and VEETC have provided a solid base of incentives for producers and users of ethanol. Much like the federal government, many states have demonstrated a significant amount of confidence in this industry. The fol-

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35. Nat'l. Biodiesel Bd., Tax Incentives, http://www.biodiesel.org/news/taxincentive/ (last visited May 19, 2007).

36. Nat'l. Biodiesel Bd., Small Agri-Biodiesel Producer Credit FAQ, http://www.biodiesel.org/news/taxincentive/MEMO-Small%20AgriBD%20Producer%20Credit%20FAQ.pdf.

37. Energy Policy Act of 2005, Pub. L. No. 109-58, § 1342, § 30C(a), 119 Stat at 1049-50 (amending subpart B of part IV of subchapter A of chapter 1 of §1342).

38. *Id.* § 1342, § 30C(c)(1)(A)-(B), 119 Stat. at 1050.

39. *See* American Jobs Creation Act of 2004, Pub. L. No. 108-357, §§ 301-02, 118 Stat 1418, 1459-66 (2004).

40. *Id.* § 302(a), § 6426(b)(3), 118 Stat at 1464; § 302(a), § 40A(d)(2), 118 Stat 1464 (defining agri-biodiesel as biodiesel derived from first use vegetable oils and animal fats).

41. *Id.* § 302(a), § 40A(b)(1)(A)-(B), 118 Stat 1463.

42. *See* I.R.S., Form 8864 Biodiesel and Renewable Diesel Fuels Credit (2006), *available at* http://www.irs.gov/pub/irs-pdf/f8864.pdf.

43. American Jobs Creation Act of 2004, Pub. L. No. 108-357, §6426(b)(2),118 Stat. 1418, 1459 (2004).

lowing section will survey the state incentives that exist for ethanol, biodiesel, and their implications.

Section II. State Incentives

According to U.S. Department of Energy statistics, there are currently 296 state laws and incentives regarding ethanol in the United State.[44] As of January 2007, there were twelve laws and incentives regarding ethanol production and consumption in Illinois, fourteen in Iowa, and four in Nebraska[45]. While forty-eight out of fifty states have passed at least one law or incentive in respect to greater ethanol production or consumption, the majority of state legislation has been similar in structure, as evident by the laws and code in Illinois, Iowa, and Nebraska.[46]

Of the twelve laws and incentives Illinois has passed in regard to ethanol, three relate to research, three to infrastructure development, three to ethanol powered vehicle procurement, two to rebate or tax incentives, and the final incentive is accounted for by Governor Blagojevich's Energy Independence Plan.[47] Announced in August 2006, "Governor . . . Blagojevich . . . unveiled a comprehensive long-term energy plan to replace Illinois' dependence on foreign oil with homegrown alternatives."[48] The Energy Independence Plan "sets a goal of replacing 50% of the state's energy supply with homegrown fuels by 2017."[49] Specifically, in relation to biofuels, the plan will 1) "[i]nvest in renewable biofuels by providing financial incentives to build up to 20 new ethanol plants" and 2) "[i]ncrease the number of gas stations that sell biofuels, so that all gas stations [in the state] offer . . . [E85] by 2017." and 3) help the auto industry increase and improve the flexible fuel vehicles[50] they produce.[51]

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44. U.S. Dep't. of Energy, Incentives & Laws: State Summary, http://www.eere.energy.gov/afdc/progs/tech_matrx.cgi (last visited Apr. 5, 2007) [hereinafter *State Summary*].

45. *Id.*

46. *Id.*

47. *Id.*

48. Press Release, Office of the Gov. of Ill., Gov. Blagojevich Unveils Ambitious Energy Independence Plan to Reduce Illinois' Reliance on Foreign Oil (Aug. 22, 2006), http://www.illinois.gov/PressReleases/ShowPressRelease.cfm?SubjectID=3&RecNum=5200.

49. *Id.*

50. Defined as a vehicle that is able to use E85 and other alternative fuels.

51. Press Release, Office of the Gov. of Ill., Gov. Blagojevich Unveils Ambitious Energy Independence Plan to Reduce Illinois' Reliance on Foreign Oil (Aug. 22, 2006), http://www.illinois.gov/PressReleases/ShowPressRelease.cfm?SubjectID=3&RecNum=5200.

Illinois' Ethanol Tax Exemption eliminates sales taxes to majority blended ethanol fuel (containing between 70% and 90% ethanol),[52] specifically stating that it "does not apply to the proceeds of sales made on or after July 1, 2003 and on or before December 31, 2013."[53] Similarly, Nebraska's Ethanol and Biodiesel Tax Exemption states that "[m]otor fuels sold to an ethanol or biodiesel production facility and motor fuels manufactured at an ethanol or biodiesel facility are exempt from certain motor fuel tax laws."[54] Iowa's Ethanol Tax Credit provides

> [a] tax credit . . . to retail service stations at which more than 60% of the total gallons of gasoline sold through metered pumps are blended with ethanol. Once station owners surpass the 60% threshold, they are eligible for a tax credit of $0.025 for every additional gallon of gasoline blended with ethanol and sold during the tax year, until December 31, 2008.[55]

In addition to the tax incentive provided by Illinois, Nebraska, and Iowa, all these states share a law that encourages state government agencies to purchase biofuel (ethanol) compatible vehicles. In Illinois, this initiative is known as the State Vehicle Procurement – Biofuels Preference Statute.[56] Nebraska's Alternative Fuel Use Executive Order 05-03, issued in 2005,[57] and Iowa's Alternative Fuel Vehicle (AFV) Acquisition Requirements[58] also encourage the procurement of biofuel compatible vehicles. Furthermore, many states contain legislation that awards grants for research and infrastructure development. For example, in Iowa, the Alternative Fuel Vehicle Grant distributes grants for the "purpose of

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52. Use Tax Act, 35 ILL. COMP. STAT. 105/3-44 (2003).

53. Retailers' Occupation Tax Act, 35 ILL. COMP. STAT. 120/2-10 (2003), *available at* http://www.ilga.gov/legislation/ilcs/fulltext.asp?DocName=003501200K2-10.

54. U.S. Dept. of Energy, Incentives and Laws: State Summary, http://www.eere.energy.gov/afdc/progs/view_ind_mtx.cgi?tech/ETH/NE/0 (last visited Apr. 21, 2007); *see also* Neb. Rev. State. §§ 66-489, 66-496 (2006).

55. U.S. Dept. of Energy, Incentives and Laws: State Summary, http://www.eere.energy.gov/afdc/progs/view_ind.cgi?afdc/5237/0 (last visited Apr. 21, 2007); *see also* Iowa Code § 422.33(11)(2007).

56. U.S. Dept. of Energy, Incentives and Laws: State Summary, http://www.eere.energy.gov/afdc/progs/view_ind.cgi?afdc/5699/0 (last visited Apr. 21, 2007); *see also* 30 ILL. COMP. STAT. 500/45-60 (2007).

57. Office of the Gov. of Neb., Exec. Order No. 05-03, Use of Ethanol in State Vehicles and Use of Biodiesel in Diesel Powered Vehicles, *available at* http://www.nlc.state.ne.us/docs/pilot/pubs/eofiles/05-03.pdf.

58. U.S. Dept. of Energy, Incentives and Laws: State Summary, http://www.eere.energy.gov/afdc/progs/view_ind.cgi?afdc/5879/0; *see also* Iowa Exec. Dept., Exec. Order No. 41, *available at* http://www.eere.energy.gov/afdc/progs/view_ind.cgi?afdc/5879/0.

conducting research connected with the fuel [ethanol] or the vehicle, and not for the purchase of the vehicle itself."[59]

While each of the initiatives discussed above support the further development and use of ethanol and biodiesel, the methods of producing ethanol must be examined in order to appreciate the validity and effectiveness of the various policies developed at the federal and state level.

PART III. PRODUCTION

Section I details the main production method involved with ethanol, after which section II outlines the net energy balance issue that exists for ethanol and biodiesel.

Section I. Ethanol Production

Ethanol is defined as a "clear, colorless liquid"[60] that can be "produced from any biological feedstocks that contain appreciable amounts of sugar."[61] Since ethanol production is contingent upon the presence of simple sugars such as starch, "it works best when [it is] derived from crops that concentrate starches in their seeds."[62] This explains why 95 percent of all U.S. produced ethanol is made from corn.[63]

There are two common methods of ethanol production: dry milling and wet milling.[64] As the most common method of ethanol production in the United States, dry milling occurs when "the entire corn kernel is first ground into flour and the starch in the flour is converted to ethanol via fermentation."[65] Conversely, wet milling is "the process of separating the corn kernel into starch, protein, germ and fiber in an aqueous medium prior to fermentation."[66]

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59. Iowa Code § 214A.19 (2007).

60. U.S. Dep't. of Energy, Alternative Fuels Data Center: What is Ethanol?, http://www.eere.energy.gov/afdc/altfuel/whatis_eth.html (last visited Apr. 24, 2007).

61. U.S. Dep't. of Energy, Alternative Fuels Data Center: How is Ethanol Made?, http://www.eere.energy.gov/afdc/altfuel/eth_made.html (last visited Apr. 24, 2007).

62. Maywa Montenegro, *The Big Three: The Numbers Behind Ethanol, Cellulosic Ethanol, and Biodiesel in the U.S.*, GRIST, Dec. 4, 2006, http://grist.org/news/maindish/2006/12/04/montenegro/.

63. *Id.*

64. Nat'l. Corn-to-Ethanol Research Ctr., Frequently Asked Questions, http://www.ethanolresearch.com/about/faq.php (last visited May 20, 2007).

65. *Id.*

66. *Id.*

The dry mill ethanol production process contains six basic steps.[67] First, the corn is ground to physically prepare the feedstock so that it is more easily and quickly processed in the following steps.[68] Second, the ground corn is cooked at high temperature and pressure in order to chemically break the starch polymers into glucose molecules.[69] Third, the resulting product from the second step is allowed to ferment.[70] After fermentation, the fourth step requires the material to be "fed into a distillation column where heat is added to boil off the ethanol and separate the ethanol from the non-fermentable components . . . and water."[71] Fifth, the ethanol produced from the previous step is dehydrated through a process of distillation.[72] Finally "[a]fter distillation, the non-fermentable components of the feedstock are processed before sale."[73]

Maywa Montenegro states that the important issue within ethanol production is the fact "it can use only a relatively small portion of each plant" to make the actual fuel which leaves a lot of biomass unused and wasted.[74] In comparison, the production of biodiesel requires "new or used vegetable oils and animal fats . . . chemically reacted with an alcohol (methanol is the usual choice)," thus creating little or no waste.[75] For corn, the kernel is the active agent within the ethanol production process and the stover (leaves, stalks, and cobs) is left for waste.[76] This creates a situation where the net energy balance of different biofuels becomes a critical issue, as the next section will discuss.

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67. Scott Kohl, *Ethanol 101: Overview of Ethanol Production*, ETHANOL TODAY, Jul. 2003, at 36.

68. *Id.*

69. *Id.*

70. *Id.* at 37.

71. *Id.*

72. *Id.*

73. *Id.*

74. Maywa Montenegro, *The Big Three: The Numbers Behind Ethanol, Cellulosic Ethanol, and Biodiesel in the U.S.*, GRIST, Dec. 4, 2006, http://grist.org/news/maindish/2006/12/04/montenegro/.

75. U.S. Dep't. of Energy, Alternative Fuels Data Center: How is Biodiesel Made?, http://www.eere.energy.gov/afdc/altfuel/bio_made.html (last visited Apr. 24, 2007).

76. Susan Trulove, *New Processing Steps Promise More Economical Ethanol Production*, VIRGINIA TECH NEWS, Mar. 30, 2006, http://www.vtnews.vt.edu/story.php?relyear=2006&itemno=115.

Section II. Energy Balance of Ethanol Production

The core question surrounding corn based ethanol is whether production consumes more energy then it creates.[77] The controversy and uncertainty surrounding this question is in part a function of ethanol's complexity and "variations in data and assumptions used among [different] studies."[78]

> In June 2004, the U.S. Department of Agriculture updated its 2002 analysis of the issue and determined that the net energy balance of ethanol production [was] 1.67 to 1. (For every 100 BTUs [British Thermal Units] of energy used to make ethanol, 167 BTUs of ethanol is produced). In 2002, USDA had concluded that the ratio was 1.35 to 1.[79]

Furthermore, a 2002 Michigan State University study "found that ethanol produced from corn provided 56 percent more energy than is consumed during production (1.56 to 1)."[80]

Douglas Tiffany of the University of Minnesota attributed ethanol's energy balance to corn's "storage of solar energy in starch molecules."[81] In addition to the positive energy balance, Tiffany reported that:

> [C]orn-derived ethanol results in a six-fold displacement of liquid fuels. This means that every gallon of ethanol produced requires only one-sixth of a gallon of liquid fuels. This is due to the fact that corn production and ethanol processing utilize coal for electrical energy and natural gas for fertilizer production.[82]

Despite the findings above by the USDA, Michigan State University, and Douglas Tiffany, there has been evidence to indicate a negative energy return for ethanol production using corn and liquid fuels from biomass energy. David Pimentel of Cornell University states that "ethanol production does not enhance energy security" due to the fact that energy needed to produce ethanol is greater

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77. HOSEIN SHAPOURI, JAMES A. DUFFIELD & MICHAEL WANG, U.S. DEP'T. OF AGRIC., THE ENERGY BALANCE OF CORN ETHANOL: AN UPDATE 1 (2002), *available at* http://www.usda.gov/oce/reports/energy/aer-814.pdf.

78. *Id.* at i.

79. Nat'l. Corn Growers Ass'n., Ethanol & Energy, http://www.ncga.com/ethanol/main/energy.htm (last visited May 20, 2007).

80. *Id*.

81. Douglas G. Tiffany, The Growth of Alternative Fuels: Minnesota and U.S. Perspectives 14 (Aug. 26, 2002) (unpublished manuscript), *available at* http://www.apec.umn.edu/staff/dtiffany/tiffany.pdf.

82. *Id.*

than the energy output from its production.[83] Pimentel's study supports his claim and concludes:

> The total energy input to produce 1000 [liters] of ethanol is 8.7 million kilocalories . . . . However, 1000 [liters] of ethanol has an energy value of only 5.1 million kilocalories. Thus, there is a net energy loss of 3.6 million kilocalories per 1000 [liters] of ethanol produced. Put another way, about 70% more energy is required to produce 1000 [liters] of ethanol than the energy that actually is in the ethanol . . . .[84]

These findings were unanimously approved by many scientists such as Sparks Commodities (1990); Giampietro, Ulgiati, and Pimentel (1997); Youngquist (1997); Croysdale (2001); Fuel's Gold (2002); CalGasoline (2002); Lieberman (2002); and Hodge (2002).[85]

The discrepancy that exists between the arguments for a positive and negative balance of energy can be found within the accounted inputs of ethanol production. Pimentel states that those who argue for a positive energy balance omit some energy inputs.[86] Similarly, the United States Department of Agriculture states that those who argue for a negative energy balance "overestimate the amount of energy needed to grow corn and convert corn to ethanol."[87] Ultimately, the consensus within the scientific community supports the findings of USDA.[88] Table 2 below summarizes the argument of both parties and illustrates the accounting differences that create the polar opinions.

Table 2. Comparison of the David Pimentel and United States Department of Agriculture Results[89]

Process	Pimentel and Patzek	USDA	Difference
	Btu per Gallon of Ethanol		

83. David Pimentel, Biomass Utilization, Limits of, 2 ENCYCLOPEDIA OF PHYSICAL SCI. AND TECH. 159, 162-63, (3d ed. 2002).

84. *Id.* at 163.

85. David Pimentel, *Ethanol Fuels: Energy Balance, Economics, and Environmental Impacts are Negative*, 12 NATURAL RESOURCES RES. 127 (2003).

86. *Id.*

87. OFFICE OF THE CHIEF ECONOMIST, U.S. DEP'T. OF AGRIC., RECONCILING ALTERNATIVE ESTIMATES OF THE NET ENERGY BALANCE OF ETHANOL PRODUCED FROM CORN AND BIODIESEL PRODUCED FOR SOYBEAN OIL 1 (2005), http://www.usda.gov/oce/energy/Alternative%20Estimates.pdf [hereinafter *Energy Balance Report*].

88. Interview with Jim Pease, Professor, Virginia Tech (Feb. 16, 2007) (on file with author) [hereinafter *Interview*].

89. *Energy Balance Report, supra* note 87, at 2.

Corn Production	37,860	18,713	-19,147
Corn Transportation	4,834	2,120	-2,714
Ethanol Conversion	56,399	51,220	-5,179
Energy Input Excluding Coproducts	99,093	72,053	-27,040
Coproduct Value	6,680	26,250	19,570
Energy Input Including Coproducts	92,413	45,803	-46,610
Total Energy Output	77,011	76,330	-681
Net Energy Balance	-15,402	30,527	45,929

While corn is currently the primary source of ethanol, it is possible that more efficient sources of energy may be developed. For example, switchgrass, also called tall panic grass, is a warm-season plant that is thought by many experts as the ideal alternative to corn for cellulosic ethanol production.[90] In the 2006 State of the Union Address, President Bush pressed the need for "research in cutting-edge methods of producing ethanol, not just form corn, but from . . . switch grass."[91] Preliminary research by USDA scientists has found that switchgrass has an energy output/input ratio more than 3.5 times greater than corn ethanol.[92] Similarly, sugar feedstock such as sugar cane and sugar beets offer "more efficient" alternatives to corn based ethanol.[93] According to scientific data reported by Larry Rohter, Brazil's sugar cane ethanol yields nearly eight times as much energy as corn-based options.[94]

Aside from corn, sugar, and switchgrass based ethanol, cellulosic ethanol is another type of ethanol derived from biomass which "refers to a wide variety of plentiful materials obtained from plants—including certain forest-related resources . . . , many types of solid wood waste materials, and certain agricultural

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90. David Bransby, Bioenergy Feed Stock Info. Network, Switchgrass Profile, http://bioenergy.ornl.gov/papers/misc/switchgrass-profile.html (last visited May 20, 2007). *See also* Bernheim Aboretum & Research Forest, Kentucky's Least Wanted, http://www.bernheim.org/leastWanted.htm (last visited May 20, 2007); Bioenergy Feedstock Info. Network, Biofuels from Switchgrass: Greener Energy Pastures, http://bioenergy.ornl.gov/papers/misc/switgrs.html (last visited May 20, 2007) (discussing the many benefits of switchgrass as fuel).

91. *State of the Union, supra* note 24.

92. Hal Collins, et al., U.S. Dep't of Agric., *Biodiesel Ethanol*, http://www.ars.usda.gov/Main/docs.htm?docid=10250 (last visited May 20, 2007).

93. ENVTL. ENTREPRENEURS, DEVELOPING LOW CARBON ETHANOL FOR CALIFORNIA 1 (2006), http://www.e2.org/ext/doc/AB32BiofuelsV5.pdf.

94. Larry Rohter, *With Big Boost From Sugar Cane*, *Brazil is Satisfying Its Fuel Needs*, N.Y. TIMES, Apr. 10, 2006.

wastes (including corn stover)—as well as plants that are specifically grown as fuel for generating electricity."[95] Cellulosic ethanol may be seven to eight times more efficient in respect to corn-based ethanol's net energy balance ratio.[96] Y.H. Percival Zhang of Virginia Tech stated that "[i]f we want to produce 30 to 60 billion gallons of ethanol, which is what is needed to meet the President's goal, we have to use the entire plant, or the stover (leaves, stalks, and cobs)."[97] The technology necessary to utilize the entire plant lies in cellulosic ethanol and requires the "technologies that can break the cellulose into the sugars that are distilled to produce ethanol."[98] Unfortunately, at this point in time, such technologies are not economically viable alternatives.

PART IV. PROBLEMS & POTENTIAL IMPACTS

The use of ethanol and other biofuels will undoubtedly provide the United States an alternative to petroleum and a potential renewable source of energy for generations to come. While the previous section discussed the energy and science behind ethanol, the economics and potential impacts of this fuel will be the topic of this section.

A bushel of corn will produce 2.79 gallons of ethanol.[99] As stated earlier in this paper, the Energy Policy Act of 2005 has set a production goal of 7.5 billion gallons of ethanol by 2012.[100] As of 2006, the annual corn production in the United States was approximately 11 billion bushels.[101] Under the assumption that an average acre of land yields 146 bushels of corn[102] and that a bushel of corn can currently produce 2.8 gallons of ethanol,[103] in order to achieve the 7.5 billion gal-

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95. Allen Baker & Steven Zahniser, *Ethanol Reshapes the Corn Market*, AMBER WAVES, Apr. 2006, http://www.ers.usda.gov/AmberWaves/April06/pdf/EthanolFeatureApril06.pdf.

96. *Interview, supra* note 88.

97. Trulove, *supra* note 76.

98. Baker & Zahniser, *supra* note 95.

99. Lester R. Brown, *Distillery Demand for Grain to Fuel Cars Vastly Understated*, EARTH POLICY INST., Jan. 4, 2007, http://www.earth-policy.org/Updates/2007/Update63.htm (stating that one ton of corn equals 39.4 bushels which produces 110 gallons of ethanol).

100. Energy Policy Act of 2005, Pub. L. No. 109-58, § 1501(a)(o)(2)(B)(i), 119 Stat. 594, 1069 (2005) (amending Section 211 of the Clean Air Act (42 U.S.C. 7545)).

101. U.S. DEP'T OF AGRIC., CROP PRODUCTION 2006 SUMMARY 5 (2007), http://usda/mannlib.cornell.edu/usda/nass/CropProdSu//2000s/2007/CropProdSu-01-12-2007.pdf.

102. BARRY WARD, OHIO STATE UNIVERSITY, OHIO CROPLAND VALUES AND CASH RENTS 2005-06 (May 2006), http://aede.osu.edu/resources/docs/pdf/O5W0OWRJ-TM0K-Y99T-FBJJ2QIF808OR3A2.pdf (This figure is for average cropland in Ohio).

103. MICHAEL LADISCH & NATE MOSIER, DEPT. OF AGRIC. AND BIOLOGICAL ENG'G, PURDUE UNIVERSITY, A SNAPSHOT OF BIOFUELS IN INDIANA (Jan. 28, 2007), http://fairway.ecn.purdue.edu/~lorre/16/Biofuel%20Factsheets/snapshot.biofuels.pdf.

lon goal set forth by the Energy Policy Act of 2005, current ethanol production methods and technology will require 2.7 billion bushels of corn,[104] nearly a quarter of current production. Although this rough estimate leaves variables, such as supply and demand constant, it is certain that an increase of ethanol production will have an unpredictable impact on the corn market, which will in turn create significant repercussions upon national and world food markets.

Lester Brown, president of Washington D.C. based environmental research group Earth Policy Institute, stated that "[t]he competition for grain between the world's 800 million motorists who want to maintain their mobility and its 2 billion poorest people who are simply trying to survive is emerging as an epic issue."[105] The economic pressure created by corn's increasing demand and limited supply has already been felt around the world. Since the summer of 2006, "average corn prices have leapt to nearly $4 a bushel," [106] the highest in a decade. Due to the fact corn is the largest component of animal feed, the National Chicken Council has estimated that "ethanol demand has already increased the price of chicken by six cents per pound wholesale."[107] In Mexico, increasing corn prices have tripled or quadrupled the price of tortillas.[108] This has exposed the "country's outsize dependence on tortillas in its diet -- especially among the poor."[109] The situations within the U.S. chicken and Mexican tortilla industries illustrate the interconnectedness of the agricultural market system. According to William Lapp, the president of Advanced Economic Solutions, such a situation may foreshadow "a fairly dramatic inflation scenario for food costs."[110]

Another significant impact of ethanol revolves around the environment. Although ethanol has been praised for its ability to reduce harmful vehicle emissions, the removal of biomass for energy production intensifies soil erosion, water runoff, and soil nutrient loss. As Pimentel states, "the removal of biomass for all purposes, but most especially for energy production, threatens the integrity of the entire natural ecosystem."[111] More specifically, this environmental concern

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104. Derived from calculation based on figures above.

105. Brown, *supra* note 99.

106. *Food vs. Fuel,* BUSINESSWEEK, Feb. 5, 2007, *available at* http://www.businessweek.com/magazine/content/07_06/b4020093.htm?chan=top+news_top+news+index_top+story.

107. Press Release, Nat'l Chicken Council, Chicken Industry Issues Warning on Price Impact of Greater Demand for Ethanol (Jan. 24, 2007), http://www.nationalchickencouncil.com/pressroom/pr_detail.cfm?id=61 (quoting William P. Roenigk, senior vice president and chief economist for NCC).

108. Manuel Roig-Franzia, *A Culinary and Cultural Staple in Crisis*, WASH. POST, Jan. 27, 2007, at A01.

109. *Id*.

110. *Food vs. Fuel*, *supra* note 106.

111. Pimentel, *supra* note 83, at 168.

stems from the fear that an increase in corn farming will further stress the environment through fertilizer and pesticide runoffs, which will create eutrophication within surrounding watershed areas.[112]

In addition to the issues presented directly above, ethanol subsidies present another significant issue. From 1995 through 2005, corn producers received $51.2 billion in subsidies, which is double that received by producers of wheat, the next highest subsidy recipient, at $20.9 billion.[113] The concern is that such price supports may create a "completely artificial demand for ethanol."[114] The reason for concern lies in the fact such a condition may propel supply beyond demand which may encourage inefficiency and market distortions.[115] Such market distortions reflect surging corn prices which led the National Cattlemen's Beef Association simply to call for "a transition to a market- based approach to renewable energy production, which would help level the playing field for cattle producers and other feedgrain users."[116] Such sentiment expresses the fact that growth of the corn-based ethanol industry may have been purely "artificial," propelled by eight to eleven billion dollars in annual subsidies.[117]

In terms of problems and threats to corn based ethanol, competition or substitute products offer significant trouble to future prospects. According to Jim Pease, commercial production of economically viable cellulosic ethanol may only be three to five years away.[118] Furthermore, due to cellulosic ethanol's great efficiency and a large energy balance ratio, it represents the "biggest challenge" as a substitute and competitor to corn-based ethanol.[119] Yet, "Informa Economics analyst Jim Wiesemeyer told producers at the recent Illinois Commodities Conference that 'corn shouldn't be worried' in the near term about the drive toward biomass fuels."[120]

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112. Alice Friedman, *Peak Soil: Why Cellulosic Ethanol, Biofuels are Unsustainable and a Threat to America* (April 10, 2007), http://www.energybulletin.net/28610.html (defining eutrophication as low oxygen in bodies of water).

113. Envtl. Working Group, Farm Subsidy Database, 1995-2005, http://www.ewg.org/farm/region.php?fips=00000 (last visited May 20, 2007).

114. Gloria Lee, *Ethanol Continues to Reap Subsidy Windfall*, Taxpayers for Common Sense, June 28, 2002, http://www.c4aqe.net/IS_ETHANOL_VIABLE/Taxpayers%20for%20Common%20Sense%20BAILOUT%20WATCH%20Ethanol.htm.

115. *Interview, supra* note 88.

116. Nat'l. Cattlemen's Beef Ass'n., Renewable Fuels and Ethanol Production (2007), http://www.beefusa.org/goverenewablefuelsandethanolproduction.aspx.

117. *Interview, supra* note 88.

118. *Id.*

119. *Id.*

120. FarmWeek, *Corn's Role in Cellulosic Ethanol Appears Solid*, Dec. 6, 2006, http://farmweek.ilfb.org/viewdocument.asp?did=9774&drvid=114.

PART V. CONCLUSION

What is the answer to oil dependence? No simple answer can be given. Although many scientists, environmentalists, economists, and politicians believe that ethanol can be the savior to our energy crisis, ethanol would simply solve one problem by introducing more problems. The impact of biofuel production has not been clear, and to qualitatively and quantitatively assess this impact is not trivial. A complex multi-sectional and cross-country model will need to fulfill the task which will require dedicated efforts from the academic community. But, as "the legendary Saudi oil minister Sheik Ahmed Zaki Yamani was fond of telling his colleagues: Remember, the Stone Age didn't end because we ran out of stones."[121] Unsubsidized ethanol and some biofuels may not be market place competitive if technology and demand temper the type of fuel needed in the future.

While there is ambiguity within the subject of biofuels, a few lessons may be learned form this inquiry. First, funds need to increase in order to finance the research necessary to improve or development new technologies of biofuel production. Ethanol and other biofuels must remain economically competitive with existing fossil fuels in the absence of government supports. Second, "in trying to solve one problem – our dependence on imported oil we [must] not create a far more serious one: chaos in the world food economy."[122] The ethics and morals of a "tug-of-war between ethanol plants and food" is one that must be carefully dealt with.[123] Finally, biofuels "should be viewed not as a silver bullet, but as one of [the] many renewable fuels we will and should rely upon."[124]

In conclusion, there is no question that oil and fossil fuels are going to dominate energy use for a long time. Nothing will go wrong if the United States tries to diversify its source of energy. However, the course, extent, and speed at which such action should take place remains unclear. Further research will determine the most efficient, economical, and effective method of using bio-fuels to reduce energy dependence.

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121. Thomas L. Friedman, *The Energy Harvest,* N.Y. TIMES, Sept. 15, 2006, at A5 (Any time OPEC got a little overzealous in pushing up oil prices in the 1970's, the Saudi oil minister reminded his colleagues that high energy prices would encourage less use and substitutes).

122. Brown, *supra* note 99.

123. *Food vs. Fuel*, *supra* note 106.

124. DAVID MORRIS, INST. FOR LOCAL SELF-RELIANCE, THE CARBOHYDRATE ECONOMY, BIOFUELS AND THE NET ENERGY DEBATE 3 (2005), http://www.newrules.org/agri/netenergyresponse.pdf.