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Coordinating California's Efforts to Promote Waste to Alcohol Production*

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ABSTRACT

Alcohol fuels produced from biomass can improve air quality, enhance energy security, create employment opportunities, and reduce waste disposal problems. Opportunities in California exist to produce alcohols from waste streams from various sectors of the economy. Government agencies have promoted waste-to-alcohol activities, but efforts have been inconsistent and intermittent. Often these efforts have been hindered by contradictory but mandate-driven policies.

A prudent approach to coordinate statewide efforts includes the development of an integrated statewide policy to examine barriers that impede private sector business efforts to produce alcohols from biomass. A multiagency task force to promote research, development, commercialization, and marketing efforts for biomass-produced alcohols is desirable.

Index Entries: Biomass; ethanol; methanol; partnerships; government.

INTRODUCTION

For a variety of environmental and economic reasons, much attention has been devoted to the development and commercialization of nonpetroleum energy sources. Indeed, few areas within the scope of environmental and energy fields have garnered as much interest as the search for clean burning, renewably-based fuels. Since the 1973–1974 oil embargo, the search for renewable energy sources has often been intense, albeit somewhat sporadic in nature.

Modern industrial economies, such as California's, have become heavily dependent on petroleum-based fuels. Gasoline and diesel make up more than 97% of the state's transportation fuel mix. In California, vehicles travel approx 200 million miles each day, resulting in the consumption of approx 18 billion gallons of gasoline and diesel fuel per year *(1,2)*.

*The views and opinions contained in this document do not necessarily reflect those of the California Energy Commission, its staff, management, or the State of California.

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The near-exclusive reliance upon petroleum-based fuels increases vulnerability to economic dislocations from oil price instabilities, contributes significantly to air quality degradation, and strongly affects the national balance of trade. These issues, combined with the intrinsic long-term limitations of nonrenewable fuels, have provided the basis for government-led activities devoted to developing viable alternatives to petroleum-based fuels.

Additionally, the recent trend in the manufacturing sector to completely eliminate waste products in order to develop a sustainable business environment may also create opportunities to generate alcohol from waste (*3*). Many private sector concerns are faced with rising disposal costs and, simultaneously, shortages of critical inputs, such as suitably high quality process water. In some cases, these businesses are seeking the means to convert waste streams into useable and potentially valuable products (e.g., alcohol) as part of the water re-use and recycle process.

Alcohol fuels have the potential to replace petroleum-based fuels. For example, if the United States converted 14% of its farmland to produce crops for ethanol, the results would be sufficient to supply the nation's entire gasoline use (*4*). Tree farming cultivation of perennial grasses is a plausible means of producing the enormous quantities of biomass needed to replace fossil fuels. Short rotation intensive culture (SRIC) farming techniques can be applied to a variety of tree species. Various nonwoody crops, such as switchgrass, are also efficient producers of lignocellulosic biomass. However, completely replacing petroleum-based fuels in the near term is not practical and may not be desirable. Only the most cost effective and environmentally benign efforts should be pursued.

The conversion of waste biomass to ethanol holds a good chance of becoming both environmentally and economically attractive. Given the potential availability of biomass, one might reasonably ask: Why isn't more ethanol now produced from waste? The answer is that although biomass can be relatively inexpensive to purchase, it is difficult (and therefore costly) to convert into ethanol. Historically, many proposed processes have suffered from inherently low yields and high costs (*5*). Moreover, biomass streams may be erratic or seasonal in nature, and collection and transportation costs are often significant, due to the low energy density of the materials.

Unlike energy crops, biomass from waste is often available for no or negative cost (e.g., waste generators would be willing to pay to dispose of waste). And although there is currently a significant amount of USDA-designated cropland not in production in the United States, the conversion of arable farmland from production of foodstuffs to energy feedstocks may pose long-term concerns. For these reasons, the focus of this paper is limited to discussions on waste biomass-to-alcohol production.

This paper will examine some of the current waste-to-alcohol activities presently underway in California, with a particular focus on ethanol.

The more promising technologies for converting biomass to alcohol will be reviewed and suggestions will be made to better coordinate state agencies that are involved with or interested in waste-to-alcohol activities.

PROBLEMS WITH CURRENT TRANSPORTATION AND WASTE DISPOSAL SYSTEMS

Consequences of Long-Term Petroleum Dependence

The sharp volatility in oil prices has had a devastating effect on the US national economy. The Oak Ridge National Laboratory estimates this cost to be up to $4 trillion during the period 1973–1990 *(6)*. Similarly, California's economy has suffered substantially during times of high petroleum-based fuel prices.

Because California and other developed economies are heavily dependent on petroleum for transportation, they are vulnerable to oil price and supply constraints. Much like the approach taken by investors to diversify their assets in order to reduce risk, energy strategists advocate a similar approach in regard to transportation fuels. Developing alternatives to petroleum-based fuels could significantly reduce the economic risks of petroleum price swings. Therefore, the development of nonpetroleum fuels represents a prudent approach to energy and transportation planning.

Trends in Sources of Petroleum Supply

California consumes most of its petroleum from domestic sources. Historically, about 50% of the petroleum used in the state came from instate production, 45% from Alaska, and 5% from foreign sources. However, the percentage supplied from foreign sources will increase as both Alaska and California production decline *(7)*.

California energy markets, however, are thoroughly integrated with national and international markets. By contrast, the United States as a whole currently imports more than 50% of its oil from foreign sources. This fraction is expected to increase in the future. Dependence on imported oil is a major contributor to the unfavorable trade balance that the United States maintains with much of the world. Imported petroleum accounts for approx 45% of the US trade deficit *(8)*.

Fully two thirds of the world's oil reserves are found in the Middle East. Given the area's history of political instability, and regional antiwestern sentiment, access to this resource likely will remain worrisome for decades to come. The extent of US military expense in maintaining commercial access to the oil reserves of this region are a matter of dispute but are enormous.

Environmental Impact of Petroleum Use

The most serious air quality problem in California (and the United States) is the production of ground-level ozone. This reactive form of oxygen (O_3) is produced when hydrocarbons and oxides of nitrogen (considered to be "ozone precursors") chemically react when exposed to the ultraviolet radiation in sunlight. Often referred to as photochemical smog, exposure to ground-level ozone results in a variety of health-related problems and agricultural crop damage. The majority of these ozone precursors are produced from the combustion of gasoline and diesel in motor vehicles.

Ozone and other forms of air pollution, such as carbon monoxide, particulate matter, and toxic air contaminants, cause widespread health problems in California. Some individuals, notably children and the elderly, are particularly susceptible and may be severely affected. Especially at risk are the four million Californians who suffer from heart and lung diseases *(9)*.

In addition to vehicle tailpipe emissions, significant quantities of hydrocarbons escape from vehicles through evaporation from the vehicles' fuel system and during refueling. Although substantial improvements in reducing tailpipe and evaporative emissions have been made in recent years, both deliberate tampering with emission control systems and malfunctioning in vehicles remains problematic.

Emissions (predominantly hydrocarbons) also are produced during the refining and transporting of petroleum. Without stringent controls and continual monitoring, petroleum-based fuel production, transportation, and consumption can generate massive amounts of regulated pollutants.

Greenhouse gas emissions, primarily carbon dioxide from hydrocarbon fuels combustion, is also a cause for concern. While CO_2 emissions are not currently regulated, these are nonetheless of great concern. Strong and accumulating scientific evidence suggests that the increase in atmospheric concentrations of greenhouse gases will induce global climate change. In the United States, approx 32% of the CO_2 released into the atmosphere is from transportation sources *(10)*. Thus, it may be prudent to develop fuels derived from renewable biomass. The production and subsequent use of ethanol and methanol from biomass tends to be "CO_2 neutral" as the production of biomass from plant sources involves CO_2 absorption on the same timescale as its release from combustion and does not contribute to the atmospheric carbon burden.

Problem of Lignocellulosic Waste Disposal in California

Agriculture has been and remains a foundation of the state's economy, contributing some $22 billion dollars annually in gross revenues *(11)*. This sector also produces enormous volumes of residual biomass, which poses significant disposal problems. Forestry activities (thinning, timber production, etc.) also generate large amounts of cellulosic material, as does urban waste in the form of paper, wood waste, and landscaping debris. Altogether California produces abundant cellulose-containing residues, approx 46 million bone dry tons per year *(12)*.

The state's biomass power industry provides some avenues for productive use of woodwaste and some agricultural residues as boiler fuel, but the future of this industry is uncertain at present. Historically, however, much agricultural residue, such as rice straw and orchard prunings, has been disposed of by open-field burning, in part to control pests and plant diseases. The environmental impacts of this activity have been sufficiently severe that restrictions are being imposed on open-field burning as a means of disposal. The existing alternatives, such as incorporating crop residues into the soil, can impose substantial costs on farmers, and may exacerbate some crop diseases. Nevertheless, at least in regard to the burning of rice straw, state law (e.g., Assembly Bill 1378 of 1991) calls for a gradual phase-down of open-field burning in the Sacramento Valley; ultimately, the law envisions that no more than 25% of the straw will be disposed of by burning, but only for purposes of crop disease management.

An economic use for these wastes is preferable and is envisioned under the laws that restrict open burning. Each waste type poses specific disposal problems. For example, more than 1.5 million tons per year of rice straw is generated from rice production in California's Central Valley. This material is high in silica and resistant to decomposition, requiring extensive tillage to incorporate into the soil. Proposals to convert rice straw into ethanol suggest attractive alternatives that could divert a large fraction of the existing supply. Other off-farm uses, such as conversion to construction material, landscaping and erosion control are possible, but do not at present appear likely to absorb more than a small share of the available residue. Accordingly, conversion to alcohols or other chemical feedstocks could offer benefits to this sector of the economy.

Forest waste also represents a significant component of California's biomass resource. In many of the state's forests, excessive fuel loading increases the risk of catastrophic forest fires that destroy life, property, and natural habitats, cause significant air quality impacts (as particulates or PM_{10}) and contribute to severe soil erosion.

Similarly, municipal solid waste is increasingly a problem in the state. Constraints on landfill capacity led to the passage of legislation in 1989—AB 939, the California Integrated Waste Management Act. This Act mandates stringent goals for diverting solid waste from landfills using a hierarchy of reuse, recycling, composting, or transformation to energy products to avoid disposal. Municipalities operating solid waste disposal facilities were required to divert 25% of the waste stream to these uses beginning in 1995 and must attain 50% diversion rate by the year 2000. A subsequent law (AB 688) set forth additional conditions for calculating the credits for diverting waste materials and limited the degree to which biomass transformation (either combustion or fuel production) could be counted to satisfy the diversion requirements.

Apart from yard and construction wastes, cellulosic wastes (primarily paper products) constitute a major fraction (estimated at approx 60%) of the municipal solid waste stream. This portion represents a high value, relatively pure stream of cellulose. Although much of this material can be directly recycled for use as paper products, part of this stream is either too degraded or too contaminated for paper recycling and could be used for fuel production. Like other forms of biomass, conversion of municipal wastes to ethanol and other valued chemicals could be an effective way to reduce this burden.

VALUE AND UTILITY OF ALCOHOL FUELS IN CALIFORNIA TRANSPORTATION

Alcohol in California's Alternative Transportation Fuels Programs

The repeated experience of strong fuel price volatility and concerns over security of access to overseas oil supplies has spurred development of nonpetroleum transportation fuels, often referred to as alternative fuels. Alcohol fuels, including ethanol and methanol, are popular alternative transportation fuels.

The efforts of the California Energy Commission and others have led to the use of methanol by fleet operators and individual citizens as an alternative to gasoline in the state. Developed first in the mid 1980's, the flexible fuel vehicle (FFV) allows the operator to use either gasoline, M85 (85% methanol blended with 15% unleaded gasoline), or any combination of the two fuels. By the end of 1996, approx 14,800 FFVs were operating in California *(13)*.

In contrast to methanol, ethanol as a motor fuel is almost nonexistent in California. And unlike many midwestern states, where corn growers and grain processors support conventional ethanol production, California does not have a comparable economic interest group supporting alcohol fuels. California does possess, however, a nascent methanol fuel distribution system, and the continued development of this alcohol fuel distribution infrastructure could potentially benefit both fuels. Additionally, methanol and ethanol FFVs utilize nearly identical engine technologies.

In California during the 1980's and early 1990's ethanol was used as an octane booster in gasoline *(14)*, typically in blends of up to 10%. At its peak in 1991, over five million gallons of ethanol per month were blended with gasoline in the state, making up approx 5% of California's gasoline supply. The average from 1981 to 1991 was 36 million gallons per year consumed in motor fuels *(15)*.

The growing concern over the role of gasoline-based emissions on urban air quality problems led to the requirement that oxygenates be added to the gasoline pool to reduce carbon monoxide and ozone precursors. These oxygenates typically were in the form of ethanol or alcohol-derived ethers. These ethers, principally methyl tertiary-butyl ether (MTBE), now dominate the oxygenated fuel market, in part because current California air quality regulations for reformulated gasoline limit oxygen content in gasoline to 2% by weight (ethers contain less oxygen by weight than their associated alcohols), and limit fuel volatility (California regulations limit Reid vapor pressure to a maximum of 7.0 pounds per square inch). Refiners would be required to use gasoline blends with very low volatility to utilize ethanol. Because of higher costs associated with this formulation, no refiner has sold gasoline/ethanol blends (e.g., 10% ethanol) in the state since reformulated gasolines became required in early 1996.

Past Experience with Fuel Alcohol Production in California

A number of ethanol production demonstration projects were conducted by state agencies in the early 1980's, under the impetus of state Senate Bill 620. These efforts were intended to exploit agricultural waste products from cultivation and food processing, using then available fermentation and distillation technology. Projects under this program were based on project economics and volatility in the larger fuel markets. The technology of the day, which depended upon reliable and constant sources of high quality sugar and starch feedstocks in order to be economically viable, proved unsuccessful *(16)*. The successful ethanol industry model that has developed in the Midwest, based on rainfall-watered starch crops (primarily corn) and substantial federal tax incentives, was judged to be ill-adapted to irrigated agriculture in California.

These project failures strongly influenced subsequent thinking about in-state fuel alcohol production. However, technological improvements in feedstock processing, biotechnology, membrane-based separation processes, and process engineering have altered the technical and economic landscape to the point where a strong potential now appears to exist for biomass-derived alcohol production. Furthermore, reliance upon feedstocks that are plentiful and that have a low or negative cost may change the equation for industrial-scale alcohol production in the state. Currently, there are two ethanol production plants operating in California, one utilizing beverage industry waste as a feedstock and the other using cheese whey. Total production is on the order of six million gallons per year.

Benefits of Alcohol Fuels

United States and California efforts in the area of biomass-derived alcohol from the early 1980's on were driven primarily by the need to reduce dependence upon imported oil. It has since been recognized that other benefits may accrue from developing this source of primary energy. In particular, both ethanol and methanol fuels hold important potential benefits for California, in the following four principal categories.

Energy

- Can be produced from renewable resources;
- Aids biomass industry by creating demand for biomass feedstocks;
- Could be developed in conjunction with electric power generation, improving overall efficiency of plant operation;

- Allows use of less refined blend stock to achieve requisite octane values in gasoline, thereby reducing energy consumption during refining;
- Domestically produced, thereby reducing oil imports;
- Can be used with advanced transportation technologies such as hybrid electric- or fuel cell-powered vehicles, as ultra low-emission motor fuel (energy and air quality benefit); and
- Potential for combustion efficiency improvements in conventional internal combustion engine vehicles.

Air Quality and Emission Reductions

- Reduces the generation of CO_2, a principal greenhouse gas, since the use of biomass displaces consumption of carbon-based fossil fuels;
- Important oxygenate source for reformulated gasolines (ethanol and its ether ETBE);
- Reductions of toxic air contaminants (e.g., 1–3 butadiene and benzene) commonly found in gasoline; and
- Reduces emissions that would otherwise result from disposal of biomass in landfills (e.g., methane, another greenhouse gas) or by open-field burning (particulates and carbon monoxide).

Waste Disposal

- Potential for reduction in waste volumes through economic use of waste stream components;
- Recovery of economically valuable by products from waste streams, and reduction in process costs by enabling reuse of inputs such as process water; and
- Extend the operating life of existing landfills.

Economic Benefit

- Provides benefits of competition to conventional fuel markets;
- Creates employment opportunities through new economic development (including the economic multiplier effects of new primary economic activities);
- Liquid fuels are convenient to handle, store and use, due to higher energy density; and
- Can produce marketable byproducts in addition to alcohol.

Ethanol Price History

Presently, the cost of ethanol derived from biomass has dropped dramatically from approx $0.95/L ($3.60/gal.) in 1980 to less than $0.32/L ($1.22/gal.) at the pilot plant level. Research is continuing to further improve biomass pretreatment, cellulase enzyme production, cellulose conversion, five-carbon sugar utilization, lignin use, and product recovery, with the goal of reducing the cost to \$0.18/L (\$0.67/gallon by 2010, National Renewable Energy Laboratory) *(17)*. At the level of \$0.18/L, ethanol can compete with gasoline as a neat fuel at an oil price of \$25/barrel, or \$0.30/L at an oil price of \$33/barrel *(18)*.

As the production efficiencies improve and its cost of production correspondingly fall, biomass-derived ethanol will approach competitiveness with fossil-based fuels *(19)*. Although some ethanol operations are now, or will soon be cost competitive, on the whole the fuel's competitiveness as a neat motor fuel is marginal. Because of this, government support will continue to be necessary for the near-term. Government programs to stimulate continued production efficiencies also will be needed to advance ethanol's commercial prospects.

At present, biomass-based alcohol receives a blenders' tax credit of 54 cents per gallon; at the gasoline pump for 10% "gasohol" blends this results in a tax break of 5.4 cents per gallon. Producers can instead opt for a tax credit taken at the time of production. Under the Energy Policy Act of 1992, a tax credit for production of energy from "closed-loop" biomass cultivation was instituted, but this provides little assistance to business seeking to exploit existing waste streams for alcohol feedstocks.

BRIEF CHARACTERIZATION OF OVERALL PROCESS TECHNOLOGIES

Biomass

Many types of biomass, including wood, agricultural residues, herbaceous crops, and municipal solid waste, can be used as feedstocks for ethanol production. The various forms of biomass outwardly appear to be very different, but their chemical makeup is quite similar. About 35% to 50% of the material is cellulose, a polymer of glucose sugar that forms a crystalline structure. Another 15% to 30% of lignocellulosic biomass is hemicellulose, generally a heterogeneous polymer of various sugars often dominated by the five-carbon sugar xylose. The remaining 20% to 30% is composed primarily of lignin, with lesser amounts of extractives, ash, and other components *(20)*.

Both cellulose and hemicellulose are carbohydrates and can be hydrolyzed by enzymes to simple sugars. These sugars are then converted through fermentation to ethanol. Lignin (a heterocyclic phenolic polymer) can not be converted to ethanol, but may be used as a high energy content boiler fuel in the ethanol production process and for electric power generation. Some potential exists to use the lignin as feedstock for chemical synthesis to produce a variety of products.

Technology Approaches

Methanol synthesis from syngas is a well demonstrated, commercially available industrial scale technology. Incremental improvements in efficiency of conversion continue to be made, and liquid phase synthesis processes may hold some promise. Similarly, distillation and refining technologies for ethanol are well-proven. In both cases, the issue for utilizing biomass feedstocks is the production of useful precursors for the upstream synthesis or fermentation processes. In the case of methanol, it is the production of clean, hydrogen-balanced synthesis gas (a mixture of carbon monoxide, carbon dioxide, steam, and hydrogen). For ethanol production, it is the hydrolysis of lignocellulosic substrates into simple sugars that can be efficiently fermented to produce alcohol. Hence, the choice of process for feedstock processing and conversion is at the heart of the various technology options.

Thermochemical processes entail the production of methanol and other products from syngas. These processes include gasification, pyrolysis, and combustion. Thermochemical processes have grown out of considerable past work in the conversion of coal and lignite to synthetic fuels and other products. Specific issues related to the chemical composition of many types of biomass affect the utility and efficiency of these processes when applied to biomass feedstocks. High alkali and silica content of some feedstocks, such as rice straw, can result in severe problems with slagging and fouling of combustors and gasifiers *(21,22)*. Technical measures to overcome these problems have been under development for some time. However, it appears that biologically-based conversion processes may hold significant promise for utilizing other relatively intractable biomass feedstocks.

Ultimately, some combination of these two approaches, such as an initial fermentation-based process with offstreams being fed to a thermochemical conversion process, may prove most effective to capture the full value of the feedstocks.

Biological processes are typically fermentation based, leading to the production of ethanol and other coproducts, depending upon the technology and microorganisms used. Process economics may be strongly influenced by the nature and value of coproducts obtained. These could include sodium silicate; animal feeds; boiler and/or lignin-derived engine fuels. Although the fermentation stage may vary by process design, these processes may all be distinguished primarily by the feedstock pretreatments that are employed to obtain fermentable sugars from the raw biomass. This pretreatment may be seen as consisting of three basic steps: mechanical processing and sizing of the feedstock; disruption of the microstructure of the biomass to expose its components to hydrolysis, and subsequent hydrolysis of these components to simple sugars for fermentation by the alcohol producing organisms.

The various forms of pretreatment may be configured in different ways, with the products of a particular disruption process particularly suited to a subsequent hydrolysis process. Hydrolysis processes include:

- Strong acid hydrolysis;
- Weak acid hydrolysis;

- Enzymatic hydrolysis; and
- Lime-based hydrolysis (laboratory scale only).

CUSTOMER BASE AND ECOSYSTEM MARKET ANALYSIS

Potential beneficiaries of a biomass-based fuels industry in California are diverse and will depend upon the specific feedstocks and processes employed. In general, however, present opportunities for biomass utilization exist that could help the following sectors of the state's economy, loosely characterized in terms of either disposal, or production and consumption.

Disposal

Avoided costs of disposal could be a significant benefit to certain economic sectors, and at some point it might be feasible to achieve revenues from the sale of former waste products. Economic interests that would benefit from a viable biomass-to-alcohol industry in California would potentially include the following.

Various Agricultural Producers

These include crop producers (prunings, orchard clearing for replanting, crop processing wastes, such as almond shells); rice growers (straw disposal for disease control); poultry, livestock and dairy producers (manure and bedding disposal); and cotton growers (gin trash).

Forest Products

Disposal of forest slash, mill residues (such as sawdust, bark and slab wood) can be problematic for the wood products industry. Although new uses for wood fiber can potentially consume much of this material (such as particle board, oriented strand board, pulp, etc.), substantial amounts of biomass remain unutilized and now represent economic costs to the industry.

Natural Resource Managers

Public and private forest land owners confronting the need to reduce fuel loading in fire-prone forests and manage vegetation for watershed and soil conservation purposes. Such essential activities could generate substantial quantities of biomass, which could make them at least partially self-funding.

Municipalities

Cities, counties, and sanitation districts that face the need to divert wastes from landfills, either because of economic pressures or regulatory requirements, such those created by State Assembly Bill 939.

The distribution of total potential of biomass resources in California is as follows *(23)*:

Livestock manure	26%
Chaparral	16%
Field and seed crops	14%
Lumber mill waste	12%
Forest slash	11%
Urban yard waste	7%
Fruit and nut crops	4%
Food processing waste	4%
Urban wood waste	3%
Other	3%
Total	*100%*

Production and Consumption

A number of economic sectors could benefit directly from the production and consumption of fuel alcohols from biomass.

Agricultural Producers

Farmers would benefit from the conversion of problematic wastes into economic resources. Opportunities for vertically integrating alcohol fuels production with existing production and for value-added processing could prove attractive.

Biomass Power Generators

The large biomass power industry in California was developed partially in response to the availability of cheap biomass feedstocks for conversion to electricity. At present, the market price of electricity is too low to support operation of many of these plants, especially as existing power sales contracts with more favorable price terms expire. Operating costs are typically high, owing to problems with boiler fouling and slagging from combusting raw biomass. Combining an ethanol plant with biomass power unit could improve the economic viability of both processes by added value production. Initial processing of biomass fuels for conversion to ethanol would result in a valuable commodity product. The remaining biomass residue would then be usable as a clean-burning fuel stream for power generation, reducing plant operating and maintenance (O&M) costs.

Alternative Fuel Consumers

The Energy Policy Act of 1992 (EPACT) mandates alternative fuel use by fleet operators, in particular state and local government fleets, fuel providers, and possibly private fleets. EPACT and other federal laws also encourage alternative fuel deployment by means of a number of economic incentives. Replacement of diesel fuel with cleaner burning alcohol fuel in heavy duty applications both on and off road would be helped by a domestic alcohol fuel production.

Chemical Manufacturers

Ethanol, methanol, and other possible products from biomass feedstocks are widely used as chemical intermediates and solvents.

Electronics Industry

Manufacturers require silicon for producing semiconductor chips and other electronic components. Certain feedstocks, such as rice straw, may have the potential to provide high purity sodium silicate for this purpose.

The general public would also benefit, in terms of economic growth, and the reduction or elimination of environmental externalities associated with the generation of these biomass wastes. Note that each of these sectors above is not likely to absorb more than a portion of the available biomass feedstocks.

Competing or Displaced Interests

It should be recognized that some economic interests would view the emergence of a fuel alcohol industry as a competitive threat.

Petroleum Producers, Refiners, Distributors, and Retailers

Although petroleum refiners and blenders would benefit from the availability of sources of oxygenates within the state, they may view a largescale alternative fuel production industry as a competitive threat. Retailers could, however, choose to offer the alternative alcohol fuels as part of their product slates. Independent or small refiners and marketers might prefer ethanol as an oxygenate or at least welcome a choice of blending agents.

Wood Products Industries

Biomass feedstock uses could compete for the lower grade fractions of timber and/or forestry wastes, thereby resulting in higher costs for these inputs.

Midwestern Ethanol Producers

As competing suppliers for California ethanol demand, these producers may view the development of biomass ethanol as problematic, even though in the near term, they will probably remain price competitive. In the longer term, the commercialization of biomass-to-ethanol technologies would be likely to benefit firms in agricultural regions outside of California by securing the broad market and public acceptance for this fuel. Moreover, the market developments necessary to establish a commercially viable biomass ethanol industry are likely to benefit all producers. It is worth noting that technologies for converting cellulosic biomass to ethanol may find their first broad application in converting corn fiber (a residue from conventional ethanol production) to alcohol.

Natural Gas-Based Methanol Producers

As with ethanol, to the extent that markets expand for alcohol fuels, this would benefit the conventional natural gas-based methanol industry. The development of biomass-derived methanol could conceivably pose a problem to the methanol industry to the extent that growth in market demand could not absorb the output from biomass-based methanol plants. Given the current low cost of natural gas-derived methanol, however, it seems unlikely that biomass-derived methanol would be a competitive threat in the near-term.

Waste Disposal Companies

Firms operating landfills on a for-profit basis could lose tipping fees as wastes are diverted to biomass conversion facilities.

Note that there may exist possibilities for strategic alliances with some of these competing interests. For example, a firm that operates landfills might also be interested in diverting biomass to a utilization facility (perhaps sited at the landfill), while still deriving revenue on collection and transport of the biomass from the waste generators. Existing commodity alcohol producers also could opt to expand into biomass-based alcohol production, capitalizing upon their established expertise and experience with alcohol process technologies. Because biomass-based alcohol production may be developed in smaller increments of production capacity, the market impacts of new plant additions could be reduced. This is in contrast, for example to the sustained and periodic collapses to which methanol prices have been subject due to the commissioning of new large natural gas-based methanol plants.

GOVERNMENT'S ROLE WITH CURRENT AND FUTURE BIOFUEL ACTIVITIES

Numerous government agencies have developed programs or have participated in waste-to-alcohol related activities.

Federal Agencies

The various federal agencies that have been or may be involved in these efforts include: the US Department of Energy (DOE) and its national labs, especially the National Renewable Energy Laboratory (NREL), the US Environmental Protection Agency (EPA), the US Department of Agriculture (USDA), and others. Unlike California state government, the federal government through NREL has a multitude of nationwide programs to conduct research and development, pilot production biomass-to-alcohol activities and other efforts to aid commercialization activities. NREL has accomplished a great deal of research and technology development in this area. To the authors' knowledge, NREL has not formed regional coalitions to promote these efforts. It may in fact be more appropriate for state and regional governments to act as catalysts in bringing together disparate groups of similar interest.

State Agencies

On the state level a number of agencies have been involved with or have shown interest in waste-to-alcohol, including: the California Integrated Waste Management Board (CIWMB), the California Air Resources Board (CARB) and its parent agency the California Environmental Protection Agency (CalEPA), the California Department of Food and Agriculture (CDFA), the California Department of Forestry and Fire Protection (DFFP), the California Trade and Commerce Agency (TCA), the California Energy Commission (CEC), the California Department of Water Resources (DWR), and other agencies.

Local Government Agencies

Myriad regional, local, and tribal governmental bodies exist in California. Of particular importance in this context are waste disposal agencies and air quality/air pollution districts throughout the state, as well as sewage and reclamation districts, agricultural conservancy boards, and economic development agencies. The Sacramento Metropolitan Air Quality Management District (SMAQMD) has shown strong interest in developing local green waste or rice straw-to-ethanol projects, given its jurisdiction within a major rice straw burning area. In particular, the SMAQMD would like to see locally produced, inexpensive ethanol for use in heavy-duty vehicles in the region and has been studying the potential for waste-to-alcohol in the area *(24)*. Although other air districts may be less enthusiastic about waste-to-alcohol, they do stand to benefit from the work and may similarly act as a support resource around the state. Other local agencies such as waste disposal agencies, agricultural offices, etc., may also have interest in waste-to-alcohol efforts.

Disparate Nature of Organizations Promoting Biofuels

Government-backed programs that have been implemented over the last two decades aimed at encouraging the development of waste-to-alcohol activities have rarely resulted in long-term success stories. Furthermore, regulations developed and enforced by governmental bodies in the pursuit of other objectives often slow or halt hopeful entrepreneurs pursuing biomass conversion efforts.

Quite often government's lack of ability to develop effective programs in this area stems from the approach taken by agencies. Individual governmental agencies tend to approach problems separately and independently. State agencies generally focus on a singular problem or field in response to specific legislative directives. When issues arise that involve multiple agencies, the results are often less than satisfactory. One such example is the complex issue of open-field burning rice straw in the Sacramento Valley region. Burning the remains of rice straw after harvest potentially affects three state agencies: the California Air Resources Board, the California Integrated Waste Management Board, and the Department of Food and Agriculture, as well as local air pollution control districts and county agricultural commissions.

Moreover, if the remaining rice straw was collected and converted to an energy product such as alcohol fuel rather than being burned, yet another state agency—the California Energy Commission—could become involved. Because each agency has its own set of directives—air quality, waste management, agriculture, and energy—and because the state has not created a specific statewide policy, insufficient cooperation exists between these agencies. Also, the independent nature of these state-directed efforts can cause a variety of new problems or result in duplicative efforts. Additionally, these various organizations often maintain conflicting interests. For example, the Energy Commission may promote ethanol as a viable transportation fuel, only to have the California Air Resource Board resist its use because of concerns over potential increases in certain regulated pollutants. Rather than partnering together as sister state agencies, the result is an unintended struggle to move forward mandated agendas.

Therefore, an integrated statewide policy is needed to coordinate efforts by various state agencies and other affected parties. The single most important point made by representatives of the private business community to the authors is the need for an integrated, crossagency policy. Working cooperatively between agencies to remove barriers to commercializing waste-to-alcohol can significantly change the economic outlook for rural and urban development with the potential for creating a substantial number of jobs. It is unlikely that the situation will improve without a unified statewide policy.

BRINGING KEY PARTIES TOGETHER

Government's Role in Facilitating Development

The role of government in promoting waste-to-alcohol activities can assume a variety of forms, ranging from direct involvement in attempting to establish a new technologies in the marketplace, to research, to demonstration, to providing information-only support. The approach considered here suggests that government can function best as a catalyst in promoting introduction of new technologies, but that their successful adoption depends upon market acceptance by both producers and consumers. Private sector investment is more likely to account for the risks and rewards of a new technology. Public involvement is best leveraged in the form of public/private partnerships.

Another role of government in promoting waste-to-alcohol efforts can include what agencies accomplish by removing hindrances to economic development. In the course of exercising essential functions to serve legitimate public purposes, regulatory and development agencies often work at cross purposes. The creation of barriers to market entry by new technologies can be an unintended but important consequence of measures undertaken in pursuit of public goals (e.g., environmental or public health protection). It is desirable that public agencies function with an eye toward coordination and flexibility, so that burdens to private economic activity are minimized without compromising the necessary protection of public interests.

Direct market creation for alcohol fuels has functioned with mixed results. For example, the technical success of the fuel methanol demonstration program in California has not been followed by significant economic penetration of methanol into the transportation fuel market. This can be attributed to a wide variety of factors, most of which focus on the difficulty of establishing a nonfungible transportation fuel in competition with existing, universally accepted petroleum fuels. The present price trends for petroleum and its enormous economies of scale in an integrated worldwide market pose competitive challenges for any alternative motor fuel seeking to gain market share based on pricing alone.

A quick overview of quarterly usage data from the California Energy Commission's fuel methanol program is instructive in this regard. Methanol usage in light duty vehicles peaked in August 1993 at 115,641 gallons of methanol per month, which was blended with gasoline to make M85. Despite the addition of a few thousand more FFVs added to the total population each year, fuel use has declined precipitously. In December 1996, usage had fallen to 22,360 gallons. Ultimately the commercialization of a neat ethanol blend (e.g., E85) and vehicles that operate on such a fuel face similar challenges.

Although the Energy Commission is presently investigating the reasons behind the volume decline, it is unclear what government-driven efforts could be employed to reverse this trend. Contacts with fleet customers have revealed a number of complaints including: inconvenience of fuel access system, too few stations, high fuel price, requirement of unique and expensive motor oil formulations, and others. Because ethanol and methanol are similar in many respects, it appears likely that ethanol may face many of the same issues. It should be noted that ethanol is a less aggressive solvent than methanol, requiring less extreme measures to prevent degradation of fuel-wetted parts. However, at least one automobile manufacturer has indicated experience with some fuel corrosion problems particularly associated with ethanol blends.

Ethanol does hold a long-term potential that is lacking for methanol, in that it can be used directly as a gasoline oxygenate. The potential ability to penetrate the motor fuel market on this basis affords a unique near-term opportunity for the development of biomass-based ethanol.

Coordinating Efforts of State Agencies

A unique example of cooperation among public and private efforts to construct a waste-to-alcohol facility is the Gridley Rice Straw-to-Ethanol Project, initiated in February 1996. Located approx 60 miles north of Sacramento, Gridley is a small agricultural community with a sizable rice industry in and around the area. Originally, project partners included the City of Gridley, the National Renewable Energy Laboratory (NREL), the California Institute of Food and Agricultural Research (CIFAR, at the University of California, Davis), the Rice Research Board of California, Stone and Webster Engineering (as project manager), SWAN Biomass Company, the California Energy Commission and other private and municipal organizations. An energy company, BC International, has recently become a project partner, whereas SWAN Biomass Company is no longer involved.

The impetus for the Gridley project was the requirement under California law to phase down open-field burning of rice straw over a period of several years to improve air quality. Converting the straw to ethanol is seen as one of the more promising ways of disposal *(25)*.

Funding is coming from the US Department of Energy through NREL and from other project participants. Phases I and II are expected to cost $2.2 million to complete. If the project is shown to be feasible, several rice grower's cooperatives may be interested along with private investors in supplying the required capital resources. The project operator will be determined during the feasibility study, and the owners will ultimately be private investors. Although premature to predict the outcome of this project, the effective partnership that has developed can serve as a model for future alcohol production efforts.

Development of Multidisciplinary/Multiagency Consortium

One way of effectively coordinating activities among government and private entities is to create an organization to pull their often diverse interests together. A consortium of interested parties could be established to leverage resources, share information, and jointly address related problems, including the following.

- Legislation;
- Regulatory issues;
- Technology issues;
- Economic barriers;

- Capital investments;
- Partnering projects;
- Biomass resource availability (feedstock issues);
- Market penetration;
- Environmental restraints and permitting; and
- Other issues.

Furthermore, a consortium must work in an environment of cooperation. The following is an example of goals for interagency cooperation efforts.

- Establish a state policy to encourage sustainable economic development;
- Policy carried out through collaboration; coordinate with state, local, tribal governments and public;
- Phase in implementation of cross agency management process—i.e., Interagency Biomass Activities Task Force;
- Establish specific overarching goals and general guidelines for cross agency ecosystem planning and management process; and
- Direct agencies to interpret their existing authorities as broadly as possible to implement the ecosystem management policy and process.

In sum, work should be directed toward understanding, inclusiveness, and breaking away from traditional piecemeal approaches.

One of the advantages of forming a consortium would be its ability to proactively advance the pertinent issues. Ideally, this consortium should include: state air quality management/air pollution control districts; state agencies (i.e., CEC, CARB, CDFA, CIWMB, etc.); local waste disposal offices; federal agencies (NREL, DOE, EPA, etc.); ethanol producers; members representing agricultural, forestry, food processing industries; nongovernmental organizations and other interested parties.

Because the California State Resources Agency and CalEPA are the umbrella organizations that oversee numerous state environmental/resource agencies, it seems most appropriate to seek participation of these two agencies in a multiagency ethanol task force. The Resources Agency and CalEPA could shepherd their constituent agencies and interested local agencies in an efforts to bring a biomass-based alcohol industry to maturity in California.

CONCLUSION

In surveying California ethanol production facilities, it became evident that few exist today, and none of substantial size (e.g., greater than 10 million galls./yr). Furthermore, ethanol will likely remain in a role of fuel oxygenate rather than as a neat fuel, in terms of its potential in near term transportation fuel markets. Ethanol market economics as a fuel oxygenate or as a fuel in flexible fuel vehicles will be tied to those of petroleum fuels, due to the dominance of the latter in the transportation sector. The degree to which air quality and other regulations (e.g., groundwater protection) allow or drive the use of ethanol as a fuel oxygenate will determine the viability of a biomass-derived ethanol production industry in California.

Ethanol's current price, even with the current federal subsidy, is comparatively high, rendering it problematic to market as a neat fuel. However, advances in production efficiencies are likely to continue to drive down the price of biomass-derived alcohols to better compete with conventional petroleum motor fuels.

The diffuse nature of biomass resources hinders their competitiveness with petroleum fuels. Accounting for externalities associated with the choice of petroleum fuels could shift the competitive balance. Such externalities include: resource depletion, air quality impacts, land conservation, carbon emissions, energy security, rural economic development, and balance of trade. If these benefits could be "monetized" and credited to biomass-based alcohols, these fuels could become a significant contributor to the US energy supply.

Numerous federal, state, and local agencies have participated in waste-to-alcohol activities, but many have abandoned these efforts. Development of a coordinated state energy policy, natural resource policy, environmental policy, and economic development policy from the national level down to the local level must be a top priority if a sustainable transportation system, including one incorporating fuels produced from waste biomass, is to emerge. A directive from the executive branch to develop a statewide policy on producing renewable fuels from biomass is a key element.

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