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A REVIEW OF BARRIERS TO BIOFUEL MARKET DEVELOPMENT IN THE UNITED STATES

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I. INTRODUCTION

In recent years, biofuel markets have begun a resurgence. At one time, biofuels were the only way humanity obtained useful energy, but they were almost totally displaced by fossil fuels during the last century.[1] Now, due to a range of drivers, they have begun a small but seemingly solid comeback.[2] This Article reviews the remaining barriers to full commercial success for biofuels in the United States with an emphasis on transportation fuels. While recent success has been impressive, markets for transportation biofuels are hardly "self-sustaining" in the purest sense of the concept. The author does not seek to disparage the opportunity for development of biofuel markets or for more significant penetration of biofuels into the overall transportation marketplace. Rather, the goal of this Article is to set the agenda for work remaining to be done. Additionally, this Article does not seek to conduct an evaluative comparison between emerging biofuel and fossil fuel markets and industries because they are so different that any such comparative rating would be both fruitless and misleading.

This Article starts by framing the elements, reminding the reader of the broad range of feedstocks, conversion technologies, fuels, and uses that make up the biofuel industry. A brief review of the drivers for biofuels follows. From there, the author describes nine distinct categories of market barriers facing biofuels. In conclusion, these barriers are mapped to a typical value-chain model to illustrate the breadth of the barriers across the potential biofuels enterprise. The Article then closes by offering a few closing ideas as food for further thought on the relationships between the key benefits of developing and using biofuels and the ultimate challenges that face market growth.

II. BIOFUELS: WHAT ARE WE TALKING ABOUT?

Broadly speaking, biofuels are any fuels derived from recently formed organic material.[3] Biofuels can be distinguished from fossil fuels simply by the time needed for them to reach their usable state and by the years required to replenish them by natural growth.[4] Biofuel feedstock sources fall into four major categories—forestry, farming, livestock management,

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1. *See* Energy Info. Admin., Energy in the United States: 1635–2000, http://www.eia.doe.gov/emeu/aer/eh/frame.html (asserting that virtually all commercial energy sources in the United States were renewable prior to 1700) (last visited Mar. 10, 2008).

2. *See* Press Release, Int'l Energy Agency, Renewable Energy – Markets and Policy Trends in IEA Countries (June 1, 2004), http://www.iea.org/Textbase/press/pressdetail.asp?Press_REL_ID=128; *see also* JOEL MAKOWER, RON PERNICK & CLINT WILDER, CLEAN ENERGY TRENDS 2007 9–10 (2007) (discussing recent efforts at innovation in the field of biofuel energy production).

3. U.S. Dep't of Energy, Biomass Program: Biomass FAQs, http://www1.eere.energy.gov/biomass/biomass_basics_faqs.html (last visited Mar. 10, 2008).

4. *Id*.

and human activity.[5] They can be converted (economically or not) by physical, chemical, or biological processes into solid, gaseous, or liquid fuels. These fuels can then be used in a wide array of systems to provide useful energy for the production of heat, electricity, and transportation services.[6]

It is important to note that as organic materials, there are several options for the utilization of biofuels and their feedstocks, as demonstrated in Figure 1 below. For example, wood can be directly burned (carbonized), gasified, pyrolyzed,[7] or converted into component elements through hydrolysis for potential fermentation or digestion processes. As such, wood can be used as a solid, gaseous, or liquid fuel for the production of heat, steam, and electricity, and as a transportation fuel.[8] The cumulative impact of market incentives drives business and, ultimately, markets toward one of these several paths. Therefore, markets are the children of a constellation of parents, including customer demand, government intervention, technology, economics, and, because we are dealing with naturally grown feedstocks, the availability of fuel.[9]

Because of the relatively small size of biofuel markets, there are many markets emerging simultaneously, each driven by its own unique characteristics.[10] For example, corn ethanol is enjoying rapid growth under the aegis of strong government incentives and a well-established feedstock infrastructure in the American Midwest.[11] In contrast, in Hawaii, it makes greater sense to anticipate sugar cane ethanol developing into a viable market with the help of government incentives.[12]

Due to the number of diverse markets, any analysis within the confines of a short article must be general. While the broad contours of the assertions herein remain valid at that level, both subtle and obvious differences are likely to arise upon closer examination of any particular pathway. Likewise, an instrument of policy or attribute of customer

5. U.S. Dep't of Energy, Biomass Program: Biomass Feedstocks, http://www1.eere.energy.gov/biomass/biomass_feedstocks.html (last visited Mar. 10, 2008).

6. *Id*.

7. Pyrolysis is defined as a chemical change brought about by the action of heat.

8. *See* ASIA-PACIFIC ECONOMIC CORP., FUTURE FUELS FOR THE APEC REGIONS – AN INTEGRATED TECHNOLOGY ROADMAP 69 fig.12 (2005), *available at* http://strategis.gc.ca/epic/site/trm-crt.nsf/vwapj/future_fuels-carburants_avenir_eng.pdf/$file/future_fuels-carburants_avenir_eng.pdf.

9. *See generally* Stephan Slingerland & Lucia Van Geus, *Drivers for an International Biofuels Market* 6–11 (Discussion Paper, Dec. 9, 2005), *available at* http://www.nbiz.nl/publications/2005/20051209_ciep_misc_biofuelsmarket.pdf (outlining various economic and geopolitical drivers for biofuel development).

10. *Id.* at 3-5.

11. *See* JOSEPH DIPARDO, ENERGY INFORMATION ADMIN., OUTLOOK FOR BIOMASS ETHANOL PRODUCTION AND DEMAND (2000), *available at* http://tonto.eia.doe.gov/ftproot/features/biomass.pdf (noting that "the feedstock is located in the corn-processing belt, an area that has an established infrastructure for collecting and transporting agricultural materials").

12. *See* Dan Morgan, *Brazil's Biofuel Strategy Pays off as Gas Prices Soar*, WASH. POST, June 18, 2005, at D01.

demand can be a boon to one pathway and a bane to another. For example, direct production payments or fuel standards favor the current technology leader, but often retard the development of less commercial, but potentially more efficient, technology pathways. These emerging technologies benefit far more from research funding and support.[13]

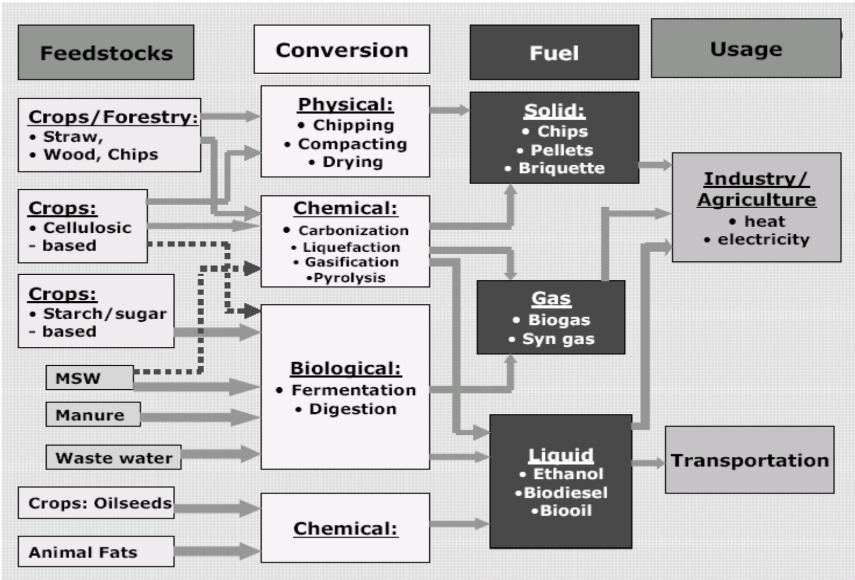

Figure 1: Foresighting Future Fuel Technology [14]

III. WHY ALTERNATIVE ENERGY?

Biofuels are one aspect of a growing tide of interest and support for development of fuels and energy resources—so called "alternative energy"—that can help meet the growing demand for energy without the burdens associated with conventional fossil fuels. Essentially, the drivers for biofuel market development are fourfold: growing demand for energy, energy security, public policy, and technology.[15]

Population and economic growth support increased demand for energy in all forms. In the United States, even though there are abundant untapped energy resources and the economy has made strides in improving energy *intensity* (the energy input per unit of economic growth),[16] system-wide subsidies for energy prices and relatively low energy tax rates have

13. *See* DIPARDO, *supra* note 11, at 14.

14. ASIA-PACIFIC ECONOMIC CORP., *supra* note 8, at 69 fig. 12.

15. *See generally* MAKOWER ET AL., *supra* note 2 (charting the growth and outlook for the clean energy sector).

16. U.S. Dep't of Energy, Highlights of the Energy Intensity Trends – Total Energy, http://intensityindicators.pnl.gov/total_highlights.stm (last visited Mar. 10, 2008).

supported growth in vehicle miles traveled ("VMT").[17] Coupled with overall decreases in fleet fuel economy for personal transportation, the trend has shown a steady growth in petroleum fuel consumption.[18] This growing demand supports markets for all fuels that are capable of helping to meet this increased need, including biofuels.[19] As the use of fossil fuels grows, so do the environmental, public health, economic, and energy security problems associated with these fuels.

The second major driver for interest in alternative energy sources and systems is generally described as an increasing need for "energy security."[20] While the term has considerable recent and widespread use, the exact conceptual contours of energy security are not clearly defined. In general, energy security seems to connote several principles well-served by alternative feedstocks and fuels, including: domestic control and production of feedstocks, technological self-sufficiency, acceptable environmental impacts (including climate change), and economic power to resist external market manipulations. In the context of such concerns, biofuels offer considerable energy security benefits.[21]

Emerging markets are always heavily influenced by public policy. This includes both the policy instruments aimed directly at the particular feedstock, conversion technology, or fuel, as well as those setting the context for conventional market leaders. For example, feedstock incentives or fuel use requirements can spur growth in biofuel markets.[22] The lack of any policy to internalize societal costs of climate change effectively subsidizes the continued use of fossil fuels and renders the inherent climate benefit of biofuels of relatively little market value.[23] Over the last several

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17. Steven E. Polzin & Xuehao Chu, *A Closer Look At Public Transportation Mode Share Trends*, 8 J. TRANSP. STAT. 41, 43 fig.2 (2005), *available at* http://www.bts.gov/publications/journal_of_transportation_and_statistics/volume_08_number_03/pdf/entire.pdf (illustrating VMT continues to grow, although the rate of growth has been consistently declining).

18. *See* ENERGY INFO. ADMIN., INT'L ENERGY OUTLOOK 2007 29 (2007), *available at* http://www.eia.doe.gov/oiaf/ieo/pdf/0484(2007).pdf (noting that certain projections shown an increase in global consumption of petroleum and other liquid fuels from 83 million barrels oil per day in 2004 to 118 million per day in 2030).

19. *Id.* at 3 (projecting that global production of "unconventional resources," including biofuels, that totaled 2.6 million barrels per day in 2004 will "increase to 10.5 million barrels per day and account for 9 percent of total world liquids supply in 2030, on an oil equivalent basis").

20. *See* ETHANOL ACROSS AMERICA, ISSUE BRIEF: ENERGY SECURITY (2005), *available at* http://www.ethanol.org/pdf/contentmgmt/Energy_Security_Issue_Brief.pdf (describing energy security as the "need to be secure in our energy in terms of the source, i.e. where it comes from, control of the flow and distribution of that energy, and having alternatives in place to allow us to withstand highs and lows associated with any commodity").

21. *Id.* at 4.

22. *See* U.S. Dep't of Energy, Biomass Program: Resources for Policymakers, http://www1.eere.energy.gov/biomass/for_policymakers.html (last visited Mar. 10, 2008) (outlining a list of existing biomass incentives).

23. *See* THE WORLD BANK, RENEWABLE ENERGY TOOL KIT – RE RATIONALE (2007), http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTENERGY/EXTRETOOLKIT/0,,conten

decades, an increasing array of local, state, and federal policy instruments have begun to create a supportive environment for the emergence of alternative energy markets, including biofuels.[24]

Finally, alternative energy markets are greatly dependent upon underlying technologies. While most of the basic processes for conversion of bio-based feedstocks are well understood, a particular biofuel can only enter the market when the technology for economic commercial manufacturing of the biofuel is broadly available. Technology development and improvement follows from market growth as sustained profits are reinvested in research and development and as markets strengthen political constituencies for government-funded research and development.[25]

IV. MARKET BARRIERS

Although the drivers of biofuel market growth are increasingly strong and apparently quite durable, a number of issues need to be addressed in order for sustained orderly markets for biofuels to emerge. Biofuel market development faces a broad range of barriers. Indeed, many elements of appropriate solutions are market pathway-specific, and mechanisms to overcome barriers are often more effectively targeted at more than one barrier. To help illustrate this point, it is instructive to review the following eight distinct categories of market barriers to biofuels that exist in the United States.

- Feedstocks
- Financial
- Industry structures
- Inadequate infrastructure
- Technology
- Laws, regulation, and political will
- Customer demand

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tMDK:20750927~menuPK:2069844~pagePK:64168445~piPK:64168309~theSitePK:1040428,00.html (indicating that "[g]iven the market distortion that environmental externalities and diversification values are not recognized in the market place as well as a series of market barriers, financial incentives are required to attract investors to achieve the economically viable optimum quantity of renewable energy").

24. *See* U.S. Dep't of Energy, Biomass Program: Federal Biomass Policy, http://www1.eere.energy.gov/biomass/federal_biomass.html (last visited Mar. 10, 2008).

25. ENERGY INFO. ADMIN., POLICIES TO PROMOTE NON-HYDRO RENEWABLE ENERGY IN THE UNITED STATES AND SELECTED COUNTRIES, 6–8 (2005), *available at* http://www.eia.doe.gov/cneaf/solar.renewables/page/non_hydro/nonhydrorenewablespaper_final.pdf#page=1.

- Public goods/private goods differences

A. Feedstocks

First and foremost, the current U.S. systems of biofuel manufacturing are heavily dependent upon the country's two dominant commodity agricultural crops: corn and soybeans.[26] As a result, biofuel market growth may be affected by the inherent risk of competition between feed and fuel uses.[27] While surplus production levels do not currently create a direct competition between food and fuel, there is the potential for competitive economic impacts. Many analysts assert that ethanol-driven demand for corn and biodiesel-driven demand for beans have already significantly raised commodity prices.[28]

Feedstock availability is also an issue for biofuel market development. Crops are produced annually, and the amount available each year is a function of acreage planted, weather conditions, competing uses, and other factors.[29] Not all feedstocks are successfully grown or produced in all regions of the country. Although these availability issues should largely dissipate as the markets for biofuels achieve scale, they still can present vexing problems in the early stages of the market.

Biotechnology offers great benefits for the economic production of biofuels. For example, genetically modified bacteria can enzymatically hydrolyze raw materials directly into liquid fuels.[30] Crops themselves can be hybridized, genetically modified, or both, in order to produce better fuel yields.[31] Farming can benefit from broader application of sustainable and scientific methodologies (so-called "precision agriculture") for improving productivity on a continuous basis.[32] However, development of these technologies is expensive and, in some cases, long-term. Despite some high-profile support for development of technologies for cellulosic

26. *See* ECON. RESEARCH SERV., AGRICULTURAL BASELINE PROJECTIONS: U.S. CROPS, 2008–2017, http://www.ers.usda.gov/Briefing/Baseline/crops.htm (last visited Mar. 10, 2008) [hereinafter AGRICULTURAL BASELINE PROJECTIONS] (discussing the effects that the future expansion of ethanol production will have on corn, soy, and other field crops).

27. *See* Steve Karnowski, *Cargill, ADM Differ on Agriculture's Priority*, ASSOCIATED PRESS, May 30, 2006, *available at* http://www.pantagraph.com/articles/2006/05/30/business/doc447c4bb68fb59785206210.txt (discussing arguments on either side of the feed versus food divide).

28. Allen Baker & Steven Zahniser, *Ethanol Reshapes the Corn Market*, 5 AMBER WAVES 66, 68–69 (2006).

29. AGRICULTURAL BASELINE PROJECTIONS, *supra* note 26.

30. *See* U.S. Dep't of Energy, Biomass Program: Enzymatic Hydrolysis, http://www1.eere.energy.gov/biomass/enzymatic_hydrolysis.html (last visited Mar. 10, 2008) (discussing the various processed involved with enzymatic hydrolysis).

31. Dave Nilles, *Maximizing Corn's Ethanol Yield*, ETHANOL PRODUCER, Aug. 2007, http://www.ethanolproducer.com/article.jsp?article_id=3168 (noting that "[f]armers will also be able to utilize the data to tailor specific corn hybrids and farming practices to maximize yield").

32. *See* ECON. RESEARCH SERVICE, PRECISION AGRICULTURE: INFORMATION TECHNOLOGY FOR IMPROVED RESOURCE USE 19–23 (1998) (providing an introduction to precision agriculture).

ethanol,[33] a coherent national agenda for the biotechnological support of biofuels has yet to emerge.

Feedstock pricing, availability, and current use patterns are significantly impacted by both domestic and international subsidy and support regimes.[34] While several recent initiatives seek to support growth of biofuels markets, there are many barriers inherent in the current systems. Grain merchants, who have profited significantly from agricultural price supports, can be resistant to rising prices for commodity crops, even if prices do encourage greater production of crops for biofuel feedstocks.[35] At both the state and federal level, conservation reserve programs are not fully rationalized for a world in which significant demand for energy crops exists. Efficiently produced ethanol from South American sugar cane faces protectionist excise taxation.[36] While some advocates see an opportunity in upcoming Congressional consideration of an omnibus Farm Bill,[37] the many interlocking and complex issues that would need to be successfully addressed suggest that existing subsidy and support-related barriers will be an issue for some time to come.

Biofuel feedstocks are inherently less energy dense than fossil fuels. That is, there is more usable energy in a pound of crude oil than in a pound of corn and more in a pound of coal than in a pound of wood.[38] As a result, in a system where the end result is an economically competitive commodity fuel like gasoline or diesel fuel, biofuel feedstocks and systems face a number of challenges. For example, biofuel production systems can be highly sensitive to transportation and feedstock gathering costs.[39] Transport and production systems have yet to be fully optimized for biobased energy feedstocks and intermediary products.

Finally, feedstock markets for biofuels have not yet matured to the point where risk can be fully managed through the use of secondary market mechanisms like hedges and derivatives.[40] As a result, entrants into the

33. *See* Press Release, Dep't of Energy, DOE Selects Six Cellulosic Ethanol Plants for Up to $385 Million in Federal Funding (Feb. 28, 2007), http://www.doe.gov/news/4827.htm.

34. INT'L FOOD & AGRIC. TRADE POLICY COUNCIL, WTO DISCIPLINES AND BIOFUELS: OPPORTUNITIES AND CONSTRAINTS IN THE CREATION OF A GLOBAL MARKETPLACE 15, 16 (2006), *available at* http://www.agritrade.org/Publications/DiscussionPapers/WTO_Disciplines_Biofuels.pdf.

35. Karnowski, *supra* note 27.

36. Anna Gangadharan & Albert Larcadas, *U.S. Lifting of Tariff on Brazil Ethanol Might Spell Trouble for Amazon and Sugarcane Cutters*, BRAZZIL MAGAZINE, August 2007, *available at* http://brazzilfile.com/index2.php?option=com_content&do_pdf=1&id=9960.

37. *See* Press Release, H. Comm. On Agric., 110th Cong., U.S. House of Representatives Passes Historic Farm Bill (July 27, 2007), http://agriculture.house.gov./list/press/agriculture_dem/pr_072707_FarmBillPassesHouse.html.

38. Bioenergy Feedstock Information Network, Biomass Conversion Factors, http://bioenergy.ornl.gov/papers/misc/energy_conv.html (last visited Mar. 10, 2008).

39. This would be especially true for "next generation" biofuels from cellulosic feedstocks. *See* Helen H. Jensen & Bruce A. Babcock, *Do Biofuels Mean Inexpensive Food Is a Thing of the Past?*, 13 IOWA AGRIC. REV. 4–5 (2007).

40. Anuj Gangahar, *U.S. Sees Mileage In Biodiesel*, FIN. TIMES, Feb. 7, 2007, at 39.

fuel manufacturing segment of the market face not only a fuel price volatility risk, but also an underlying risk associated with the prices for key feedstock inputs. To the extent that these price risks remain unmanageable, market entrants face a risk not experienced in the more developed markets, like those for natural gas, petroleum diesel, or gasoline.

B. Technology

The technologies underpinning biofuel conversion and use also create barriers to the rapid development of commercial markets. Processing plants often require generations of development to reach acceptable performance levels, as has been the case with corn ethanol plants.[41] New technologies or improvements in technologies take time to be effectively distributed throughout the marketplace and often require extensive practical demonstration before their track records become acceptable to investors and users alike.[42] Uneven public and private support for research and development can delay the orderly sustainable development of new technologies.[43] Finally, as discussed above, rapid technological evolution has the potential to quickly render obsolete prior investments.

C. Financial Barriers

Biofuel markets face a number of financial barriers as well.[44] These include barriers associated with the capital intensity of the industry, lag times between investment and return, technological risk, and the relative lack of experience among investors and advisors.[45]

In order to reach economies of scale in operations, biofuel conversion and production facilities must be sized appropriately.[46] While the biofuel industry is not necessarily more capital intensive than its conventional fossil fuel counterparts, the financial community sees biofuel markets as new and highly dependent upon policy mechanisms which make the

41. *See* NAT'L RENEWABLE ENERGY LABORATORY, ETHANOL: SEPARATING FACT FROM FICTION (1999), *available at* http://www.cleanairchoice.org/outdoor/PDF/Ethanol_SeparatingFactFromFiction.pdf; JOHN WHIMS, AGRIC. MARKETING RESOURCE CENTER, CORN BASED ETHANOL COSTS AND MARGINS (2002), *available at* http://www.agmrc.org/NR/rdonlyres/AA5DBE03-C649-4679-8A29-BCA18E376F2D/0/ksueth1.pdf (providing a detailed treatment of corn ethanol production technologies and costs); RICK SELLERS, INT'L ENERGY AGENCY, RENEWABLE ENERGY MARKETS: PAST AND FUTURE TRENDS (2005), *available at* http://www.iea.org/Textbase/work/2005/Biofuels/Biofuels_Sellers_Paper.pdf.

42. *See* SELLERS, *supra* note 41.

43. *See* INT'L ENERGY AGENCY, RENEWABLE ENERGY: MARKET & POLICY TRENDS IN IEA COUNTRIES 53–60 (2004) (providing an overview of renewables research and development funding in IEA countries).

44. SUSTAINABLE ENERGY FIN. INITIATIVE, SCOPING STUDY ON FINANCIAL RISK MANAGEMENT INSTRUMENTS FOR RENEWABLE ENERGY PROJECTS 29 (2005), *available at* http://www.uneptie.org/energy/projects/frmi/doc/Reference%20doc-RE%20risk%20study.pdf.

45. *Id.*

46. *See id.*

biofuel markets more risky.[47] This added risk translates into a higher cost of capital and a market-development barrier.

Investors in biofuel facilities also face potentially longer lead times between investment and return.[48] Managers of new enterprises in the biofuel sector must be prepared to deal with a wider range of issues than conventional energy counterparts. For example, biodiesel manufacturers may have to deal with the absence of clear precedent and their own inexperience in dealing with regulatory agencies;[49] lack of confidence among customers;[50] or other issues associated with emerging markets. All of these issues could potentially extend the time frame between investment of capital and any ultimate return on that investment.[51]

Financial markets charge a premium for technological risk.[52] Although the basic concepts behind the conversion of biobased feedstocks into usable fuels are well known, the technologies and systems for their cost-effective implementation on a commercial scale are somewhat novel.[53] Moreover, because technologies and systems continue to evolve, there is a risk of relatively rapid technological obsolescence that also must be factored into financing of commercial biofuel facilities and businesses.[54]

Lastly, biofuel market entrants often face a lack of direct experience with financial investors and advisors.[55] This lack of experience translates into delay, additional process, requirements for more supporting information, and other factors that act as barriers to the development of biofuel markets.[56] Again, these barriers are likely to decrease as markets grow and financial community members gain comfort and familiarity.[57] Specialization among members of the financial community will also help in confronting the rapid technological evolution in the sector.[58]

D. Industry Structures

Mature energy sectors enjoy relatively efficient integration between segments of their respective value chains.[59] Biofuel markets do not yet enjoy such integration, and as a result, transactions between and among

47. *Id.* at 20.
48. *Id.* at 29.
49. SUSTAINABLE ENERGY FIN. INITIATIVE, *supra* note 44, at 34.
50. *Id.* at 18.
51. *Id.* at 29.
52. *Id.* at 35.
53. *Id.* at 76.
54. *Id.* at 23.
55. *See* MAKOWER ET AL., *supra* note 2, at 2.
56. *See id.* at 9.
57. *See id.*
58. *See id.* at 2.
59. *See* RHONDA R. LUMMUS, SUPPLY CHAIN OPTIONS FOR BIOBASED BUSINESSES 33–34 (2004), *available at* http://www.leopold.iastate.edu/research/grants/files/2004-M13_supplychain.pdf.

segments are not as efficient as they will be when the businesses reach full maturity.[60] The relative immaturity of the biofuel industry also means that instruments and mechanisms present in conventional energy systems are not yet fully developed, well understood, or highly standardized in the biofuel industry.[61] A fairly typical example relates to standard contracts for renewable energy attributes.[62] A standard contract for renewable energy credits was only developed in the last few years.[63] Also, many issues relating to ownership, contract liquidity, transfer of title, and other aspects of a mature industry structure remain undeveloped.[64]

In addition, biofuel industry structures are, in many cases, typified by a great number of relatively small players.[65] While this is both typical of, and appropriate to, the rapid expansion stage of new markets based on rapid technological evolution, it also imposes inefficiencies on transactions which can act as significant barriers to rapid market growth.[66]

E. Inadequate Infrastructure

Biofuel markets cannot fully displace conventional fuel markets in the near- or even mid-term.[67] While these new markets must depend on existing infrastructure to a large extent, they also need new infrastructure investment.[68] Consider the case of E85 or B50 biodiesel sold at retail for personal or small commercial markets.[69] Moving fuel from a production facility into the fuel tank of a personal or commercial vehicle requires investment in infrastructure for blending, transport, storage, and retailing.[70] These infrastructure requirements give rise to several barriers to development of biofuel markets.[71]

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60. *Id.*

61. *Id.*

62. *See e.g.*, AMERICAN COUNCIL ON RENEWABLE ENERGY, ET AL., MASTER RENEWABLE ENERGY CERTIFICATE PURCHASE AND SALE AGREEMENT iv, *available at* http://www.acore.org/pdfs/ABA_EMA_ACORE_Master_RECs_Agreement.pdf.

63. *Id.*

64. *Id.*

65. MAKOWER ET AL., *supra* note 2 at 2.

66. *See id.* at 16.

67. U.S. DEP'T OF ENERGY & U.S. DEP'T OF AGRIC., BIOMASS AS FEEDSTOCK FOR A BIOENERGY AND BIOPRODUCTS INDUSTRY: THE TECHNICAL FEASIBILITY OF A BILLION-TON ANNUAL SUPPLY 1 (2005) [hereinafter BIOMASS AS FEEDSTOCK FOR A BIOENERGY AND BIOPRODUCTS INDUSTRY], *available at* http://www1.eere.energy.gov/biomass/pdfs/final_billionton_vision_report2.pdf (investigating "whether the land resources of the United States have the potential to produce a sustainable supply of biomass that can displace 30 percent of the country's current petroleum consumption").

68. *Id.* at 11.

69. *See* LARA MOURA ET AL., INTELLIGENT ENERGY EUROPE, PROCURA – MANUAL FOR INFRASTRUCTURE DEVELOPMENT FOR AFVS 6–7 (2006), *available at* http://www.procura-fleets.eu/Documents/2.2%20Manual%20for%20infrastructure%20development%20for% 20AFVs.pdf.

70. *Id.*

71. BIOMASS AS FEEDSTOCK FOR A BIOENERGY AND BIOPRODUCTS INDUSTRY, *supra* note 67, at

First, the ability to justify large infrastructure investments is dependent on economies of scale.[72] A new E85 pump at a local gasoline station requires sufficient E85-capable ("flex-fuel") vehicles to return the investment for the station's new tanks, lines, and dispensing equipment.[73] An obvious "chicken and egg" dilemma arises: consumers are less likely to purchase flex-fuel vehicles if they do not believe the fuel will be widely available.

Therefore, the requirement for investment in supporting infrastructure also implies problems of free-drivers (initial infrastructure investors) and free-riders (subsequent market entrants).[74] This inefficiency characteristic of newly developing markets reinforces barriers to the biofuel markets' ability to rapidly achieve commercial scale.[75] The primary effect of this inefficiency is a delay of investments in necessary infrastructure.[76] For example, the first biofuel retailer must be served by a distributor who must make investments in blending, storage, and transportation.[77] Subsequent retailers then receive the benefit of this installed infrastructure and encounter fewer barriers when they decide to enter the market, provided that the market is not saturated.[78]

Infrastructure investments are also dependent on subsidiary markets for skilled labor, supplies, parts, and other supporting functions.[79] Organizing and supporting these subsidiary markets require scale and volume not yet fully present in all biofuel markets.[80] The lack of mature supply chains for some biofuel markets, like corn ethanol and, increasingly, soy biodiesel, is being ameliorated by rapid growth in these markets.[81] To achieve more significant market penetrations of biofuels, especially with technologies like cellulosic ethanol, much more growth in these subsidiary markets will be required.[82]

Markets are also served by policy infrastructure. As markets mature, this policy infrastructure becomes more effectively adapted to support orderly conduct and development of the market.[83] Because biofuel markets

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xvi.

72. *See* Natural Resources Defense Council, Move Over, Gasoline: Here Come Biofuels, http://www.nrdc.org/air/transportation/biofuels.asp (last visited Mar. 10, 2008).

73. *Id.*

74. *See id.*

75. *See id.*

76. *See id.*

77. *See* BIOMASS AS FEEDSTOCK FOR A BIOENERGY AND BIOPRODUCTS INDUSTRY, *supra* note 67, at xvi.

78. *See id.*

79. *Id.* at 35–36.

80. *See id.*

81. *See* LUMMUS, *supra* note 59, at 9.

82. *See* BIOMASS AS FEEDSTOCK FOR A BIOENERGY AND BIOPRODUCTS INDUSTRY, *supra* note 67, at 35–36.

83. Natural Resources Defense Council, *supra* note 72.

are relatively immature, albeit growing rapidly, policy mechanisms have not yet been fully adapted and, in some cases, are unsupportive of these markets.[84] For example, biodiesel fuels are not technically a distillate like petroleum diesel and, therefore, may not be within the jurisdiction of air regulators whose authority is related to distillate fuels.[85] This can delay or prevent the regulatory acceptance of biodiesel as a permitted motor fuel, regardless of the actual performance of the fuel in engines.

F. Laws, Regulations, and Political Will

Laws and regulations relating to biofuels are immature[86] and not well adapted to a world in which biofuels are a major part of transportation fuel markets. In some cases, the laws are actually inimical to biofuel market growth.[87] Storage, transportation, and dispensing rules for petroleum distillates may be inappropriate for biobased transportation fuels. While the former carry significant health and environmental risks—consider benzene in gasoline[88]—biofuels may warrant less stringent regulation due to inherently safer characteristics.[89] One regulatory barrier includes inconsistency in treatment between jurisdictions.[90] In some cases, regulators and policy makers may not have the resources or interest to deal with issues relating to extremely small market players.[91] Legacy issues relating to early market introductions—for example, variation in fuel quality prior to widespread adoption of standards—may result in extraordinary burdens for new generations of fuel products.[92] Policy incentives, such as investment or production tax credits, may have a lifetime much shorter than required to support full market commercialization.[93] Finally, the reactive nature of such law and policy

84. *See id.*

85. This was an issue in Texas in relation to low-emissions diesel regulations. *See* Stephen Lacey, *Texas Biodiesel Ban Delayed*, RENEWABLEENERGYACCESS.COM, Jan. 8, 2007, http://www.renewableenergyaccess.com/rea/news/story?id=47033.

86. SUSTAINABLE ENERGY FIN. INITIATIVE, *supra* note 44, at 23.

87. *See id.* at 127.

88. *See* Chemical Profile for Benzene, http://www.scorecard.org/chemical-profiles/summary.tcl?edf_substance_id=71-43-2 (last visited Mar. 10, 2008).

89. *See* Chemical Profile for Ethanol, http://www.scorecard.org/chemical-profiles/summary.tcl?edf_substance_id=64%2d17%2d5 (last visited Mar. 10, 2008); ANTHONY RADICH, ENERGY INFO. ADMIN., BIODIESEL PERFORMANCE, COSTS, AND USE (2004), http://www.eia.doe.gov/oiaf/analysispaper/biodiesel/index.html (noting that "the use of soybean B100 in urban transit buses reduces net carbon dioxide emissions by 78.45 percent").

90. *See* Lacey, *supra* note 85.

91. *See id.*

92. *See e.g.*, John Deere, What Does Biodiesel Mean for John Deere Engines?, http://www.deere.com/en_US/rg/infocenter/biodiesel/what_biodiesel_means/index.html (last visited Mar. 10, 2008) (discussing use of biodiesel in John Deere diesel tractor engines).

93. For a comprehensive index of state and federal incentives in the U.S, see Databases of Federal and State Incentives for Renewables & Efficiency, http://www.dsireusa.org/ (last visited Mar. 10, 2008).

may create inherent timing mismatches between the surfacing of problems and their solutions.

Closely related to legal and regulatory barriers are other obstacles associated with the lack of political will to support sustainable commercial markets for biofuels.[94] While political will can become a driving force behind new and innovative laws and regulations, the lack of political will to promote biofuel market development becomes apparent in the temporal mismatch between political and market commercialization time tables and in the lack of courage to challenge incumbent industries with mechanisms designed to spur the success of new entrants.[95]

G. Customer Demand

Markets ultimately succeed when they provide a product that customers demand. However, when it comes to biofuels, customer demand—either for the product or for the policy mechanism supporting development of biofuel markets—has not yet reached a strong and sustainable level. The barriers underlying this unformed demand may be some of the most intractable. They include a lack of general knowledge of the attributes, performance, and benefits of biofuels. In some cases, customers labor under the effects of misinformation or outdated information about biofuels.[96] The popular assumption that corn ethanol never pays its embedded energy debt is one such instance of lingering outdated information.[97] When it comes to customer demand for policy that supports biofuel markets, public apathy and a general lack of focus on the problems posed by conventional fuels constitute additional significant barriers.[98]

H. Public Goods v. Private Goods

A final category of barriers arises in relation to what we seek to accomplish from commercializing biofuels—delivering both public and private goods. The mechanisms for accomplishing each are often different and sometimes come into conflict. Private goods are maximized by reducing barriers to market entry and supporting relatively unfettered market operation.[99] For example, private actors demand the most affordable transportation services (new entrants win on price), return opportunities on new technology investments greater than those in established markets, and a gradual transformation of market leadership

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94. SUSTAINABLE ENERGY FIN. INITIATIVE, *supra* note 44, at 27.

95. *See id.* at 32.

96. *See id.*

97. *See id.*

98. *See* LUMMUS, *supra* note 59, at 9.

99. *See id.* at 20.

from one technology class to another (to allow recovery of legacy investments).[100] At the same time, the public benefits of energy security, environmental performance, economic development, and relief for rural communities may best be obtained by policies that seek to affirmatively shape opportunities for biofuels more quickly than the unfettered market would otherwise accomplish on its own.[101] The potential for conflict amongst the means of securing these worthy goals makes successfully launching sustainable biofuel markets all the more challenging.

V. MAPPING TO A SIMPLIFIED VALUE CHAIN: BIOFUELS BUSINESS VENTURES

One way to confront the range of barriers facing the successful development of biofuel markets in the United States is to map the categories of barriers to a generic value chain for biobased materials, as seen in Figure 2 below.[102] Like the value chain for manufactured products ultimately sold at retail, a biofuel business venture's value chain includes value components for:

- Feedstocks and raw materials;
- Conversion plant financing and construction;
- Product distribution;
- Infrastructure support;
- Business operations;
- Regulatory process management; and
- Customer demand.

Interestingly, mapping the barriers discussed above to this simple value chain model shows that potentially significant barriers to commercialization arise at every step of the chain. While it is beyond the scope of this paper to delve into the potential solution sets implied by this analysis, it seems clear that systematic solutions are likely to be more effective than an incremental approach to problem solving. Unfortunately, system analysis and problem solving activities are challenging for both government and business. In a real sense, the need to develop system-level strategies is the biggest barrier facing biofuel markets.

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100. *See* BIOMASS AS FEEDSTOCK FOR A BIOENERGY AND BIOPRODUCTS INDUSTRY., *supra* note 67, at xvi.

101. *See id.*

102. *See* AMERICAN COUNCIL ON RENEWABLE ENERGY, ET AL., *supra* note 62, at 51.

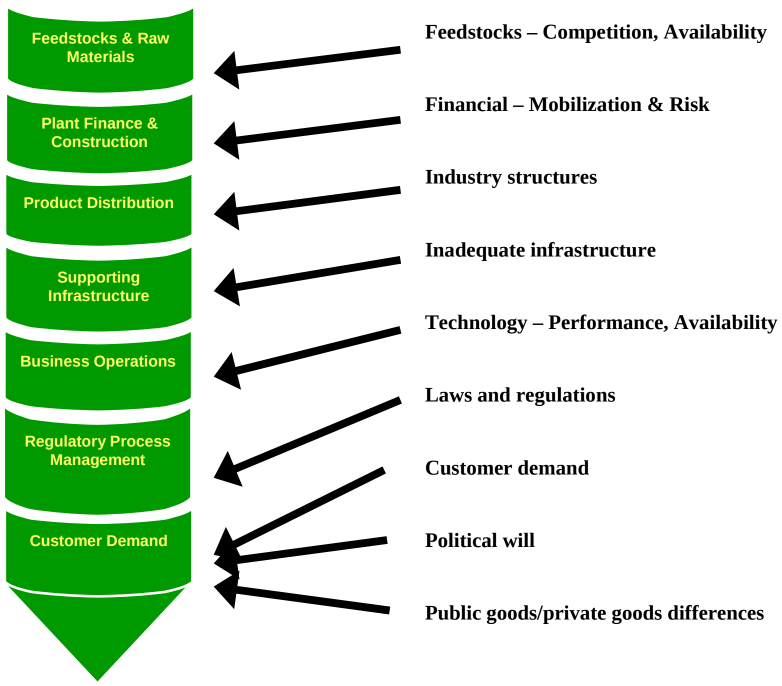

Figure 2: Value Chain: Biofuels Business Venture

VI. KEY BENEFITS HINT AT CHALLENGES

This discussion concludes with one hopefully thought-provoking final point. There is great potential benefit in the successful and sustainable commercialization of markets for biofuels in the United States and in the rest of the world. Just as the barriers facing biofuel markets occur along the entire biobased product value chain, so must our search for solutions look to a wide range of benefits offered at a systems level.[103] The point is this: it would be a mistake to pursue biofuel commercialization for any single reason, no matter how acute the issue may seem at the time. The incumbent fossil fuels industry is vast and well-established. It required decades for successful establishment and accrual of the varied benefits of fossil fuel use.[104]

The key benefits of biofuels are several, and each may be necessary. Regardless, none of these benefits are individually sufficient to support full commercialization. Moreover, each benefit, if too narrowly pursued, hints at further challenges. Climate change and greenhouse gas emissions are an

103. *See id.* at 4–7.
104. *See id.* at 2.

obvious driver for biofuel market developments. However, if climate performance is the only metric for success, it must be acknowledged that, absent a transition to cellulosic biofuels, biofuels are not necessarily the best way to reduce greenhouse gas emissions.[105] As another example, public policy incentives will likely achieve more successful and timely commercialization of biofuels if coupled with incentives for improved efficiency in transportation.[106] Ironically, improvements in fuel economy directly reduce emissions from fossil fuels use and, by themselves, could forestall investments in alternative biofuels.[107]

Likewise, while biofuels are often cited as strongly driven by energy security objectives, the concept of energy security is not well understood and remains subject to evolution over time as circumstances change.[108] In addition, while growth of the biofuel market is often seen as a boon to the agricultural sector, the near-term benefits of an additional market for surplus commodity grain may not be sustainable over high levels of market penetration by biofuels.[109] Simply put, we either will not or will not want to displace high volumes of fossil fuel use solely by growing more corn and soybeans the way we grow them today.[110]

There are additional system-level concerns relating to an incremental approach to introducing biofuels into conventional markets. While it may make sense economically to ratably increase the penetration of biofuel into transportation fuel markets—such as through a renewable fuels standard or other policy—it is not entirely clear that blending biobased products with petroleum products does not risk creating "monstrous hybrids" of biological and technical nutrients.[111] As a current example, the U.S. biodiesel blenders credit provides an incentive for biodiesel and petroleum diesel blends, provided that at least one in a thousand gallons of blended fuel is petroleum-based.[112] In other words, to earn the incentive, a blender must at least minimally-contaminate biodiesel.[113]

As a final example, consider the realm of regulated pollutants.

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105. *See* Natural Resources Defense Council, *supra* note 72.

106. *See id.*

107. *See id.*

108. ETHANOL ACROSS AMERICA, *supra* note 20, at 4.

109. *See* Giles Clark, *Template for Successful Biofuels Production Developed*, BIOFUEL REVIEW, June 7, 2007, http://www.biofuelreview.com/content/view/1023/.

110. *See id.*

111. *See* William McDonough & Michael Braungart, *Between Biology, Technology and Culture: Building a Cradle-to-Cradle Framework for the Biotech Debate*, GREEN@WORK, Nov.–Dec. 2003, http://www.mcdonough.com/writings/between_biology.htm.

112. NAT'L BIODIESEL BD., ISSUE BRIEF: BIODIESEL TAX CREDIT IMPLEMENTATION 2 (2005), *available at* http://www.biodiesel.org/news/taxincentive/Biodiesel%20Tax%20Credit%20NBB%20Issue%20Breif.pdf (noting that, for purposes of claiming the tax credit, "a 'biodiesel mixture' is a mixture of biodiesel and diesel fuel containing at least 0.1 percent (by volume) of diesel fuel. Thus, for example, a mixture of 999 gallons of biodiesel and 1 gallon of diesel fuel is a biodiesel mixture").

113. *See id.*

Biofuels typically offer a broad range of emissions benefits but must come to market in a world largely shaped by a regulatory approach focused on criteria pollutants. In some ways, biobased fuels must, among many other tasks, carry the standard for broad multi-pollutant strategies. Success for biofuel markets depends on effectively promoting a wide range of value propositions to customers and regulators in a market characterized by a customer ethos that focuses almost exclusively on a single trait, that is—price.

These benefits of biofuel market development are no less real because they are mirrored by a broad range of challenges. These markets will require additional time, effort, and investment of resources. The key point of this Article is that we would be wise to have the problems clearly recognized by utilizing a systemic "cradle to grave" value chain approach so that solutions can be systematically implemented.