Biomass, Energy, and Jobs:
Feasibility Study for an Eco-Industrial Park Anchored by an Ethanol Bio-Refinery

Final Report

Submitted by

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The final report on *Biomass, Energy,and Jobs: Feasibility Study for an Eco-Industrial Park Anchored by an Ethanol Bio-Refinery* has been prepared under the overall supervision and guidance of Leonard Mitchell, Executive Director and Deepak Bahl, Program Director, USC Center for Economic Development.

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In addition, Michael Fatigati, Consultant and Dion Jackson, Adjunct Faculty, USC Price School of Public Policy were instrumental in advising on strategic sections and shaping the final report.

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Other Attachment:

Proforma of Small Scale Biomass Gasifier (Excel file)

Introduction

Growing concerns about the economic and environmental sustainability of continued reliance on traditional energy products made from fossil fuels—such as gasoline, coal, and natural gas—for transportation and other fuels used in the United States have led to serious exploration and funding in pursuit of alternative energy sources. While the majority of energy sources will remain the traditional energy products mentioned above, development of alternative sources carries the potential to ease the economic and environmental pressures caused by increasing energy use. Alternative energy sources span many forms and methods from the well-known—solar, wind, corn ethanol, and cellulosic ethanol—to the lesser-known—methanol and biomass-based DME.

The exploration of these alternative energy sources provides opportunity for economic development in the forms of human capital, technological innovation, stronger business networks, and indirect economic activity. Other goals can also be achieved in the process of certain alternative energy pursuits. For example, the use of municipal waste, forest thinnings, and agricultural residue for the production of cellulosic ethanol can decrease the need for and cost of disposal. This report was inspired by the idea of adding value to a negative product, namely untouched forest debris that serves as potent fuel for dangerous and harmful fires during the dry months, as well as yard clippings and other municipal green waste that are converted to cheap mulch, at best, or simply stored in a landfill. There is a potential opportunity, instead, to use these resources for the production of valuable fuel. This report therefore focuses on the technological, economic, and socio-political feasibility of cellulosic ethanol production using forest thinnings and municipal green waste in Southern California and the economic development potential of that production.

Any alternative fuel faces technical, regulatory, economic, and market-related challenges on the way to its commercialization, on which this report focuses. There have been some notable failures at cellulosic ethanol commercialization, which can be analyzed and used as cautionary tales.[1] Nevertheless, the opportunities in biomass-based fuel production and the overall overview of the technologies' potential, including production of cellulosic biofuel at the pilot and

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[1] Doggett, 2011; Wall Street Journal Editors, 2011; Werkman, 2011.

demonstration scales, suggest a promising industry that can serve as part of the total efforts to reduce the negative effects of fuel consumption while creating positive economic effects.[2]

The next section of this report will elaborate on the economic, environmental, and social issues that may be ameliorated by biomass-based energy production, particularly cellulosic ethanol. After a short description of the role of the USC Center for Economic Development, the report will describe the inherent value of biomass in its potential role in the energy sector. Following that, the report will cover the current status of the technologies concerning biomass-based energy, including commercial examples at different scales, a necessary step before discussing the potential of the technologies. A discussion of the energy and ethanol market follows with considerations of supply and demand related to public policy and private market activity, as well as resource supply and pricing. Then, the report projects construction and production costs and revenues with a feasibility model using cash flow analysis. The section after that assesses the potential economic impact of pursuing cellulosic ethanol production. The report then describes biomass resource availability, particularly in southern California. We develop a model using the latest GIS technology to analyze the best opportunity sites for locating cellulosic ethanol production in the tri-county area (Los Angeles, Riverside, and San Bernardino Counties). In the following section, we provide a proforma for an eco-industrial park and finally a visualization of an eco-industrial park anchored by a biofuel facility.

Unemployment Issue

Although national unemployment has declined fairly steadily since its peak of 10.6% in January 2010, it did not reach below 9% until April 2011, and as of October 2011, it was 8.5%, double of what it was at the same time in 2006.[3] Unemployment in California in September 2011 stood at 11.4%, representing more than 2 million unemployed people. Unemployment in the Los Angeles Metropolitan Statistical Area (MSA), meanwhile, stood at 11.7%, representing over 755,000 unemployed people.[4] This means that over 36% of the unemployed workforce in California seeks work in the Los Angeles MSA. Growth in new technologies, such as converting green waste into energy products like ethanol and electricity can boost available employment in

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[2] Abengoa, Ineos, BlueFire Ethanol, Fiberight, KiOR, Mascoma, DuPont Cellulosic Ethanol.
[3] Bureau of Labor Statistics, "Labor Force Statistics from the Current Population Survey," 2011.
[4] Bureau of Labor Statistics, "Local Area Unemployment Statistics," 2011

southern California while lessening negative effects on the environment and reducing dependence on petroleum.

According to government and industry officials, the fastest-growing segment of the country's economy is now the cleantech market. Because of the strong national growth in cleantech, a region could greatly benefit from investing in green technology even if it does not yet contain a significant workforce. The establishment of an eco-industrial park, therefore, could serve as a strategy for addressing the need for employment in Southern California. In addition to creating local jobs, converting locally available biomass resources to energy can help the U.S. reduce its dependence on foreign oil, decrease costs of transportation, and reduce overall carbon emissions.

Environmental Issue

The desire to reduce negative impacts on the environment among Americans goes back at least to Rachel Carson's *Silent Spring*, published in 1962, in which Carson documented the environmentally harmful effects of agricultural pesticide use. More directly, the Climate Change Action Plan (CCAP), released in October 1993 under President Clinton, called for public/private partnerships to harness "economic forces to meet the challenges posed by the threat of global warming."[5]

Recognition that this nation's biomass resources can serve to offset use of fossil fuels is best explored in the joint 2005 USDA/USDOE publication referred to as the "Billion Ton Study" which is considered critical in moving Congress towards support of renewable energy policy measures.[6] The Billion Ton Study described the potential for the United States to produce and harvest incremental sustainable biomass resources from forests, agricultural wastes, and purpose grown energy crops without impact to existing uses. These "green" resources would serve to offset a portion of the use of fossil resources by their conversion to fuels like ethanol and electric energy.

Production of cellulosic ethanol stands as a viable method of reducing the country's carbon emissions. While corn ethanol provides some economic and social benefits, its effect on carbon emissions may be positive or negative when considering the full life-cycle process.

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[5] Clinton, 1993.
[6] Perlack et al., 2005.

Cellulosic ethanol, meanwhile, provides the benefits of corn ethanol in addition to greatly reduced life-cycle carbon emissions.

California has stepped into national prominence with:

- AB32, the California Global Warming Solutions Act, which establishes long-term goals for the reduction of greenhouse gas emissions through use of renewable fuels like ethanol, and

- The Renewable Portfolio Standard, which mandates the production of renewable electricity of up to 33% of the state's energy mix and provides for quotas in solar, hydro, geothermal, and biomass power.

Each of these policies favors the use of sustainable and renewable biomass for our energy needs using market mechanisms intended to help overcome market barriers associated with new and advanced technology.

Forest Fire Issue

Another issue facing southern California residents is the perennial danger of forest fires. Such fires are part of the natural, cyclical ecological processes in the forest, but they can spread quickly and damage much of the personal and real property located on the Wildland Urban Interface (WUI). In addition to the costs of containing and putting out the fires, higher insurance rates due to the potential for fire damage represent another cost for these residents. While preventing people from building in the WUI may serve as an alternate policy solution to this issue, it is too late for those who have invested and now live there. Green waste is already removed, per US Forest Service Policy, from the forests as a fire mitigation strategy. Redirecting this green waste to be used in the production of ethanol will decrease the costs of securing resources for the production of ethanol while simultaneously reducing the severity, cost, and danger of the forest fires.

Although forest fires serve a positive purpose in forest ecosystems, the forests of southern California have changed significantly in their density and composition. Due to these changes, the trees do not receive sufficient nutrients or water. They therefore become prone to insect

infestation, die, and dry up, turning, as Richard A. Minnich, Professor at UC Riverside specializing in biogeography and fire ecology, describes them, into "big, dry match sticks."[7]

Exceptionality of Southern California

Although the forest fire issue applies to much of California, it is especially an issue for southern California. According to the California Department of Forestry and Fire Protection (CALFIRE), Los Angeles County has the most acres qualifying as high priority landscape for preventing wildfire threats for community safety, followed by San Diego, Riverside, San Bernardino, and Orange Counties, with 51, 37, 29, 23, and 23 communities located in high-priority areas, respectively. In terms of population, the largest counties are Los Angeles, San Diego, Orange, Ventura, and San Bernardino respectively. The City of Los Angeles, moreover, contains 58 acres, with 354,000 people living therein, in high-priority areas. Out of the 20 largest California wildfires by acres burned, 11 occurred in southern California.[8] Out of the 20 largest fires by structures destroyed, 13 occurred in southern California.[9]

In addition to geographic concentration, forest fires in California have increased over time. The three largest fire years for California since 1950 have occurred since 2000. The fires of November 2008 were especially damaging. The Montecito Tea Fire lasted four days, destroyed 210 residences and damaged nine others, and forced the evacuation of 5,400 homes and 15,000 residents. During the evacuation, 13 people were injured, 10 from smoke inhalation and three from burns. The Sayre Fire lasted a week, destroyed 489 residences, and injured six people. Finally, the Freeway Complex Fire lasted 10 days, destroyed 314 residences, and injured 14. These fires, along with those in 2007, were the worst California wildfires in two decades.[10]

Moreover, indicators suggest that the costs of fire containment have increased greatly over time. While CALFIRE needed to spend more than $71 million in a single year from its emergency fund for fire suppression twice from 1979 (the first year presented in the data) to 1999, it averaged over $235 million between 1999 and 2009.[11] During the latter decade, the lowest annual suppression cost was $117 million, $10 million more than in any year prior to

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[7] Minnich, 2009.
[8] CALFIRE, "20 Largest California Wildfires (By * Acreage Burned)," 2009.
[9] CALFIRE, "20 Largest California Wildfires (By Structures Destroyed)," 2009.
[10] Dorrell, 2009.
[11] CALFIRE, "Emergency Fund Fire Suppression Expenditures," 2005; CALFIRE, "Statistics," 2010.

1999. Since the 2007 and 2008 fires were the worst in two decades, it is not surprising that in those years, expenditures were $524 and $460 million, respectively.

In terms of direct cost, the cost of fire damages has also increased over time. From 1933 to 1989, California fires caused more than $100 million (in 2009$) of damage four times, with a maximum of $145.8 million. Since 1990, fires caused more than $100 million (in 2009$) of damage 11 times, including five times over $200 million, a maximum of $1.13 billion in 2003, and $899 million in 2008.[12] The large expenditures for fire suppression and large amounts of damage could be redirected to forest waste collection, if that collection reduces the severity and costs of the fires.

Local Economic Development Efforts

The USC Center for Economic Development (CED), through studies and analyses, focuses on finding and exploring methods of promoting economic development, including methods that can simultaneously address such issues as the environmental and forest fire concerns described above. In an effort to describe these methods in detail so that they may be implemented, the USC CED releases reports such as this one. The CED's efforts focus especially on strategies aimed at reducing unemployment and increasing new business development in the local economy.

The Los Angeles Mayor's Office of Economic and Business Policy (MOEBP) also promotes economic development, though with a different approach. For example, MOEBP has designated a large industrial area just east of downtown as a cleantech cluster. In other words, MOEBP welcomes industries specializing in addressing environmental and energy issues to co-locate in this area in order to benefit mutually from the advantages of clustering effects.[13] Policy-based incentives are another method that local municipalities can employ to encourage economic development, and such policies can focus on meeting environmental and energy goals as a qualification for funding assistance to support environmentally-beneficial and cutting edge emerging technology projects.

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[12] CALFIRE, "Jurisdiction Fires, Acres, Dollar Damage, and Structures Destroyed," 2011.
[13] CleanTech Los Angeles, 2011; Porter, 1998.

Given California's leadership in clean technology, environmental sustainability is a major driver of job creation.[14] In Orange County, for example, the clean tech industry contains 200,000 jobs and 30 companies.[15] The popularity of the green sector, as environmentally-conscious industry is called, makes sense, given the synergy found therein between job creation and reducing the negative impact on the environment. Production of energy products like cellulosic ethanol and electricity, as outlined in this report, can add to that synergy—the reduction in the severity of forest fires and the provision of a less expensive automotive fuel.

The Value Proposition

As a feedstock for industry, biomass may be used for its structure (e.g., lumber, furniture, paper, etc.), its energy value, or its chemical and fuel value. This study focuses on biomass not specifically grown for its uniformity and suitability as a structural product and will therefore focus on potential uses in energy and as a feedstock for chemical production. Technology to convert biomass to electricity is considered commercial and readily available. Technology to convert biomass to fuels and chemicals is experiencing a sort of renaissance as state-of-the-art advances in chemical and biological conversion techniques are applied and approach commercialization. Any consideration of the utilization of the biomass as a feedstock to a conversion process should reflect an assessment of risk, profitability and sustainability. For example, biomass may be converted to electricity, ethanol, or diesel fuel via several viable methods. To compare the value of these potential products, one can convert their market value to a common basis which, in this case, is expressed in terms of energy content (mmBtu = million Btu's). Exhibit 1 below illustrates this conversion and comparison.

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[14] Ellis-Lamkins, 2011; Gordon et al., 2011; Green Collar Jobs Campaign; Green Jobs Act of 2007; Jones, 2010; Solis, 2010.
[15] Hsu, 2010.

Exhibit 1

Relative Values of Commodities from Biomass Conversion				
Commodity	Unit of Measure	Price/Unit	Conversion (Btu/unit)	Effective Price ($/mmBtu
Electricity	kWh	$0.10	3,412	$29.31
Ethanol	gallon	$1.83	75,700	$24.17
Diesel	gallon	$3.50	128,700	$27.20
Gasoline	gallon	$3.01	115,400	$26.08

Source: Fatigati, 2011.

It is clear from the table that the production of electricity provides the most potential revenue on a unit basis. As the relative prices of the commodities change, though, the potential revenue from converting feedstock into the commodities will likewise shift. Moreover, this table alone cannot be used to determine how much of the feedstock must be used to produce a unit of the final commodity; this depends on the specific feedstock and conversion process used.

Among the factors to consider in selecting a potential path forward is the conversion efficiency (the efficiency at which the feedstock is converted to a given commodity) of the process. The electric industry uses a metric termed 'heatrate' to illustrate the efficiency of a given facility. Heatrate is expressed in terms of Btu's supplied into the process divided by the amount of electricity produced. For example, a state-of-the-art natural gas-fired combined cycle power plant is said to have a heatrate of 6,500 Btu/kWh. The lower the heatrate, the more efficient the conversion process. According to the US Energy Information Administration, an average heatrate for the production of electricity from biomass is 13,500 Btu/kWh, and from MSW, it is 13,648.[16] Both are less than half as efficient as the natural gas unit, due largely to the solid characteristics, the moisture, and the chemical composition of the fuel, and less efficient than solar and wind sources. With the energy content of a ton of biomass, one can calculate the effective value of that resource and use that figure to help determine the best use of that resource. Exhibit 2 below illustrates the potential economic value-added of the conversion process.

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[16] Energy Information Administration, 2011.

Exhibit 2

Resource	Commodity	Conversion Efficiency	Units	Amount of Commodity Produced	Units	Price/Unit	Value Produced per Ton UWW
Relative Energy Efficiencies and Values of Commodities from Biomass Conversion							
1 ton Urban Wood Waste = 1,300 dry pounds	Electricity	13648	Btu/kWh	879.25	kWh	$0.10	$87.92
	Ethanol	45-115	gal/dry ton	29.00-75.00	gallon	$1.83	$53.00-$137.00
	Diesel	50	gal/dry ton	32.50	gallon	$3.50	$113.75
	Gasoline	50	gal/dry ton	32.50	gallon	$3.01	$97.83

Note: Resource = 1 ton of Urban Wood Waste, 35% moisture. Energy content of 1 ton Urban Wood Waste = approximately 12 mmBtu.

Source: Fatigati, 2011.

On the strength of the potential revenues provided via conversion of biomass to other products, it would seem that its conversion to liquids is most promising, given assumptions for conversion efficiency. These revenues must also be sufficient to offset costs of operation, debt service, and provide for a reasonable profit on investment. Selecting a technology must include consideration of these factors to insure sustainability of any business endeavor for which the technology is used.

Opportunities and Challenges Overview

The opportunities and support for biofuels include the large amount of biomass available in the US and in California and the public concern for creating a fuel that is cheaper and more environmentally sustainable than gasoline and would enable the US to reduce its dependence on foreign oil. In addition, the California Energy Commission (CEC) notes that venture capital has shifted from supporting IT and life sciences to the energy sector.[17] As this concern grows, the political and financial support for alternative fuels, including cellulosic ethanol, will increase. In addition to reducing carbon emissions and providing for greater domestic fuel production that may not damage the environment as much as drilling for oil, the pursuit of cellulosic ethanol is touted for its potential to create jobs and add municipal revenue. This could occur if domestic production of biofuel replaces importation of foreign oil, which it has the potential to do. By using forest residues and municipal waste, moreover, the process may also reduce the frequency and severity of forest fires (which need to occur to maintain the forests' ecological health, but

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[17] Schuetzle et al., 2007.

not as frequently or severely as they have in California, particularly in 2008 and 2009) and may slow the filling of landfills.

On the other hand, challenges to producing biofuels include the fact that the various technologies have not been proven to produce biofuel. Although some firms claim successful production at the demonstration scale, none have done so at the commercial scale. Harvesting the raw resources presents technical difficulties, such as accessing biomass in unreachable or ecologically sensitive areas, and economic difficulties, such as competition with other uses and industries, such as mulch production. Other industries may also compete with biofuel production for intermediate products, such as chemicals. Although biofuels should provide environmental benefits with reduced emissions, the environmental impacts of facility construction and fuel production may vary, so biofuel production potentially also faces environmental and regulatory barriers. As with any new technology, the physical, institutional, and market infrastructure for biofuel production are currently nonexistent or weakly developed, including production facilities, supply chains, private loans, and automobile engines that can handle alternative fuels.

These challenges can best be addressed by expanding the number and size of demonstration scale facilities to validate and improve technologies for greater efficiency and financial return. Public sector support for biofuels should avoid mandating any specific technology, instead incentivizing production and enticing private investment. In terms of technical aspects, co-location with other processes, such as electricity production or municipal waste disposal can diversify operations and reduce risk. Production ventures should also utilize best available technologies when possible, build public support, and proceed through permitting processes carefully.

Electricity Production

The production of power from biomass is well established in California. Between the years of 1980 to 1993, California placed nearly 1,000 MW of biomass power into service under the provisions of the Public Utilities Regulatory Policy (PURPA). Prior to PURPA, only a few biomass boilers were in operation. PURPA provided the market context to build the independent power producer industry. Circumstances, however, later conspired to instill uncertainty in the marketplace as fixed-price contracts for power expired, the power industry was deregulated, and

the use of cheap, natural gas became widespread. Many of the existing facilities were shut down and decommissioned. Without the federal price supports provided by PURPA, the state's beneficial use of biomass for power generation dropped from a high capacity of 800 MW from 66 power generating units to 30 units today with a capacity of 640 MW of renewable power[18].

With the issuance of Executive Order S-06-06 in 2006, market mechanisms were again emplaced to foster the development of renewable power with specific provision for the use of biomass. The Governor then released the *Biomass Energy Action Plan* in July 2006 which laid out the framework of market mechanisms intended to foster the use of biomass and other renewable sources of energy for the production of electricity.

However, with ever heightened attention on air quality and the imposition of stricter limits on air emissions, technology for the combustion of biomass has become more expensive. Feedstock costs, while stabilized following the run-up during the PURPA years, challenge the ability of older technology to be profitable even with premium rates as provided by the CEC and the CPUC for renewable power under the executive order. Newer technologies, based around gasification, promise to deliver higher production efficiencies and the potential for profitability. This paper focuses upon the potential use of the available feedstocks for ethanol production. As such, an extended discourse of biomass power plant development is beyond the scope of this study.

Biomass to Liquids Production

The conversion of sugars through fermentation is a centuries old process that creates products ranging from alcoholic beverages to fuel-ethanol. Using that process to create fuel, however, has been limited to the use of dextrose, a simple sugar obtained from sugar beets, sugar cane, and the hydrolysis of corn starch. Recently, developments in enzymes and other technology have made it feasible for the production of fuel and other chemicals from green waste, such as straws, corn stalks and cobs, grasses, sweet sorghum, recycled newspaper, wood chips, sawdust, leaves, grass clippings, and vegetable and fruit wastes.

These biomass resources can be processed using thermochemical means to reduce their composite molecular structure to basic building blocks in gaseous form, which is normally called

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[18] California Energy Commission, "Biomass Energy in California," 2010.

synthesis gas (syngas). Syngas is defined as a mixture of hydrogen and carbon monoxide which may be reacted over a catalyst from which higher valued fuels and chemicals may be derived. Typical yields of product are low and scaling up has proven difficult, indicating that costs of production are not congruent with today's markets in the absence of price supports. Work continues apace to reduce associated production costs and, simultaneously, favor the industry with policy and regulation to assist its incubation and maturation.

Centering a facility that focuses on green waste to ethanol conversion on a campus that includes complementary processes—ranging from research and development to a facility that accepts and sorts municipal solid waste to processes that utilize the byproducts of the ethanol production, such as gypsum and ash—i.e., an eco-industrial park, would maximize the environmental benefits and economic feasibility of such a facility. This study will therefore analyze the overall feasibility of creating an eco-industrial park, as described above.

As the California Energy Commission describes it, there are currently three main approaches to the processing and conversion of biomass to fuels, products, and power:

- A *biochemical* approach breaks the biomass down into sugars using either enzymatic or chemical processes and then converts the sugars to fuels like ethanol or another higher-valued chemical via fermentation.
- A *thermochemical* approach breaks the biomass down into intermediates using heat and upgrades the intermediates to fuels using a combination of heat and pressure in the presence of catalysts.
- A *thermochemical/biological hybrid* approach which uses heat to break biomass down into intermediates followed by a biological process (i.e., fermentation) to convert those intermediates into fuels and chemicals.[19]

Each of these approaches makes use of carbon which has been converted by photosynthesis into complex structures from living plants collectively referred to as "lignocellulose". Lignocellulose is comprised of three main biopolymers (cellulose, hemicellulose, and lignin) that form the structure of plant residues, woody materials, and grasses. The first two form the cell walls of plants, while the third acts similarly to glue, holding together

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[19] Schuetzle et al., 2007.

the parts of the plant cells. Of the three components, lignin has been found to be the most stable, the most resistant to conversion, and requires high heat and pressure to depolymerize. All biochemical processes focus on the conversion of cellulose and hemicellulose which are made of long chains of six- and five-carbon rings, each ring representing a sugar monomer.

Cellulose and hemicellulose molecules are similar to another sugar polymer, starch, but less cooperative. Starch requires only mild heat, a very weak acid, or inexpensive enzymes to break the long chain into individual sugar molecules. In addition to being easier to process into sugar, the starch molecule breaks down into easily digestible six-carbon sugars like dextrose. As a food source, dextrose is easily metabolized by common yeasts into ethanol; but most of the five-carbon sugars (e.g., xylitol) and some of the six-carbon sugars (e.g., arabinose, galactose) are only usable by microbes via accelerated or synthetic genetic selection and modification. The resulting microbes have so far not proven to be sufficiently robust in industrial use.

The production of ethanol from sugar (i.e., corn, sugar cane, sugar beets) via fermentation is well understood. Throughout history, the fermentation process has served to preserve food crops by converting them into a product (e.g., grapes into wine, grain into beer, and honey into mead) for easier transportation, storage, and utilization. In recent history, its energy content was recognized for its ability to provide the motive force for mechanical engines.

The Corn Dry Mill

Today's most common means of producing ethanol in the United States is the corn dry-mill. Its process has been continually refined to reduce the costs of producing ethanol. Improvements in the amount of energy required by the dry mill have been reduced from about 160,000 Btu's per gallon of ethanol produced to a rather miserly 36,000 Btu's per gallon of ethanol produced.[20, 21] The total energy balance of ethanol depends upon assumptions for the source (e.g., fossil or renewable) of the energy used for its production, transportation, and processing and is a source of controversy unrelated to energy policy and beyond the scope of this paper. However, the dry mill is notable as a cost-effective means producing ethanol and the model to which competing technologies must aspire. Exhibit 3 below illustrates the steps used in the dry-mill to process corn into ethanol.

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[20] Shapouri, Duffield, and Wang, 2002.
[21] Shapouri, Duffield, and McAloon, 2004.

Exhibit 3
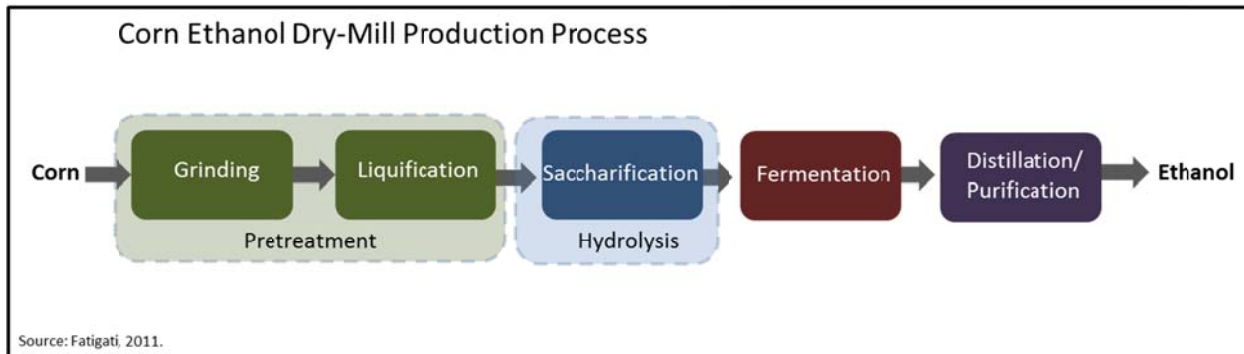
Each of the second-generation processes discussed are comparable to the dry-mill model and may be considered to have the same general four process steps: pretreatment, hydrolysis, fermentation, and purification. Since the product output (i.e., ethanol) is the same, we should be aware of the parameters that impact the economics of each competing process in order to assess viability. For example, the purification of ethanol is standardized technology having capital costs and costs of operation that are readily available. Where available, these costs can be expressed on a "per-gallon" basis for comparison. For example, capital costs for a corn dry-mill average $1.50 per installed gallon of capacity (i.e., a 100 million gallon per year plant will have $150 million in capital costs).

Another example would be the amount of energy used to distill and purify ethanol from a 12% solution to 99.5% purity. The past 40 years have seen significant improvement made in the energy used to distill and purify ethanol that results in real savings from 140,000 Btu/gallon of ethanol to 36,000 Btu/gallon. Each of the alternate technologies that purport to produce ethanol would benefit from this improvement. These costs can be used to identify and compare points of incongruity between the technologies.

The dry-mill model represents the standard for ethanol production in the US today, and is responsible for almost 13 billion gallons of annual production. Any competing process must meet or improve in some way to the cost structure of the dry mill.

Biochemical Hydrolysis

In the biochemical conversion process, enzymes or acid are used to break down the long chains of sugars forming the complexly structured cell walls (Exhibit 4). Once broken down, the sugars can be converted into biofuels through fermentation. Research and development to

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improve the biochemical conversion process focus on reducing processing and capital costs, improving the efficiency and selectivity of enzymes that breakdown the cellulose and hemicellulose polymers to their individual sugar monomers, reducing the cost per gallon of ethanol produced, improving the efficiency of the pretreatment of cellulosic biomass, finding or creating and using more efficient enzymes, and finding more robust microorganisms for the fermentation stage of the process.[22]

Exhibit 4

Biochemical Ethanol Production Process
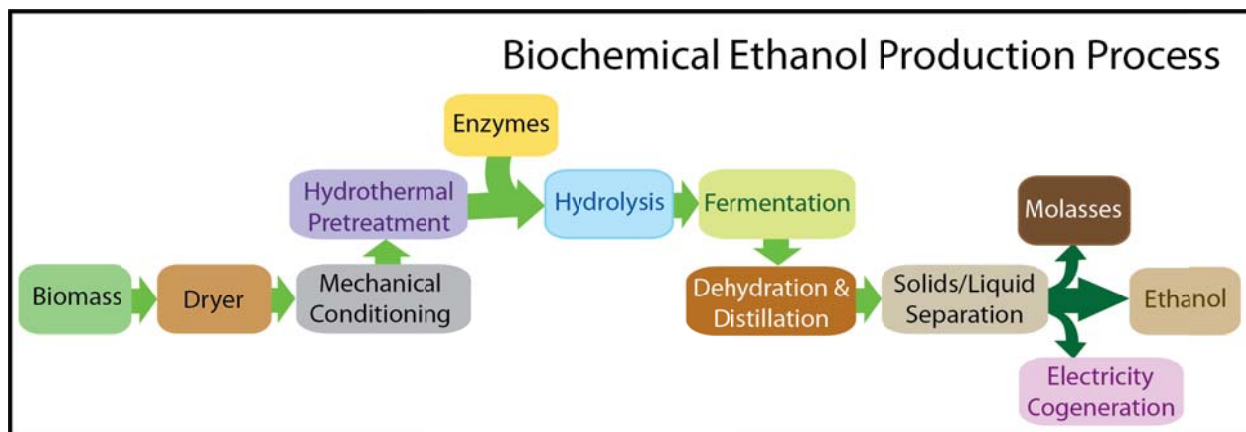
The biochemical process, whether reliant upon acid or enzymes, shares the need (a) to ferment sugars to ethanol and (b) to purify the final product with the corn dry mill. The common process areas that are shared between the two processes represent commonalities of production cost. If the fermentation and purification steps are similar to each other, then it seems reasonable that expectations for the cost structure of the biochemical conversion process must be somehow superior to that of the dry mill to achieve parity in the marketplace.

Thermochemical Production

Thermochemical conversion uses heat and pressure in gasification to convert biomass into syngas (Exhibit 5). A product-specific catalyst is then added to turn the syngas into liquid fuels. The thermochemical approach is more flexible than the biochemical approach in the feedstock that it can use and in its potential yield rate efficiency, but it is a less-proven and newer

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[22] Department of Energy Office of Energy Efficiency & Renewable Energy, "Biochemical Conversion," 2011.

technology than the biochemical approach (humans have used fermentation for millennia).[23] The thermochemical process therefore still requires demonstration of reliable reactor operation, development of improved catalysts for liquid fuel production, and refinement of efficient gas cleaning technologies.[24] The California Energy Commission suggests that thermochemical conversion is the most promising technology for cellulosic ethanol production.[25]

Exhibit 5

Thermochemical Ethanol Production Process
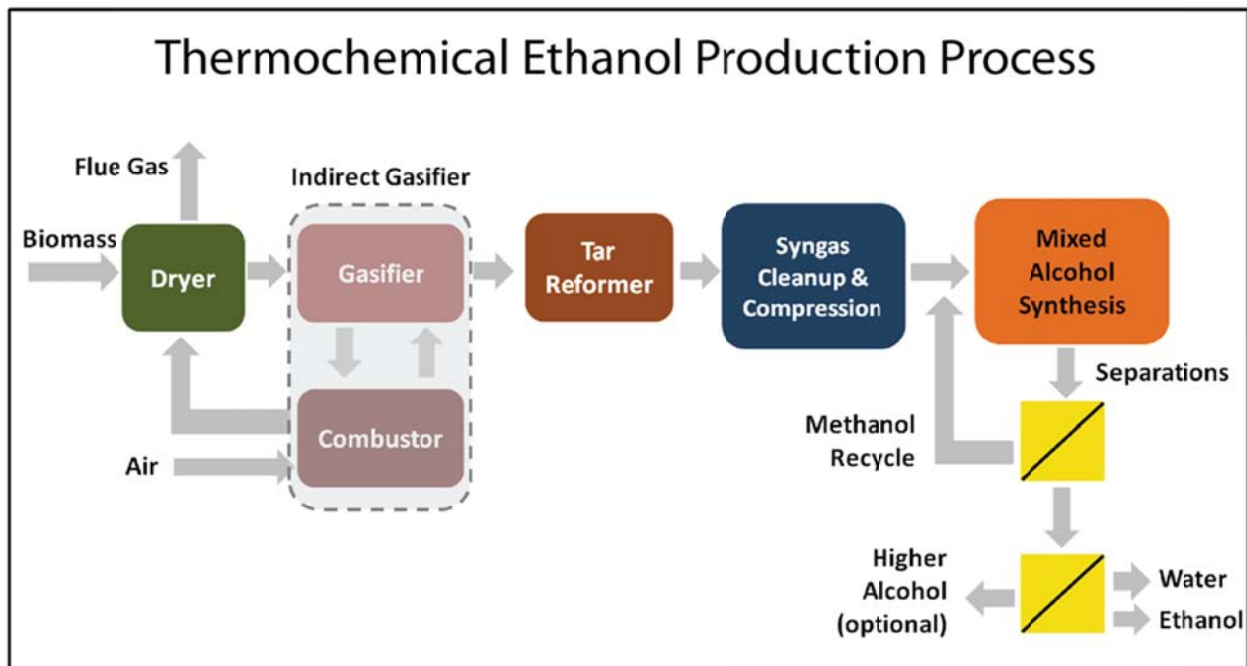
The thermochemical conversion process for ethanol production still seems to be a largely unproven option. The largest plan for a facility to use thermochemical conversion is that of Range Fuels in Soperton, Georgia, which Range Fuels projected to produce 20 million gallons of ethanol annually from woody biomass and forest residues and thinnings. After receiving a $76 million grant from the DOE in March 2007, a $6 million grant from the state of Georgia, and with $158 million in venture capital investment, the Range Fuels facility has failed to produce

[23] National Renewable Energy Laboratory, 2007.
[24] Department of Energy Office of Energy Efficiency & Renewable Energy, "Using Heat and Chemistry to Make Fuels and Power: Thermochemical Conversion," 2010.
[25] Schuetzle et al., 2007.

any cellulosic ethanol. Instead, Range Fuels produced four million gallons of methanol, "a biofuel that others have been making in quantity for decades."[26]

It should be noted that liquids (diesel and gasoline) production from low rank coals, a feedstock similar to biomass, has been commercialized around the world and is represented by such world class companies as Sasol. It is generally accepted that large scale facilities are required to achieve desired economics; such facilities are easily 10x the scale considered for the largest biomass thermochemical plants.

Hybrid Bio/Thermo Technology

Hybrid technologies which utilize the thermochemical conversion of biomass to its simplest building blocks (CO, H_2) have been demonstrated by Ineos and Coskata where the resulting gas is fed to a bioreactor (using a "biocatalyst") for conversion to ethanol. Both Ineos and Coskata have announced projects and have applied to the US loan guarantee program for support in their efforts to develop and construct technology at commercial scale.

Alternate chemical pathways avoid the co-production of CO_2 during the fermentation pathway, instead directing most of the incoming carbon to ethanol production.

Comparison to Corn Dry Mill

It is useful to estimate the potential profitability of a cellulosic ethanol plant as compared to a corn ethanol dry mill by comparing unit costs and performance as published in the public domain, extracting figures for capital expense, labor, and operating expense against figures available for the well documented dry mill. Exact costs and performance estimates are known only to purveyors of the technology. But using figures found in the literature provides reasonable estimates and useful information to determine the impact of capital and feedstock cost on potential profitability, the relative fermentation efficiency of a microbe in the dry mill, and other vital questions related to cellulosic ethanol production. It becomes possible to list what is known and lump into an unknown other associated costs of operation, solving for the unknown and comparing results for profitability.

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[26] Wall Street Journal Editors, 2011.

Exhibit 6 below demonstrates such a comparison, focusing on the impact of the amount of energy required to remove water assuming that the titer of a lignocellulosic fermentation is limited to 10% (due to the inability of the microbe to tolerate higher concentrations of ethanol) as compared to the titer commonly found at a dry mill of about 15%. Other assumptions used in the calculation are listed in Exhibit 7.

Exhibit 6

Cost Comparison of Corn Dry Mill and Cellulosic Ethanol Production						
Dry Mill Production per Gallon			Cellulosic Ethanol Production per Gallon			
Dry Mill	(per unit)			Enzymatic	(per unit)	
Revenue	$2.55	EtOH		*Revenue*	$2.55	EtOH
	$0.26	WDGS			$0.06	Lignin
Expenses			*Expenses*			
Feedstock	$2.66		Feedstock		$1.32	
Capital recovery	$0.20		Capital recovery		$0.80	
Interest on capital	$0.02		Interest on capital		$0.08	
Enzymes	$0.05		Enzymes		$0.50	
Energy for distillation	$0.40		Energy for distillation		$0.63	
Operations and maintenance	x		Operations and maintenance		y	
Profit	$0.38		Profit		$0.38	

$$3.71 + x = \$2.81 \qquad\qquad 3.72 + y = \$2.61$$
$$x = \$ (0.89) \qquad\qquad y = \$ 1.11$$

$$delta = \$ 0.21*$$
$$-24\%$$

*Note: Delta value > 0 indicates cost advantage to corn dry mill.

Source: Fatigati, 2011.

Exhibit 7

Assumptions	
Value	Variable
$2.55 per gallon EtOH	
15% profit margin	
$7.60 per bushel corn	
2.86 gallons EtOH/bushel corn	
30.31 gallons/ton lignocellulosic feedstock	
$40.00 per ton lignocellulosic feedstock	
10% interest on capital	
$8.00 capital cost per gallon EtOH capacity, cellulosic ethanol	
$2.00 capital cost per gallon EtOH capacity, 100 million gallon per year EtOH dry mill	
10 years amortization on loan	
$0.05 enzyme cost per gallon, dry mil	
$0.50 enzyme cost per gallon, cellulosic ethanol	
$80.00 per ton wet distillers grains with solubles	
$15.00 per ton lignin (coal)	
$8.00 per mmBtu, effective energy cost	
15% fermentation titer, dry mill	
10% fermentation titer, enzymatic	

Source: Fatigati, 2011.

In this specific model, we see that by accounting for feedstock pricing differences, capital cost differences, production efficiency differences, and so on, the impact of ethanol tolerance between the dry mill and the cellulosic ethanol processes is about 23¢/gallon of ethanol produced in favor of the dry mill. This figure in itself does not provide a clear picture of profitability though it is generally revealing. The model seems to indicate that the lignocellulosic facility must perform optimally across a range of performance and cost parameters to achieve the same profitability that has evolved with the dry mill over its 40-plus years of evolution. If true, then one must compare across a range of values to gain additional information.

For example, this model can be used to compare microbe efficiency (the ability of the microbe to convert sugar into ethanol) and examine the potential impact on capital cost, again

comparing with the dry mill to determine the ability of the cellulosic ethanol plant to 'compete' against the industry standard of production. Exhibit 8 below illustrates such a comparison.

Exhibit 8
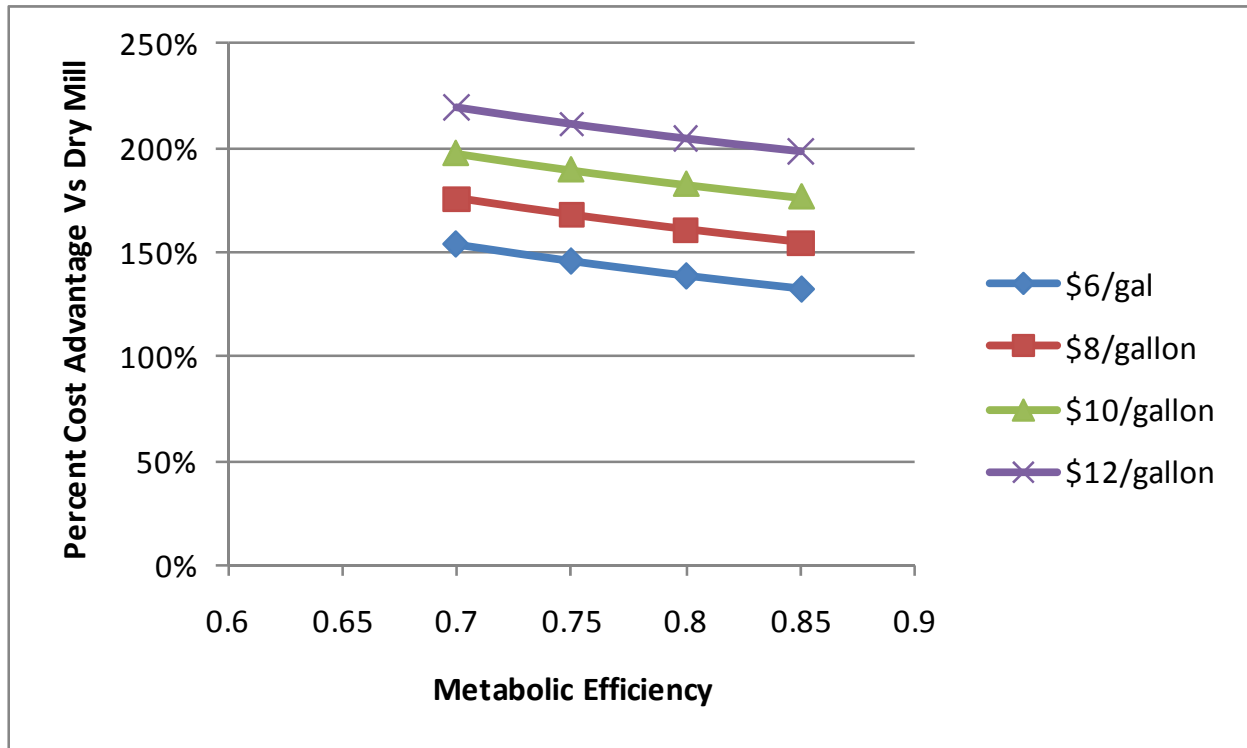
It is easily seen that improvements in the capital cost of lignocellulosic ethanol are necessary, under the set of assumptions used, to achieve parity with regard to profit against the U.S. dry mill. One of the advantages of the lignocellulosic ethanol plant is its ability to substitute inexpensive (or waste) feedstocks for corn - a cost differential that can help defray the additional costs of capital required to pretreat cellulosic feedstocks. In the graph above, corn is assumed to cost $3/bushel (1 bushel corn = 56 pounds). Lignocellulose is here assumed to cost $40/ton (2¢/lb) delivered to the site with minimal additional processing (i.e., classification, sizing) required. If we allow corn to rise to $6/bushel, the resulting graph becomes the following as represented in Exhibit 9.

Exhibit 9

Comparison of Lignocellulosic Ethanol Production to Corn Ethanol Production

A line chart plotting "Percent Cost Additional to Dry Mill" (y-axis, from -20% to 100%) against "Metabolic Efficiency" (x-axis, from 0.6 to 0.9). Four series are shown: $6/gal, $8/gallon, $10/gallon, and $12/gallon, each declining as metabolic efficiency increases.
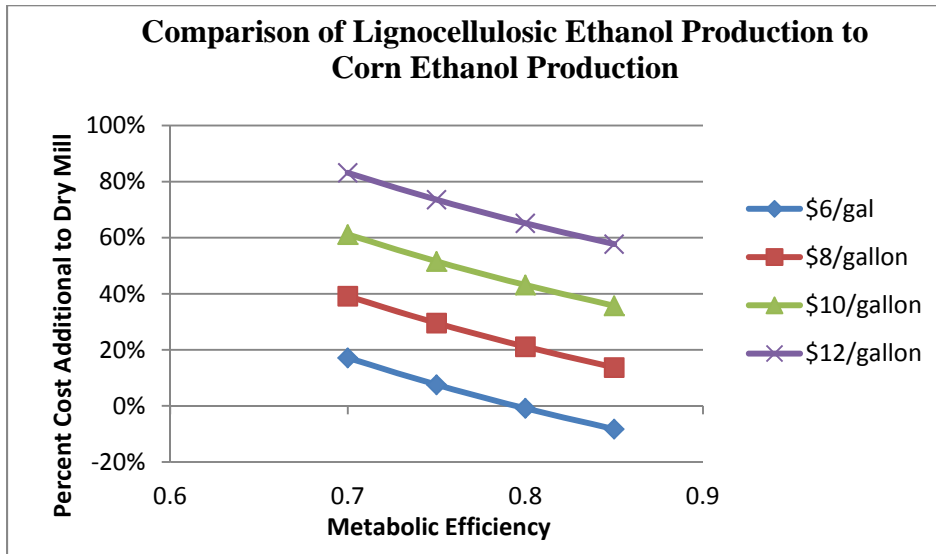
It can be seen that the advantage of a dry mill is reduced dramatically, by approximately half in this example, but still retains a significant advantage over the lignocellulosic facility except in the most favorable case for lignocellulose.

Nonetheless, supplementing green waste from municipal solid waste (MSW) would make an ethanol producing plant less "risky," making financial credit easier to obtain. Since the population in southern California has risen consistently, MSW is similarly consistent in its availability. The EPA believes that MSW and forest residue will be used in cellulosic ethanol production at a ratio of 15:1.[27] Furthermore, collocation with an MSW processing facility would decrease the negative environmental effect of the operation and the costs of securing inputs.

As a third option, raw materials for sustainable energy production as described above may also consist of dedicated crops. Growing an inedible crop that requires low energy inputs and provides relatively high ethanol yields, such as switchgrass, or using inedible parts of edible crops, such as corncob or corn stover, can provide another material for ethanol production. However, given the relative scarcity of water in Southern California, an intention to avoid effects on food production, and the higher cost of agricultural residue and switchgrass, this report focuses on using green waste from forests and from MSW.

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[27] "Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Final Rule." 40 CFR 80.

Other Biofuel Technologies

As an alternative method of producing biofuels, algae-based fuel presents some market competition for cellulosic ethanol. DOE describes two pilot facilities and one demonstration facility working with algae, most notably Algenol in Fort Myers, Florida. Algae's most promising aspect is its cheap and simple production process, but because they rely on solar exposure, algae facilities require large, flat areas for production.

Landfill to gas or electricity production also represents competition for the cellulosic ethanol industry. The simplest option for turning MSW into a source of energy is to burn it for electricity. Colmac Energy operates such a facility in Mecca, California, where it provides 47 megawatts from approximately 325,000 tons per year of wood waste, landscape and right-of-way tree trimmings, broken pallets, and used boxes. To improve its business plan, Colmac ensures that no biomass fuel stays on site for more than 30 days, thanks in part to a large drying area.

Assessment and Comparison of Biofuel Processes

Within the realm of cellulosic ethanol, firms hoping to commercialize the process use numerous different approaches. On the biochemical side, Bluefire focuses on acid hydrolysis, Verenium pursues enzymatic hydrolysis, STAKE Technology employs steam explosion, and Lignol explores solyolysis, Mascoma features consolidated bioprocessing, and POET includes anaerobic digesters. On the thermochemical side, Enerkem and Fulcrum follow gasification of biomass to catalysis to the final product, while Rentech and Sasol exercise the Fischer-Tropsch process. Coskata and Ineos, meanwhile, represent examples of the hybrid bio/thermochemical approach, and Abengoa explores both biochemical and thermochemical approaches separately.

The California Energy Commission uses its 5E assessment approach to compare thermochemical to biochemical conversion. The 5 E's are:

E1 - validation of technical performance and stage of development

E2 - estimation of energy efficiency

E3 - environmental impact assessment

E4 - economic analysis

E5 - appraisal of socio-political effectiveness.[28]

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[28] Schuetzle et al., 2007, page 3.

Using this strategy, the commission compared a) thermochemical conversion producing mixed alcohols and electricity, b) biochemical conversion producing ethanol and electricity, and c) thermochemical conversion producing electricity only. The comparison generally favors scenario "a." The thermochemical process can be implemented at a smaller-size plant and has greater efficiency than scenario "b," and it offers more opportunity for synergy than scenario "c." The CEC also recommends using the best available control technology (BACT) in order to reduce environmental impact and maximize socio-political effectiveness.[29] The comparison, however, ignores the issue of scalability—either technology, while requiring a larger scale for economic feasibility, has not been proven to be technologically ready for larger scales of production.

Real World Technology Examples

The California Energy Commission believes that the thermochemical process presents a more feasible option for commercialization. Specifically, the commission suggests that an integrated pyrolysis/steam reforming process incorporating syngas to bioalcohol and electricity co-production systems".[30] This is expected to produce an 80-85% ethanol/10-15% methanol mix, plus possibly other alcohols. "Distillation can be employed to separate ethanol from such a mixed alcohol if necessary", but it makes the process more expensive, perhaps even too expensive.[31] The CEC therefore recommends adjustments among the automotive industry and regulatory agencies to allow for these forms of mixed alcohols.[32] While it may seem unrealistic to expect the industry and regulatory agencies to adjust quickly, the example of how Flex-Fuel Vehicles were quickly developed and introduced to the market provides proof that it can be done. Furthermore, research on improving the performance of enzymes and reducing their cost, on creating new steps in the conversion process that may enhance yields and efficiencies, and on broadening the scope of what raw materials can be used effectively could change the feasibility of cellulosic ethanol production in a punctuated equilibrium type of way.

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[29] Schuetzle et al., 2007.
[30] Schuetzle et al., 2007.
[31] Schuetzle et al., 2007, page 4.
[32] Schuetzle et al., 2007.

Common stages in any biomass to biofuel conversion process include harvest and collection, handling and transportation, storage, preprocessing, the conversion of sugar to ethanol, and the distillation of ethanol.[33] Technological and other improvements in any of these stages can improve the feasibility of cellulosic ethanol production. The preprocessing stage, however, is especially critical in making cellulosic ethanol cost competitive, because it is the major difference in production between cellulosic and corn ethanol. In corn, the sugars are easily accessible for fermentation, while the sugars of biomass, as described above, require the additional step of preprocessing.

Robert Service elaborates on this additional difficulty in the August 13, 2010 issue of *Science*, claiming that

> *Breaking those biopolymers into intermediate compounds that can be converted to ethanol remains a difficult problem. Researchers call it "recalcitrance," and it currently limits brewers to converting just 40% of the energy content available in cellulosic feedstocks to ethanol. Fermentation, by contrast, converts about 90% of the energy in simple sugars to ethanol.*

The resulting need for much more feedstock to produce the same amount of ethanol, Service suggests, is the main factor holding cellulosic ethanol back.[34] Examination of case studies, particularly a few in California, would shed light on how past efforts at commercialization fared and on the status of current companies exploring commercial-scale production.

Sacramento Ethanol and Power Cogeneration Plant (SEPCO)

A joint venture between the Sacramento Municipal Utility District and a private company named Sacramento Ethanol Partners, formed specifically for the project, wanted to establish an ethanol and electricity cogeneration plant on a 90-acre tract in a northern suburb of Sacramento. Planning to produce 150 MW of natural gas fired electricity and 12 million gallons per year of ethanol from rice straw, the project was to employ the technology of Arkenol (now known as BlueFire Ethanol). The project was meant to address the issue of overabundant rice straw that could not be burned in the fields and had to be expensively disposed. In a certain respect, the

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[33] US Department of Energy Office of Energy Efficiency & Renewable Energy, "Feedstock Logistics," 2011.
[34] Service, 2010.

electricity and ethanol production processes were two separate projects sharing a site and incorporating operational synergies. A Memorandum of Understanding between the CEC, which would typically have supervised environmental approval of the natural gas pipeline and power plant, and Sacramento County, which would typically have been responsible to permit the ethanol facility, united the project in terms of regulatory approval.

In its review of the project, the CEC claims that the reason that the project, fully reviewed and permitted, did not follow through to construction and operation. Focusing on the positive aspects, the CEC states that it may have been due to complexities in the joint venture approach, a lack of technological readiness at the time (mid 1990s), or other, unstated reasons. The CEC describes the SEPCO project as a partial success, and the approach to a unified regulatory process truly provides an example that can be followed by today's parallel efforts.[35]

Gridley Ethanol Project

Also aiming to address California's rice straw disposal problem, the Gridley Ethanol Project was intended "to validate the economic production of ethanol from rice straw, acquire additional cost-share funding for the development and ultimate construction of a rice straw-to-ethanol facility, and acquire financial commitments from the private sector to design, construct, and operate a commercial ethanol production facility in the Gridley area" located in Butte County.[36] After the original private technology developer/operator, Swan Biomass, withdrew from the project, NREL decided that, given the state of the technology at the time, economic feasibility would be enhanced with cogeneration using orchard prunings and forest waste stocks.

Further development of the project showed that rice straw collection and use was problematic. Harvesting and delivery of the rice straw was estimated at over $30/bone dry ton, not including grinding and processing. This may have been due to the total lack of existing infrastructure for harvesting the rice straw. The further complication of wastewater pretreatment and discharge necessary for the project has kept it from moving past the demonstration scale as of the publication of the CEC's overview. The CEC cited the most important lessons from this project as the need for verification from the technology developer, a mismatch between public agency funding mechanisms and the process of technology development, and the extreme

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[35] Schuetzle et al., 2007.
[36] Schuetzle et al., 2007, page 14.

complexity of emerging biomass-utilizing technologies.[37] Recent news indicates that the project has run into potentially project-ending legal problems related to land acquisition and a conflict of interest among the rice straw farm-owning city council members.[38]

Collins Pine Cogeneration Facility

The third California project described here is the Collins Pine Cogeneration Project, which aimed to reduce the risk of catastrophic wildfire in the northern Sierra Nevada forests by converting forest biomass to ethanol. Assessing that biomass availability was sufficient and funded by the CEC and the US DOE, the project was going to integrate with an existing Collins Pine sawmill in Chester, California, which already produced process heat and electricity from sawmill operations. The CEC halted the project during testing of wood waste on the grounds that key participants were not fulfilling project objectives in progress and performance. The CEC reiterates from this project that technology developer claims require verification and that the economic stability of the technology developers is fragile, adding that this project at least supported the finding that California's forest residue is sufficient for cellulosic ethanol production.[39]

BlueFire Ethanol

BlueFire Ethanol provides an example of which tools to incorporate in approaching facility startup. Based in Irvine, California, the company has begun construction preparation for a cellulosic ethanol production facility in Fulton, MS, with the advantage of $81.1 million allocated for the facility as part of $564 million of Recovery Act funds invested in December of 2009 in advanced biorefinery projects.[40] For the construction of the 18-million gallon per year facility, Bluefire signed an Engineering, Procurement, and Construction contract with MasTec for $296 million[41]. For its feedstock, BlueFire agreed to a contract with Cooper, Marine, and

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[37] Schuetzle et al., 2007.
[38] Van De Hay, 2011.
[39] Schuetzle et al., 2007.
[40] Department of Energy, 2009.
[41] The figure published by Bluefire includes $100 million allocated to a co-located power plant. Thus, the figure of $196 million cost for a cellulosic ethanol plant that produces 18 million gallons of ethanol for an installed project cost of $10,89/gallon of ethanol. Using EIA indicative figures of $2377/kw, it could be estimated that Bluefire will

Timberlands to provide wood chips, forest residues, forest thinnings, and urban wood waste as the raw material for ethanol production for up to 15 years. For sale of ethanol produced, BlueFire agreed with Tenaska Biofuels for a 15-year Off-Take Agreement. BlueFire plans to use the concentrated acid hydrolysis process in order to maximize the efficiency of their ethanol production.

After securing third-party guarantees that the individual aspects of their process each work, BlueFire's management team is very optimistic about the Fulton facility's chance for success, and that success could greatly accelerate the market for cellulosic ethanol.[42]

Inbicon

To compare with BlueFire's progress in commercial-scale cellulosic ethanol, Danish bio-company Inbicon, has built a commercial-scale facility in Kalundborg, Denmark. Currently, the facility is operating at a demonstration-scale level, but Inbicon claims the facility is financially sustainable. The facility is planned to be the center of Inbicon's Biomass Technology Campus. Through cooperation with DONG Energy, Inbicon explores the possibilities of co-firing with an electric utility to increase overall efficiency. The Technology Campus also includes research and development into enzyme efficiency and other aspects of cellulosic ethanol production.

Inbicon's process consists of mechanical conditioning, hydrothermal pretreatment, and enzymatic hydrolysis. The company claims that its pretreatment yields a higher concentration of sugar in the liquid that continues to fermentation, decreasing water content, and increasing ethanol content in each batch of processed material.[43] It will be beneficial to continue monitoring Inbicon's progress in commercial-scale production and the results of their research efforts.

Demonstration Scale Projects

The EPA recognizes Dupont Cellulosic Ethanol (DCE), Fiberight, KiOR, KL Energy, and Zeachem as having existing cellulosic biofuel production in 2011, all at the pilot or demonstration scale. Abengoa, Mascoma, and POET also claim to have pilot or demonstration

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also construct a 40 MW biomass power plant that would require an additional 1000 TPD of wood, presumably augmented by the lignin produced in their process.
[42] Klann et al., 2011; Velshi, 2010.
[43] Inbicon. "Inbicon Biomass Refinery at Kalundborg."

scale facilities operating in the US. Many of these companies hope to begin construction and/or operation of commercial scale facilities in 2012 or 2013, as does BlueFire Ethanol. While they employ different raw materials and technologies, the companies operate their demonstration projects at a loss in order to research and develop the technologies that they use for commercial scale production. Total investment for demonstration scale facilities can cost as much as $200/gallon produced. Support for these facilities is not derived from the sale of ethanol, but rather through grants, endowments, and other funding mechanisms whose donors derive benefit in other ways.[44]

Other Production Factors

Resource Yields

The issue of resource yields, the number of gallons that can be produced from a ton of biomass, is important for the feasibility of cellulosic ethanol. Robert Rapier, Chief Technology Officer for renewable energy company Merica International, suggests that the high yields necessary for economic production are simply impossible given the energy content of green waste and the energy necessary to separate the ethanol from the water with which it is produced. When produced from corn, a high-cellulose resource, ethanol yields can reach 90 to 95 gallons per ton of feedstock. From green waste, a more reasonable figure to expect currently is 70 gallons per ton of feedstock.[45] Cost and revenue calculations in this study therefore use 70 gallons per ton of feedstock as a standard assumption, which is approximately an average of the various resource yields claimed by producers. This yield, though, may improve with investment in efficiency measures and/or technological advances.

Corncobs and sugar cane bagasse, for example, may have resource yields over 110 gallons per bone dry ton of feedstock. Forest thinnings, due to the structure of their biopolymers are likely to yield closer to 80 gallons per bone dry ton.[46] To make up for the lesser yield, forest thinnings would need to provide cheaper access. In addition, forest thinnings must be collected

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[44] DDCE, January 2010; Energy Insight, 2010; Federal Register, 2011, p. 38852; Hay & Forage Grower, 2010; Piersol, 2011; POET, 2011; St. John, 2009.
[45] Rapier, February 21, 2011.
[46] DDCE, n.d.

carefully due to federal restrictions on access in National Forests. On the other hand, forest green waste is abundant and its availability levels are predictable.

Development Risk

While government agencies providing grants and loans are eager to invest in promising new technologies, the typical suppliers of debt and equity have hesitated due to the high financing risk of cellulosic ethanol projects. Risk can be mitigated partially by the use of technology or process guarantees, by feedstock contracts, and by product off-take contracts. Backstopping each piece of the project, to some degree, can help to entice funding, but this can be especially difficult with new, commercially unproven technologies. Long-term focused government assistance, including in the form of a loan guarantee program, mitigates some of the risk. But it is important for the government agency granting financial assistance to perform due diligence and act cautiously so as to avoid wasting resources that could be better used, and because failed projects with government funding cast a long dark shadow on further investment in the same type of technology and on government funding generally.[47] Phillip Kenkel and Rodney B. Holcomb, both professors of Agricultural Economics at Oklahoma State University, suggest that policies providing continuing and stable incentives, the rapid standardization of technology, and business models that consider feedstock and processing facilities are required to overcome the uncertainty surrounding commercial cellulosic ethanol production. They emphasize that the process requires "a clear understanding of the ordering of tasks" in order to produce cellulosic ethanol in large quantities.[48]

This in itself is not sufficient to offset project risk. The world of project finance expects feedstock and product off-take contracts that extend to the period of the loan for the project. In other words, a 20-year project loan would expect to be accompanied by 20-year terms for biomass supply and product off-take. Unfortunately, these mechanisms are not typically available in the industry, and only recently are commercial structures being developed. Their suitability for acceptance by lending institutions is yet to be tested.

The use of genetically modified organisms (GMO) for fermentation of the mixed sugars derived from cellulosic feedstocks has been under development for many years, achieving

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[47] Bevill, October 2011; Furchtgott-Roth, 2011.
[48] Kenkel and Holcomb, August 2009.

certain success in an attempt to mimic the hardiness and effectiveness of the naturally occurring yeast used in industrial fermentations. Since most of the R&D work done to date is on a small scale, these facilities tend to resemble the high-tech pharma labs which require a "kill" step prior to disposal of waste materials. This "kill" step uses steam to sterilize any material exposed to the outside world. In the world of corn ethanol, this material ("spent" or dead yeast cells) is added to the distiller grains by-product to enhance protein content and is typically fed to cattle.

To dispose of spent GMO's that have been used for fermenting mixed sugars at industrial capacity, local regulations must be modified to accept the conditions that typically describe the effectiveness of the "kill" step. For example, a "kill" step that has six-nines effectiveness, or 99.9999% effectiveness, necessarily means that some live cells will escape to the environment. The level at which spent cells may be benignly disposed will soon enter public discourse as operating permits for these facilities are pursued by their sponsors.

This section has focused on the risks associated with the production of ethanol and liquids from new technologies. It has not addressed risks associated with the development of a power generation facility using biomass as a feedstock. This model has been well established in industry and has been accepted by funding institutions. Relative to cellulose conversion technologies, all permit risks (save that of the NIMBY influence) have been demonstrated as acceptable to the general public.

E85, E15/E10, Flex Fuel Vehicles, and Background for the Ethanol Market

Currently gasoline stations may provide ethanol—cellulosic or other—in two main ways. First, a growing number of stations, particularly in the Midwest, carry E85, which is a blend of 85% ethanol and 15% conventional gasoline. Flex Fuel Vehicles (FFVs) can operate on any mixture of ethanol and conventional gasoline that contains up to 85% ethanol. The U.S. Department of Energy estimates that there were 8.35 million FFVs in use in the U.S. in 2009.[49] Since these vehicles can operate on conventional gasoline as well and the availability of stations carrying E85 is relatively limited (2,000 in the US, mostly in the Midwest), many of the vehicles capable of using E85 do not do so.[50]

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[49] Department of Energy Office of Energy Efficiency & Renewable Energy. "Data, Analysis, & Trends: E85 FFVs in Use in U.S."

[50] Austin, 2008; Curtis, 2011; Jessen, 2010; Motavalli, 2009; Woodall, 2010.

Many people may not even realize their contribution to the second method of ethanol consumption. Through 2010, all conventional gasoline could contain up to a 10% blend of ethanol (E10). In October 2010, the Environmental Protection Agency (EPA) approved an increase of that standard to the 15% blend E15 for vehicles made in 2007 or later. In January 2011, the EPA approved an extension of the new standard for vehicles made since 2001. Motorcycles, heavy-duty vehicles, and non-road engines, however, are not allowed to use the E15 blend. The EPA is currently developing standards for labeling at gasoline stations so that it will be clear which pumps provide the E15 blend.[51] Concerns about corrosion, overheating, and other ill effects of the E15 blend on motor engines and other car parts, as well as the process of developing labeling standards to avoid confusion, have led to efforts by manufacturers and equipment associations to combat the new EPA standards and a lack of implementation of the new blend.[52] The EPA explains that E15 has not been registered as of November 17, 2011, making it "not legal for distribution or sale as a transportation fuel."[53]

Supply, Demand, and Price of Ethanol

Policy-Related Supply

The Energy Independence and Security Act of 2007 (EISA), as shown below, requires larger fuel producers to include 36 billion gallons of ethanol and other renewable fuels by 2022, including 16 billion gallons reserved for cellulosic ethanol (Exhibit 10).[54] Obligated parties under these standards include all firms that produce gasoline for use in the U.S. such as refiners, importers, and blenders (except for oxygenate blenders). The Energy Information Administration (EIA) predicts that these requirements will not be met by 2022—and that 2.1 billion gallons of cellulosic ethanol will be produced that year—but will be surpassed by 2035.[55] Although the legislative act set certain mandates, the EPA has the authority in its rulemaking to decrease the mandate "if it were determined that a significant renewable feedstock disruption or other market circumstance might occur."[56]

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[51] Parker and Chipman, 2011.
[52] "Engine Products Group Files Legal Challenge to EPA's Partial Waiver for Ethanol (E-15) Fuel." 2010.
[53] Environmental Protection Agency, "E15 (a blend of gasoline and ethanol)." November 21, 2011.
[54] Motavalli, 2010.
[55] US Energy Information Administration, "Annual Energy Outlook 2010." Page 77.
[56] Congressional Research Service, 2007. Page CRS-5.

In response to lagging cellulosic ethanol production, the EPA used that authority to scale the mandate for 2010 from 100 million to 6.5 million gallons and the mandate for 2011 from 250 million to 6.6 million gallons.[57] For 2012, the EPA is considering adjusting the mandate from 500 million to between 3.45 and 12.9 million gallons.[58] Production through June 2011 qualifying for the program was zero.[59] The EPA lists a number of firms that produce cellulosic ethanol on a demonstration scale (potentially 0.25 to 6.4 million gallons in 2012), but none are expected to produce on a commercial scale.[60] Some scientists and industry specialists have argued that setting a mandate on an unproven technology is ineffective and harmful.[61] As a possible solution, Chief Technology Officer at Merica International, Robert Rapier recommends a production-based per-gallon tax credit.[62]

Exhibit 10. Renewable Fuel Standards Established by EISA 2007
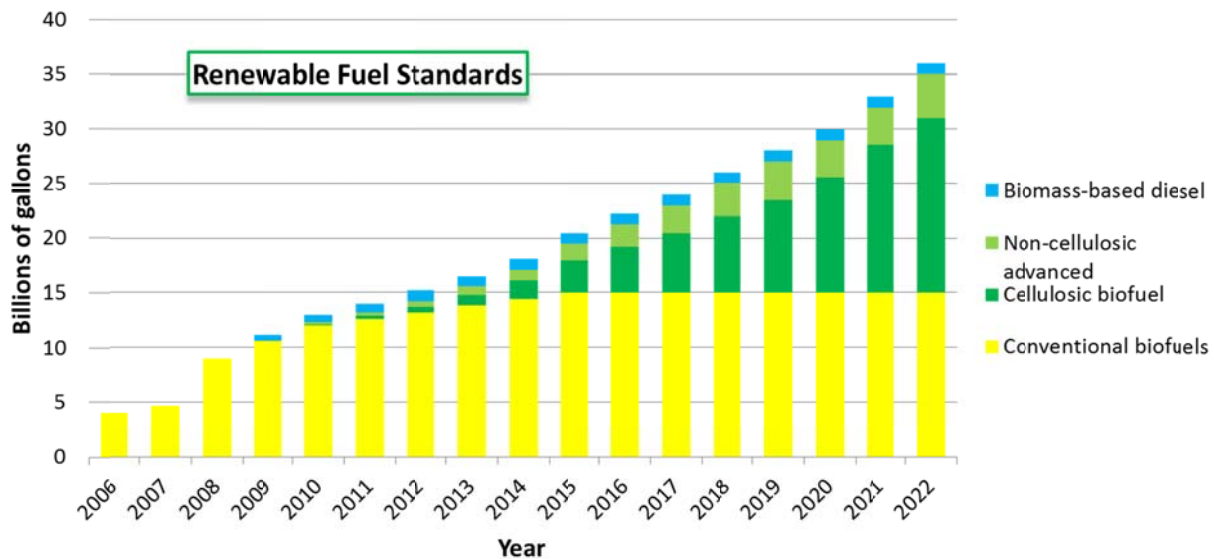
Policy-Related Demand

The recent decision by the EPA to allow the use of E15 ethanol in cars and light trucks made in 2001 or later may accelerate the demand for ethanol. This decision means that the share

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[57] Environmental Protection Agency, February 2010; November 2010.
[58] Federal Register, 2011, page 38848.
[59] Environmental Protection Agency. "2010 EMTS Data;" "2011 EMTS Data."
[60] Federal Register, 2011, page 38847.
[61] National Petrochemical and Refiners Association, 2011; Nicklaus, 2011; Rapier, Sept. 2011; Dec. 2010.
[62] Rapier, September 2011.

of ethanol in the 130 billion-gallon-market related solely to the E15 blend can be up to 19.5 billion gallons. Critics such as Nathanael Greene of the Natural Resources Defense Council have charged that the decision will harm engines, damage catalytic converters, and thereby cause more pollution; but the EPA's decision is backed by extensive DOE research. [63, 64] Despite such concerns expressed by Greene and some automobile parts industry leaders, it seems that the government generally supports the extension of the cellulosic ethanol market, including ways of inducing greater demand thereof.

In terms of more local demand, the City of Los Angeles, in an effort to improve its air quality, planned to convert 85% of all City fleet vehicles to be powered by alternative fuels by FY 2012-2013 and to have 100% of all refuse collection trucks and street sweepers converted by 2010.[65] Elsewhere, the City states as its goal to have nearly half of the city's refuse trucks and street sweepers and 188 buses run on alternative fuels, as well as another nearly 1,000 hybrid passenger cars.[66] More broadly, Los Angeles plans to invest $10 billion in the City's Cleantech industry in the next decade.[67] California, meanwhile, contains 9,400 FFVs in its State Fleet, since the Federal Energy Policy Act requires the state to purchase alternative fuel vehicles for 75% of its light-duty, non-law enforcement vehicle needs and FFVs are the most common type of alternative fuel vehicle available.[68,69] Given these government initiatives to use alternative energy, a second alternative to straight grants or loans from government agencies could involve an off-take agreement for E85-using government vehicles.

Market Supply

In terms of capacity, the National Renewable Energy Laboratory estimates that the U.S. has enough agricultural and forest resources to produce 60 billion gallons of cellulosic ethanol per year, enough to displace 30% of the current gasoline consumption, by 2030.[70] The logistics, though, may not be sufficient: due to the low energy density of biomass relative to fossil fuels,

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[63] Greene, 2010.
[64] Lane, 2010.
[65] Mayor's Office of Economic and Business Policy, "Alternative Fuel Fleet."
[66] Mayor's Office of Economic and Business Policy, "Clean Technology."
[67] Mayor's Office of Economic and Business Policy, "Green Business."
[68] Guenther, 2011.
[69] Department of Energy Office of Energy Efficiency & Renewable Energy, "Data, Analysis, & Trends: AFVs in Use."
[70] National Renewable Energy Laboratory, 2007.

cellulosic ethanol conversion facilities need to be located close to their biomass source, limiting the ability to utilize economies of scale. Moreover, cellulose generally makes up less than 50% of the composition of biomass, so purifying cellulosic ethanol requires large amounts of energy inputs.[71]

Certain energy experts suggest that, without subsidies, cellulosic ethanol could become a biofuel niche, i.e., a fuel that in the long term, supplies 10% of the US's present liquid fuel consumption.[72] Because of the lower energy density of biomass, in order for cellulosic ethanol to satisfy such a market segment, its production would need to be located near it energy source, i.e., the biomass.[73] Even if cellulosic ethanol is limited to about 10% of the transportation fuel market, it could approach its EISA mandate of 16 billion gallons in 2022.

In terms of infrastructure, as of November 2011, there were 2,200 public fueling stations in the US offering the E85 blend, mostly in the Midwest. Over another 200 E85 stations offer private access and another 70 (some private, some public) are planned. California contains 47 public E85 stations, 11 private ones, and seven planned ones. Fourteen of the public stations, two of the private stations, and two of the planned stations are in southern California.[74] Propel Fuels provides E85 for California's Fleet FFVs, and with a grant from the California Energy Commission, Propel plans to build more than 75 stations where the state's vehicles and other FFVs can access E85.[75] Expanding the infrastructure for E85 fueling stations is an important aspect of improving the feasibility of ethanol production plants.

According to the EIA, ethanol production in the US in 2011 through August totaled 9.21 billion gallons, compared to 8.62 billion gallons from January through August of 2010, although daily production has leveled off since November 2010. Using an exponential regression to explain the rapid growth of ethanol production from 2002-2011, expected ethanol production in the United States in 2012 would be about 20.49 billion gallons.[76]

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[71] Rapier, December 2010.
[72] Rapier, September 2009.
[73] Rapier, September 2009.
[74] Department of Energy Office of Energy Efficiency & Renewable Energy, "Alternative Fuels & Advanced Vehicles Data Center."
[75] Guenther, 2011.
[76] Energy Information Administration. "Table 10.3 Fuel Ethanol Overview."

Market Demand

The U.S. has more than 6 million Flex Fuel Vehicles on the road. About 500,000 of these vehicles belong to fleets, which have a dedicated source of E85. The rest of the 6 million are privately owned. Due to the lagging infrastructure of E85 stations, most of the 5.5 million potential E85 users nationwide are expected to rely on conventional gasoline.[77] California has more than 300,000 FFVs, and the EIA estimates that fewer than 52,000 of these run on E85.[78,79] This represents a significant pent-up demand for California and the US as a whole.

Other factors suggest that ethanol demand will only continue to grow. NASCAR started using Sunoco Green E15 in all three of its national series starting with the 2011 season, and CEO Brian France expressed satisfaction with the first season using E15.[80] According to an estimate by the Alternative Energy Foundation (AEF), worldwide ethanol production is expected to reach 27.7 billion gallons by 2012.[81] The AEF cites "the need to skirt stinging hikes in crude oil prices, reduce greenhouse gas emissions, and lower international dependence on oil" as factors that will lead to the high ethanol production number by 2012. Europe, China, and Brazil have plans for commercial scale cellulosic ethanol production by 2013.[82]

In the US, ethanol consumption has seen increases similar to those of production. Consumption of 38.10 Mg/d (million gallons per day) in August 2011 represents the second highest figure for the statistic ever, behind only that of December 2010 (38.68 Mg/d), although consumption has leveled off since November 2010. Using an exponential regression to explain the rapid growth of ethanol consumption from 2002-2011, expected ethanol production in the United States in 2012 would be about 20.75 billion gallons.[83] Considering consumption of ethanol from another perspective, the percentage of transportation fuel used in any given month

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[77] US Energy Information Administration. "Estimated Number of Alternative Fueled Vehicles in Use, by State and Fuel Type, 2009.

[78] California Environmental Protection Agency Air Resources Board, "Workshop on Updates to E85 Specifications."

[79] US Energy Information Administration. "Estimated Number of Alternative Fueled Vehicles in Use, by State and Fuel Type," 2009.

[80] Associated Press, 2010; Brandon, 2011; Piller, 2010.

[81] Alternative Energy Foundation, 2008.

[82] Bevill, August 2010; Bevill, November 2011; D'Altorio, 2011; Lombardi, 2011.

[83] Energy Information Administration. "Table 10.3 Fuel Ethanol Overview."

that came from biomass has increased steadily since 2002 from 0.59% to a high of 4.46% in August 2011.[84]

The launch and acclaim of electric cars has the potential to dampen the market interest in cars running on ethanol. Supported by tax incentives of up to $7,500 per vehicle purchased and popular for their very high fuel efficiency of up to 99 miles per gallon equivalent, electric cars such as the Chevy Volt and Nissan Leaf have attracted significant attention. Their sales numbers, though, remain low. In the nine months since they entered the national market, the Volt and the Leaf have sold just over 11,000 vehicles total. In comparison, Chevy sells about 20,000 of its Cruze sedans monthly. About 5,760 of the 11,000 were sold in California, perhaps because of the allowance of electric vehicle drivers to use high occupancy lanes while driving alone and the large potential for solar electricity generation in sunny Southern California. Charging stations have also been installed in many locations, but the sales figures described above are very low given the high R&D investment the companies made. J.D. Power & Associates predicts that 102,000 all-electric vehicles will be sold in 2018, equal to less than 1% of U.S. auto sales.[85]

Resource Supply

According to 1999 data from the Oak Ridge National Laboratory, California has the second most amount of cheap (<$20/dry ton) biomass due to its abundance of urban waste.[86] The costs of collection favor MSW and forest residue as raw materials for cellulosic ethanol production. MSW costs about $15/ton, forest residue costs $20.79/ton, agricultural residue costs $34.49/ton, and switchgrass costs $40.85/ton, in addition to hauling, secondary storage, and grinding costs of $32.53 per ton, regardless of the resource.[87] But certain policies and restrictions can greatly increase the cost of procuring and transporting the necessary biomass.[88]

Within Los Angeles, Riverside, and San Bernardino Counties, a vast amount of biomass is available on a sustainable basis for cellulosic ethanol production. In terms of forest residue, Riverside and San Bernardino Counties contain greater resources with over 228,000 and 639,000 bone dry tons (BDT) available each year (Exhibit 11). San Bernardino County has the best

[84] Energy Information Administration. "Table 2.5 Transportation Sector Energy Consumption."
[85] Hirsch, 2011; Hagerty, 2011.
[86] Walsh et al., 1999.
[87] Federal Register, 2010, Page 14821.
[88] Carlton, 2010.

potential to supply biomass from forest thinning, 3,700 BDT. Though Los Angeles County can only provide 125,200 BDT of forest biomass per year, it greatly surpasses the other two counties in biomass from MSW available annually, with over 2.5 million BDT. Riverside and San Bernardino Counties can each supply about 500,000 BDT of MSW biomass per year. It would be helpful to locate the cellulosic ethanol production plant where it can utilize the MSW of Los Angeles County and the forest residues of Riverside and San Bernardino Counties.

Exhibit 11

Comparison of Available to Necessary Biomass for Commercial Scale Production - Annually							
	Requisite Biomass	Los Angeles County	County Resources Required	Riverside County	County Resources Required	San Bernardino County	County Resources Required
Total Tons of Biomass	437,500	2,652,440	16.50%	979,640	44.70%	1,332,535	32.80%
Tons of Forest Biomass	27,344	125,200	21.80%	228,700	12.00%	639,500	4.30%
Tons of MSW Biomass	410,156	2,522,580	16.30%	581,950	70.50%	522,165	78.50%

Source: Williams et al., 2008.

If the plant operates for 350 days out of the year and uses 1,250 tons of biomass per day, the plant will use 437,500 tons of biomass per year. Using a 15:1 ratio of MSW green waste to forest green waste, which allows for the removal of some extraneous forest fire fuel without making the project reliant on that removal, would require about 410,000 tons of MSW biomass and 27,000 tons of forest biomass per year, as indicated in the table above.

Considerations for Cost

With the social and environmental advantages that cellulosic ethanol provides over corn ethanol, the market share for the cellulosic version can grow rapidly if it can compete financially with the latter. Corn ethanol carries heavy political support from corn farmers of the Midwest and their representatives in Congress. Moreover, corn ethanol requires significantly lower capital costs than cellulosic ethanol.[89] In order to advocate for cellulosic ethanol most comprehensively,

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[89] Energy Information Administration. "Federal and State Ethanol and Biodiesel Requirements." 2007.

a policy advocacy campaign is necessary to convince Congress to adjust policy-based incentive structures to favor cellulosic ethanol more strongly relative to corn ethanol.[90]

An additional consideration lies in the relative price of gasoline. The annual average of weekly gasoline prices has risen steadily since 2002 with the exception of a decline from 2008 to 2009 that coincided with an economic decline in the US, and 2011 features the highest annual average since 1993, the earliest year of data provided by the EIA.[91] The highest peak in weekly gasoline prices ($4.17/gallon in July 2008) correlates with the sharpest increase in ethanol production. Since then, while gasoline prices have declined significantly, ethanol production has continued to increase, albeit at a slower rate.[92] The ability of cellulosic ethanol to share in the growth of ethanol use depends on how well the cellulosic version can compete with corn ethanol.

Relative Fuel Efficiency, Implications for Cost, and Public Policy

Cellulosic ethanol contains a lower energy content relative to gasoline. The much lower cost of ethanol relative to gasoline makes up for some of the lower energy content. To account fully for ethanol's lower energy content among E85 blends, the relative price of ethanol must be about 65% that of gasoline. (This represents a worst-case scenario estimate, i.e., if the least estimate of ethanol efficiency holds). A calculation of this finding follows.

Assuming a $3.40 gallon of gasoline, an E85 blend, and the estimate that ethanol is 30% less efficient than gasoline in terms of miles per gallon (estimates suggest ethanol is 20% to 30% less efficient than gasoline, so this calculation favors underestimation[93]):

Because ethanol is 30% less efficient than gas, an E85 blend should cost

70% of the conventional gas price

0.70 x $3.40 = $2.38

To achieve this price

0.15 gallons of gasoline x $3.40 =$0.51

$0.51 + cost of 0.85 gallons of ethanol ≤ $2.38

[90] Campoy, 2009; Mandel, 2010; Zeller, 2010.
[91] Energy Information Administration. "Weekly U.S. All Grades All Formulations Retail Gasoline Prices."
[92] Energy Information Administration. "Weekly U.S. All Grades All Formulations Retail Gasoline Prices."
[93] Environmental Protection Agency. "E85 and Flex Fuel Vehicles: Technical Highlights." 2010.

0.85 gallons of ethanol ≤ $1.87 (2.38 - .51 = 1.87)

Thus,

1 gallon of ethanol ≤ $2.20

To compete with conventional gasoline, E85 should cost about 65% as much as gasoline, since ethanol is 70% as efficient as conventional gasoline. With a $3.40 gallon of gasoline, E85 should cost no more than $2.38. 0.15 gallons of gasoline would cost $0.51, so the 0.85 gallons of ethanol should cost no more than $1.87, which requires a gallon of ethanol to cost no more than $2.20 before being mixed with conventional gasoline.

If gasoline prices rise, the maximum price that allows ethanol to compete commercially with conventional gasoline will also rise. When that maximum price is greater than the cost of producing ethanol, then the market should adjust for more ethanol production. Public policy can facilitate this transition by providing loan guarantees, helping with the large startup costs, and promoting other policy measures that offer a more favorable competition for ethanol versus conventional gasoline. It seems that public policy will be the deciding factor on whether the potential increase in ethanol production will consist mostly of advanced, cellulosic ethanol or the less beneficial but more heavily supported corn ethanol.

Current Pricing for Ethanol

The rack ethanol price is the wholesale price, what refineries will pay for ethanol before mixing it with conventional gasoline and distributing it to gas stations. Through July 2010, rack ethanol prices remained as low as $1.62/gallon. Then, they increased rapidly, so that by November, rack ethanol prices were at $2.47.[94] On November 28, 2011, the national average ethanol rack price reached $3.05.[95] The cash flow model in this report assumes a rack price of $2.25/gallon to allow for additional contingency in feasibility.

Typically, ethanol producers sell ethanol to a gasoline distributor, who mixes the ethanol with conventional gasoline, most likely for the E10 ratio, before taking it to the gasoline station. For example, BlueFire Ethanol signed an off-take agreement with Tenaska Biofuels for the sale of its projected 19 million gallons of cellulosic ethanol per year. While complete terms of this

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[94] Green Power Conferences, 2011.
[95] Progressive Farmer, 2011.

contract have not been released, Bluefire reports that the contract will run for 15 years, and its price structure is designed for flexibility, to adjust according to a "premium allowed for cellulosic ethanol compared to corn-based ethanol."[96]

As an alternative, the production entity could contract with government agencies to provide ethanol in E85 for the agencies' alternative energy fleets. As an illustration of the potential benefits of this strategy, California purchased over 1,000 Flex Fuel vehicles between 2005 and 2007, with the intention of reducing the state's carbon footprint. Due to lagging infrastructure, though, the Flex Fuel vehicles rely almost entirely on conventional gasoline.[97] With AB 236 (2007), California vowed to continue purchasing alternative energy vehicles and to use alternative fuel.[98]

Cost of Construction and Production

Financial Feasibility Model

In response to a Congressional inquiry regarding the feasibility of achieving production costs of $1.07/gallon of ethanol, comparable to the costs of a corn dry mill, the National Renewable Energy Laboratory studied operations at 38 corn stover ethanol plants in Iowa. Although costs for corn stover ethanol production could vary from those for other forms of biomass-to-energy production, the study offers some helpful data, particularly for costs of machinery and labor and for cash flow projections. Costs for production using MSW and forest residues could be lower than for production from corn stover if the biomass feedstock can be provided at a lower cost (e.g., if tipping or disposal fees for accepting municipal green waste reduce access costs). In the corn stover study, biomass feedstock represented about 61% of the costs per gallon. The study concluded that with 75% equity and a 15% IRR (middle of the road estimates), the minimum ethanol selling price would be about $1.23.[99] This report uses the corn stover study and other studies and sources to construct feasibility and cash flow models for biomass conversion to energy.

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[96] BlueFire Ethanol, September 2010.
[97] O'Dell, 2007.
[98] California General Laws. Assembly Bill No. 236, Chapter 593. 2007.
[99] Aden et al., 2002.

The major assumption in NREL's study is that of nth plant economics. In other words, all of the projections are based on the development of a number of plants resulting in an exponential drop in cost from the first plant. The fact that the first cellulosic ethanol production plant has yet to be built thereby qualifies all of the projections in this report. Nevertheless, an early analysis such as this can help to determine the potential benefit of pursuing the technology and other arrangements for the eventual construction of the nth plant. The report also states that costs due to impacts of sourcing the requisite feedstock from a 50-mile fetch radius were not incorporated into the analysis.

Exhibit 12. Summary of Yield, Costs, and Other Assumptions

Summary of Yields, Costs, and Assumptions		
Feedstock Rate	1250	dry short tons/day
Ethanol Yield	70	gallons/dry ton feedstock
Ethanol Production	30.6	M gallons/year
Total Equipment Cost	140.4	M$
Total Project Investment Cost	243.8	M$
Feedstock Costs	21	M$/yr
Non-Feedstock Raw Materials Costs	6.1	M$/yr
Fixed Costs	8.9	M$/yr
Excess Electricity Generated	2.27	kWh/gallon of ethanol
On-Line Time	8400	hrs/yr
Estimated Ethanol Selling Price	2.25	$/gallon
Net Operating Income	37.1	M$/year

Note: 2009$. Adjusted from Aden et al., 2002.

Exhibit 12 provides a summary of key variables and estimates for this report's model. Using 1,250 tons of biomass per day and assuming a yield of 70 gallons of ethanol per dry ton feedstock, an ethanol production plant operating for 350 24-hour days (8400 hours per year) could create 30.6 million gallons of ethanol per year. Equipment cost for the plant would be a one-time cost of $140.4 million, based on which the project investment would need to be $243.8 million. Data shown later in this report suggests that feedstock would cost $21.0 million per year, while raw materials other than the feedstock would cost $6.1 million per year. Fixed costs would equal $8.9 million per year. The estimates assume that the production process would create 2.27

kWh of excess electricity per gallon of ethanol, which can be sold to LADWP. The resulting rack price is $2.25 per gallon, leading to a net operating income of $37.1 million.

Logistics and Co-location

Financing has been difficult to find, but "it's really about getting the first plant built," says Wes Bolsen, VP of government affairs at Coskata. If that plant is successful, he believes this would prove to investors that the technology works, and make them more willing to invest in other plants". After the first plant is open, banks will be begging to help finance them," he says.[100] Co-location with other uses may help lead to the first facility. One estimate suggests that a commercial plant's startup costs can range from $600 million to $100 million, including financing costs, but it is not clear what exactly would cause the reduction. Some firms believe that a plant will be more likely to succeed if it includes a niche benefit, e.g., feedstock costs being very low or negative, employing used equipment from a previously existing plant, co-location with another facility such as waste treatment, or a combination of these features.[101]

Electricity generation presents a potential type of co-location. Some studies of cellulosic ethanol production indicate that the production process includes electricity generation. LADWP purchases electricity using a competitive bidding process. Average purchase price of electricity by DWP equals $60/mWh, or 6 cents/kWh, a figure which the model in this report assumes.[102] Due to the instability of electricity demand and cost, "in-house electricity production makes sense as a way to keep the costs controlled unless capital costs are controlling the decision."[103]

Scaling

One of the greatest risks in undertaking cellulosic ethanol production revolves around the fact that it has not been done on a commercial scale. The technology risk increases as the size of the facility increases, because what works in a lab or on a small scale may not work in the same way on a commercial scale. For this reason, an entity attempting to produce cellulosic ethanol should follow a scaling of the process.[104] This report therefore includes, in addition to financial

[100] Bullis, 2010.
[101] Novazymes, 2010.
[102] Ingalsbe, 2011.
[103] Aden et al., 2002, page 77.
[104] Rapier, February 2011.

projections for a commercial-scale cellulosic ethanol plant, similar projections for a demonstration-scale plant. The findings from the latter financial projections suggest that the demonstration scale requires significant subsidies. These may be accumulated more easily by promising early investors the first rights to participate in the commercial scale project.

The demonstration scale would use 14.29 tons of biomass per day, and assuming a yield of about 70 gallons of ethanol per dry ton feedstock, the plant could create 250,000 gallons of ethanol per year. Initial costs for the project were estimated using the $50 million investment into DDCE's demonstration plant in Vonore, Tennessee. Based on that figure, equipment cost for the plant would be a one-time cost of $28.8 million. Feedstock materials would cost $171,000 annually. Raw materials other than the feedstock would cost $50,000 per year. Fixed costs—i.e., labor, overhead, maintenance, taxes, and insurance would equal $2.8 million per year. The estimates assume that the production process would create 2.27 kWh of excess electricity per gallon of ethanol. This model assumes that production would be on-line for 2000 hours per year (8 hours per day for 250 days). Finally, the estimated rack price is $2.25 per gallon of ethanol, leading to a net operating income of -$2.4 million.

According to these estimates, the demonstration-scale of cellulosic ethanol production would require $6.3 million annually in subsidies to compensate for the negative net operating income. This could be in the form of direct investment or as provision of services. This could represent any combination from a local university, a government grant, and a corporate sponsorship. Demonstration-scale production would most likely conclude as soon as commercial-scale production became ready since the former is not financially sustainable.

Construction

The construction period is crucial because it features greater expenditures with less revenue than after construction is complete. The research suggests production can run at about 50% during construction with about 75% expenditure of variable expenses and 100% of fixed expenses. Estimates suggest the construction period will last between 18 months (for smaller projects) and 42 months (for larger projects). A probable estimate for purposes of this report is 24-30 months. Therefore, this model assumes production to be nonexistent for the first two years, at 50% capacity for Year 3, and at 100% capacity starting in Year 4.

BlueFire completed phase 1 of construction of its commercial-scale production facility in Fulton, MS.[105] The company signed an Engineering, Procurement, and Construction contract with MasTec Inc. for $296 million, including $100 million for a biomass power plant, which will be part of the facility. This report's model expects higher facility costs, approximately $140 million, though it expects lower total project costs, $244 million.

The model in this report decreases the NREL's cost of corn stover calculations with the expectation of less expensive feedstock procurement and increases the startup costs to account for inflation, as displayed in the tables below. (Their assumptions in terms of machinery, scientific process, etc. are described in great detail in their study.) Cost estimates for machinery from the corn stover model are adjusted to 2009 dollars, while cost estimates for soft costs are estimated using the formulas provided in the corn stover study. Materials costs aside from biomass feedstock are left unchanged since change in the cost thereof is harder to predict, and since different materials may be used with forest residue and MSW than with corn stover.

Installed Equipment Costs assume that the machinery used for cellulosic ethanol production based on forest and MSW green waste is similar to that used for corn stover-based ethanol production. Project Investment uses the Total Installed Equipment Cost (TIEC) and adds costs for a warehouse (1.5% of TIEC) and for site development (9% of TIEC). The sum of these three costs is the Total Installed Cost (TIC). In addition to TIC, Project Investment includes the following indirect costs: field expenses and prorateable expenses (together 20% of TIC), a home office and construction fee (25% of TIC), and a project contingency (3% of TIC). The sum of Total Installed Cost and the aforementioned indirect costs represent the Total Capital Investment (TCI). Adding to the TCI a consideration for other costs—including startup, permits—(10% of TCI) provides the Total Project Investment: $243.8 million.[106] See Exhibit 13 and Exhibit 14.

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[105] BlueFire Ethanol, November 2011.
[106] Adjusted from Aden, A., et al., 2002.

Exhibit 13. Total Installed Equipment Costs

Total Installed Equipment Costs		Capital Costs
Process Area		
A100	Feed Handling	$9,252,000
A200	Pretreatment	$23,438,000
	Neutralization/Conditioning	$9,622,000
A300	Saccharification/Fermentation	$11,596,000
A500	Distillation and Solids Recovery	$26,892,000
A600	Wastewater treatment	$4,071,000
A700	Storage	$2,467,000
A800	Boiler/Turbogenerator	$47,246,000
A900	Utilities	$5,798,000
	Total Installed Equipment Cost	$140,382,000

Note: 2009$. Adjusted from Aden et al., 2002.

Exhibit 14. Total Project Investment

Total Project Investment	
Total Installed Equipment Cost	$140,382,000
Warehouse	$2,106,000
Site Development	$7,272,000
Total Installed Cost	$149,760,000
Indirect Costs	
Field Expenses + Prorateable Expenses	$29,952,000
Home Office & Construction Fee	$37,440,000
Project Contingency	$4,493,000
Total Capital Investment	$221,645,000
Other Costs (Startup, Permits, etc.)	$22,165,000
Total Project Investment	$243,810,000

Note: 2009$. Adjusted from Aden et al., 2002.

Production: Variable Costs

Enzymes that catalyze the conversion of green waste into ethanol are an important element in the production of cellulosic ethanol. Novozyme is an international firm that specializes in research and application of enzymes, including the ones necessary for cellulosic ethanol. Adam Monroe, North American president of Novozyme, believes that the company's enzymes make production of cellulosic ethanol possible at $2 per gallon. About 50 cents of that cost covers the enzymes themselves (after factoring in production tax credits). So a reduction in the cost of enzymes presents an opportunity to make cellulosic ethanol more competitive in the market.[107]

Exhibit 15. Variable Operating Costs

Variable Operating Costs (30.6 MM annual gallons of ethanol)				
Raw Material	Lbs/hr	Cost ($/lb)	(MM$/yr)	Cents/gal Ethanol
Biomass Feedstock	104,167	$0.0239	$20.953	68.42
Clarific Polymer	30	$1.2500	$0.312	1.02
Sulfuric Acid	3,494	$0.0124	$0.364	1.19
Lime	2,545	$0.0348	$0.744	2.43
Corn Steep Liquor	1,388	$0.0804	$0.937	3.06
Purchased Cellulase	7,251	$0.0552	$3.362	10.98
Diammonium Phosphate	173	$0.0706	$0.103	0.34
Propane	21	$0.0022	$0.000	0.001
Make-up Water	198,315	$0.0001	$0.167	0.54
BFW Chemicals	1.1	$1.3497	$0.012	0.04
Cooling Water Chemicals	2	$1.0204	$0.017	0.06
WWT Chemicals	61.5	$0.1579	$0.082	0.27
WWT Polymer	0.2	$2.5510	$0.005	0.01
Ash Disposal	4,773	$0.0000	$0.000	0
Gypsum Disposal	7,668	$0.0000	$0.000	0
Electricity Credit	-8,285 (kWh)	$0.060/kWh	-$4.175	-13.63
Total				74.72

Note: Adjusted from Aden et al., 2002.

In addition to the enzymes involved, various chemical products are required for the ethanol production process. The NREL study of corn stover suggests that the chemicals seen in Exhibit 15 are necessary. The table has been modified from the NREL version to account for a

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[107] Motavalli, 2010.

few differences. The cost of biomass feedstock is based on estimates by the EPA and has been set to include the costs of transportation, storage, and handling.[108] The costs of ash and gypsum disposal have been zeroed with the belief that collocation with processes that use these two materials will allow for zero cost in their transfer, if not some revenue generation. Finally, all of the estimates are scaled to expected production levels. Although some of these inputs may vary because of the use of forest and MSW green waste instead of corn stover, pinpointing this variation is beyond the scope of this report and is expected to be minimal in terms of financial feasibility impact.

Exhibit 16 Fixed Operating Costs

Salaries and Other Fixed Operating Costs			
Position	Annual Salary	Number of Personnel	Total Annual Cost
Plant Manager	$90,000	1	$90,000
Plant Engineer	$85,000	1	$85,000
Maintenance Supervisor	$65,000	1	$65,000
Lab Manager	$53,000	1	$53,000
Shift Supervisor	$50,000	5	$250,000
Lab Technician	$28,000	2	$56,000
Maintenance Technician	$30,000	8	$240,000
Shift Operators	$31,000	20	$620,000
Yard Employees	$21,000	32	$672,000
General Manager	$109,000	1	$109,000
Clerks & Secretaries	$30,000	5	$150,000
Total Salaries		77	$2,390,000
Factor			
General Overhead	60% Of Total Salaries		$1,434,000
Maintenance	2% Of Installed Equipment Cost		$2,808,000
Insurance & Taxes	1.5% Of Total Installed Cost		$2,246,000

Note: 2009$. Adjusted from Aden et al., 2002 using Bureau of Labor Statistics data for Los Angeles Metropolitan Statistical Area.

Besides the variable costs of raw materials, the plant will incur fixed operating costs related to labor, overhead, maintenance, insurance, and taxes (Exhibit 16). The numbers and type of personnel required for the plant's operation are based on the NREL corn stover study. The salaries for those positions are based on the same study and adjusted using data from the Bureau of Labor Statistics' Occupational and Employment Statistics database for the Los Angeles

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[108] Federal Register, 2010, page 14821.

Metropolitan Area. On top of these costs, there will be expenses for General Overhead (60% of total salaries), Maintenance (2% of Installed Equipment Cost), and Insurance and Taxes (1.5% of Total Installed Cost). The model assumes the plant will operate 24 hours per day for 250 days (50 5-day weeks).

Revenue

The revenue from cellulosic ethanol production equals the product of the rack price of ethanol and the amount of ethanol produced and sold. Since the marginal cost of producing a gallon of ethanol is fairly minimal, there are large potential returns to scale for ethanol production. While the commercial-scale model described in this report has the potential for financial sustainability, the demonstration-scale model also described here requires substantial subsidy for operation. As mentioned earlier, however, implementing cellulosic ethanol production on a smaller scale will help to prove the technical feasibility—which affects the risk and the ability to secure financing—for commercial-scale production. See Appendix B for Construction Activities Timeline and Appendix C for Cash Flow Analysis and Metrics.

Policy Incentives

One of the strongest criticisms of the pursuit of cellulosic ethanol and alternative fuels more generally lies in the waste of public monies being used to subsidize private firms in the alternative energy sector which go bankrupt or sell their alternative energy division, usually without delivering on their promises of alternative energy production.[109] Considered from another perspective, this reflects a lack of diversity and creativity of public support for alternative fuels. Given the importance of public support in advancing new technologies, diversification of that support could make it more effective, efficient, and politically popular.

The loans and grants provided by the DOE and USDA represent most of the existing public-sector support for alternative fuels. But they may require some modification to make them more effective, and they should not be the sole method of encouraging cellulosic ethanol production.[110] The public sector should consider production-based assistance. Rather than providing upfront support, this form of assistance would guarantee a subsidy for the product

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[109] E.g., Range Fuels, Solyndra, and Verenium.
[110] Government Accountability Office, 2010.

itself, for example cellulosic ethanol, which would make that product more competitive in the retail market. This approach could help attract private investment in the front end.

Thirdly, government procurement can greatly benefit the cellulosic ethanol market by guaranteeing a certain level of demand. McNutt and Rodgers point out that fleet consumption of alternative fuels has not worked; in fact, fleets are perhaps more susceptible to price differences, have to consider lifecycle spans, and are often more reluctant to take a risk on a new technology.[111] Still, the large number of public-sector fleets represent an opportunity, if the hurdles described by McNutt and Rodgers can be overcome. Finally, indirect public support can further the alternative energy sector. By encouraging research and development, job training, and early investment, the public sector can promote economic development for cellulosic ethanol. As the market for cellulosic ethanol grows, it could positively feed back into the economic cycle.

Specific policies and funding sources could include existing programs and funds. The DOE awarded BlueFire an $81.1 million grant from ARRA funds to begin preparation and construction of its Fulton, MS commercial-scale plant.[112] In addition, BlueFire has advanced to the second phase of the loan guarantee process with the DOE. From a similar program, Fulcrum BioEnergy received a $70 million loan guarantee from the DOE for their plant in McCarran, Nevada, preparation on construction for which Fulcrum has already begun.[113] The DOE and USDA seem to be the federal agencies most supportive of ethanol, including research thereon. The Volumetric Ethanol Excise Tax Credit focuses on produced ethanol. Appendix E provides a list of funding programs available on the federal and state level.

There are also policies that support the alternative energy market without direct aim at production. AB 118, signed by Governor Schwarzenegger in 2007, provides $120 million in annual incentive funding to develop and deploy innovative technologies that transform California's fuel and vehicle types to help attain California's climate change policies.[114] AB 32, signed by Governor Schwarzenegger in 2006, requires "the maximum technologically feasible and cost-effective reductions in greenhouse gas emissions" by 2020.[115] Under SB 375, which relates specifically to decreasing GHG emissions by reducing non-commercial traffic's footprint,

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[111] McNutt and Rodgers, 2004.
[112] Department of Energy, 2010.
[113] Bevill, January 2011.
[114] California Energy Commission, 2009.
[115] California Environmental Protection Agency, n.d.

future implementation of alternative energy sources such as cellulosic ethanol will greatly help all Metropolitan Planning Organizations reach their reduction quotas, as cited in their community strategies. Enterprise Zones and New Market Tax Credits offer development-based incentive funding in California and elsewhere.

Cash Flow Analysis

Commercial-Scale Facility

To provide a more complete analysis of the feasibility of a cellulosic ethanol production facility, this report includes a cash flow analysis of such production in an nth plant, building on the assumptions provided earlier in this document and shown in the tables in Appendix C. The nth facility symbolizes a cost reduction experienced through the development of a number of previous plants. The first facilities will most likely experience greater difficulties because the technology has not been proven at that scale. Therefore, this kind of cash flow analysis is meant more as a projection of potential future flows, once the initial facilities have worked out some of the currently unknown technological challenges of scaling up.

The analysis uses the $140.4 million installed equipment cost and the $243.8 million initial project investment. The latter represents the total constant cost. Variable cost represents the sum of three costs: 1) material cost, 2) labor cost, and 3) overhead, maintenance, insurance, and taxes. These costs sum to $21.0 million annually during production. For Year 3, production is expected to occur at 50% capacity, so the variable cost and net operating income are reduced by half; and since the machinery will be newly installed, the maintenance cost is again reduced by half.

On the revenue side, the analysis uses a $2.25 per gallon rack ethanol price, which leaves considerable room below current rack ethanol prices, providing an added contingency buffer. Multiplied by the 30.6 million gallons of expected production, this provides annual gross revenue of $68.9 million. After subtracting the annual variable cost, the annual net operating income (NOI) equals $37.1 million, except in Year 3, when it equals $20.0 million. The plant life, for purposes of calculating return, is assumed to be 22 years from the beginning of construction.

If the project can secure a loan for the startup cost on a 70% loan-to-value ratio, this would lead to a $170.7 million loan, combined with $73.1 million needed in equity. To account for the two and a half years of construction, during which the facility could not operate, the model assumes: a) no payments on the loan; b) interest accumulating to the principal; c) no production costs or revenues; d) phased funding for construction. The model withdraws 75% of the loan balance in the first year, 25% of the loan balance in the second year, and all of the equity funding in the second year. In the third year, the model assumes 50% production. Assuming a 10% rate on the loan, it can be fully repaid in 20 years from the completion of construction with annual debt service of $24.2 million. Again Year 3 provides an exception: because that year's revenue will be approximately $20.0 million, it is all used for debt service in the model, with interest accumulating as it would normally. After Year 3, since the NOI equals $37.1 million, this comes to a net cash flow of $13.0 million. The model projects cash flow through 22 years, including the two and a half construction years. The net present value (NPV) with a 20% discount rate (to account for the high risk of commercial-scale cellulosic ethanol production) of such cash flows annually over 21 years from equity investment (Year 2) equals $43.7 million.

Although the aforementioned NPV is less than the $73.1 million equity investment required (meaning that investors would not want to participate in the project), government funding in the form of grants equal to 45% of the equity investment ($32.9 million) would allow the private equity funding to decrease to $40.2 million. Under these circumstances, since government grants do not require a return, investors could be willing to invest the necessary $40.2 million for an NPV of $43.7 million. Although the government would not receive fiscal compensation, it would benefit from reduced pollution, reduced reliance on foreign petroleum, and other factors that, in the long run, could decrease the government's expenditures.

The figures described above can help to determine other metrics by which investors and lenders evaluate projects. The NOI divided by the total constant cost provides a return on cost of 15.24%. The NOI divided by the equity contribution provides a return on equity of 50.79%. The net cash flow divided by the equity investment provides a cash-on-cash return of 17.77%. The project's NOI divided by the annual debt payment provides a debt coverage ratio (DCR) of 1.54, which should qualify as sufficiently high for most lenders. The project's overall internal rate of return (IRR) is 10.21%, while the IRR for the investors' portion equals 11.20%.

If the project can secure an 80% loan, it would shift many of the metrics to even more favorable levels; and while the DCR would decrease to 1.33, this is still a very attractive level for most lenders. Alternately, many of the assumed parameters can be adjusted, changing the results in either direction. Even with the 70% loan and the other stated assumptions provided throughout this paper, however, it seems that the project should be very fiscally attractive if it can secure 45% of its equity from grant-type sources that do not require repayment.

Demonstration-Scale Facility

The demonstration-scale project, due to the lack of certain efficiencies of scale present in the commercial-scale version requires more support to make it financially feasible. In addition, because the scale is smaller, the level of risk inherent in the project differs, affecting the basic assumptions behind the analysis for the demonstration-scale project. Also because of its smaller size, a demonstration-scale project would have minimal economic development impact on a region. The major goal of a demonstration-scale facility is to support the feasibility of the commercial scale version and to attract attention for that later stage.

This analysis assumes a total constant cost of $50 million for a facility that can produce 250,000 gallons of cellulosic ethanol per year.[116] The demonstration-scale version operates for less than one-fourth the annual time of the latter and uses machinery with one-thirtieth the production rate capacity. The demonstration scale, however, uses the same assumptions about resource yield as the commercial scale. Moreover, the demonstration scale adjusts the required construction, no-loan-payment, interest-accumulation-to-principal, and no-production time period to one year; and it maintains the 50% discounted maintenance cost in the first year of production.

A $35 million loan (based on a 70% loan to value ratio) with an interest of 8% leads to a $3.9 million annual payment that can completely pay off the loan in 20 years from the completion of construction. Because of the small scale, though, the NOI is negative $2.4 million, because even just the variable cost of labor exceeds the revenue generated from the sale of the 250,000 gallons of cellulosic ethanol, not to mention the overhead and other related costs and the material cost.

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[116] DDCE, January 2010.

With an annual subsidy of $6.3 million during production, however, the NOI would be enough to cover the annual debt payment. This subsidy could come from universities (which may gain from the access to research that a demonstration-scale cellulosic ethanol production facility could provide), government sources (which are interested in promoting cellulosic ethanol for policy reasons), and private or corporate entities (which either share an interest in promoting cellulosic ethanol, can use the funding opportunity as part of their philanthropic efforts, or may provide funding on the condition of the right to participate in the more-likely-to-be-profitable commercial stage). Finally, the project would require $15 million to form the equity portion of the initial constant cost. This could come from a federal grant.

Economic Impact Assessment

Locating a commercial-scale cellulosic ethanol production facility, its feasibility having been described above, would promote direct and indirect economic activity throughout the area. Many variables affect the scale of job creation, from the state of the national economy to the extent of existing local business activity.

Revenue and cost information have been assembled based on comparing and synthesizing numerous sources. These sources include news articles, interviews, NREL studies, mandated public information provided by ethanol companies receiving DOE grants, and studies conducted by research university departments focused on economic development, agriculture, and/or forestry. Although no single one of these sources may necessarily apply perfectly to southern California, the combination of these sources should approximate the related numbers for southern California reasonably closely.

Principles of the Economic Impact Assessment

The economic impacts of any new business enterprise include one-time and permanent direct and indirect effects. Construction of the cellulosic ethanol facility and other various facilities catalyzed by the activity of the initial facility would create the one-time effects. Permanent effects represent those related to operations and maintenance within the cellulosic ethanol facility directly and within supporting industries indirectly, including changes in household spending due to changes in economic activity generated by direct effects. The total

economic impact, therefore, is the sum of direct and indirect effects. These effects are often expressed in terms of output (sales), labor income (employee compensation and proprietary income), employment (jobs), and tax revenue.[117]

Exhibit 17. National Median and 25th Percentile for Wage Levels and Associated Skills in Biofuels Jobs[118]
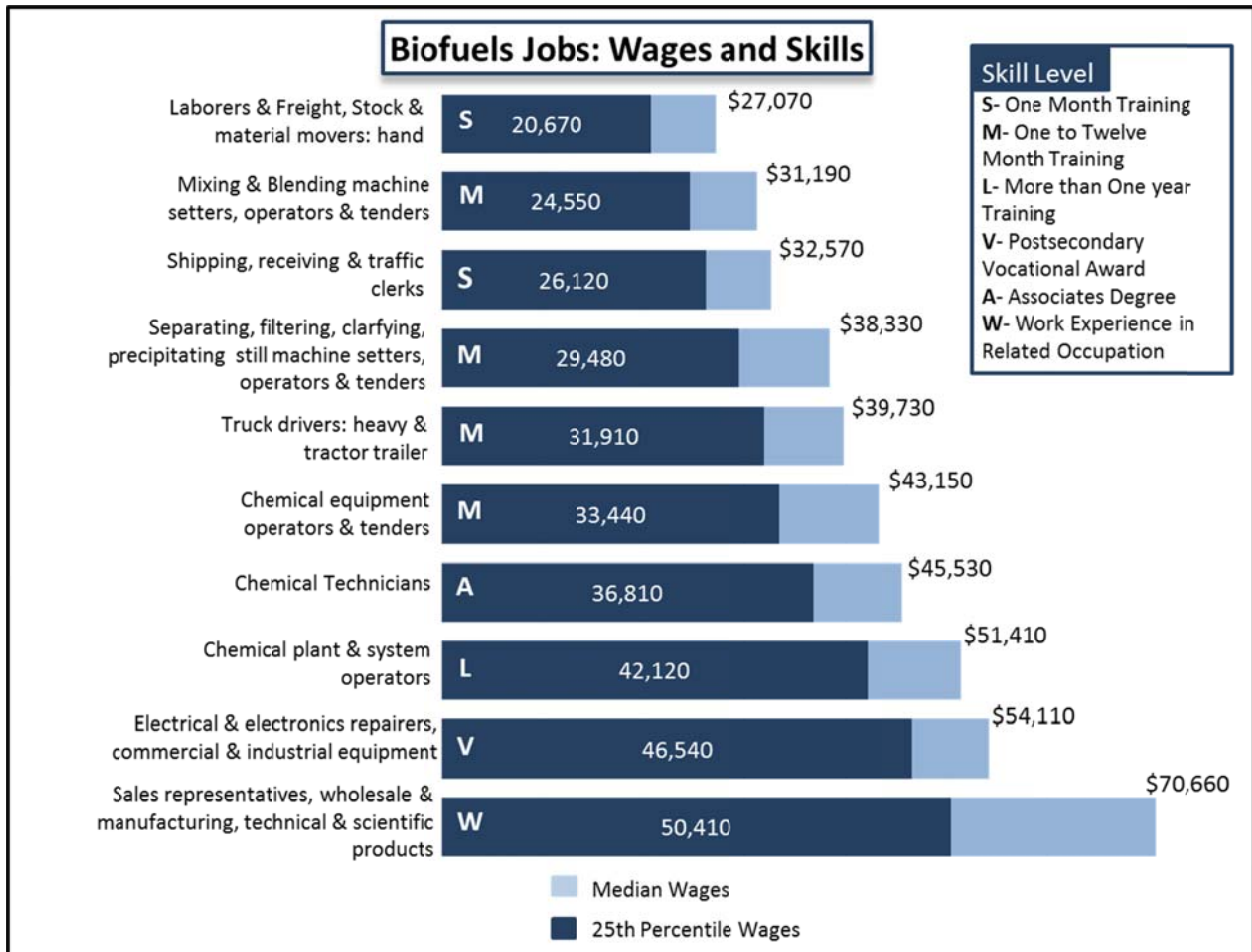
In order to estimate indirect effects on retail spending and property sales spurred by the salaries and wages provided to employees, the Center for Economic Development utilizes a multiplier factor based on the industry in which the business enterprise operates. Based on a previous analysis of the job-creating potential of a cellulosic ethanol production facility,

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[117] Flanders and McKissick, 2007.
[118] Newcomb, 2009.

reasonable multiplication factors are 1.56 for the construction phase and 2.81 for the operation phase.[119] These numbers are used in calculating the expected economic impacts of such a facility in Southern California.

Economic and Fiscal Impacts of a Cellulosic Ethanol Production Facility

Based on previous studies and estimates, the possible cellulosic ethanol production facility would create 77 permanent on-site jobs. The incomes for these jobs vary, as shown in Table C, "Fixed Operating Costs." The median income would be $30,000 with a range from $21,000 for Yard Employees to $109,000 for the General Manager (Exhibit 17). New business activity created by the production facility would generate a significant amount of tax revenue for both the County and the State of California. Exhibit 18 estimates the economic and fiscal impacts of cellulosic production.

Exhibit 18. Annual Fiscal Impact of Cellulosic Ethanol Production

Ethanol Production: Annual California Economic Impacts			
	Direct Impact	Indirect Impact	Total Impact
Output ($)	68,906,000	9,300,000	78,206,000
Labor Income ($)	2,390,000	2,263,000	4,653,000
Employment	77	139	216
State Taxes ($)			290,244
City Taxes ($)			17,449
County Taxes ($)			4,362
Transportation Fund ($)			26,174
Sum of Taxes ($)			338,229

Note: Adapted from Flanders and McKissick, 2007 using information from Los Angeles County Economic Development Corporation.

Exhibit 19 illustrates the economic and fiscal impacts due to cellulosic ethanol production. The estimates assume the site will be located in Los Angeles County. For location in San Bernardino or Riverside Counties, the estimates could vary slightly. The direct impact of

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[119] Flanders and McKissick, 2007.

output is based on the expected annual production of 30.6 million gallons of cellulosic ethanol and a rack price of $2.50 per gallon. Numbers for labor income and employment are derived from the table on employment figures presented earlier in this report. Since cellulosic ethanol has not been produced at the commercial scale, determining the exact multiplier for indirect job estimates represents a challenge. The indirect impacts above are based on a multiplier from a study on the economic impacts of cellulosic ethanol production in Treutlen County, Georgia.[120]

Similar numbers can be estimated for the economic impacts of the construction of the cellulosic ethanol production facility. The total project investment amount of $243.8 million would not be entirely captured by local and state employees and firms, as some of this cost represents materials and machinery that will be brought from other states. After accounting for this "leakage," estimates of the fiscal impact are provide below.

Exhibit 19. One-time Fiscal Impact of Cellulosic Ethanol Facility Construction

Ethanol Production: One-time California Economic Impacts			
	Direct Impact	Indirect Impact	Total Impact
Output ($)	32,970,000	22,228,000	55,198,000
Labor Income ($)	19,211,000	5,646,000	24,857,000
Employment	349	196	546
State Taxes ($)			731,593
City Taxes ($)			43,983
County Taxes ($)			10,996
Transportation Fund ($)			65,975
Sum of Taxes ($)			852,547

Note: Adapted from Flanders and McKissick, 2007 using information from Los Angeles County Economic Development Corporation.

Considering the scope beyond the facility itself, locating an ethanol-producing facility in Southern California can attract further business development to the vicinity on three levels. First, businesses that work directly with ethanol production will want to locate near the ethanol production facility. The byproducts of the ethanol production process can serve as raw materials for other facilities, as described in greater detail in the following section, in eco-industrial parks. Facilities that can utilize the byproducts of cellulosic ethanol production may locate near the

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[120] Flanders and McKissick, 2007.

proposed ethanol production facility. On the other side of the supply chain, companies that already gather the inputs for cellulosic ethanol may find increased benefits by locating near the ethanol production facility. Some of the impacts of these secondary firms are captured in the calculations of indirect impacts above.

Secondly, a jurisdiction can set aside an area to function as an eco-industry park, which would contain numerous supporting facilities, ranging from manufacturing and production to research and development. For example, a research center exploring methods of making ethanol production more efficient could locate near the ethanol production facility itself. The positive effects of this type of economic development, clustering, have been touted by Harvard School of Business researcher Michael Porter. According to Porter, clusters of related industry functions develop around and support each other, creating a situation in which the whole is greater than the sum of its parts. The branding of a site as focusing on environmentally responsible business activity can then create partnerships—such as between the businesses and local universities—that will reinforce that branding and attract attention to the eco-industry park. The impacts of these firms are additional to the impacts calculations above.

Thirdly, the development of the eco-industry park could attract new and expand existing tertiary support activity, such as office supply stores, retail food establishments, and other commercial activity. While it is not advisable to pursue this third level of development as a main objective, its benefit should be considered when calculating the long-term effects of the potential ethanol production facility. Together, these three levels of business development resulting from the creation of the ethanol production facility could establish a hub of job creation and tax revenue generation. This possibility serves as leverage when trying to earn a municipality's and the public's support for such a project.

The Eco-Industrial Park: Collaboration Improving Feasibility and Sustainability

Economic and Environmental Benefits of Co-location

The eco-industrial concept seeks to increase economic and energy efficiency by co-locating several facilities that operate complementarily. One aspect of the focus on efficiency considers individual entities acting on their own. This is usually manifest through sustainable

architectural design, recycled construction materials, and other similar features. More importantly, eco-industrial parks (EIP) create a collection of benefits that is greater than the sum of its parts because of the inter-firm cooperation. Mimicking a natural eco-system, members of an eco-industrial park utilize the wastes of other members to supply their own necessary inputs. Maximizing the potential of such an arrangement requires some careful planning and foresight, but it provides numerous benefits for the environment and for the firms' fiscal outlook.

Member companies within a park co-locate for logisitical and economic benefits. While traditional industrial parks may be found in many regions of the United States, EIPs represent a relatively new business model, so researchers are still analyzing the precise long-term economic benefits of EIPs. Some of the benefits, broadly defined include:

- Decreased production costs due to the use of other member companies' by-products
- Decreased energy consumption due to reduced transportation costs
- Decreased waste management due to other member companies reusing by-products
- Decreased costs of regulatory compliance due to relatively easily reduced emissions
- Decreased cost of R&D due to cooperation with other companies[121]

In order to maximize its leverage on economic development, the members of an EIP should cooperatively communicate with local government actors in order to streamline the regulatory and infrastructure processes. Especially in California, where businesses tend to perceive a disdainful attitude from government often related to the regulation of environmental impacts, an EIP can approach licensing and approvals with a clear presentation of its environmental impacts. Although nothing is guaranteed, clear and effective communication of its relative environmental benefits can help EIPs to establish sites in California. Moreover, local communities would benefit from local economic development and environmental sustainability, including job creation and resource management.

Cellulosic ethanol production represents a very real opportunity for a form of EIP. The fact that the conversion technology has not been proven at the commercial scale and lies at the forefront of current research naturally suggests co-location with research and development facilities. These could be a mix of recycling, manufacturing, or office-type space with flexible or

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[121] Cushman-Roisin, n.d.

light-industrial research labs (Exhibit 20). The mix of zoning required for such research facilities will likely require discretionary approval, so location in an EIP would be easier than location in a traditional office park or in traditional industrial areas. If the members of a potential EIP can identify each other beforehand, then they can approach the entitlement process cohesively seeking unified approval, which could reduce the waiting time and thereby reduce the cost of waiting. This arrangement would not preclude other companies moving into the park at a later date.

Exhibit 20. Eco-Industrial Park: Possible Industry Linkages
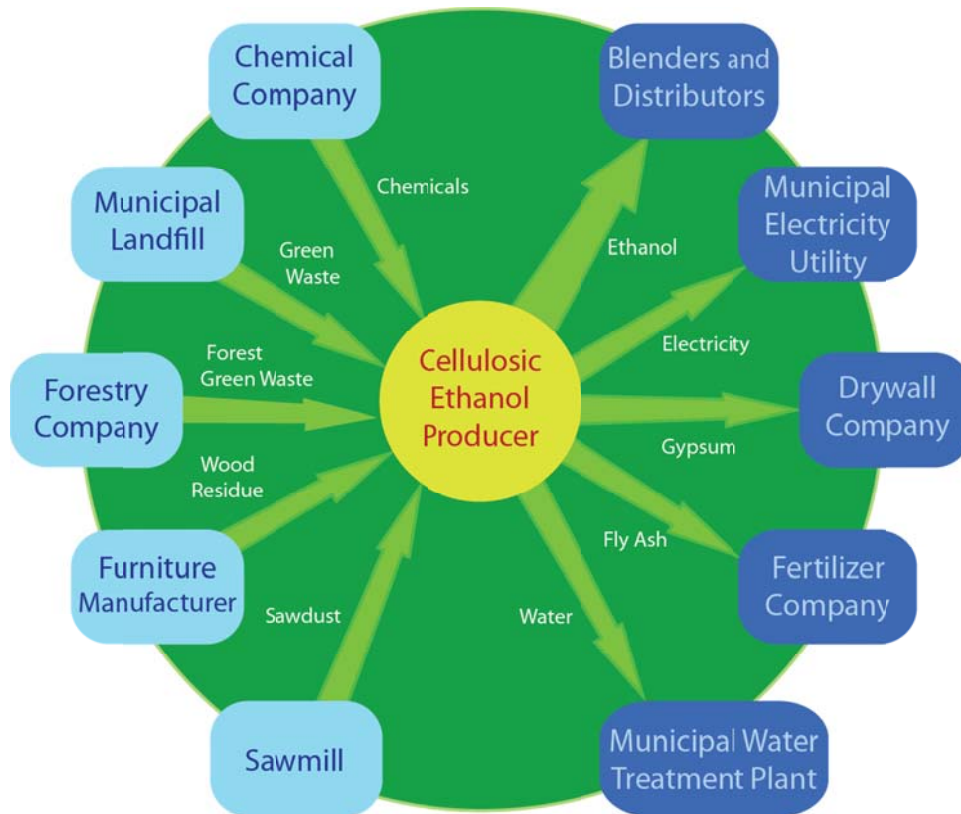
Given that enzymes represent a high proportion of production costs, their creation on-site may be a more cost-effective option. Reinforcing the complementing aspect behind eco-industrial parks, on-site enzyme production would benefit greatly from nearby research and development. Other opportunities for co-location in terms of inputs are waste management and

production of wood-based products. The former would help in bringing municipal green waste to the facility and sorting it for ethanol production. The latter would help similarly in collecting forest-based green waste and maximizing its use. As shown in the figure above, an EIP centered on cellulosic ethanol production has many potential member firms, which include all of, but are not limited to, the ones shown and described here.

In terms of outputs, cellulosic ethanol production typically also produces electricity, molasses, and ash. Some of the produced electricity may be recycled as an energy input for the production process, but excess electricity, which most assessments expect, could be sold to the local utility company, such as the Los Angeles Department of Water and Power. Gypsum can be used in a number of industrial and chemical processes, including as a component in drywall. Ash, meanwhile, can be used as part of fertilizer for the nearest farms in Southern California.

Partners in an Eco-Industrial Park

In *Fieldbook for the Development of Eco-Industrial Parks*, a report prepared for the U.S. Environmental Protection Agency, the authors suggest that one of the major challenges to creating a solvent EIP is building a collaborative of local stakeholders who can help to build and guide the creation of the EIP from vision through construction and maintenance. Types of stakeholders may include represenatives of:

- Financial institutions for venture funding and capital
- Universities and colleges for intellectual property and workforce training
- Prospective business members of the EIP, such as the cellulosic ethanol producer, a research and development center, and the electric utility
- Suppliers of the materials for the cellulosic ethanol production process, such as waste management and forestry companies
- Users of byproducts of the cellulosic ethanol production process, such as drywall and fertilizer producers
- City, county, state and federal government for regulatory foresight and permit streamlining
- Chamber of Commerce and other regional eco-development organizations

- Neighborhood organizations, labor unions, and environmental organizations to gauge potential reasons for EIP development

As with most large ventures, securing capital often poses the last hurdle before beginning the construction process. Since EIPs represent a relatively new model and their level of risk is therefore hard to determine, public sector entities can play a large role in the initial stages of development of sustainably-focused industries such as ethanol production. [122] Depending on the location of the EIP, types of public owners may include the local port authority, economic development agency, or university or college.[123] As familiarity with EIPs develops and investors have a better sense of the risk involved, more private entities may be willing to assume creation and control of EIPs.

The *Fieldbook for the Development of Eco-Industrial Parks* provides examples of how government can contribute to the development of a sucessful EIP. These contributions include leading the EIP development strategic planning process; incorporating the EIPs into the economic development component of state and local General Plans; streamlining permitting and other regulatory processes; providing financial support through incentives, bonds and grants; faciliating technology transfers; and providing technical assistance and workforce training. Normally, access to public lands is restricted due to the fragility of the ecosystems therein. The public sector, therefore, could also be instrumental in allowing access to the forest green waste located on public lands and helping to ensure that collection of the green waste does not damage any of the ecosystems.

Investment banks, commercial banks, venture capital firms, municipal and industrial bonds, and public sector grants and incentives can contribute to the financing for these parks. Appendix E provides a full list of available incentives and public sector funding. Having representatives from financial insitutions in the EIP stakeholder collaborative will assist in opening access to available private capital.

Cooperative partnerships, particularly between sectors, reinforce the ideas behind clustering, i.e., that the product of multiple groups working together becomes greater than the sum of their work individually. For example, a partnership with the US Forest Service and with

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[122] Lowe, Moran, and Holmes, 1996.
[123] Lowe, Moran, and Holmes, 1996.

CALFIRE can help facilitate access to forest residue located in National Forests and California's state forests, respectively. A partnership with a local municipality can provide an off-take agreement, i.e., a guaranteed supply and purchase of a certain amount of cellulosic ethanol. Refiners would typically be those interested in purchase of pure ethanol.

Supporting the idea of partnerships, Mascoma received $50 million in equity from Valero Energy to advance its commercial plant in Kinross Township, Michigan.[124] J.M. Longyear, an umbrella corporation working in timber, mineral, and real estate markets and located in Marquette, Michigan, is slated to provide the hardwood and pulpwood for the process. Mascoma's project, however, has been stalled because it has not been able to secure a loan guarantee.[125]

BlueFire signed a 15-year agreement for Cooper, Marine, & Timberlands to provide biomass feedstock in the form of wood chips; forest residual chips; pre-commercial thinnings and urban wood waste such as construction waste, storm debris, and land clearing; and manufactured wood waste from furniture manufacturing. A week earlier, BlueFire signed a 15-year takeoff agreement with Tenaska Biofuels for the purchase of cellulosic ethanol to be produced at the former's Fulton, Mississippi facility.[126] Moreover, BlueFire executives expressed gratitude at and admiration for the eager cooperation and accommodation of Itawamba County, in which Fulton is located, and of the county's Economic Development Council, as well as of the Mississippi Development Authority.[127]

Cellulosic ethanol producers would likely find many opportunities for such regional cooperation in southern California. Due to the large population segment of Los Angeles and the surrounding region, there are numerous waste management companies that would likely be interested in reducing their disposal cost, energy companies seeking to diversify their interests, and other private companies interested in additional business activity. Although government entities in California are stereotyped as being anti-business, such a description is an over-generalization. Certain cities are more eager to attract businesses actively, such as the City of Industry. And almost all cities are interested, at least at some level, in attracting some business

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[124] Mascoma, 2011.
[125] Yung, 2011.
[126] BlueFire Ethanol, November 2011.
[127] Klann et al., 2011.

activity. Using an EIP and cooperation among business more generally to create energy-saving synergies should help to attract public interest and support due to lower environmental impacts overall.

Biomass Resources

A dual focus on forest-derived and municipal green waste provides for flexibility in ethanol production. The two resources are complementary in that the former is more abundant in rural and wooded areas and the latter is more abundant in urban areas. Moreover, coordination with efforts to minimize the risk and extent of forest fire damage to lives and property can facilitate the collection of forest green waste. Meanwhile, a growing population in southern California ensures that municipal waste will continue to be available in increasing amounts.

Wildfire Mitigation Efforts

Due to a long history of wildfires and steady increase in population growth, several federal, state and local policies and programs have been implemented to help mitigate disaster risk for vulnerable communities. There are currently 1,272 communities at a high level of wildfire risk in the state of California. The Disaster Mitigation Act of 2000 provides a key source of grant funding that allows state and local governments to coordinate, plan and implement disaster mitigation plans. Furthermore, the Bureau of Land Management has provided funding for wildfire protection projects in 51 of the state's 58 counties.

Southern California has experienced increasing forest damage due to a significant bark beetle infestation. The bark beetle consumes forest wood and leaves, and mostly trees that are either dying or dead remain. Most of the land at risk of a bark beetle epidemic is near communities where widespread tree mortality could result in extreme fire danger. To combat the infestation, San Bernardino and San Diego counties have created task forces to reduce fire risk by removing dead trees that have been affected by the beetle.[128]

Every California county and city is required to prepare a long-term, Comprehensive General Plan that explains its development goals. That plan must include a Safety Element which describes how that community will reduce potential hazard risk from natural disasters like

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[128] CALFIRE, "Southern California Beetle Infestation," n.d.

wildfires that could result in death, injury, property damage, and dislocation. The California Public Resources Code 4290 outlines requirements for the creation and maintenance of defensible space, which is the maintenance and design of landscaping around roads and buildings in a way that reduces the risk of fires spreading. The code also sets regulations on the minimum private water supply reserves for emergency use and road standards for fire equipment access.

The California Department of Forestry and Fire Protection, CALFIRE, has a Vegetation Management Program that uses the intentional use of fire, referred to as "prescribed fire," to reduce fuel hazards in the Wildland Urban Interface (WUI). Also, the California Forest Improvement Program provides financial assistance to private forest landowners, Resource Conservation Districts, and non-profit watershed groups for wildlife habitat improvement and land conservation activities. CALFIRE, along with the State Board of Forestry and Fire Protection, maintains a statewide California Fire Plan. The Plan focuses on reducing wildfire risk, firefighting costs, and property losses. Los Angeles, Orange, and Santa Barbara counties contract fire protection from CALFIRE for the WUI in unincorporated areas that qualify as state responsibility areas—i.e., areas where California has financial responsibility for wildland fire protection.

With financial support from the Federal Emergency Management Agency (FEMA) Los Angeles, Riverside, and San Bernardino Counties have created a FEMA-approved Local Hazard Mitigation Plan. In these local plans, the counties emphasize fire prevention education. The education components focus on vegetation modification, management awareness, and fire-safe- and fire-prevention-oriented design for developments. Additionally, the counties use prescribed burning to reduce wildfire fuel and limit public access to open fire-hazardous areas. Neither the state nor any municipality uses eco-industrial development as part of its wildfire mitigation plans.

Biomass Resource Assessment

The California Biomass Collaborative (CBC) and the CEC estimate that 32 million tons of biomass is annually available in California for conversion to biofuel on a sustainable basis, including 14.3 million dry tons of removable biomass coming from forestlands and 9.1 million tons coming from municipal waste. To break down the forestland even further, the CBC and

CEC suggest that 4.1 million dry tons are from forest thinnings, 4.3 million dry tons from forest slash, 2.6 million dry tons from shrub, and 3.3 million dry tons from mill residue. The 9.1 million dry tons of municipal biomass represents the amount that is currently landfilled, separate from biomass diverted from landfills, so the entirety of that amount can be available for biofuel production. While the availability of forest-derived biomass would remain essentially constant through 2020, municipal waste, the CBC and CEC predict, will increase to 9.7 million dry tons in 2010, 10.3 million dry tons in 2017, and 10.7 million dry tons in 2020.[129]

All of the above amounts represent "technical" availability, which accounts for "terrain limitations, environmental and ecosystem requirements, collection inefficiencies, and a number of other technical and social constraints [that] limit the amount of biomass that can actually be used."[130] Additional economic constraints may further limit the potential available biomass, but the CBC and CEC do not consider these since they are site specific and can vary greatly. Based on the availability of biomass as described here, biomass availability should not be the limiting factor for cellulosic ethanol production in the state of California. The model of cellulosic ethanol production presented in this report would require 437,500 tons of biomass per year, equal to 5.5% of biomass available in southern California from forestlands and MSW (i.e., excluding agricultural residues) or 8.8% of forest and MSW biomass available in Los Angeles, San Bernardino, and Riverside Counties.

Forest Biomass Collection Process

Collection of forest biomass requires a delicate approach in areas of forests that are inaccessible by motorized transport, either due to restrictions imposed by the US Forest Service or due to terrain and other natural features. More accessible and convenient areas lie on the outer boundaries of the forests, which provide for easier collection and transportation. Limiting collection to the outer boundaries, however, reduces the available supply. Decisions on where to collect forest residue and on how much of it to collect should include the above considerations.

Meanwhile, collection of forest green waste may be most convenient and inexpensive if partnered with the standard efforts of CALFIRE related to fire prevention through forest waste collection and controlled burning. The model used in this report assumes that forest green waste

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[129] Williams et al., 2008.
[130] Williams et al., 2008, page x.

can be harvested and hauled to the forest edge for $20.79 per ton, plus $21.53 per ton for hauling and storage and $11.00 per ton for grinding, resulting in a total cost of $53.32 per ton from collection to the beginning of use in production.

MSW Biomass Collection Process

To maximize the efficiency of the MSW green waste collection process, it should coordinate with current MSW waste disposal procedures. As an example, the City of Los Angeles collects yard trimmings and other compostable materials in green bins that accompany black bins for general waste and blue bins for recycling. The material from these green bins is transported by truck to one of three mulching and composting facilities in the City of Los Angeles: Griffith Park Composting Facility, Harbor Yard Trimming Facility near San Pedro, and Lopez Canyon Environmental Center. After removing the non-compostable material, Department of Public Works employees set the remaining material into windrows, large rows of compost, under which special pipes trap odorous air to reduce the impact of bad smells on the surrounding communities. Once the mulch and compost are ready, the city provides some of it for free to farmers and some of it for city residents at ten pick up locations, presumably using the rest.[131,132]

This service is provided mostly for single-family homes and multi-family homes with four or fewer units. Larger multi-family buildings and some municipalities in the County of Los Angeles rely on privately contracted waste, recycling, and yard trimming collectors and processors. Other municipalities in the county have their own collection systems.[133] Instead of giving away its mulch, the City of Los Angeles could sell some of its green waste to a cellulosic ethanol producer, perhaps even without processing it, depending on the technology the producer would use. Using both MSW green waste and forest-based green waste provides the ethanol producer with some flexibility in response to fluctuations in the availability and corresponding price of each.

Since there would be some market competition for the MSW green waste, negative cost on its collection may not be attainable. That market competition, however, features simple uses

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[131] City of Los Angeles, Department of Public Works, "Mulching and Compost," n.d.
[132] City of Los Angeles, Department of Public Works. "Free Mulch Give-Away," n.d.
[133] MacVean, 2011.

that can turn to other sources, such as manure for fertilizer, suggesting that a low price is possible. The model used in this report assumes that MSW green waste can be collected for $15.00 per ton, including the cost of contaminant removal, plus $21.53 per ton for hauling and storage and $11.00 per ton for grinding, resulting in a total cost of $47.53 per ton from collection to the beginning of use in production.

Carbon Emissions Reduction

Benefits of ethanol include lower greenhouse gas (GHG) emissions compared to gasoline. Corn ethanol offers a 15-20% reduction in lifecycle GHG emissions compared to gasoline, while cellulosic ethanol offers about a 70% reduction. This difference is due to the energy necessary to grow and process corn into ethanol and represents another advantage of cellulosic ethanol over corn ethanol.[134] EISA 2007, meanwhile, requires that alternative fuels create at least a 20% reduction in lifecycle GHG emissions in order to qualify toward the mandated amount. Most of the ethanol currently produced in the US is based from corn, suggesting that the market for cellulosic ethanol, with its advantages over corn ethanol, could grow quickly.

The potential for carbon emissions reduction is maximized through the very local collection of raw materials, both from forest brush and urban green waste. As the production process uses raw materials collected from closer locations and distributes ethanol to closer markets, then the entire process will result in fewer GHG life-cycle emissions. This consideration requires a balance in locating the ethanol production facility so that it is close to available municipal green waste and forest-derived green waste.

Proposing a Site

GIS Modeling

A GIS-based selection model helps to identify potential eco-industrial development sites for economic redevelopment, in or adjacent to the disaster-impacted regions suffering economic distress. This method allows for the input of multiple spatial variables to find the locations that would offer the optimal synergy—providing the most suitable environment for the production of

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[134] Environmental Protection Agency, "E85 and Flex Fuel Vehicles: Technical Highlights," 2010.

ethanol, supplying employment for the communities within close proximity to the eco-industrial park, and reducing the risk of forest fires where they may create the most damage on residential communities. The model builder of ArcCatalog within ArcGIS 9.3 was used in order to view and edit the data, while ArcMap was used to build and test the model.

Data Collection

Multiple sources provided the data used for this model: Southern California Association of Governments, U.S. Census Bureau's American Community Survey and Tiger Files, U.S. Bureau of Labor Statistics, and California Department of Forestry and Fire Protection's Fire and Resource Assessment Program. Year 2008 serves as the base year for this model's spatial variables, because it is the most recent and complete data available. Furthermore, the three major fires that were the catalyst for this feasibility analysis occurred in 2008. In order to capture the effects of the recession on economic activity, however, unemployment and per capita income data come from 2009.

Basic municipal boundaries for the model came from shapefiles of cities and counties in California from the Fire and Resource Assessment Program. Fire perimeter data collected by CALFIRE on all fires since 1980 defined the areas affected by fires, from which an ethanol production plant could collect the maximum biomass to produce its fuel. For further definition of fuel source locations, vegetation data that ranks land cover as a potential fuel source was gathered from CALFIRE.

To ensure a synergy between job creation and the proposed eco-industrial park the model uses data on potential workers housed in the administrative boundaries from CALFIRE. This data includes measures of population, per capita income, and unemployment rate for every city with a population over 65,000 residents for years 2000, 2008, and 2009 from the U.S. Census Bureau's American Community Survey detailed tables. Using the latest street files for the counties of Santa Barbara, Los Angeles, Riverside, and San Bernardino from the Census Bureau's Tiger Files ensures that the plant will be built in a location with sufficient transportation access. The Tiger Files were polylines, so the information was already in shapefile format. Meanwhile, the American Community Survey data was downloaded in table format, allowing it to be customized to the city level.

Since an eco-industrial park can only be developed within certain zones in a city, securing shapefiles of universalized general plan and zoning designations by parcel for each jurisdiction within the counties of Los Angeles, San Bernardino, and Riverside from the Southern California Association of Governments was necessary. SCAG's Existing Land Use shapefile for 2008 indicates whether appropriate parcels are still available. This shapefile has the current usage as of 2008 of every parcel, including vacancy, within the three counties.[135]

Model Process

The selection process discerns important variables for a successful ethanol production facility, selects economic or spatial attributes that represent those variables, and creates a model that selects ranges of interval attributes and defines desired proximity to all spatial attributes. This combination results in the simultaneous exclusion and inclusion of parcels based on the appropriate conglomeration of appropriate attributes. Therefore, the model does not look for the perfect location, but rather teases out the most apt locations relative to the pool of possible parcels. Thus, the model must keep the sensitivity of each variable flexible so that a practical collection of site locations can be achieved.

The four main variables within the model are:

- Work Force Characteristics
- Biomass Supply
- Development Potential, and
- Transportation Access

These four variables are the parameters of the model and each of them is applied to Los Angeles, San Bernardino, and Riverside Counties - the areas within the study's scope. Each of these variables is represented through measurable attributes, which are spatially represented either through their own geographical footprint, an area of influence, or justifiable jurisdictional boundaries.

The Work Force Characteristics variable is represented by two attributes: unemployment rates and per capita income. The data is gathered by city and spatially represented within a

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[135] Vacancy, as referred to in this model, indicates that the land is undeveloped, e.g., open space.

shapefile whose polygons match city boundaries, as shown in Maps 1.1 and 1.2 of Appendix D. A work force would likely benefit from or be drawn to work in a facility constructed near but not in the city limits if a parcel which better fits the other attributes is found in neighboring cities or unincorporated areas. Therefore, a buffer of 30 miles is placed around these communities in consideration of the common 45-minute commute planning guideline and a reasonable average travel distance of 45 minutes.

Economic development generally aims to create jobs while accomplishing other goals. This project therefore desires to ensure that the proposed facility creates a synergy between using unwanted or dangerously excessive woody biomass and creating jobs in an area in need of employment and economic activity. Therefore, to ensure this synergy occurs, the workforce variable is represented by selecting the cities with the highest unemployment and lowest per capita income. This is accomplished by selecting cities with an unemployment rate that is equal to or higher than 10 percent and a per capita income that is less than or equal to $20,000. Since data for cities with a population of 65,000 or less is not available, all such cities were included in the selected pool so the selection would err toward over-inclusion rather than over-exclusion.

The Biomass Supply variable is represented through a conglomeration of 10 years of fire burn footprints. This was already spatially represented by CALFIRE, but to represent Biomass Supply as a whole rather than as individual incidents of fires, the individual polygons representing each fire were dissolved into one large polygon. This procedure allows for a better representation of biomass supply since the model aims to pinpoint areas with large quantities of woody biomass; and areas that have had at least one fire in the last ten years would be an indicator of where excess biomass will be located. Furthermore, this procedure allows for easier comparison to other variables' attributes. This attribute is demonstrated in Map 2 of Appendix D.

For the attribute that measures biomass supply to be meaningful, it must select potential sites that are within a reasonable proximity of both municipal solid waste and forest biomass locations. The measurement of the workforce attribute accommodates the need for access to municipal biomass. As for forest biomass, the dissolved burn footprints polygon is increased by a 30 mile buffer to ensure that any potential site would be within 30 miles of at least one location of woody biomass. Given the concentration of these burn footprints, the 30-mile buffer ensures that any selected site would also be fairly close to multiple other woody biomass sites.

The Development Potential variable is represented through two attributes, as well. The potential to construct a facility within a city depends on the selected parcel having the appropriate zoning and general plan code as well as that parcel being available. Therefore, the attributes that represent this variable are: first, a shapefile from SCAG that contains universalized land use codes for all parcels within the three counties; and second, a shapefile from SCAG which contains existing land use as of 2008. These two attributes were merged into one shapefile so that appropriate use and availability could be measured and represent the Development Potential variable; as shown in Map 3 of Appendix D.

To ensure the development potential of an eco-industrial park, multiple selections are made from the two attributes. First, only parcels with industrial general plan designations and zoning codes are selected, and of those industrial parcels, only the parcels deemed vacant by the existing land use designations are chosen. This selection process ensures that all potential parcels are available and permitted for industrial use.
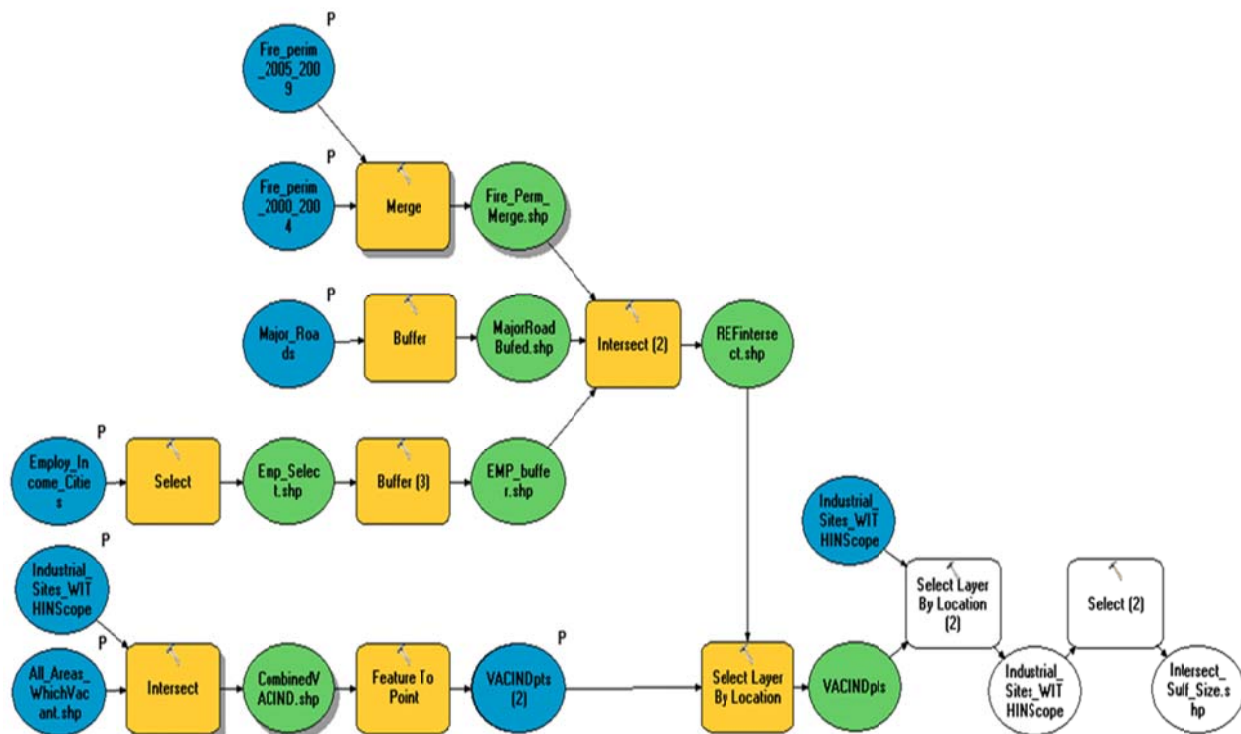
The last variable is Transportation Access. The ethanol production plant will depend on the road network to gather biomass from forests and municipal sources; access to the primary arterials of the road network is therefore important. The attribute representing this variable is drawn from the entire road network within the three counties being studied. This road network is gathered from the Census Bureau's Tiger Files, so the information is already spatially represented; however, the primary concern is the plant's access to primary arterials, so freeways and highways are selected from the network of streets. The resulting collection of major roads is the attribute that represents transportation access, as shown in Map 4 of Appendix D.

The transportation access variable is measured by selecting the freeways and highways attribute and placing a buffer of three miles around these major thoroughfares. This buffer selects only the parcels which are very close to any major freeway and therefore close to the primary arterials of the road network. This ensures that the eco-industrial park will have sufficient access to the municipal biomass collection locations as well as the multiple locations where woody biomass may be collected.

After the multiple attributes have been selected, combined, spatially represented, and measured to represent their corresponding variables, these variables are placed within the model. Exhibit 21 shows a flow chart of the model. Each of the blue ellipses is an attribute or a

combination of attributes inserted into the model and meant to represent each of the four important variables. The yellow squares are particular manipulations of the information which move the data through the model, and the green ellipses are the outcomes of each manipulation.

Exhibit 21. Flow Chart of the GIS Model to Identify Eco-Industrial Park Sites

In the next step, a requirement for simultaneous qualification according to the Biomass Supply, Work Force Characteristics, and Transportation Access variables further narrows the possible sites. Then, the parcels which have development potential are selected separately, because the other three variables select their appropriate locations by proximity, while Development Potential selects individual parcels. Furthermore, parcels which have development potential are converted into points, using the centroid of the selected parcels, because this allows for more accurate comparison to the other variables. The model at this point in the process contains points that represent parcels with development potential and a collection of polygons which represent locations that satisfy the requirements for the other three variables. The select-by-location tool indicates all of the points that fall within the polygons, which represent the

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locations satisfying all four variables. Those points are selected and matched with their corresponding parcel.

A glance at the map of qualifying parcels indicates that few available parcels meet the 30-acre minimum for a commercial-scale cellulosic ethanol facility. For a few sites, adjacent, qualifying parcels could be combined to form a total of at least 30 acres. This combination of smaller parcels into sufficiently sized sites represents the final step in the model.

The model was run several times with different ranges and buffers on each of the variables until an acceptable selection of less than 20 sites were selected. Aforementioned ranges and buffers that may seem arbitrary were actually calibrated for this purpose. This reflects the flexibility of the model and allows for locations to be chosen based on their comparison to other parcels within the area and results in maximum amount of compatibility to the four essential variables: Work Force Characteristics, Biomass Supply, Development Potential, and Transportation Access.

Site Selection

For final potential locations, this model selects sites in or near economically disadvantaged cities that are in dire need of development and job creation. These sites are close to locations affected by natural disasters, and they comply with the General Plans and Zoning Codes of the cities within which they reside (Exhibit 22). Finally, the potential sites are accessible in terms of transportation and are vacant lots of sufficient size, albeit requiring a combined group of parcels. Further investigation should filter these sites based on financial assistance or incentives attached to specific locations which would render development more feasible for a specific site. Although this site selection model provides a list of potential parcels that may be suitable for the development of an eco-industrial park, any actual site development should consider the sites in more depth than this report.

Exhibit 22

Model Produced Potential Sites

City	Acreage	Development	Nearest major Road	Potential Biomass	Zoned	APN of Largest Parcel
City of Industry	54.16	Vacant	Pomona Fwy, Orange Fwy	Excellent	Industrial	8719007924
Lancaster	44.39	Vacant	Antelope Valley Fwy, Sierra Fwy	Excellent	Heavy Industrial	3118005023
Lancaster	37.73	Vacant	Antelope Valley Fwy	Excellent	Light Industrial	3114013001
San Bernardino	38.12	Vacant	I-215 Fwy, I-15 Fwy	Good	Industrial Extraction	262042170000
Twenty-nine Palms	48.59	Vacant	29 Palms Hwy	Fair	Industrial/Commercial	624241080000
Near Banning	47.21	Vacant	I-10 Fwy	Good	Industrial	532100001

Based on the model used in this report, six locations have the highest potential to ensure a successful cellulosic ethanol plant anchored eco-industrial park while creating local jobs for economically distressed municipalities. All of the sites listed above are a collection of parcels that would need to be combined under a single ownership.

The model was not limited to sufficiently sized single parcels based on the expectation that the local municipality would cooperate with the developer of the cellulosic ethanol facility and that the process of unifying the parcels would represent a very small portion of total development costs. Moreover, the sites made up of a collection of parcels that are better positioned for cellulosic ethanol production than potential locations composed of a single parcel, and interviews with developers revealed that multiple parcel development may not be more complicated than single parcel development, depending on factors such as zoning and the city's administrative process.

All six locations are located on the periphery of cities, either barely outside or barely inside the city boundaries. This could result from common industrial zoning practices; whatever the cause, the peripheral location of these sites matches the balanced goals of providing access to jobs and access to municipal and forest green waste.

There are some potential complications with each site, such as awkward parcel form, multiple owners of the collection of parcels needed for the facility's size, or extensive grading requirements to make the site suitable for development. However, the size of each site is either more than sufficient or can be expanded by adding other available parcels adjacent to the site. This means that each site has sufficient size to support an eco-industrial park where other

facilities can develop near the cellulosic ethanol facility to create an agglomeration of synergistic industrial firms. These potential site locations are spatially represented on a map in Appendix D.

Eco-Industrial Park Anchor and Tenants

An eco-industrial park featuring an ethanol bio-refinery as an anchor tenant could potentially include recycling facilities to make the park more financially feasible. Recycling represents a well-established industry with little risk. It thereby provides a fitting complement to the risky developing technology of commercial scale bio-ethanol. Complete recycling requires recovering materials from the waste stream and incorporating those materials into manufactured products available for consumers. To follow the material-to-product model proposed for bio-ethanol, recycling facilities in the eco-industrial park could similarly accept recycled materials and manufacture them into products.

The California Department of Resources Recycling and Recovery, commonly known as CalRecycle, provides information about recycling for consumers, businesses, recycling and waste-hauling industries, nonprofit organizations, educational facilities, and others. CalRecycle provides information on recycling locations, programs for schools and agencies to boost recycling efforts, best practices, special instructions such as dealing with used oil recycling, and other useful information. The department collects and provides this information in order to encourage recycling and material recovery, which furthers the preservation of California's natural resources and materials.[136]

This report focuses on four recyclable materials, based on a set of recyclable materials identified by CalRecycle. These materials have been chosen based on their large volume in common waste streams, the ease and benefits of recyling them, and the availability of a market for finished products made from them. Endorsement by CalRecycle helps because California has "Buy Recycled" programs that provide financial and other incentives supporting the market of products using recycled materials identified by the state.[137] The best recycling materials to include in an eco-industrial park with bio-ethanol production, according to this report, are glass, plastic, paper, and tires.

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[136] CalRecycle, 2011a.
[137] CalRecycle, "Buy Recycled Programs," 2012.

Glass

The majority of recycled glass in California is gathered through buyback centers and curbside collection. The process for recycling glass involves sorting according to color, cleaning the glass, and crushing it into small pieces called cullet. After the cullet is mixed with sand, soda ash, and limestone, the new mixture is melted in a furnace into a thick liquid. Dropped into a glass forming machine, the melted glass is poured into molds. After the mold is removed and the glass cools, workers inspect and ship the glass. Recycling glass can save 30% of energy consumption in comparison to creating new glass.[138]

Demand for recycled glass in California is supported by the state's minimum content requirements for food and beverage containers and for fiberglass. Glass food, drink, and beverage containers manufactured in California must contain at least 35% postconsumer cullet according to state law. Fiberglass producers in the state must use at least 30% postconsumer cullet in fiberglass building insulation made or sold in California.[139] These requirements do not seem to have deterred glass manufacturers, as California has more glass and glass product manufacturing establishments (252) and employees (8,574) than any other state. These numbers even rank California among the top 20 states in glass and glass product manufacturing establishments and employees per capita.[140] Minimum requirements for using postconsumer glass and a large total volume of glass manufacturing in California indicate that demand for cullet will continue to make glass recycling an attractive alternative to glass disposal in landfills.

Plastic

Like glass, the majority of recycled plastic in California originates from containers collected at buyback centers and curbside recycling programs, as well as film collected from agricultural operations, retail grocery stores, warehouses, distribution centers, and manufacturing facilities. The raw material usually falls into one of six major resin type categories for commercial grade plastic. The price for recycled plastic depends on whether it is loose or baled. The latter option increases the density of the collected plastic to decrease transportation cost and energy use. Once the plastic arrives at the reclaiming facility, workers sort, chop, and wash the

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[138] "The Truth about Recycling," 2007.
[139] CalRecycle, 2010b.
[140] US Census Bureau, 2009.

plastic. The reclaiming facility generates three categories of plastic feedstock for manufacturing new products: flakes, powder, and pellets.[141] Recycling plastics can save 70% of energy consumption in comparison to using virgin materials.[142]

California features two main policy-based programs that support the market for recycled plastics. The At-Store Recycling Program requires stores to make available plastic bag collection and to encourage the recycling of plastic bags. The law also requires plastic bag manufacturers to develop educational materials to encourage reduced use and recycling of plastic bags.[143] The second program relates to the use of recycled plastics in new goods. It requires plastic trash bag manufacturers to use an amount of plastic postconsumer material for bags sold in California equal to at least 10% of the weight of the regulated bags or 30% of material used in all of its plastic products, and the state provides information on recycled plastic (and other material) availability from suppliers at various levels of the consumer product chain, from manufacturer to converter to distributor, throughout the country.[144]

Paper

Although residential curbside collecting is the most visible method of paper recovery, the largest sources of recovered paper are the business and industrial sectors. National recovery rates for paper reached 74 percent in 2009, but CalRecycle believes that a higher rate can be recovered.[145] Recycling paper can save 40% of energy consumption compared to using new resources.[146] CalRecycle provides links to websites and directories with more information on paper and other recycling. These are meant to overcome informational barriers to recycling and the purchase of recycled materials.

Waste Tires

The Tire Recycling Act of 1989 has helped to divert a large portion of waste tires in California. The legislation marked the state's response to the danger of potential fires and vector

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[141] CalRecycle, 1997.
[142] "The Truth about Recycling," 2007.
[143] CalRecycle, 2010a.
[144] CalRecycle, 2011c.
[145] CalRecycle, 2011b.
[146] "The Truth about Recycling," 2007.

harborage associated with improperly stored waste tires. Of 41 million waste tires in 2010, more than 33 million were recycled for beneficial use through reuse, retreading, and combustion. The Tire Recycling Act authorizes CalRecycle to award grants and loans to businesses and public entities for activities supporting the recycled tire market, including polymer treatment, crumb rubber production, retreading, shredding, and the manufacture of rubber asphalt, playground equipment, crash barriers, and other products that use recycled rubber. CalRecycle currently aims to strengthen the statewide market infrastructure for products using recycled tires.[147]

Possible Tenants

Given that the state has prioritized the glass, plastic, paper, and tire recycling industries, we believe these industries have the best potential to support an eco-industrial park centered on bio-fuel production. California has set goals for increased recycling of these materials and for improving the market and infrastructure for the products of these recycled materials. Among uses that qualify for heavy industrial zoning, necessary for bio-fuel production, recycling of these products promises the most stability and job creation. Other recycling services and other types of sustainably oriented businesses can promote the feasibility of the eco-industrial park, as well. CalRecycle has identified a list of businesses in California and elsewhere in the US that use recyclables, from manufacturing to distributing to retailing. This directory can be used to find tenants for the eco-industrial park.

Marketing Strategy for an Eco-Industrial Park

To attract the most appropriate, best-fitting tenants to the eco-industrial park requires well-directed and well-managed marketing. In some respects, an eco-industrial park can be treated in mostly the same way as a traditional business park. Marketing for a business park begins before the construction ground breaking and continues after the project is complete. As with other projects, the threat of vacancy increases the risk of investing in the project. Effective marketing for the eco-industrial park is especially important because of the risk inherent in developing biofuel production technology.

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[147] CalRecycle, 2011d.

According to an Urban Land Institute handbook on business parks and industrial development, "major steps in marketing a project generally include making contacts with prospective users or tenants, developing a marketing plan, establishing a marketing budget, preparing and distributing marketing documents, and establishing a leasing program through in-house resources or with real estate brokers."[148] This report establishes the target tenants and provides resources on how to find them. Further assistance in the latter may be found through local chambers of commerce, economic development corporations, the Los Angeles Business Council, and the Sustainable Business Council of Los Angeles. Catering to the specific interests of such tenants involves energy efficiency and other synergies, which this report describes in Economic and Environmental Benefits of Co-location in the section on The Eco-Industrial Park: Collaboration Improving Feasibility and Sustainability.

The marketing plan should leverage the use of value-creating synergies, environmental responsibility, the potential for cheap energy, and other benefits related to the eco-industrial park. Such benefits include the strength of Los Angeles's transportation networks; the local presence of a large, urban labor force; landfill diversion; and the credits and programs available for environmental and job creation efforts. Los Angeles's transportation networks carried 24,000 twenty-foot equivalent units daily in 2009 to and from the Ports of Los Angeles and Long Beach.[149] The metro area's labor force exceeds 6.6 million people.[150] Landfill diversion will occur with the marketable reuse of green waste, as well as waste glass, plastic, paper, and tires.

Another important marketing factor for the eco-industrial park involves an anchor tenant. Anchor tenants occupy large amounts of space, providing stable rent and a lure in marketing to attract additional tenants. The importance of anchor tenants is often reflected in the lower rental rates that they are able to secure from property managers. Having an anchor tenant signed may even be a requirement to secure project financing. Although biofuel is riskier than most anchor-type uses, it can be used to attract certain tenants willing to pay higher rents for colocation with biofuel production, such as research and development (R&D). Since R&D requires office quality space, it will pay higher rent than industrial uses. An R&D firm in the biofuel industry would be willing to pay office-quality rents in an otherwise industrial area for the benefit of being located

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[148] Frej et al., 2001, p. 149.
[149] Bureau of Transportation Statistics, 2011.
[150] US Census Bureau, 2010.

next to biofuel production, i.e., ample opportunity to conduct research and develop new methodologies.

Managing an Eco-Industrial Park

There are three options for management of an industrial or business park. The less centralized option, a loosely knit network of entrepreneurs, also known as an incubator model, provides greater flexibility among tenants. The eco-industrial park proposed in this report, however, is more appropriate for the master developer and manager model or the contract manager model, in which control of the property is centralized either by the developer or by a developer-hired contractor. As with traditional business parks, the management's focus must be on "property maintenance, the retention of tenants, operational efficiency, ongoing market-sensitive and investor-sensitive modifications, and the space and services the project offers."[151] Proper management of an industrial park helps to attract tenants when vacancies arise. Maintaining a project's occupancy requires familiarity with businesses that could become tenants and with the people involved in those businesses. Since biofuel represents a nascent industry, it may be more difficult to find businesses to replace tenants. As firms with different technologies find their niche within the eco-industrial park, that will lead to greater occupancy stability. The recycling uses, meanwhile, provide stability for the project's beginning.

Efficiencies and synergies in the project will help tenants to succeed. As stated in the Urban Land Institute's handbook on business parks and industrial development, "More and more techniques are being developed to help individual buildings conserve energy and to create 'green buildings' that are environmentally friendly. These techniques range from design features such as building shape and orientation to construction methods and materials such as insulation or solar energy panels, and water/energy conservation. Innovative building management systems that use computerized controls for lighting and monitoring temperatures are also used more frequently."[152] The handbook adds that access to public transportation for employees and careful integration with the surrounding community are two other increasingly important factors for sustainable business parks.[153]

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[151] Frej et al., 2001, p. 176.
[152] Frej et al., 2001, p. 297.
[153] Frej et al., 2001, p. 297.

As the market changes, the property managers should adjust. For example, if California reduces support for paper recycling and increases support for aluminum recycling, the property managers should prepare to replace the paper recycling tenant with an aluminum recycler. These kinds of adjustments will not occur instantaneously but will require careful planning and opportunistic timing. Effective property management that attends to tenants' needs, focuses on leveraging efficiencies and synergies, and adapts to market changes as necessary is instrumental to the success of an eco-industrial park centered on biofuel production.

Financial Feasibility of Eco-Industrial Park

A financial feasibility analysis was conducted to understand what conditions were needed to make an eco-industrial park feasible and to refine the development scenario as needed. Based on our analysis and site selection criteria, we developed a proforma for a 35 acre site. The original scenario consisted of an ethanol bio-refinery as the anchor tenant and four recycling facilities for glass, plastic, paper, and waste tires. See visualization of the eco-industrial park (site layout and renderings) in Appendix F. The total cost to develop the EIP is $45 million including land and improvements. Equity participation in the project is $9 million with the remainder financed at an interest rate of 10% for 15 years. The financial feasibility analysis using the current cost estimates shown in Table A resulted in a revision to this development plan. The addition of flex space for green and cleantech companies was necessary to meet the investment requirements of an industrial developer.

Table A: Cost Estimates for Financial Feasibility Analysis

Land Cost		
Price per Acre		$200,000
Land Area (acres)		35
Price per square foot		$4.59
Total Land Cost		$ 7,000,000
Development Cost		
Construction Cost		$ 38,000,000
Total Cost to Develop		$ 45,000,000
Financing		
Term (years)	15	
Annual Interest	10%	
Loan-to-Value Ratio	80%	
Annual Debt Service		$ (4,642,294)

The revised development plan is shown in Table B. The development plan assumes anchor tenant lease rates to be charged to the eco-industrial park tenants and market lease rates to be charged to tenants in the flex space who will receive green marketing benefits for their businesses to be co-located in the eco-industrial park. The new uses also increase the job return from the investment. The ethanol bio-refinery and recycling tenants are projected to bring 200

jobs to the site, many of which would be net new jobs to the community. The flex space tenants are projected to support 875 jobs.

Table B: Development Plan

EIP Revenue

Annual lease rate per sq. foot	$	0.40	
Leasable area (square feet)		400,000	
Annual revenue			$ 160,000

Flex Space Revenue

Lease rate per square foot	$	$1.35	
Leasable area (square feet)		437,500	
Annual revenue			$ $590,625

Average Lease Rate	$	$0.90

The Eco-Industrial Park Proforma Analysis (see Exhibit 23) follows on the next two pages and includes cash flow projections at lease-up and with projected sale in year 7. Table C provides return figures for the final development scenario from the proforma analysis and from a scenario in which a $2 million grant is used to make the project more attractive to investors. The return on investment is 20% (with no grant) and 25% with a $2 million grant. Both scenarios yield positive net present values making it a desireable investment opportunity for investors and developers alike.

Table C: Investment Return

		With a $2
Pre-Tax Returns	**Proforma Analysis**	**Million Grant**
Return on Investment	20%	25%
Undiscounted Payback Period	5.1 years	4 years
Net Present Value @ 10%, 7 yrs at Sale	15,826,731	17,826,731

Exhibit 23: Eco-Industrial Park Proforma Analysis

Land Cost

Price per Acre	$200,000
Land Area (acres)	35
Price per square foot	$4.59
Total Land Cost	$7,000,000

Development Cost

Construction Cost	$38,000,000
Total Cost to Develop	$45,000,000

EIP Revenue

Annual lease rate per sq. foot	$0.40	
Leasable area (square feet)	400,000	
Annual revenue		$160,000

Flex Space Revenue

Lease rate per square foot	$1.35	
Leasable area (square feet)	437,500	
Annual revenue		$590,625
Average lease rate		$0.90

Maximum Loan Determination

Loan to Value Ratio	80%
Maximum Allowable Mortgage	$36,000,000
Required Equity	$9,000,000
Required Debt Coverage Ratio	1.2
Actual Debt Coverage at 80% LTV	1.38

Financing

Term (years)	15
Periods/yr	12
Annual Interest	10%
Payment	$(386,858)
Annual Debt Service	$(4,642,294)

Exhbit 23 (cont'd.): Cash Flow Projections

		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Average lease rate per square foot		$0.90	$0.90	$0.90	$0.90	$0.90	$0.94	$0.94
Leasable Space		$837,500	$837,500	$837,500	$837,500	$837,500	$837,500	$837,500
Gross Income		$750,625	$750,625	$750,625	$750,625	$750,625	$788,156	$788,156
Vacancy	5%	$(37,531)	$(37,531)	$(37,531)	$(37,531)	$(37,531)	$(39,408)	$(39,408)
Effective Gross Income		$713,094	$713,094	$713,094	$713,094	$713,094	$748,748	$748,748
Operating Expenses	25%	$(178,273)	$(178,273)	$(178,273)	$(178,273)	$(178,273)	$(187,187)	$(187,187)
Net Operating Income (NOI)		$534,820	$534,820	$534,820	$534,820	$534,820	$561,561	$561,561
Annual NOI		$6,417,844	$6,417,844	$6,417,844	$6,417,844	$6,417,844	$6,738,736	$6,738,736
Debt Service		$(4,642,294)	$(4,642,294)	$(4,642,294)	$(4,642,294)	$(4,642,294)	$(4,642,294)	$(4,642,294)
Net Profit Before Taxes	$(9,000,000)	$1,775,550	$1,775,550	$1,775,550	$1,775,550	$1,775,550	$2,096,442	$2,096,442
Tax	28%	$(497,154)	$(497,154)	$(497,154)	$(497,154)	$(497,154)	$(587,004)	$(587,004)
Net Profit After taxes	$(9,000,000)	$1,278,396	$1,278,396	$1,278,396	$1,278,396	$1,278,396	$1,509,438	$1,509,438

Cap Rate	11%						
Sale Price, Year 7							$61,261,236
Mortgage Pay-off							$(25,494,508)
Net Profit from Sale							**$35,766,728**

Pre-Tax Returns

Return on Investment, Yr. 1		20%
Undiscounted Payback Period (years)		5.1
Net Present Value @ 10%, 7 years	10%	($10,077)
Net Present Value @ 10%, 7 yrs at sale	10%	$15,826,731

Scenario Testing: $2,000,000 Grant Reducing Equity

Return on Investment		25%
Undiscounted Payback Period (years)		4
Net Present Value @ 10%, 7 years	10%	$1,989,923
Net Present Value @ 10%, 7 yrs at sale	10%	$17,826,731

Appendix A

Leading Firms in Cellulosic Ethanol

The following list describes some of the organizations, public and private, with whom partnership may prove beneficial based on their expertise in cellulosic ethanol production or one or more aspects of the endeavor:

1. BlueFire

http://www.bluefireethanol.com/

- Currently building commercial facility in Fulton, MS
- Signed contract to receive wood chips from Cooper Marine & Timberlands
- Signed takeoff agreement with Tenaska Biofuels

2. Colmac Energy

Operates a 47-megawatt net biomass-fueled facility in Coachella Valley. Consumes approximately 325,000 tons per year of wood waste, landscape and right-of-way tree trimmings, broken pallets, and used boxes. Company also accepts construction waste, but not treated wood or painted materials. About 12% of the plant's fuel (40,000 tons per year) is collected from local agricultural residues that would otherwise be disposed through burning. 60-80 trucks arrive at the facility, coming from a 200- to 250- mile radius, from east of Phoenix to south of Los Angeles. No biomass fuel stays on site for more than 30 days, thanks in part to a large drying area.

3. Coskata

http://www.coskata.com/

- Received $250 million loan guarantee from USDA for 55-million gallon per year facility in Boligee, Alabama.

4. Dakota Spirit AgEnergy

http://www.dakotaspiritagenergy.com/

- Creating a plant in North Dakota that will use wheat straw, corn stover, corn, and steam to make ethanol, lignin, and corn oil, C5 sugars, and DDGs.

- Changed planned output from 20 million gallons of cellulosic ethanol to 50 million gallons of corn ethanol and 8 million gallons of cellulosic ethanol.
- Currently finishing "project development and preliminary feasibility." Starting "front end engineering design, project financing, and permitting." Construction to occur 2012-2013 for Phase I corn ethanol portion and 2014-2015 for Phase II cellulosic ethanol portion.

5. DuPont Danisco Cellulosic Ethanol LLC

http://www.ddce.com/

- Established a pilot facility in Vonore, Tennessee on January 7, 2010; headquartered in Itasca, Illinois (about 20 miles from Chicago)
- Pilot facility currently uses corncob and switchgrass, but it seems like DDCE is open to using other resources.
- Describes its use of recombinant *Zymomonas mobilis*, a bacterium which aids in the conversion process.
- Works with University of Tennessee Biofuels Initiative and Genera Energy
- Says that it is interested in collaboration on "establishment of cellulosic ethanol production sites, participation in the cellulosic ethanol supply chain, sharing of management skills and knowledge, design and delivery of production equipment systems, and other vital contributions."

6. G2BioChem

http://www.g2biochem.com/

- Plans to begin construction on demonstration plant in July 2011.

7. Genencor

http://www.genencor.com/wps/wcm/connect/genencor/genencor/about_genencor/what_we_do/our_products/our_products_en.htm

- Produces enzymes for various uses, including in bioethanol.
- Works with NREL

8. Helios Scientific (sister company of Axion Analytical Labs)
   - Announced launch of cellulosic ethanol facility in Curwensville, PA on October 14th, 2010

9. Iogen

http://www.iogen.ca/
   - Demonstration plant in Ottawa, Canada has produced more than 400,000 cumulative gallons of cellulosic ethanol since 2004.

10. Mascoma Corporation

http://www.mascoma.com/pages/index.php
   - R&D in Lebanon, NH; 200,000 gallon per year demonstration plant in Rome, NY; and 1st commercial facility planned in Kinross, MI for 2013 opening.

11. Mercurius Biofuels

http://www.mercuriusbiofuels.com/

Owns rights to a technique which converts biomass into petroleum diesel and biodiesel, with a high cetane number, excellent flow properties, and no CO2 emissions in the process. Ferndale, WA-company is applying for federal assistance to build a pilot plant. It is also trying to refine its technology to produce a jet fuel blending component.

12. National Renewable Energy Laboratory

http://www.nrel.gov/
   - Part of Department of Energy. Conduct research on renewable energy, including cellulosic ethanol.

13. Novozymes

http://www.novozymes.com/en/MainStructure/Industry+in+focusbiofuels/

- Specializes in enzyme use that can make ethanol production more efficient and reduce CO2 emission even further than cellulosic ethanol does itself
- Works with NREL

14. Pacific Ethanol

http://www.pacificethanol.net/

Operates a plant in Madera, CA, which opened in October 2006 and produces 40 million gallons of ethanol per year. Pacific Ethanol plants to build 420 million gallons of capacity over the next four years.

15. POET

http://www.poet.com/

- Beginning construction on a conversion plant in Emmetsburg, IA to use corn cobs. Predicts it will contribute to 3.5 billion gallons of cellulosic ethanol production by 2022: 1 billion through introducing Project LIBERTY technology to the company's other plants; 1.1 billion through licensing technology to other producers; and 1.4 billion by expanding into conversion from other feedstocks such as wheat straw, rice hulls, woodchips, or switchgrass.
- Work with Novozyme.

16. Tenaska Company

http://www.tenaska.com/page.aspx?id=39

- Conducts marketing and power generation
- Signed an agreement to purchase BlueFire's ethanol for 15 years (http://www.bluefireethanol.com/pr/81/)
- Operates power plant in Victorville, CA (85 miles from L.A.)

17. US Forest Service

- To coordinate which areas most need to have green waste removed (i.e., are at greatest danger of fire) and from which areas removal is easiest/simplest.

18. ZeaChem

www.zeachem.com/

- Company is based on Lakewood, CO; began construction on 250,000 gallon-per-year facility in Boardman, OR in June 2010. The plant will use termite microbes to aid in the conversion process. However, the plant will produce acetic acid, which can then be made into ethyl acetate. This is used in making paints and in decaffeinating coffee. Within a year, the company plans to add equipment which will add to the existing operations to produce cellulosic ethanol.
- The company hopes to follow this with construction of a 25 to 50 million gallon per year commercial cellulosic ethanol plant by 2012, which will similarly begin by producing ethyl acetate before making ethanol.

19. 25 x '25

http://www.25x25.org/index.php

Advocates for 25% of energy used in the U.S. to come from renewable sources (from forests and ranches) by 2025 while the forests and ranches continue "to produce safe, abundant, and affordable food, feed, and fiber."

Appendix B

Table A. Construction Activities Timeline

Project Start Month	Project End Month	Activity Description	% of Project Cost
0	6	Project plan and schedule established, conceptual and basic design engineering, permitting completed. Major equipment bid packages issued, engineering started on selected sub-packages, P&IDs complete, preliminary plant and equipment arrangements complete.	8.00%
6	18	All detailed engineering including foundations, structure, piping, electrical, site, etc. complete; all equipment and instrument components purchased and delivered; all site grading, drainage, sewers, rail, fire pond, foundation, and major structural installation complete; 80% of all major process equipment set (all except longest lead items), all field fabricated tanks built, and the majority of piping and electrical materials procured.	60.62%
18	30	Complete process equipment setting, piping, and instrumentation installation complete; all electrical wiring complete; all building finishing and plumbing complete; all landscaping complete; pre-commissioning complete; and commissioning, start-up, and initial performance test complete.	31.38%
		TOTAL	100.00%
Notes: The above presumes no utility to process equipment orders placed prior to month seven.			

Appendix C

Table B: Annual Debt Service and Loan Balance (in $)

	1	2	3	4	5	6	7
Necessary Funds to Build	128,000,250	115,809,750*	0	0	0	0	0
Beginning Balance	0	140,800,275	201,813,728	202,018,100	198,069,279	193,725,576	188,947,502
Draws for Construction	128,000,250	42,666,750	0	0	0	0	0
Interest on Loan Balance	12,800,025	18,346,703	20,181,373	20,201,810	19,806,928	19,372,558	18,894,750
Payment Toward Loan	0	0	-19,977,000	-24,150,631	-24,150,631	-24,150,631	-24,150,631
Ending Balance	140,800,275	201,813,728	202,018,100	198,069,279	193,725,576	188,947,502	183,691,621

* Includes equity

	8	9	10	11	12	13	14
Necessary Funds to Build	0	0	0	0	0	0	0
Beginning Balance	183,691,621	177,910,152	171,550,536	164,554,958	156,859,823	148,395,174	139,084,060
Draws for Construction	0	0	0	0	0	0	0
Interest on Loan Balance	18,369,162	17,791,015	17,155,054	16,455,496	15,685,982	14,839,517	13,908,406
Payment Toward Loan	-24,150,631	-24,150,631	-24,150,631	-24,150,631	-24,150,631	-24,150,631	-24,150,631
Ending Balance	177,910,152	171,550,536	164,554,958	156,859,823	148,395,174	139,084,060	128,841,835

	15	16	17	18	19	20	21	22
Necessary Funds to Build	0	0	0	0	0	0	0	0

Beginning Balance	128,841,835	117,575,387	105,182,295	91,549,893	76,554,251	60,059,045	41,914,319	21,955,119
Draws for Construction	0	0	0	0	0	0	0	0
Interest on Loan Balance	12,884,184	11,757,539	10,518,229	9,154,989	7,655,425	6,005,905	4,191,432	2,195,512
Payment Toward Loan	-24,150,631	-24,150,631	-24,150,631	-24,150,631	-24,150,631	-24,150,631	-24,150,631	-24,150,631
Ending Balance	117,575,387	105,182,295	91,549,893	76,554,251	60,059,045	41,914,319	21,955,119	0

Table B2: Annual Cash Flow Model (in $)

	1	2	3	4	5	6	7	8
Net Operating Income	0	0	19,977,000	37,146,000	37,146,000	37,146,000	37,146,000	37,146,000
			-	-	-	-	-	-
Payment Toward Loan	0	0	19,977,000	24,150,631	24,150,631	24,150,631	24,150,631	24,150,631
Net Cash Flow	0	0	0	12,995,369	12,995,369	12,995,369	12,995,369	12,995,369

	9	10	11	12	13	14	15	16
Net Operating Income	37,146,000	37,146,000	37,146,000	37,146,000	37,146,000	37,146,000	37,146,000	37,146,000
	-	-	-	-	-	-	-	-
Payment Toward Loan	24,150,631	24,150,631	24,150,631	24,150,631	24,150,631	24,150,631	24,150,631	24,150,631
Net Cash Flow	12,995,369	12,995,369	12,995,369	12,995,369	12,995,369	12,995,369	12,995,369	12,995,369

	17	18	19	20	21	22
Net Operating Income	37,146,000	37,146,000	37,146,000	37,146,000	37,146,000	37,146,000
	-	-	-	-	-	-
Payment Toward Loan	24,150,631	24,150,631	24,150,631	24,150,631	24,150,631	24,150,631
Net Cash Flow	12,995,369	12,995,369	12,995,369	12,995,369	12,995,369	12,995,369

Table C: Cash Flow Metrics

Cash Flow Metrics	
Public Grant	$32,914,350
Private Investment	$40,228,650
NPV of cash flow*	$43,124,141
Return on cost	15.24%
Return on equity	50.79%
Cash-on-cash return	17.77%
DCR	1.54
Project IRR	10.21%
Equity Investor IRR	11.20%

*20% discount rate to account for high risk

Appendix D: Maps

Map 1.1 – Workforce Characteristics – Percent Unemployment

Map 1.2 – Workforce Characteristics – Income

Map 2 – Biomass Supply

Map 3 – Development Potential

Map 4 – Transportation Access

Map 5 – Potential Sites

Workforce Characteristic

Percent Unemployment (2008)

Percent Unemployment
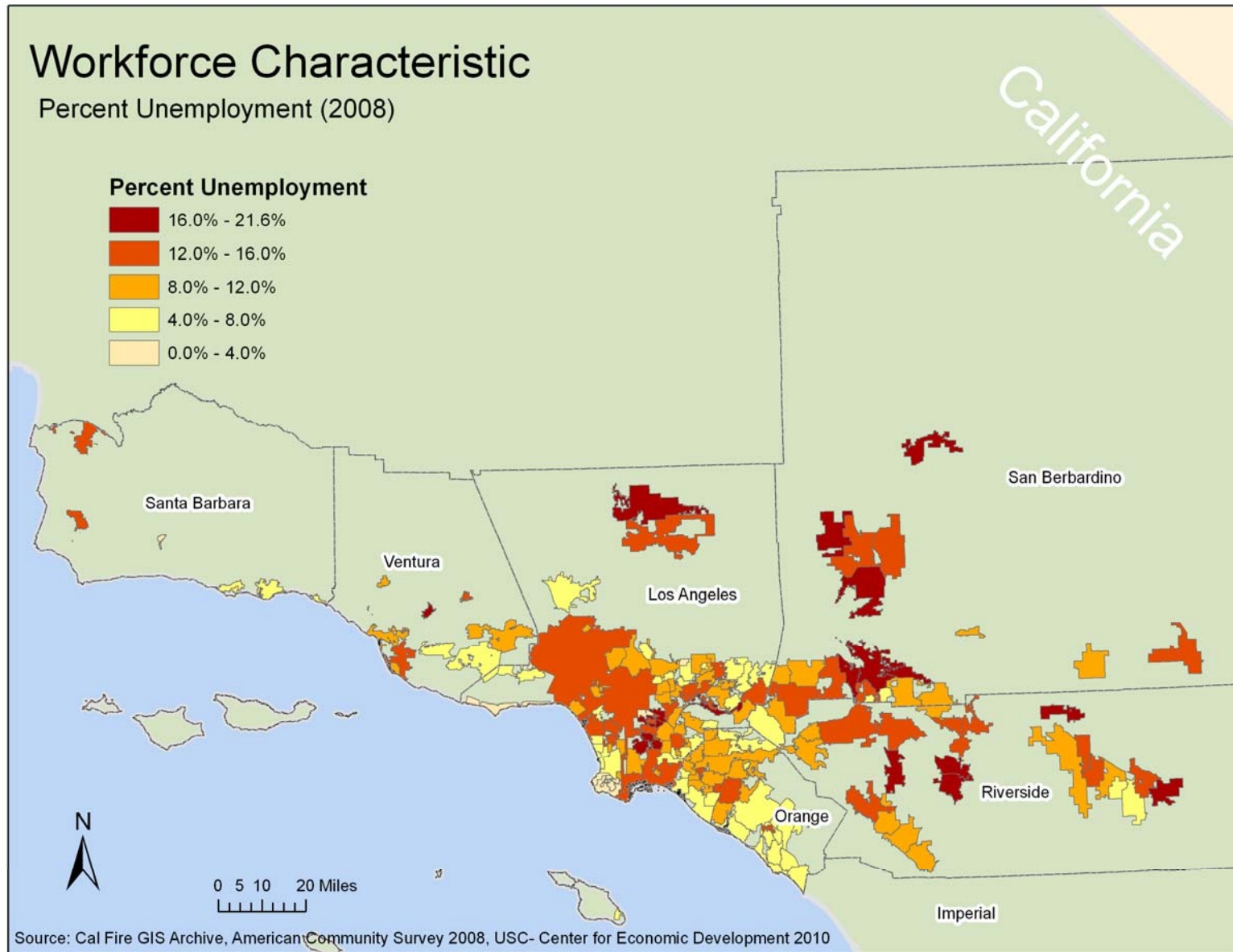
- 16.0% - 21.6%
- 12.0% - 16.0%
- 8.0% - 12.0%
- 4.0% - 8.0%
- 0.0% - 4.0%

California

Santa Barbara

Ventura

Los Angeles

San Berbardino

Orange

Riverside

Imperial

N

0 5 10   20 Miles

Source: Cal Fire GIS Archive, American Community Survey 2008, USC- Center for Economic Development 2010

Workforce Characteristic

Per Capita Income (2008)

Per Capita Income
- $11,965 - $15,000
- $15,001 - $22,000
- $22,001 - $30,000
- $30,001 - $50,000
- $50,001 - $90,000

California

Santa Barbara

Ventura

Los Angeles

San Berbardino

Orange

Riverside

Imperial

N

0 5 10   20 Miles

Source: Cal Fire GIS Archive, American Community Survey 2008, USC- Center for Economic Development 2010
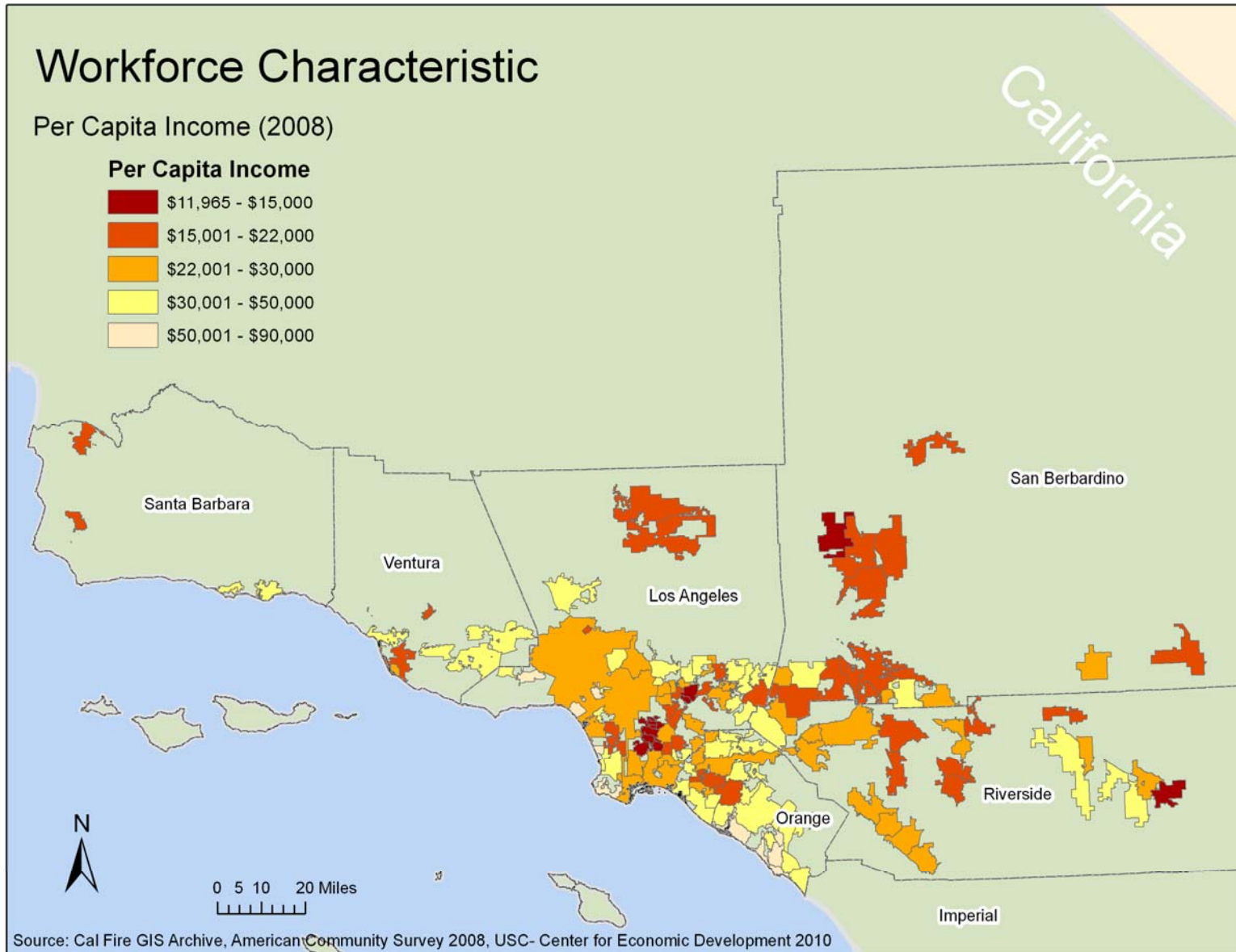
Biomass Source

Wildfire Burned Area Footprints (2000-2009)

Burn Area Footprints

California

Santa Barbara

Ventura

Tea Fire
1,940 Acres

Sayre Fire
11,262 Acres

Freeway-Complex Fire
30,305 Acres

Los Angeles

Orange

San Berbardino

Riverside

Imperial

N

0   10   20   40 Miles
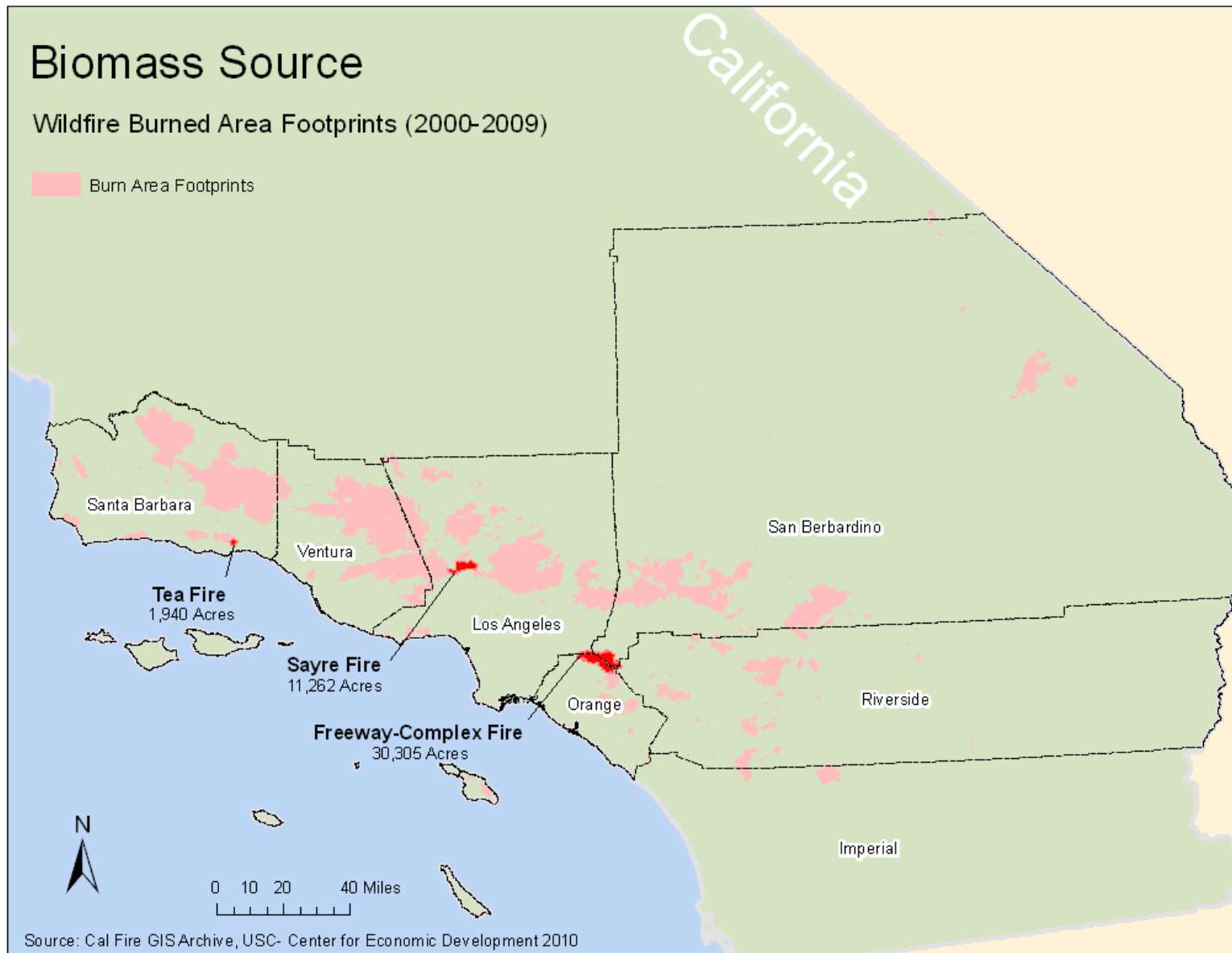
Source: Cal Fire GIS Archive, USC- Center for Economic Development 2010

Development Potential

Parcels which permit an
eco-industrial development
and are vacant as of 2008.

■ Zone code permits Industrial development
and as of 2008 this parcel was undeveloped.

California

San Berbardino

Ventura

Los Angeles

Orange

Riverside

Imperial

N

0 5 10   20 Miles

Source: Cal Fire GIS Archive, Tiger Files 2008, USC- Center for Economic Development 2010

Transportation Access

Primary Regional Arterials

— Primary Regional Arterials
▢ Land 3 Miles from Major Arterial

California

Ventura

Los Angeles

San Berbardino

Orange

Riverside

Imperial

N

0 5 10   20 Miles

Source: Cal Fire GIS Archive, Tiger Files 2008, USC- Center for Economic Development 2010

Potential Sites

San Bernardino   Twenty-Nine Palms   near Banning   Lancaster   Industry

Lancaster

San Berbardino

Los Angeles

San Bernardino

Twenty-Nine Palms

City of Industry

Banning

Orange

Riverside

California

N

0   5   10   20 Miles

Source: Cal Fire GIS Archive, Tiger Files 2008, USC- Center for Economic Development 2010

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Appendix E

Financing Resources: Grants, Loans, and Tax Incentives

State:

Program: Clean Energy Business Financing Program

Administered by: State of California - ARRA Funded

Total Amount: $30.6 million

Amount per Project: $50,000 - $5 million

Expected Expiration Year: 2010

Description: The Program will provide nearly $31 million in low-interest loans to eligible business applicants who can demonstrate profitability, leverage other project funds, and display California job creation and/or retention. Applicants will be evaluated by the California Business, Transportation & Housing Agency, four Financial Development Corporations, and the California Energy Commission.

Program: Alternative & Renewable Fuel Technology -Advanced Biofuel Production

Administered by: State of California – ARRA Funded

Total Amount: $13 million

Expected Expiration Year: 2010

Description: The purpose of the Alternative & Renewable Fuel Technology Program is to assist in the development of alternative and renewable fuel technologies that will position the state of California to meet its climate challenge goals. The Program is managed by the state's Energy Commission and is funding projects in the areas of biomethane production, corn ethanol production, vehicle & component manufacturing, and advanced biofuel production. Specifically for biofuel production, $13 million is available for the design, construction and operation of new refineries that will produce ultra-low carbon fuels.

Federal:

Program: Volumetric Ethanol Excise Tax Credit

Administered by: Internal Revenue Service

Expected Expiration Year: 2010

Description: Gasoline suppliers who blend ethanol with gasoline are eligible for a tax credit of 45 cents per gallon of ethanol.

Qualified applicant: Blenders of gasohol (i.e., gasoline suppliers and marketers)

Program: Small Ethanol Producer Credit

Administered by: Internal Revenue Service

Expected Expiration Year: 2010

Description: The small ethanol producer credit is valued at 10 cents per gallon of ethanol produced. The credit may be claimed on the first 15 million gallons of ethanol produced by a small producer in a given year.

Qualified applicant: Any ethanol producer with production capacity below 60 million gallons per year

Program: Credit for Production of Cellulosic Biofuel

Administered by: Internal Revenue Service

Expected Expiration Year: 2012

Description: Producers of cellulosic biofuel can claim $1.01 per gallon tax credit. For producers of cellulosic ethanol, the value of the credit is reduced by the amount of the volumetric ethanol excise tax credit and the small ethanol producer credit (see above)—currently, the value is 46 cents per gallon. The credit applies to fuel produced after December 31, 2008.

Qualified applicant: Cellulosic biofuel producers

Note: The credit for cellulosic ethanol varies with other ethanol credits such that the total combined value of all credits is $1.01 per gallon. As the volumetric ethanol excise tax credit and/or the small ethanol producer credits decrease, the per-gallon credit for cellulosic ethanol production increases by the same amount.

Program: Special Depreciation Allowance for Cellulosic Biofuel Plant Property

Administered by: Internal Revenue Service

Expected Expiration Year: 2012

Description: A taxpayer may take a depreciation deduction of 50% of the adjusted basis of a new cellulosic biofuel plant in the year it is put in service. Any portion of the cost financed through tax-exempt bonds is exempted from the depreciation allowance. Before amendment by P.L. 110-343, the accelerated depreciation applied only to cellulosic ethanol plants that break down cellulose through enzymatic processes—the amended provision applies to all cellulosic biofuel plants.

Qualified applicant: Any cellulosic ethanol plant acquired after December 20, 2006, and placed in service before January 1, 2013. Any plant that had a binding contract for acquisition before December 20, 2006, does not qualify.

Program: Alternative Fuel Station Credit

Administered by: Internal Revenue Service

Expected Expiration Year: 2010

Description: A taxpayer may take a 50% credit for the installation of alternative fuel infrastructure, up to $50,000, including E85 (85% ethanol and 15% gasoline) infrastructure. Residential installations qualify for a $2,000 credit (biofuels pumps are not generally installed in residential applications)

Qualified applicant: Individual or business that installs alternative fuel infrastructure

Program: Biorefinery Assistance

Administered by: United States Department of Agriculture (USDA) - Rural Business-Cooperative Service (RBS)

Expected Expiration Year: 2012

Description: Grants to biorefineries that use renewable biomass to reduce or eliminate fossil fuel use.

Qualified applicant: Biorefineries in existence at the date of enactment (2008)

Program: Repowering Assistance

Administered by: USDA - RBS

Expected Expiration Year: 2012

Description: Grants to biorefineries that use renewable biomass to reduce or eliminate fossil fuel use.

Qualified applicant: Biorefineries in existence at the date of enactment (2008).

Program: Bioenergy Program for Advanced Biofuels

Administered by: USDA - RBS

Expected Expiration Year: 2012

Description: Provides payments to producers to support and expand production of advanced biofuels.

Qualified applicant: Producer of advanced biofuels

Program: Biomass Crop Assistance Program (BCAP)

Administered by: USDA - Farm Service Agency (FSA)

Expected Expiration Year: 2012

Description: Dollar-for-dollar matching payments for collection, harvesting, storage, and transportation (CHST) of biomass to qualified biofuel production facilities (as well as bioenergy or biobased products), up to $45 per ton

Qualified applicant: Person who delivers eligible biomass to a qualified facility

Program: Rural Energy for America Program (REAP)

Administered by: USDA - RBS

Expected Expiration Year: 2012

Description: This program replaced the Renewable Energy Systems and Energy Efficiency Improvements program in the 2002 farm bill. The program provides grants and loans for a variety of rural energy projects, including efficiency improvements and renewable energy projects. Although REAP is not exclusively aimed at biofuels projects, the program could be a significant source of loan funds for such projects.

Program: Biomass Research and Development

Administered by: USDA - National Institute of Food and Agriculture (NIFA

Expected Expiration Year: 2012

Description: Grants are provided for biomass research, development, and demonstration projects. Eligible projects include ethanol and biodiesel demonstration plants.

Qualified applicant: Wide range of possible applicants

Program: Biorefinery Project Grants

Administered by: United States Department of Energy (DOE) - Office of Energy Efficiency and Renewable Energy

Expected Expiration Year: None

Description: This program provides funds for cooperative biomass research and development for the production of fuels, electric power, chemicals, and other products.

Qualified applicant: Varies from year to year, depending on program goals in a given year

Program: Cellulosic Ethanol Reserve Auction

Administered by: DOE

Expected Expiration Year: Not specified

Description: Section 942 of the Energy Policy Act of 2005 authorizes DOE to provide per-gallon incentive payments for cellulosic biofuels until annual U.S. production reaches 1 billion gallons or 2015, whichever is earlier. DOE finalized regulations on October 15, 2009. http://www.epa.gov/fedrgstr/EPA-IMPACT/ 2009/October/Day-15/i24778.htm.

Qualified applicant: Any U.S. cellulosic biofuel production facility that meets applicable requirements.

Appendix F: Visualization of Eco-Industrial Park

Site Layout & Renderings

Site Plan Layout A

SITE PLAN A
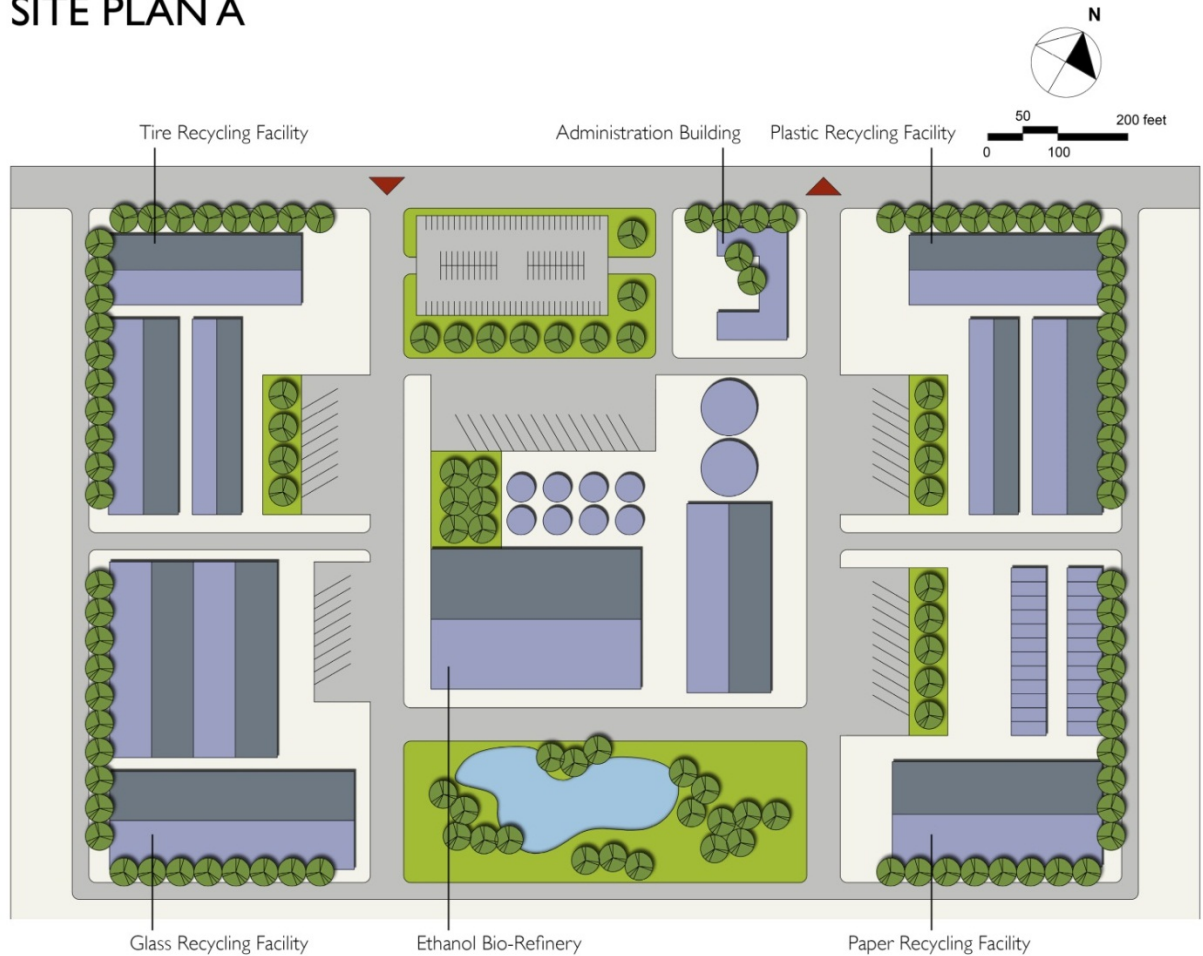
Tire Recycling Facility

Administration Building

Plastic Recycling Facility

N

50   200 feet

0   100

Byproduct Exchange

Materials Sharing

Energy Exchange

Resource Sharing

Common Administration

Efficiency Logistics

Glass Recycling Facility

Ethanol Bio-Refinery

Paper Recycling Facility

Rendering 1: Site Plan Layout A
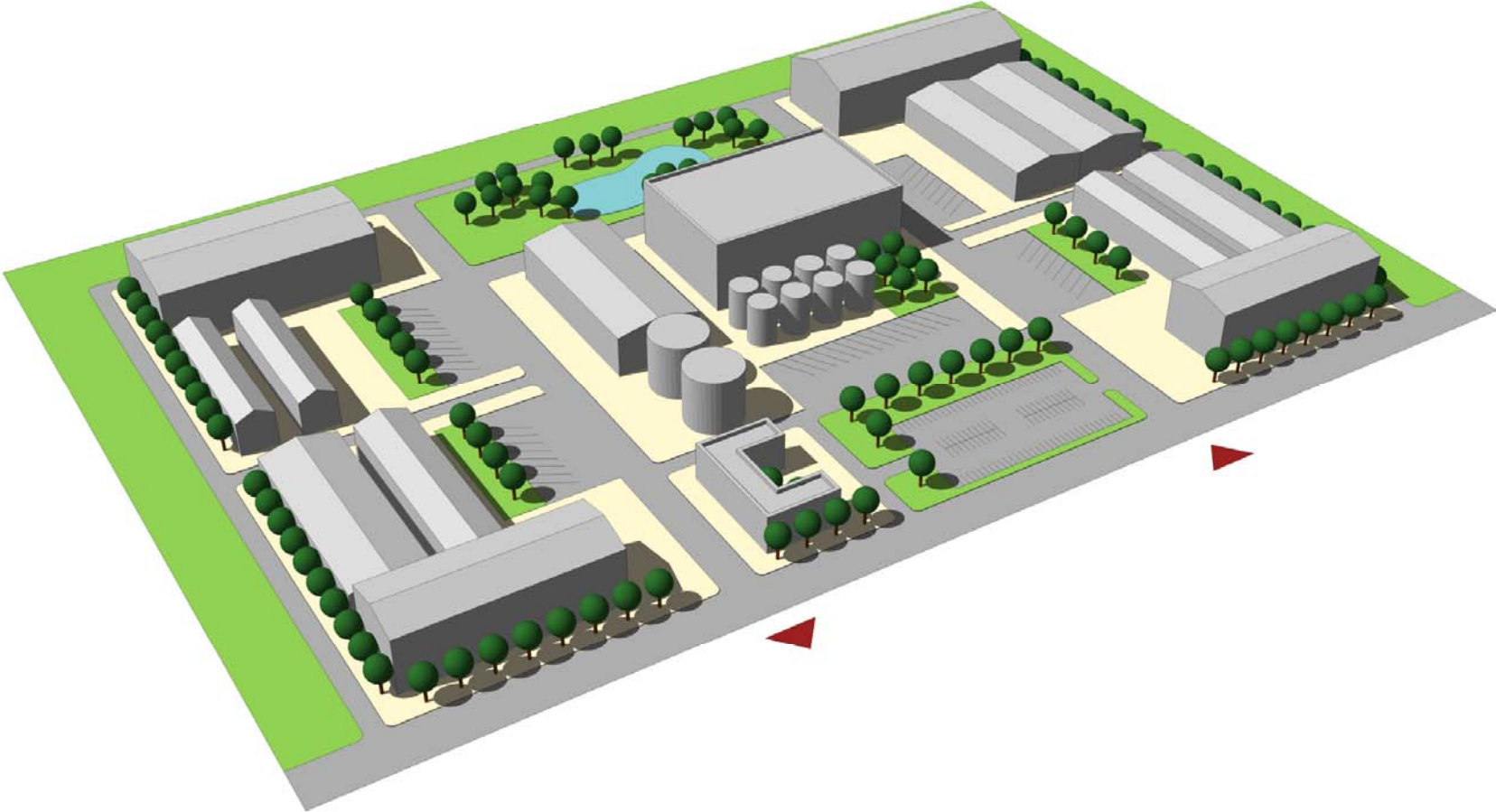
Rendering 2: Site Plan Layout A
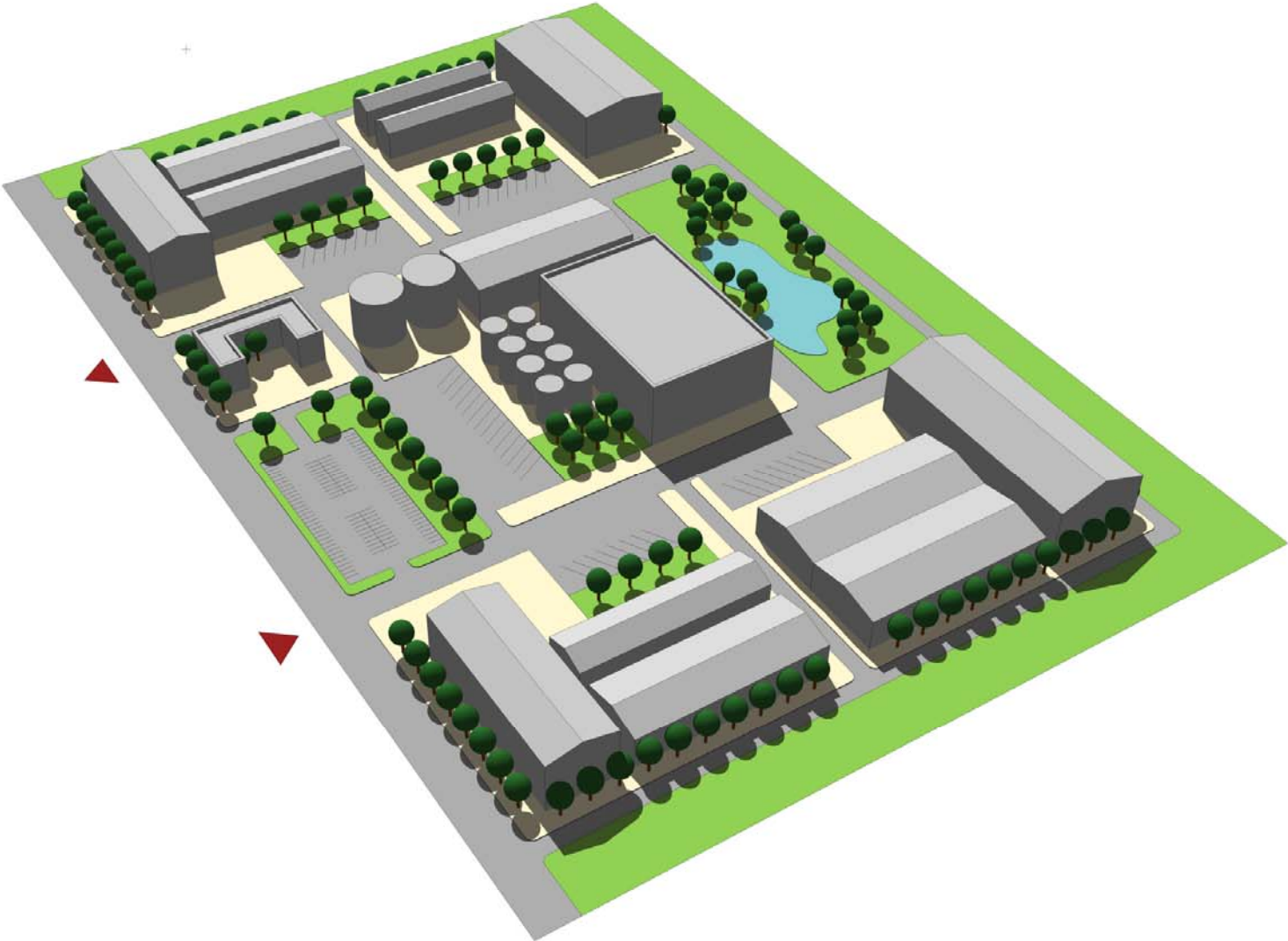
Site Plan Layout B

SITE PLAN B

N

50   200 feet
0   100

Ethanol Bio-Refinery   Administration Building   Plastic Recycling Facility

Byproduct Exchange

Materials Sharing

Energy Exchange

Resource Sharing

Common Administration

Efficiency Logistics

Tire Recycling Facility   Glass Recycling Facility   Paper Recycling Facility

Rendering 1: Site Plan Layout B

Rendering 2: Site Plan Layout B
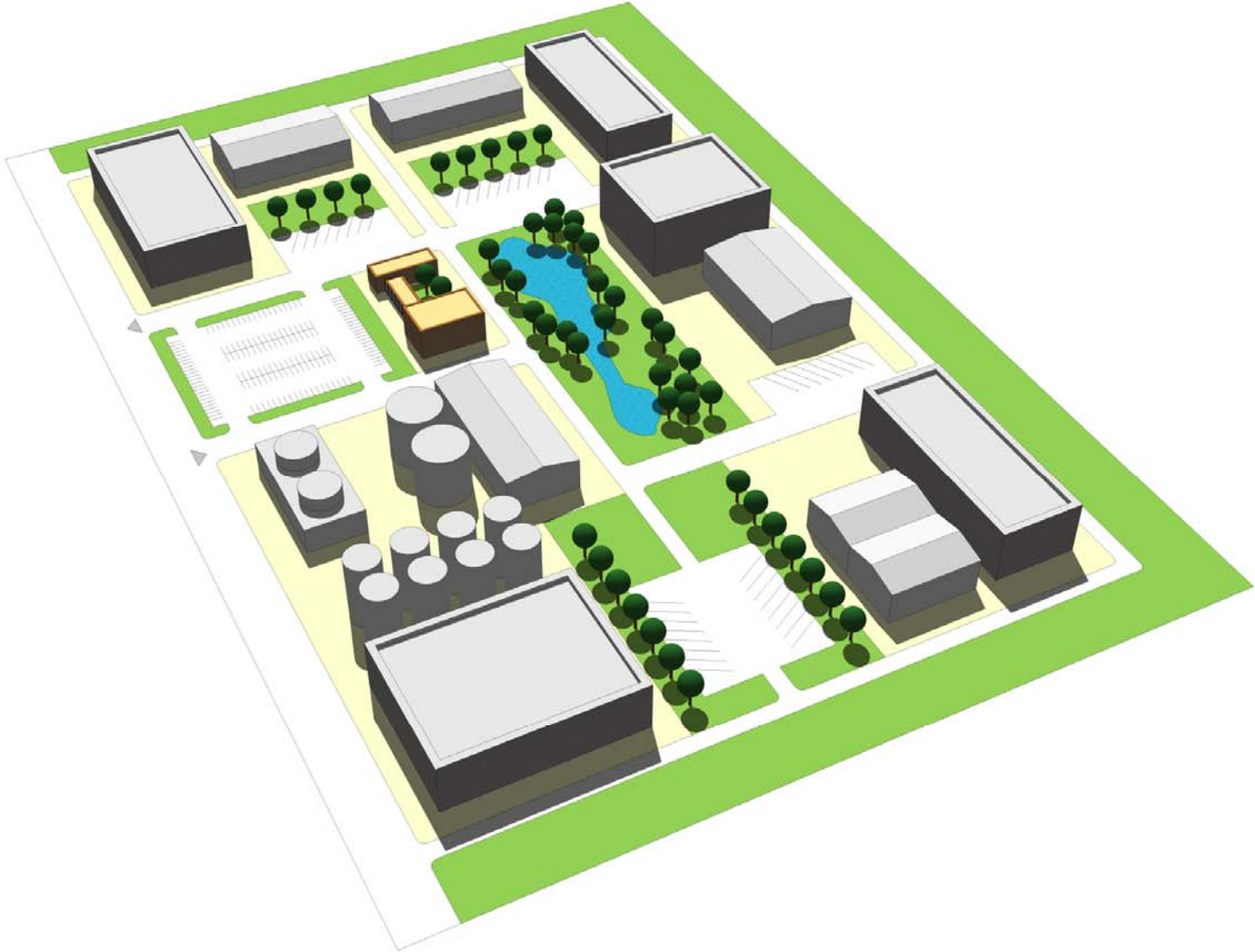
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