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BIOMASS IN CALIFORNIA: CHALLENGES, OPPORTUNITIES, AND POTENTIALS FOR SUSTAINABLE MANAGEMENT AND DEVELOPMENT

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Biomass in California: Challenges, Opportunities, and Potentials for Sustainable Management and Development

Executive Summary

Recommendations:

- Establish clear and consistent state policies for sustainable management and development of biomass to help meet the needs for environmental protection and renewable power, fuels, and products.
- Establish local and state government procurement and construction programs to increase the use of sustainable bioenergy and biobased products.
- Establish biomass education programs at all levels and coordinate with research centers for professional training.
- Expand outreach efforts to advise policy makers, inform the public, and enhance sustainable business development.

Managing the nearly 100 million tons of biomass produced annually in California presents clear challenges and opportunities for technology, policy, and economic development. The sustainable management and use of biomass will provide environmental, social, and economic benefits far in excess of current practices. Concerted state and federal efforts are needed to change management and regulatory philosophies to better reflect the value of biomass as a renewable resource. This document explores issues in management and development of biomass and makes recommendations for future actions to realize the benefits.

The three primary sources of biomass in the state are agriculture, forestry, and municipal wastes. Agriculture produces biomass as crop, animal, and processing residues such as straw, wood from orchards, animal manure, and hulls, shells, pits, pomace, and waste-water from food processing operations. Forestry results in timber harvest and sawmill residues and also generates biomass from forest and shrubland thinning and habitat improvement operations. Biomass in the form of paper and cardboard, residual construction wood, waste-wood from demolition, stumps, food waste, and green waste makes up 60% of municipal solid wastes. Municipal or post-consumer sources also include waste-water and biosolids from waste-water treatment. In the future, dedicated crops are likely to be grown specifically to increase biomass supplies for energy and biobased products and to open new markets for agriculture.

The primary uses for biomass are in electricity generation, as a renewable fuel such as ethanol, biodiesel, biomethane, and hydrogen, and as feedstock for products such as plastics, solvents, inks, and construction materials.

Of the total biomass produced each year, 30 to 40 million tons are estimated to be technically feasible to collect and use in producing renewable electricity, fuels, and biobased products. About 30% of this amount could come from agriculture, 40% from forestry, and another 30% recovered from municipal sources. Additional resource exists

in landfill gas and in biogas from waste-water treatment supplying up to 78 and 10 billion cubic feet per year of methane, respectively.

One benefit is the contribution that biomass can make towards meeting the renewable electricity requirements under the state's renewable portfolio standard (RPS). The current biomass capacity across all generating types is close to 1,000 Megawatts (MW_e). If the gross biomass resource in the state were all to be used for electricity production, more than 10,000 MW_e could be generated.

Not all of the resource can, should, or will be used for power, and the technical potential is closer to 4,700 MW_e, enough to provide roughly 12% of current statewide electrical energy consumption. With improved conversion efficiencies and resource additions, annual biomass might be sufficient to support a potential incremental generation of 7,100 MW_e by 2017, the deadline under the RPS by which at least 20% of retail electricity must come from renewable resources. A generation level of this magnitude is unlikely to occur without significant additional development emphasis and clear market signals, such as long term contracting opportunities.

Biomass resources also can contribute to renewable fuel supplies, including conversion to ethanol, methanol, hydrogen, biodiesel, Fischer-Tropsch liquids, syngas, and biomethane. All of these can help meet state goals to reduce petroleum dependency. In the near term, demand for ethanol as a gasoline oxygenate will encourage increased production of grain and sugar crops with longer-term development of cellulosic biomass conversion processes.

Recommendations:

Assess actions for:

Energy and Product Development:

- increasing the use of biomass in achieving renewable portfolio standard (RPS) and Energy Action Plan targets for renewable electricity,
- establishing a state Renewable Fuel Standard to increase transportation and other fuel production from renewable resources,
- extending federal Production Tax Credits (PTC) through 2030 or indefinitely, and including provisions for equal treatment for all renewable resources,
- expanding net metering to include all forms of biomass electricity generation and eliminating caps.
- providing additional opportunities for long term contracting,
- improving the process through which new generators are interconnected to utility systems,
- indexing production incentives under the state Renewable Resources Trust Fund to account for inflation,
- expanding and broadening programs such as the Dairy Power Production Program to encourage greater use of animal, food, food processing, and urban residues and waste waters for power generation and biofuels production,
- improving coordination of biomass and energy RDD&D efforts among private, government, and academic sectors,
- establishing bioenergy and bioproduct research and demonstration centers to facilitate technology testing and deployment in the state.

Consumer demand for renewable products will also stimulate markets for biobased products such as polymers, plastics, cleaners, solvents, lubricants, coatings, inks, composite materials, and many others.

Increasing attention towards biomass utilization is driven by environmental, social, and market considerations. Benefits include reduced severity and risk of wildfire, improved forest health and watershed protection, air and water quality improvements, reclamation of degraded soils and lands, reductions in greenhouse gas emissions, municipal waste reduction and raw material resource development, reduced dependency on imported energy sources, new economic opportunities for agriculture and other industries, improved electric power quality and support to the power grid from distributed electricity generation, jobs creation, and economic revitalization of many agricultural and rural communities. Biomass power systems can operate as base-load generators without the intermittency inherent in wind and solar power systems. Base-load operation provides firm supply of electricity during peak demand periods, allowing greater dispatch of natural gas generators to reduce fossil fuel consumption. Using the biomass currently estimated to be available for electricity generation could result in investments exceeding $14 billion, supply renewable energy with a retail value exceeding $4 billion per year, create more than 14,000 primary jobs, reduce annual greenhouse gas emissions from fossil fuels by more than 13 million tons of CO_2, and eventually generate carbon credits potentially worth more than $400 million per year.

Recommendations:

Assess actions for:

Environmental Quality:

- establishing standards for the sustainable development and use of biomass to insure environmental objectives are met.
- developing broader state greenhouse gas management and climate change policies to reduce net atmospheric emissions of CO_2 and other greenhouse gases, and coordinating with federal agencies on the possible development of national greenhouse gas policies.
- eliminating disparities among environmental policies influencing industry regulation and renewable resource development.
- replacing technology specific regulations with performance based environmental standards.
- consolidating permitting to improve and expedite application review and ensure standards for sustainable development and use are met.

Biomass in Waste:

- establishing state Extended Producer Responsibility requirements.
- limiting the organic fraction of waste allowed in conventional landfills to encourage development of waste reduction, recycling, recovery, and conversion alternatives, and increasing tipping fees at conventional landfills to support diversion programs.
- revising waste transformation definitions and allowing diversion credit to sustainable energy and other conversion technologies.

State Agency coordination:

- Coordinate state agency efforts on recommended actions for sustainable biomass management and development

Despite the benefits from increased biomass utilization, there remain a number of barriers to development. Fuel costs associated with biomass acquisition add to the cost of power generation, reducing economic competitiveness. Limited long term contracting opportunities make financing difficult. Fragmented state policies are sometimes conflicting. Siting and permitting processes can be arduous and complex. Although individual utility interconnection standards have been established under Rule 21, there is not a statewide uniform standard, and the process of connecting to the grid can be difficult and expensive. Net metering is not uniformly available for all forms of biomass generation. There is limited public awareness of the benefits and costs of biomass management.

To help realize economic, social, and environmental benefits and move toward sustainable management and development of biomass, specific strategic goals and actions are recommended. In summary, strategic goals are:

- Establish clear and consistent state policies for sustainable management and development of biomass to:
    - reduce risk and losses from wildfire, especially in wildland-urban interface zones
    - reduce waste and air and water quality impacts from present disposal practices
    - reduce net greenhouse gas emissions
    - generate renewable electricity and fuels to help satisfy the RPS and meet objectives for reduced petroleum dependency
    - reclaim drainage-impaired and other degraded lands
    - stimulate local economic development
- Establish local and state government procurement and construction programs to increase use of sustainable bioenergy and biobased products
- Establish K-12, community college, and university education programs, and coordinate university programs with research centers to provide professional education and training.
- Expand university extension and other outreach efforts to inform policy makers, industry, and the public about needs and opportunities in biomass management and development.

Actions for implementing state goals include identifying mechanisms for expanding the role of biomass in RPS and Energy Action Plans targets for renewable electricity, establishing a renewable fuel standard (RFS), working to extend production tax credits, investigating benefits and costs of expanded net metering for biomass, identifying additional long-term contracting mechanisms, improving interconnection processes, improving coordination on research, development, and demonstration, establishing standards for sustainable biomass development, improving state and federal coordination on greenhouse gas emissions, moving towards performance-based standards and away from specific technology regulations, consolidating permitting activities, establishing extended producer responsibility requirements for waste management, limiting organic material disposal in conventional landfills, assigning waste diversion credit to sustainable energy recovery systems, and defining specific roles of the various state agencies for working together on these recommendations.

1. Summary and Recommendations

1.1 Introduction

Biomass resources in California are sufficient to support much greater use in electricity generation, manufacturing of fuels and chemicals, and the production of a wide variety of biobased products with all the concomitant benefits of substituting renewable for non-renewable energy and materials. The sustainable management and use of these resources can also yield environmental, social, and economic benefits over current biomass management practices. How best to achieve these benefits remains open to public policy debate as well as private investment decisions. Many issues are contentious, and defining sustainable approaches will not always be straightforward.

As the state seeks to expand the fraction of energy from renewable resources, future contributions from biomass, an important contributor to date, remain uncertain. Biomass encompasses a diverse class of materials including residues from agriculture and forestry, a fraction of municipal solid wastes, organic material in waste waters, and perhaps increasingly in the future, crops grown specifically to be used as fuel or in the production of fuels and products, and enjoys an equally diverse array of technologies to use it. Of particular near-term importance is the question of what contribution biomass resources can make toward meeting the goal set out in the state renewable portfolio standard (RPS) for 20% of retail electricity sales to come from renewable resources by 2017. Because of the many potentially competing uses, the share of renewable power to come from biomass will depend in part on state policies supporting biomass directly or that influence the general framework of development that will either enhance or inhibit future resource utilization. This paper examines some of the issues in biomass management and development, and makes suggestions and recommendations regarding future action.

1.2 Contributions to renewable power from biomass

In 2003, biomass conversion accounted for more than 2% of electric generating capacity and energy in the state[1] and a minor share of liquid fuels. Biofuel use increased in 2004 due to the substitution of ethanol for MTBE in gasoline, but with the major share of ethanol coming from outside the state. Although electricity generating capacity in the solid-fuel biomass combustion sector declined during the preceding decade, an increased capacity in landfill gas-to-energy kept total biomass capacity nearly constant at close to 1 GW_e.[2, 3] But while electricity consumption in the state continues to increase, electrical energy from biomass has stagnated since restructuring of the electric industry began in

[1] California Biomass Collaborative. 2004. An Assessment of biomass resources in California. PIER Consultant Report, California Energy Commission, Sacramento, CA, 2004, http://biomass.ucdavis.edu.
[2] Aldas, R.E. and M.C. Gildart. 2005. An assessment of biomass power generation in California: status and survey results. Draft California Biomass Collaborative/PIER Consultant Report, California Energy Commission, Sacramento, CA.
[3] GW_e = gigawatt electric = 1 million kW electric.

1996 (Figure 1). This stagnation in energy production has led to a declining share from biomass, and facility closures in the solid-fuel combustion sector have resulted in greater amounts of biomass being landfilled or open-burned for disposal. The decline constitutes a fuel use reduction of approximately 1.5 million dry tons per year.[4] Biomass also declined in the share of renewable electricity that might be counted under the RPS, falling from 32% of renewable net system power in 2002 to 24% in 2003.[5] Although landfilling of biomass enables greater power generation from landfill gas and compensates in part for the decline in the combustion sector, the trend is counter to state goals for reducing landfill disposal. Additionally, urban wood fuels and other materials that once had been removed from the solid waste stream but are now more often landfilled, do not rapidly decompose in landfills. The slow rates of gas production in conventional landfill imply that generating capacity is not fully replaced. Disposal of biomass by open burning emits much higher levels of air pollutants than do controlled combustion in biomass power plants and other conversion methods, and does not yield useful energy or products.[6]

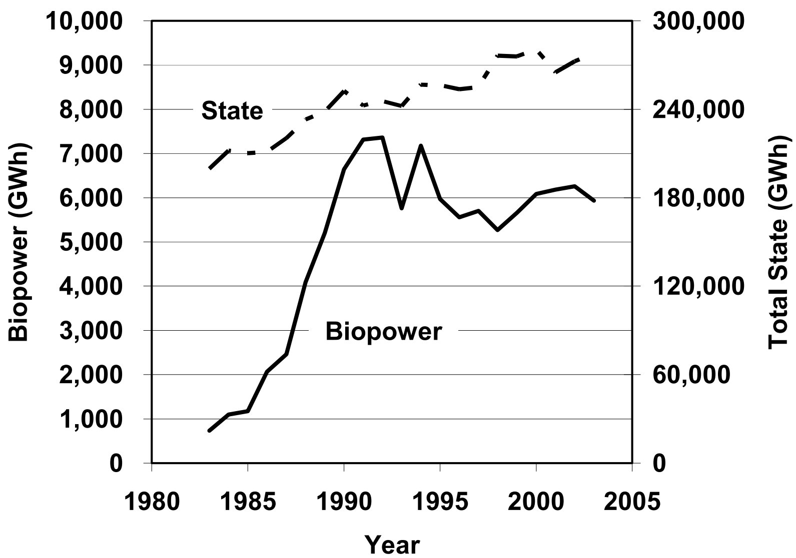

Figure 1. Electrical energy from biomass (biopower) and gross system power in California, 1982 – 2003.[7]

[4] At current solid-fuel biomass conversion efficiencies (20-25%), electrical energy generation consumes approximately 1,000 dry tons per GWh.

[5] California Energy Commission, 2002 Net system power calculation, Publication 300-03-002, and 2003 Net system power calculation, Publication 300-04-001R. Eligible renewables include biomass, geothermal, small hydro, solar, and wind.

[6] Jenkins, B.M. and S.Q. Turn. 1994. Primary atmospheric pollutants from agricultural burning: emission rate determinations from wind tunnel simulations. Paper No. 946008, ASAE, St. Joseph, MI.

[7] California Energy Commission, Electricity in California, http://www.energy.ca.gov/electricity/index.html#generation

1.3 Environmental and market drivers

Sustainable management and development of biomass resources involves enormous challenges as well as opportunities. Many current practices in agriculture, forestry and municipal waste disposal have either created or failed to address significant environmental problems and are in need of change. The sustainable use of biomass affects many environmental and social issues including energy, climate change, waste disposal, wildfire risk, wildlife habitat, air and water pollution, land and soil reclamation, and local economic development. Biomass is unique among the renewable energy sources in being able to directly sequester carbon from the atmosphere in helping to mitigate greenhouse gas emissions, although this carbon is released when biomass is converted for energy purposes or burns or decays naturally. Conversion processes that release carbon as CO_2 have lower greenhouse gas impacts than those that release it as methane.

Producing renewable energy is a key driver of biomass development, but attention is often focused on the energy markets because of their potential to use biomass to economic gain in helping to solve environmental problems. Elimination of agricultural exemptions under the Clean Air Act, restrictions on open burning of rice straw and other agricultural residues, and state policies to reduce landfilling have all resulted in greater emphasis on energy alternatives for biomass disposal. Addressing energy and environmental issues comprehensively provides opportunity for the state to shift policy towards consistent resource management objectives rather than maintaining a separate philosophy of waste management. Expanded use of biomass will depend principally on economic opportunities created by environmental legislation, regulations, and policy; escalating costs and prices of conventional fuels, limitations in power transmission and distribution infrastructure, security of supply, and consumer preferences; and other resource management activities for which biomass production is a subsidiary outcome and at least partially supported economically by the primary management activity, such as forest thinning operations aimed at reducing risk of catastrophic wildfires.

1.4 Biomass resources in California

The state's biomass resource is large and diverse. The gross annual resource is estimated at more than 86 million bone dry tons (BDT),[8] and preliminary estimates suggest that of this, 34 million BDT per year are available for use on a sustainable basis.[9] This latter value is a preliminary estimate based on technical and ecosystem limitations in resource acquisition and does not define the fraction of biomass that is economically feasible to use. Of the gross annual resource, 25% is from agriculture, 31% from forestry, and 44%

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[8] The bone dry ton is a standard industry designation for a ton of material at nominal zero moisture content.
[9] An earlier assessment for 2003 estimated 71 million gross and 26 million technically available BDT/y, see California Biomass Collaborative, 2004, An assessment of biomass resources in California, PIER Consultant Report, California Energy Commission, Sacramento, CA, http://biomass.ucdavis.edu. The current values are based on a 2005 update including a reassessment of forest resources by the California Department of Forestry and Fire Protection along with increases in municipal solid waste generation.

from municipal solid wastes. Supplementing the in-state biomass production is imported biomass in packaging and other materials accounted for in the waste stream. Landfill gas production exceeds 118 billion cubic feet per year (BCF/y) from more than 1 billion tons of waste in-place, with a potential recovery of 79 billion BCF/y. Biogas from waste-water treatment plants adds 16 - 18 BCF/y. Dedicated energy crops are not grown to any significant extent in the state presently, but might be produced in the future, particularly in association with reclamation of drainage and other impaired agricultural lands in the San Joaquin Valley. By 2017, gross annual biomass production might approach 100 million BDT, with about 40 million BDT potentially available for use.

1.5 Potential power generation from biomass

The gross biomass resource in the state, were it all to be used for power generation, would be sufficient to generate in excess of 10,700 MW_e of electricity using current thermal and biological conversion technologies. About 2,100 MW_e of this could come from agricultural biomass, 3,600 MW_e from forestry, and 5,000 MW_e from municipal wastes including landfill and sewage digester gas. Not all of the resource can, should, or will be used for power, and the technical potential is estimated to be substantially less at close to 4,700 MW_e, sufficient to generate 35,000 GWh of electrical energy or roughly 12% of the current statewide demand of 283,000 GWh. To maintain current share (20%) of renewable net system power, average additions to the state's generating capacity of 50 MW_e per year would be needed under the present RPS, and 85 MW_e per year under an accelerated plan yielding 33% renewable electricity by 2020. Currently there are no plans to achieve this level of growth in biomass power generation, although resource is sufficient to support it if shown to be economically feasible.

With improved conversion efficiencies and growth in municipal, dedicated crop, and some agricultural resources, the state's annual biomass production might be sufficient to support a potential incremental generation of 7,100 MW_e by 2017. Without improving generating efficiencies, incremental potential in 2017 would be closer to 4,800 MW_e. Electrical energy contributions could reach 60,000 GWh by 2017 or 18% of projected statewide consumption of 334,000 GWh, although generation is unlikely to reach this level without significant additional development support and clear market signals, such as long term contracting opportunities. These projections are therefore likely optimistic.

From a purely resource perspective, biomass in California cannot be expected to possess the same generating potential as direct solar conversion. Maximum net photosynthetic efficiencies for agricultural and biomass crops are typically of the order of 2%, resulting in overall efficiencies from sunlight through biomass to electricity seldom exceeding 0.5%. Overall efficiencies, including heat utilization, can approach 1%. Water will prove a limiting factor for greatly expanded production of dedicated crops to increase total resource. The stored solar energy in biomass, however, allows for base-load and firm on-peak operation, avoiding and complementing the intermittency of power generation from wind and solar. The high capacity factors of biomass systems also mean that to supply a given level of energy requires an installed power capacity roughly one-third that required for wind and a quarter to a fifth that for solar.

1.6 Costs of power from biomass

Electricity generation costs vary depending on conversion technology, fuel, and production incentives. Levelized cost of electricity (COE) from new solid-fueled combustion power plants using conventional technologies and operating at net efficiencies of 20 - 25% are in the range of $0.06 - 0.08/kWh (2004 constant dollars) for fuel costs of $20 per ton. At these efficiencies, each $10 per ton increase in fuel cost adds approximately $0.01/kWh. For facilities without fuel or debt charges, COE decreases to a minimum around $0.03/kWh. Anaerobic digestion systems and landfill-gas-to-energy facilities typically generate at costs of $0.04 - 0.07/kWh. New combined heat and power (CHP) systems able to sell heat at prices approaching the value of heat from natural gas combustion can sell electricity at prices between $0.01 - 0.05/kWh and realize overall emissions reductions by avoiding the separate generation of heat from other fuels, potentially creating emission offset credits. Matching power generation with heat utilization is an important consideration for future biomass power development.

Federal production tax credits provide support in the amount of $0.009/kWh over five years for so-called open-loop biomass including residue or waste biomass. Closed-loop biomass, or biomass grown specifically for energy in a closed cycle of growth and consumption, is eligible for twice that amount applied over ten years. These credits are of limited availability, currently applying only to facilities installed by the end of 2005. Without Congressional extension of the credits, they will not provide incentive for the majority of biomass development that will necessarily occur after this time.

1.7 Biofuels and Bioproducts

Other markets for biomass include transportation fuels and biobased products such as polymers, plastics, cleaners, solvents, lubricants, coatings, inks, agricultural chemicals, pesticides, insulation and construction composites, and other specialty applications. Biomass technologies will be applied across a range of scales from small distributed systems to large centralized facilities. Integration of production activities will lead to economic advantages. Federal emphasis on biorefinery development is intended to provide economic platforms for the production of a variety of higher value products and energy. Ethanol and biodiesel are produced commercially, although ethanol from cellulosic biomass is still developmental, and both biofuels benefit from federal subsidies intended to compensate for cost differentials compared with petroleum. Biogas and biomethane from anaerobic digestion systems can also serve as transportation fuels in addition to the current primary use in stationary power generation. Biomass can be used to produce hydrogen, and Fischer-Tropsch liquids produced by gasification can substitute for gasoline and diesel fuels, although full commercial development has not yet occurred for biomass. Near-term energy production will deploy more conventional technologies and use starch, sugar, and oil crops for any substantive increase in liquid transportation fuels from biomass. The high value and environmental and energy security benefits encourage continued research and development. The production costs of all these fuels are presently higher than the direct production costs of fossil fuels, but as the market prices of the latter escalate, biomass conversion technologies improve, and externalities are addressed through policy (for example, renewable energy and carbon trading markets), biofuels will become more competitive. Identifying financing for start-up companies will remain an important consideration in bringing new products to market.

1.8 Benefits and impacts of biomass utilization

Sustainable biomass utilization offers multiple benefits, including:

Renewable energy: Biomass energy conversion reduces demand for fossil fuels, including imports, and increases security and reliability of supply.

Local air quality benefits: Biomass conversion results in reductions in emissions of criteria and hazardous air pollutants in comparison with open burning and wildfires. It also reduces emissions of volatile organic compounds, odors, dust, and nuisances associated with agricultural operations such as dairies and animal feeding operations.

Water quality benefits: Proper management of fuel stocks in forests to reduce catastrophic wildfires can reduce post-fire soil erosion and hydrologic and water-shed impacts. Improved management of animal manure and solid wastes controls nutrient loadings and reduces ground water contamination. Digestion of food processing and other waste-waters reduces organic loadings for land application or further treatment by municipal systems.

Global climate change impacts: Biomass utilization reduces net carbon emissions to the atmosphere and provides reductions in methane emissions from natural decay processes. Increasing production of biomass can sequester atmospheric carbon over the short to medium term, and promote carbon sequestration in soils.

Ecosystem impacts: Decreased intensity of wildfires reduces tree mortality and loss of wildlife habitat.

Jobs: Biomass utilization leads to primary jobs creation in collection, construction, and facility operations, and secondary jobs through local and regional economic impacts. These jobs would be created in both rural and urban areas as greater use is made of all types of biomass in the state.

Local economic development: Biomass development yields tax benefits and creates additional economic activity to help revitalize many communities, especially in rural and agricultural areas with high unemployment.

New agricultural markets: Biomass can be used for a wide range of bio-products, providing new opportunities for agriculture.

Reduced economic losses from wildfires: Managing fuel loads in forests to reduce the intensity of wildfire decreases losses from wildfires. Currently 2.2 million acres in the state are at extreme risk of wildfire, 15 million acres are at very high risk. Total annual economic losses from wildfire exceed $160 million. Wildfire suppression costs annually exceed $900 million.

Reduced waste disposal: Using waste for energy and products reduces disposal in landfills.

Land use impacts and soil reclamation: Biomass production can contribute to soil and land reclamation through phytoremediation. Biomass crops can reduce drainage water impacts and help manage salts on irrigated lands while producing fuels and value-added products. More than 1.5 million acres of farm land are drainage-impaired in the San Joaquin Valley alone.

Local grid support: Distributed and strategically located biomass power systems, like other distributed systems, can provide local voltage support and reduce electricity transmission requirements, helping to mitigate congestion during periods of high power demand.

Flexibility in power generation: Biomass power plants can operate as base-load and in some cases as peaking facilities, providing flexibility in electricity system management and complementing generation from intermittent resources such as wind and solar.

On-site power generation: Biomass fuels can also be used at the site of generation, such as at sawmills, dairies, and food processing operations. On-site power generation, often coupled with heat utilization, serves to displace retail purchases for power and fuel, reducing demand for grid power and natural gas, and reducing costs of energy for the facility.

Using 34 million BDT/y of biomass for energy, including additional landfill gas and biogas capacity, would[10]

- lead to investments of up $14 billion,
- create as many as 14,000 primary jobs,
- displace 13 million tons of CO_2 from fossil fuels, and
- generate carbon credits that might eventually be worth more than $400 million.

More than three-quarters of these impacts would be incremental to today's utilization. Increasing development of bioproducts including biobased polymers and plastics, adhesives, lubricants, fertilizers, solvents and cleaners, sorbents, inks, and others will further increase benefits. Sustainable use requires at least

- continual renewal of biomass used,

[10] see section 10.

- proper design and attention to agronomic and ecosystem impacts such as soil degradation and erosion, fate of nutrients, salinity control, wildlife habitat, biodiversity, transmission of plant pathogens, and invasive species,
- consideration of environmental justice issues and animal health and welfare,
- effective control over air and water pollution,
- and achievement of positive life cycle impacts.

1.9 Barriers

Despite the many benefits of using biomass sustainably, there are barriers to development. The cost of collecting and delivering biomass to the point of use is often high and reduces the competitiveness of biomass energy systems compared with other renewable technologies that do not incur fuel costs. These costs cannot always be passed through directly in the sales price of the product due to the competitive nature of the market. Potential developers find difficulty in securing long-term contracts for biomass, especially from public lands agencies and in areas with fragmented federal, state, and local ownership patterns. State environmental policies and programs are fragmented and sometimes conflicting. Utility interconnection can be difficult as well as expensive and although individual utility standards have been established under Rule 21, a uniform statewide standard does not yet exist. Siting and permitting processes are in most cases arduous and complex. Adequate environmental data often do not yet exist for many new biomass industries or they have not been fully evaluated by regulatory agencies, leading to uncertainties and delays. This is a particular issue with NOx and volatile organic compound (VOC) emissions. Net metering is not uniformly available for all types of biomass power systems. Lack of demonstrated commercial success can often make financing new technologies difficult. Animal health and welfare concerns create opposition towards public incentives for technologies benefiting large animal operations where biomass utilization is integral to environmental management.[11]

Because statewide energy, air quality, water quality, waste management, resource conservation, fire protection, agricultural, and economic development policies are fragmented and lack agency coordination, there is no state system in place for assessing the overall environmental and health benefits or life-cycle costs of biomass industries in relation to petroleum or other nonrenewable alternatives. Concerted and coordinated action on the part of the state and federal partners coupled with more comprehensive policy should be considered for achieving the significant economic and environmental benefits of sustainable biomass resource management and development.

[11] http://motherlode.sierraclub.org/MethaneDigestersSIERRACLUBGUIDANCE.htm

1.10 Recommendations

The following actions are recommended to realize the environmental, economic, and social benefits associated with the sustainable management and use of biomass:

1.10.1 Strategic Goals

1. Establish clear and consistent state policies for the sustainable management and development of biomass. These policies should focus on comprehensive resource management objectives and address ways to best utilize biomass for the purposes of:
    - reducing the frequency and intensity of and losses from wildfires, especially within wildland-urban interface areas which otherwise would be subject to significant loss of life and property, and reducing air emissions from wildfires,
    - reducing the adverse air and water quality impacts from disposal of agricultural, forest, and urban residues, including landfilling of wastes, land application of animal manures, and open-field burning of crop residues and prescribed fires,
    - reducing net atmospheric emissions of greenhouse gases and mitigating other global climate change effects,
    - generating renewable electricity and fuels to
        - help meet renewable electricity goals specified under the state's Renewable Portfolio Standard (RPS) or the accelerated goals under the state's Energy Action Plan (EAP), and provide other renewable electricity where possible.
        - help meet or exceed state goals to increase use of non-petroleum transportation and other fuels and insulate the state from oil price and supply volatility, and reduce state dependence on imported ethanol and other fuels and oxygenates in meeting MTBE phase out requirements.
    - aiding the reclamation of drainage impaired, salt affected, and other impaired or contaminated soils and lands
    - stimulating local economic development especially in economically depressed rural, agricultural, and urban communities
2. Establish local and state government procurement and construction programs to increase purchases of sustainable bioenergy and biobased products.
3. Establish K-12, community college, and University level educational programs in renewable energy and biobased products. Coordinate University programs with research centers to provide for professional education and training in sustainable development.
4. Expand University Extension and other outreach efforts to inform policy makers, industry, and the public about needs and opportunities, extend technical training, and enhance sustainable business development.

1.10.2 Achieving Goals

Coordinated investigations and assessments involving government, industry, environmental, and other stakeholders should be conducted to construct a roadmap for development and make recommendations on mechanisms for accomplishing the strategic goals including but not limited to:

Energy and Product Development

a. appropriate actions to take for increasing the role of biomass in achieving renewable portfolio standard (RPS) and Energy Action Plan (EAP) targets for renewable electricity,
b. establishing a state Renewable Fuel Standard to increase transportation and other fuel production from renewable resources, including minimum target levels. Policies designed to achieve goals contained within the state's Integrated Energy Policy report to increase use of non-petroleum fuels to 20% of on-road fuel consumption by 2020 and 30% by 2030 should incorporate renewable fuel allocations at least equal to the minimum in-state targets,
c. working with state and federal agencies and services to extend the federal Renewable Energy Production Credit (Production Tax Credit or PTC) through 2030 or indefinitely, and including provisions for equal treatment for all renewable resources,
d. investigating benefits and impacts of expanding net metering allowances to include all forms of biomass electricity generation. This should include investigating compensation structures and increasing or eliminating capacity caps to encourage greater use of distributed generation, self-generation or on-site power, and combined heat and power systems. The investigation should also include an evaluation of the costs and benefits to all customers.
e. providing additional opportunities for long term contracting,
f. improving the process through which new generators are interconnected to utility systems,
g. indexing production incentives under the state Renewable Resources Trust Fund at the same levels used for the federal PTC to account for inflation,
h. expanding and broadening programs such as the Dairy Power Production Program to encourage greater use of animal, food, food processing, and urban residues and waste waters for power generation and biofuels production,
i. investigating ways to better coordinate biomass and energy research, development, and demonstration efforts among the private sector, state, federal, and academic institutions to reduce costs, improve conversion processes, and expand the range of products from biomass. Investigate ways to increase state and federal collaboration on bioenergy and bioproduct research programs to achieve larger scale demonstration of emerging technologies.
j. investigating the establishment of bioenergy and bioproduct research and demonstration centers to facilitate technology testing and deployment in the state.

Environmental Quality

k. establishing standards for the sustainable development and use of biomass to insure environmental objectives are met in all areas including air and water quality. These standards should take into account environmental review, testing, life cycle assessment, and stakeholder collaboration.
l. recognizing the potential of biomass derived fuels and power in CO_2 reduction strategies and developing broader state greenhouse gas management and climate change policy to reduce net atmospheric emissions of CO_2 and other greenhouse gases. Simultaneously, work with the US Environmental Protection Agency and other federal agencies to coordinate on the possible development of national policies to reduce net greenhouse gas emissions and improve infrastructure and public access to renewable fuels and products. These policies should be aimed at accomplishing real and effective reductions in greenhouse gas emissions and take into account enhancing the value of renewable energy and emission reduction credits to realize the intrinsic benefits of renewable resources.
m. expanding local, state, regional, and national cooperation to reduce or eliminate disparities among environmental policies influencing industry regulation and renewable resource development.
n. shifting emphasis onto performance based environmental standards and away from specific technology regulation to allow greater innovation in developing bioenergy and bioproducts from all biomass resources, including waste.
o. consolidating permitting to improve and expedite application review and ensure standards for sustainable development and use are met.

Biomass in Waste

p. establishing state Extended Producer Responsibility requirements to improve waste management and beneficial use of resources, including biomass in waste.
q. limiting the organic fraction of waste allowed in conventional landfills to encourage development of waste reduction, recycling, and conversion alternatives. In addition, investigate increasing tipping fees at conventional landfills to support diversion programs.
r. revising the definition of waste transformation in statute and assigning diversion credit to sustainable energy recovery technologies.

1.10.3 The role of the State

Investigations of how to achieve the strategic objectives should involve collaboration among all interested groups, possibly working through formal collaborative efforts.

In addition, state agency task or working groups should address specific recommendations involving agency responsibilities. Suggested state agency roles for the elements identified above under 1.10.2 Achieving Goals are as follows:

Elements a-j, Energy and Product Development:

- California Energy Commission
- California Public Utilities Commission
- California Department of Food and Agriculture
- California Department of Forestry and Fire Protection
- California Integrated Waste Management Board

Elements k-o, Environmental Quality:

- California Environmental Protection Agency
- California Air Resources Board
- California State Water Quality Control Board
- California Integrated Waste Management Board
- California Energy Commission

Elements p-r, Biomass in Waste:

- California Integrated Waste Management Board
- California Energy Commission
- Building, Transportation, and Housing Agency
- California State Board of Equalization

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2. Issues in Biomass Management and Development

2.1 Definition

In its strict definition, biomass is living material. As a feedstock for energy and industrial products, biomass refers only to biologically-derived renewable materials[12] and is distinguished from fossil fuels or materials derived from fossil fuels. Biomass is defined in federal statute (7 USC 7624 § 303) as: "any organic matter that is available on a renewable or recurring basis, including agricultural crops and trees, wood and wood wastes and residues, plants (including aquatic plants), grasses, residues, fibers, and animal wastes, municipal wastes, and other waste materials." In this sense, the definition of biomass is generally intended to exclude conventional food, feed, and fiber products from agriculture and forestry, although in practice there is much overlap. Corn grain, for example, is a staple food and feed commodity, but also is the primary feedstock for fuel ethanol production in the US and hence considered a biomass commodity as well. The definition excludes the fraction of plastics, rubbers, and tires derived from fossil resources, although in some cases these are included by statute in legislative definitions of biomass. As noted later, definitions using the word "waste" should be revised to recognize the resource value of these materials.

2.2 Sources of Biomass

The great majority of biomass originates through photosynthesis. Even animal tissues are for the most part constructed directly or indirectly from energy provided by plants harvesting sunlight through photosynthesis. The complex carbohydrate chemistry of biomass allows for a huge diversity of products. The energy in biomass also allows for the production of heat and fuels.

In California, the three primary biomass resource sectors are agriculture, forestry, and municipal wastes or post-consumer residues. Biomass is available as residue in each of these sectors. In agriculture and forestry, biomass can also be produced specifically for use in energy and industrial processing. Dedicated crops are crops grown specifically for their value in biomass markets, especially for energy and fuels. Dedicated crops are not presently grown to any significant extent in the state, but may emerge in the near-term as part of soil and land reclamation efforts and to provide feedstock for ethanol, biodiesel, and other fuels and chemicals.

12 Chum, H.L. and R.P. Overend. 2001. Biomass and renewable fuels. Fuel Processing Technology 71:187-195.

2.3 Uses for Biomass

The carbohydrate structure of biomass gives it a tremendous range of uses. Biomass can substitute for fossil resources in virtually all applications although the commercial processes to do so may not yet be fully commercialized. Historically, biomass burning provided light and heat for cooking and served as a primary energy resource for industrial development prior to the advent of larger hydroelectric facilities, fossil fuels, and nuclear energy. In many rural areas around the world, biomass remains the principal energy source, although in many applications exposure to smoke constitutes a major human health risk, and fuel collection often constitutes a major burden of labor. Throughout the world, research and development efforts exist to improve biomass utilization.

Renewed interest in biomass as an energy resource was stimulated by the oil crisis of 1973. Natural gas shortages in the US and the subsequent oil crisis of 1979 provided continuing motivation for identifying alternative energy resources. Concerns over potential climate impacts of increasing greenhouse gas emissions from fossil fuel burning and forest conversion to agriculture further stimulated interest in renewable energy resources and alternative production techniques. The nuclear reactor accident at Three Mile Island, coupled with the economics of nuclear power facilities and lack of adequate nuclear waste disposal methods stopped the growth of this industry in the US so that no new orders for nuclear power plants have been placed since 1978. Large energy markets appeared attractive for absorbing the large amounts of biomass needing improved disposal.

Enactment of the Public Utilities Regulatory Policy Act (PURPA) in 1978 (PL 95-617, USC 16§2601) provided the impetus for the development of an independent biomass power sector in the US. In California, the largest share of biomass electricity is from the solid-fueled direct combustion sector that since 1980 installed almost 1,000 MW_e of capacity.[13] This sector reached a peak operating capacity of 770 MW_e in 1990, and subsequently has declined to a net 642 MW_e at present. Peak annual incremental capacity additions for this sector totaled 240 MW_e in 1989. Compensating for the decline in solid-fuel capacity has been the growth of landfill gas-to-energy facilities with a existing and planned capacity of 258 MW_e, waste-water treatment plant digesters providing biogas with 63 MW_e, and a developing capacity in animal and food waste digesters with 6 MW_e of capacity.[14]

Growth in ethanol production in the US was stimulated by the energy crises of the 1970s, partial exemption from the motor fuels excise tax under the Energy Tax Act of 1978, demand for ethanol as a fuel oxygenate, and Clean Air Act Amendments provisions

[13] Morris, G. 2003. The status of biomass power generation in California, July 31, 2003. NREL/SR-510-35114, National Renewable Energy Laboratory, Golden, CO.
[14] Aldas, R.E. and M.C. Gildart. 2005. An assessment of biomass power generation in California: status and survey results. Draft California Biomass Collaborative/PIER Consultant Report, California Energy Commission, Sacramento, CA.

favoring ethanol blending in gasoline.[15] With the elimination of MTBE from gasoline in California, ethanol is the only approved oxygenate additive, its major market in the state currently.[16] Biodiesel has developed over the last three decades but more recently with higher diesel fuel prices it has attracted increasing attention as a diesel fuel blending stock and as a neat fuel. Soydiesel production and other biodiesel from oil seeds provide new markets for agricultural commodities. The recent provision of a $1.00 per gallon federal excise tax credit is intended to stimulate biodiesel production from agricultural sources. Other transportation fuels that can be produced from biomass include biomethane, hydrogen, and Fischer-Tropsch hydrocarbon liquids to substitute for gasoline and diesel.

An emerging industry for biomass is in renewable biobased products. These include organic acids, specialty oils, alkyd resins, glycerol, polymers, and a host of other primary and secondary chemicals, intermediates, and commercial products. Current US production within this sector exceeds 12 billion pounds per year, with a potential target market now producing more than 220 billion pounds per year of both biobased and non-biobased products.[17]

2.4 Environmental and Social Drivers

In addition to the energy and product value of biomass resources, interest in increasing utilization has accompanied concerns over environmental impacts and risks of many current management practices. Biomass development can have substantial impact on local economies and influence infrastructure requirements. Among the perceived benefits of biomass utilization are:

- Improved management of greenhouse gas emissions
- Reduced dependency on imported energy sources
- Waste reduction
- Improvements in air and water quality
- Reclamation of degraded soils and lands
- New economic opportunities for agriculture and other industries
- Reduced severity and risk of wildfire
- Improved forest health and watershed protection
- Revitalization of urban and rural communities and creation of new jobs
- Local grid support from distributed generation

Biomass energy conversion, like wind, solar, and other renewable energy sources is essentially carbon neutral. For biomass, this means that CO_2 released to the atmosphere

[15] Schnepf, R. 2005. Agriculture-based renewable energy production. Congressional Research Service Order Code RL32712, Library of Congress, Washington, D.C.
[16] California Energy Commission. 2003. Transportation fuels, technologies, and infrastructure assessment report, 100-03-013F.
[17] Vision for bioenergy and biobased products in the United States, October 2002, http://www.bioproducts-bioenergy.gov/pdfs/BioVision_03_Web.pdf

in conversion processes such as combustion is offset by an equal amount used in growing new biomass through photosynthesis with no net increase in atmospheric CO_2. To be sustainable, biomass production and use must be "closed-loop," such that the amount of biomass grown is equal to that consumed. Biomass can also be used as a shorter term carbon sequestration technique leading to net removal of CO_2 from the atmosphere when more biomass is grown than is used or consumed in wildfires and decay. Carbon is also sequestered in biomass products such as lumber used in construction. Eventually, however, the carbon is released again as the biomass decays, burns, or is converted to energy. Net carbon reductions can also occur through the production of hydrogen and sequestration of carbon from biomass. Decarbonization of fossil fuels, such as in the production of hydrogen from coal and natural gas to allow the use of the energy without the emission of greenhouse gases, will reduce carbon emissions to the atmosphere if the carbon is somehow sequestered. The technique cannot offer the same benefits as biomass in directly reducing carbon concentrations in the atmosphere. The most obvious and simplest approach to carbon sequestration, that of leaving fossil resources in the ground, does not capture the energy content and requires major short-term shifts in energy supply to achieve. California contributes to greenhouse gas emissions through fossil fuel use as well as deforestation. Approximately 60,000 acres per year of forest in the state are lost to other uses, a rate that is currently increasing,[18] and a trend that also contributes to increased fire risk due to urban development at the wildland interface. Reforestation is an important component of sustainable resource management, and will involve similar biomass management issues facing other portions of the state's forests.

If biomass is used sustainably instead of natural gas to generate electricity, at today's efficiencies every ton of biomass burned avoids 0.4 tons of CO_2 emission from the natural gas. Increasing biomass conversion efficiencies will further reduce CO_2 emissions. Over the next century, continuing increases in atmospheric CO_2 will be dominated by fossil fuel use.[19] Climate changes are already apparent, and continued unchecked these practices will result in severe economic and social consequences well before fossil resources are exhausted.[20] Mitigating global climate change impacts associated with greenhouse gas emissions has been and continues to be an important motivation for bioenergy development around the world.

Reducing waste disposal is also an important driver for biomass development. Each year, approximately 1.5 million BDT of urban fuels, mostly wood, are separated from the waste stream and used as biomass fuel for power generation. Assembly bill 939 (1989), mandated a 50% solid waste diversion rate by 2000. This rate has not yet been achieved (Figure 2), and after reaching a peak of 48% in 2002 declined to 47% in 2003. The diversion accomplished to date has extended the projected lifetime of existing landfills, but total disposal has not decreased over the last ten years. Instead, increasing diversion

[18] California Climate Action Registry Forest Protocols Overview, 2004, http://www.climateregistry.org/docs/PROTOCOLS/Forestry/04.06.14_Final_Forest_Protocols_Board_Overview.pdf
[19] Summary for Policy Makers, a report of Working Group I of the Intergovernmental Panel on Climate Change, 2001, http://www.ipcc.ch/pub/spm22-01.pdf
[20] Rogner, H-H. 1997. An assessment of world hydrocarbon resources. Annu. Rev. Energy Environ. 22:217-62.

is associated with increasing waste generation arising from state population growth and increasing per capita waste generation.[21]

An assessment conducted by the California Integrated Waste Management Board (CIWMB) in 2002 indicates a remaining 35 year landfill capacity.[22] The 43 permitted urban landfills in the state have a combined remaining lifetime of 12 years, while 132 non-urban sites have capacity for 66 years, including the Eagle Mountain and Mesquite landfills, which are not currently operating. If the latter two are excluded, non-urban fill capacity extends 22 years. The 17 landfills in the Los Angeles area have a lifetime of 9 years. Within the 2017 timeframe of the RPS, waste jurisdictions will need to make decisions regarding future waste disposal. These conditions have led the CIWMB[23] and a number of jurisdictions to investigate alternatives, including waste conversion. A key limitation in this regard are the current technology designations concerning waste transformation and conversion. Lack of diversion credit for many technologies creates a considerable economic disadvantage as jurisdictions are unwilling to support development that does not result in compliance under AB 939. The issue of conversion is also subject to contentious public debate and particular opposition to incineration and other thermochemical technologies. Despite these concerns, the resource value of biomass in solid waste constitutes a considerable potential for economic development and environmental improvement.

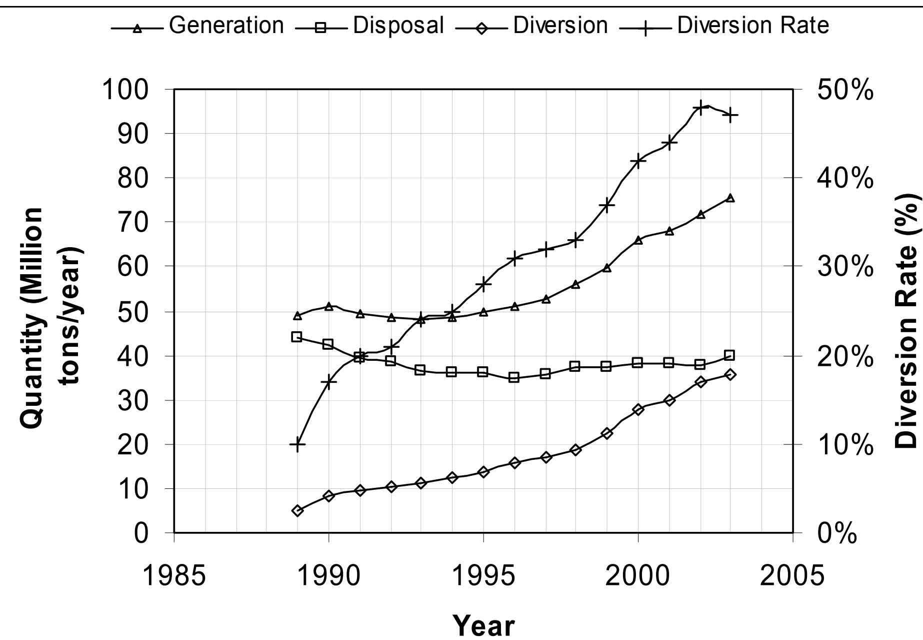

Figure 2. Solid waste generation, disposal, and diversion in California, 1989-2003.[24]

[21] Williams, R.B. and B.M. Jenkins. 2004. Management and conversion of organic waste and biomass in California. In: Van Swaaij, W.P.M., T. Fjallstrom, P. Helm, and A Grassi (eds), Second World Biomass Conference: Biomass for Energy, Industry, and Climate Protection, ETA-Florence and WIP-Munich, Vol. II:2374-2377

[22] CIWMB, 2002, Remaining landfill capacity in California, http://www.ciwmb.ca.gov/agendas/mtgdocs/2002/02/00007306.doc

[23] http://www.ciwmb.ca.gov/Organics/Conversion/

[24] http://www.ciwmb.ca.gov/LGCentral/Rates/Diversion/RateTable.htm

Air pollution from agricultural and forest burning has long been an issue supporting bioenergy development. Emissions from wildfires have become increasingly so. Emissions of criteria pollutants from agricultural burning, range improvement fires, prescribed forest fires, and wildfires are listed in Table 1. Total emissions from wood-fired boilers in California are shown for comparison. Total tonnages are of course quite different, and emissions vary by season. Wildfire emissions occur primarily during the summer, with 97% of emissions occurring between May and October. Average aggregate annual wildfire emissions exceed 1.1 million tons per year (Table 2).[25] For criteria pollutants, biomass power plants employing modern circulating fluidized bed boilers realize emission reductions for all species compared with agricultural burning (Table 2), although at present straw and other field crop residues are not used in California power plants because of problems with ash fouling. Emission reductions for wildland fires are similar. Biomass utilization results in substantial emission reductions for CO, hydrocarbons, and particulate matter compared to open fires. Emissions for all criteria pollutants from existing biomass boilers in the state amount to 0.1% of total statewide emissions, whereas agricultural, range, and prescribed forest fires account for 5% and wildfires 10% of total statewide emissions.

Table 1. Air pollutant emissions from agricultural, range, and forest burning, wildfires, and wood-fired boilers, 2004 inventory (10 year annual average tons/day).[26]

	TOG	ROG	CO	NOx	SOx	PM	PM10	PM2.5	Total
Agriculture—Prunings	13.3	7.6	74	3.8	0.01	8.9	8.7	8.2	100
Agriculture—Field	20.5	11.7	142	1.8	0.18	17.2	16.9	16.2	182
Total Agricultural	33.8	19.3	216	5.6	0.19	26.1	25.6	24.37	282
Range Improvement	41.2	23.5	309	3.7		46.1	45.3	43.0	400
Forest Management	49.8	28.4	720	6		54.2	52.1	46.3	830
Total Ag, Range, Forest	124.8	71.2	1,245	15.3	0.19	126.4	123	113.7	1,512
Wildfires	273.0	128.4	2,482	79.38	24.46	362.0	253.4	215.0	3,221
Wood-fired boilers	0.83	0.37	24.49	5.05	0.48	1.12	1.12	1.04	32
Total Statewide	8,720	4,743	16,293	3,270	279	4,079	2,361	995	32,642

TOG=total organic gases, ROG=reactive organic gases, CO=carbon monoxide, NOx=oxides of nitrogen, SOx =oxides of sulfur, PM=total particulate matter, PM10=particulate matter of aerodynamic size class 10 μm and less, PM2.5=particulate matter of aerodynamic size class 2.5 μm and less.

[25] The value of 598,000 tons per year given in the California Fire Plan (California Fire Plan, 2004, http://www.fire.ca.gov/FireEmergencyResponse/FirePlan/appendixc_part1.html) has been updated by the California Air Resources Board.

[26] California Air Resources Board Emissions Inventory, 2004, http://www.arb.ca.gov/app/emsinv/emssumcat_query.php?F_YR=2004&F_DIV=0&F_SEASON=A&SP=2005&F_AREA=CA#9

Table 2. Emission factors (lb/MMBtu of fuel energy) for agricultural field crops, tree prunings, and circulating fluidized bed (CFB) boilers in California.[27]

	Average-Field	Average-Wood	Average-Ag	CFB	Ag/CFB
CO	7.96	4.77	6.89	0	2,963
NOx	0.33	0.41	0.36	0.06	6.36
SOx	0.04	0.01	0.03	0.01	2.9
ROG	0.85	0.53	0.74	--*	31,800
PM10	0.78	0.43	0.66	0.01	47.5

*$<2\times10^{-5}$.

Emissions of dioxins and furans have been of particular concern for solid waste incineration. Improvements in incineration and emission control technology resulted in greater than 99% reduction in dioxin emissions from MSW incinerators in the US between 1990 and 2000, so that this source represents less than 1% of all dioxin/furan emissions in the nation.[28] Residential wood burning and backyard refuse incineration are one and two orders of magnitude larger in contributions of dioxins to the environment. Despite these improvements, solid waste mass-burn facilities will remain subject to considerable public scrutiny and opposition, and advanced conversion systems will likely be needed. Limited environmental data exist for many of these systems.

SB 700 (2003) eliminated agricultural exemptions from the Clean Air Act and now requires dairies and other agricultural operations over certain size thresholds to obtain air permits. Anaerobic digestion is proposed as best available control technology for ROG from new dairies with herd sizes above 1,984 animals. The production of biogas creates opportunities for power generation and a number of facilities have been installed under programs financed by the state. Conventional reciprocating engines used at most of these sites cannot meet proposed 2007 standards for NOx, which could lead to simple flaring of the biogas rather than productive utilization. NOx emissions from biomass facilities will continue to be a primary concern in design and application. This has motivated investigations into novel ways to meet emission requirements or upgrade the gas for other uses, such as transportation fuel.

Green-e green electricity certification excludes combustion of municipal solid wastes in all regional standards, although in California municipal solid waste conversion facilities

[27] Jenkins, B.M. and S.Q. Turn. 1994. Primary atmospheric pollutants from agricultural burning: emission rate determinations from wind tunnel simulations. Paper No. 946008, ASAE, St. Joseph, MI. CFB emission factors derived from Grass, S.W. and B.M. Jenkins, 1994, Biomass fueled fluidized bed combustion: atmospheric emissions, emission control devices and environmental regulations, Biomass and Bioenergy 6(4):243-260.

[28] Hackett, C. T.D. Durbin, W. Welch, J. Pence, R.B. Williams, B.M. Jenkins, D. Salour and R. Aldas. 2004. Evaluation of conversion technology processes and products. Draft Final Report, California Integrated Waste Management Board, Sacramento, California.

using non-combustion processes are eligible as long as they meet requirements for the RPS.[29] Other regions of the country exclude certain other forms of biomass from green electricity certification, including herbaceous agricultural waste and forestry biomass except for mill residue in the Mid-Atlantic region, and waste wood from landscape operations in Illinois. Treated woods, such as chromated copper arsenate (CCA) treated materials, are excluded in the New England, New York, Mid-Atlantic, Texas, and Ohio standards, and railroad ties and construction and demolition debris are excluded in the Illinois standard. Most standards set maximum emission levels for certification.

Environmental issues are principally behind the drive to find new ways to manage dairy manure and other animal, food, and green wastes in the state. The state Dairy Power Production program funded by the legislature through the California Energy Commission was initiated to support both power generation from biogas produced from dairy manure digestion and to mitigate air and water quality impacts associated with conventional management techniques.[30] Although biogas systems are generally recognized as providing environmental benefits when properly implemented, concerns remain over the use of public funds to support development. A recent Sierra Club guidance document, for example, opposes public subsidies to methane digesters and other energy generation facilities at large confined animal feeding operations (CAFOs) for reasons of environmental protection, animal health, and public safety.[31]

Economic and ecosystems losses due to intense wildfires has also stimulated interest in improving forest management and increasing wood utilization. Approximately 1 million housing units in California are within wildland-urban interface or wildland areas.[32] The total estimated replacement value is $107 billion for structures only. Between 1985 and 1994, an estimated 703 homes were lost annually to wildfire in California. The average loss per home burned is estimated at $232,000, and the average total annual loss for California is $163 million.

The State Board of Forestry and Fire Protection lists 2.2 million acres as being at extreme risk of wildfire, and more than 15 million acres at very high risk.[33] On average since 1950, more than 250,000 acres of forest and rangeland have been affected by wildfire each year. Over the last five years the average annual area burned exceeds 500,000 acres in approximately 10,000 wildfires. Average annual wildfire-related costs in California for local, state, and federal agencies exceed $900 million per year. Expanding urban development in wildland-urban-interface areas creates increasing risk from fire. Drought and bark beetle infestations have exacerbated these problems in the southern regions of the state, contributing to the devastating fires there in the fall of 2003 that cost 22 lives. Reducing fuel loads in forests greatly reduce these risks, but produce large amounts of

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[29] Green-e renewable electricity certification program, http://www.green-e.org/ipp/standard_for_marketers.html

[30] The Dairy Power Production Program is managed for the Commission by Western United Resource Development, http://www.wurdco.com/.

[31] Sierra Club, http://motherlode.sierraclub.org/MethaneDigestersSIERRACLUBGUIDANCE.htm

[32] California Fire Plan, 2004, http://www.fire.ca.gov/FireEmergencyResponse/FirePlan/pdf/fireplan.pdf

[33] Zimny, C. Fuel hazard reduction regulation: regulatory methods and rule language alternatives. State Board of Forestry and Fire Protection, Forest Practice Committee, Draft 26 April 2004, Sacramento, CA.

biomass needing disposal or utilization. Economic benefits of fuel load reduction can exceed treatment costs. Treatment benefits for areas at high fire risk have been estimated at $2,063 per acre, with treatment costs of $580 per acre, yielding net benefits of $1,483 per acre.[34] Net benefits for areas at moderate risk are estimated at $706 per acre. Concerns include environmental impacts from harvesting activities including soil erosion, damage to remaining trees, sediments from roads, and changes in quality of wildlife habitat. Despite apparent benefits, forest management technique remains controversial, especially where larger tree removals are proposed to economically support treatment operations. The federal Healthy Forest Initiative and the Healthy Forest Restoration Act are targeted towards reducing fuel loads and fire risk, with the intent of treating more than 19 million acres in the US by the end of 2006.[35]

Fuel and feedstock acquisition, plant construction, and operation of conversion or processing facilities can have positive impacts on jobs creation, tax benefits, and local economic development. Many rural communities with high unemployment can benefit from agricultural and forest biomass operations, while solid waste separation, handling, and utilization activities can provide the same in urban areas with proper attention to environmental justice issues. The renewable energy sector generates more jobs per MW of electric power installed, per unit of energy produced, and per dollar invested than does the fossil fuel sector.[36] Estimates of the number of jobs vary, but for biopower typical values are in the range of 3 to 6 per MW_e installed.[37] For corn-to-ethanol facilities, direct employment runs 1 to 1.5 jobs per million gallons per year capacity, with total employment approaching 20 jobs/million gallons per year.[38] Increasing the share of biomass energy is likely to lead to job shifts in the energy sector from mining and related activities to agriculture. More comprehensive policies that recognize the complementary effects of renewable energy, energy efficiency, and other sustainable development are likely to lead to higher levels of employment overall.

2.5 Market Drivers and Incentives

Principal market drivers for biomass include the RPS, waste diversion requirements, reduced waste disposal costs, advantages and incentives for self-generation to avoid high retail prices of electricity, public goods charges and supplemental energy payments, federal tax credits, green pricing programs, and growing economic incentives associated with renewable energy credits and a developing carbon trading market. A summary of selected incentives is included in the Appendix.

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[34] Mason, L., B. Lippke and K. Zobrist. 2004. Investments in fuel removals to avoid forest fires result in substantial benefits. RTI Fact Sheet #28, University of Washington, Seattle, WA.
[35] USDA News Release No. 0036.05, 3 February 2005, http://www.healthyforests.gov/
[36] Kammen, D.M., K. Kapadia and M. Fripp. 2004. Putting renewables to work: how many jobs can the clean energy industry generate? Report of the Renewable and Appropriate Energy Laboratory, University of California, Berkeley, CA.
[37] Kammen, et al., 2004, op cit; Oregon Department of Energy, http://www.energy.state.or.us/biomass/Assessment.htm
[38] Renewable Fuels Association, 2002, http://www.ethanolrfa.org/pr020621.html

The mandate to increase the share of renewable electricity in the state provides substantial incentive for development, but the RPS does not provide any essential mechanism discriminating among renewable resource options. The "least-cost and best-fit" criterion creates a competitive market environment in which lower cost resources will be developed first, potentially without crediting other benefits to the state such as costs of forest fire suppression and reduced waste disposal.

Long term power purchase agreements (PPA) are critical to financing biopower systems. The development of the existing industry was largely a result of long-term favorable-price contracting available under Interim Standard Offer 4 following the enactment of PURPA. To gain market share under the RPS, biomass developers will need to find ways to generate at competitive costs, such as by reducing fuel costs or greater use of CHP systems, or by benefiting from incentives and policies providing financial and economic credit for other attributes of biomass utilization.

An example of direct incentive support for biopower development is provided by the Dairy Power Production Program (DPPP). The program was initiated by the California Energy Commission (CEC) Public Interest Energy Research (PIER) program in response to Senate Bill 5X (2001) following the California electricity crisis of 2000-2001. Among other things, SB5X provided $15 million in grants to be used for pilot projects encouraging the development of "bio-gas digestion power production technologies," with $10 million used for the development of manure methane power projects on California dairies, and $5 million for peak power reduction grants through revision of system operations in anaerobic digestion of biosolids and animal wastes in Southern California. The DPPP provides two types of assistance: buydown grants that cover up to 50% of the capital costs of the system based on estimated energy production, and incentive payments based on 5.7 cents/kWh of electricity generated, totaling the same amount as a buydown grant paid out over five years. Buydown grants are capped at $2,000/kW. The DPPP is administered for the Commission by Western United Resource Development, Inc (WURD). The program is complemented or supplemented by other incentives provided by CEC PIER targeted solicitations and programmatic grants, the availability of California Pollution Control Financing Authority and SAFE-BIDCO loans, and federal incentive programs, including the Renewable Energy Systems and Energy Efficiency Improvements (RES-EEI) program through the USDA Rural Business-Cooperative Service and the USDA EQIP program. Section 319 of the federal Clean Water Act provides funds administered by the State Water Resources Control Board, and in accordance with Assembly Bill 970 the California Public Utilities Commission requires utilities to provide incentives to customers who install distributed generation systems under the Self-Generation Incentive Program.[39] Additional incentive for development has accompanied recent environmental regulation, including permitting requirements under Senate Bill 700 (2003). Net metering provisions under AB 2228 (2002) for dairy anaerobic digester systems has increased the economic attractiveness of these systems.

[39] Additional information is available through hte US EPA AgStar program, http://www.epa.gov/agstar/index.html, the California Energy Commission, http://www.energy.ca.gov/index.html, and Western United Resource Development, Inc., http://www.wurdco.com/

Dairy net metering sunsets in 2006 unless extended by legislation. The loss of net metering constitutes a disincentive to continued development.

State solid waste diversion requirements would provide greater market incentive for waste conversion if more technologies were allowed diversion credit. Currently, jurisdictions are to be at a minimum of 50% diversion, but this level has not been achieved statewide. Most conversion options are still considered under the transformation definition of the legislation and are therefore ineligible for full diversion credit, creating a disincentive for jurisdictions to pursue development of this alternative. This issue is currently being addressed under AB 2770.

The RPS requires production incentives or supplemental energy payments to cover above-market costs of renewables. Utilities are only required to pay up to an established market price referent. The CEC pays above market costs as supplemental energy payments provided by the Public Goods Charge fund. Supplemental energy payments (SEP) are available to existing biomass generators within the Tier 1 category of the Existing Renewable Facilities Program but are currently capped at $0.01/kWh above market with a target price of $0.0537/kWh. SEPs may be insufficient to support the full implementation of the RPS.

Federal Section 45 production tax credits (PTC) extended under HR 4520 (American Jobs Creation Act, 2004) provide economic support for the use of renewable energy and refined coal (principally synfuels). Geothermal, solar, wind, and closed-loop biomass are allowed 1.8 cents/kWh credit[40] Open-loop biomass, municipal solid waste, and small irrigation hydroelectric systems are eligible for half that amount, 0.9 cents/kWh. Refined coal is allowed a credit of $4.375/ton. Wind, closed-loop biomass, and refined coal can apply the credit over ten years, all others for five years beginning 22 October 2004. Assets subject to the credit must be placed in service prior to 1 January 2006. The availability of the credit should attract financing for new biomass and other renewable projects, but the short time frame for development will limit the impact of the incentive if there is not an extension. Closed-loop credits have not so far been used in the US. Unequal treatment for open-loop (e.g. residue) biomass and biomass in solid waste results in a less competitive position relative to geothermal, solar, and wind resources.

Green-pricing programs have also developed to directly value renewable energy by allowing customer choice of the source of energy provided by utilities. Allowing customers direct access to green power suppliers provides a mechanism to pass through generation costs. California suspended direct access during the electricity crisis of 2000-2001. Although green pricing was not specifically prevented, the impact of the direct access suspension had the effect of discouraging green marketing and resulted in an overall decline in green power purchases nationwide during 2002.[41] Biomass allowed within the Green-e certification standard for California includes woody wastes including

[40] The initial value of the credit was set at 1.5 cents/kWh indexed for inflation, and the credit is now valued at 1.8 cents/kWh.

[41] Center for Resource Solutions, Certified electricity products verification results, 2002, www.resource-solutions.org.

mill residues, agricultural crops or wastes, animal and other organic waste, energy crops, and landfill gas.[42] As noted above, municipal solid waste conversion facilities using non-combustion processes are eligible as long as they meet requirements for the RPS. Co-firing of landfill gas and biogas is also allowed if separately metered and contracts allow certification.

Internationally, many countries signatory to the Kyoto protocol have adopted policies to reduce greenhouse gas emissions and have put in place incentives that are encouraging greater use of biomass resources, including directives to reduce waste disposal in landfills, reduce landfill methane emissions, and expand producer responsibility for recycling and disposal of manufactured products.[43] The US has not yet ratified the agreement and so is not legally bound to meet emissions reduction targets. The US is mostly relying on strategies other than directly decreasing fossil fuel use and domestic greenhouse gas emissions.

Policies to reduce greenhouse gas emissions have typically focused on two mechanisms: carbon taxes and emissions trading. Carbon taxes are direct price-based instruments designed to increase the price of fossil fuels and reduce demand. Taxes are paid to governments which can return the tax revenue to the economy by reducing taxes on other activities, including renewable energy. With emissions trading, the right to emit becomes a tradable commodity. Trading caps fix the allowed emission level and firms that incur higher costs of emission reduction can purchase permits to emit from firms that have lower abatement costs and can reduce emissions below allowed levels, or credits from firms that do not emit, such as renewable energy generators.

Carbon taxes have not developed as a preferred approach in the US. Valuation of the renewable energy and environmental benefits is beginning to appear in the form of renewable energy credits or certificates (RECs), also known as tradable renewable energy certificates (TRCs) or green tags. RECs are a market mechanism designed to capture the environmental attributes of renewable energy and will have an important role in expanding the future use of renewable resources including biomass. Current values for RECs in the US are well below the environmental and social costs associated with non-renewable resource consumption.[44] RPS contracts in California require RECs to be bundled with energy delivery. REC value varies throughout the US. In California, the market is largely undeveloped. In some other regions of the US, RECs trade at values as high as \$0.03 – 0.05/kWh.[45]

Emission reduction credits (ERC) might provide economic incentives to biomass development but could also serve to limit new installations. ERCs are in general an important part of New Source Review under the Clean Air Act. The value of emission

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[42] Green-e renewable electricity certification program standard, 2004, www.green-e.org.
[43] Williams, R.B. and B.M. Jenkins. 2004. Management and conversion of organic waste and biomass in California. Proceedings 2nd World Conference and Technology Exhibition on Biomass for Energy, Industry, and Climate Protection, 10-14 May 2004, Rome, Italy.
[44] Morris, G. 2000. Biomass energy production in California: the case for a biomass policy inititative. NREL/SR-570-28805, National Renewable Energy Laboratory, Golden, CO.
[45] Natsource RE Trends Weekly, 4 January 2005.

reduction credits has been increasing.[46] NO_x transaction costs in California averaged $39,482 per ton in 2003, ranging from a low of $6,000 to a high of $140,000 per ton.[47] The average cost is nearly twice that incurred in 2000. For existing facilities, ERCs could help defray costs of equipment added to reduce emissions. Recent legislation (SB 705, 2003) curtailing agricultural burning potentially eliminates a number of emission credits previously available from this source and which were used to permit many existing biomass facilities. The cost of purchasing ERCs could prove prohibitive to new facilities.

The environmental benefits associated with waste management aspects of biomass have led in some cases to the conclusion that biomass development should be handled primarily in that context. Such an approach, however, does not adequately address the multiple benefits that biomass provides, as some previous approaches targeting mainly the renewable energy potential of biomass failed to integrate environmental attributes. It also ignores that part of biomass that is not waste. A management approach that recognizes both the resource value as well as the environmental benefits of biomass should be considered in creating more consistent policies and effective market incentives.

[46] California Air Resources Board, 2004. Emission reduction offsets transaction cost summary report for 2003, http://www.arb.ca.gov/nsr/erco/ercrpt03.pdf.

[47] Cost values do not include the local South Coast Air Quality Management District RECLAIM program or the Sacramento Metropolitan Air Quality Management District SEED program.

3. Biomass Resources in California

The state's biomass resource is large and diverse. The full extent to which it can be managed for the production of energy and products remains speculative, however, due to uncertainties concerning the gross magnitude of the resource, the quantity that can be used on a sustainable basis, and the costs of producing, acquiring, and converting the large number of biomass feedstocks available and those that will emerge in the future.

The principal sources of biomass in California are agriculture, forestry, and municipal wastes. All three of these sources provide biomass as residues of other operations and activities. In addition to the primary commodities already produced, agriculture and forestry can also expand or shift into production of biomass commodities for new energy and biobased product development.

The total or gross estimated statewide resource as of 2005 amounts to 86 million dry tons[48] (Table 3), although the uncertainty of this estimate may be 10% or more. Biomass is a distributed resource with development opportunities across the entire state (Figure 3). The most concentrated sources are those associated with municipal waste collection and disposal, confined animal feeding operations (CAFO), food and agricultural processing, and forest products manufacturing.

Not all of the biomass produced in the state can or should be used for industrial purposes. For example, not all agricultural crop or forest management residue should be harvested where it is needed to maintain soil fertility and tilth or for erosion control. Similarly, terrain limitations, environmental and ecosystem requirements, collection inefficiencies, and a number of other technical and social constraints limit the amount of biomass that can actually be used. For these reasons, amounts that can technically be supplied to utilization activities are substantially less than gross production (Table 3). Additional economic constraints further limit development. The latter are site specific and require detailed analyses for any proposed project. The combination of economies of scale for capital equipment, increasing feedstock acquisition cost as production capacity increases, and other effects often leads to an optimal facility size.[49] Development of biomass power systems will for this reason occur over a wide capacity range from a few kilowatts to multi-megawatt units depending on location, resource availability, transportation and other infrastructure, conversion process, regulatory conditions, product, and market. Biofuels and bioproducts manufacturing will likewise develop over a wide range of sizes and capacity.

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[48] Based on an update of a recent assessment conducted by the California Biomass Collaborative: An Assessment of Biomass Resources in California. PIER Consultant Report, California Energy Commission, Sacramento, CA, 2004. Available from http://biomass.ucdavis.edu. The value is higher than the 71 million dry tons estimated from 2002 data due to a reassessment of forest biomass by the California Department of Forestry and Fire Protection. The value is subject to further change as agricultural and municipal waste resource estimates are updated.

[49] Jenkins, B.M. 1997. A comment on the optimal sizing of a biomass utilization facility under constant and variable cost scaling. Biomass and Bioenergy 13(1/2):1-9.

Table 3. Estimates of annually available biomass in California, 2005.

(Million dry tons/year except as noted)	Gross[4]	Technical[4]
Total Biomass	***86.0***	***33.6***
Estimated Use by Thermal Conversion	69.3	28.9
Estimated Use by Biochemical Conversion	16.7	4.6
Total Agricultural	***21.6***	***9.6***
Total Animal Manure	11.8	4.5
Total Cattle Manure	8.3	3.0
Milk Cow Manure	3.8	1.9
Total Orchard and Vine	2.6	1.8
Total Field and Seed	4.9	2.4
Total Vegetable	1.2	0.1
Total Food Processing	1.0	0.8
Total Forestry	***26.8***	***14.3***
Mill Residue	6.2	3.3
Forest Thinnings	7.7	4.1
Logging Slash	8.0	4.3
Chaparral	4.9	2.6
Total Municipal	***37.6***	***9.7***
Biosolids Landfilled	0.1	[2]
Biosolids Diverted	0.6	0.5
Total MSW Biomass Landfilled	18.5	[2]
Total MSW Biomass Diverted	18.4	9.2
Landfill gas	118 BCF/y [1]	79 BCF/y
Biogas from waste-water treatment plants (WWTP)	16 BCF/y[3]	11 BCF/y

[1] Total landfill gas potential is 118 billion cubic feet per year (BCF/y) for an assumed composition of 50% methane from waste already in place. Diversion of MSW shown as landfilled will reduce future landfill gas potential but may increase generating capacity through use of conversion technologies. Increased diversion would also support potential increases in biofuels.
[2] assumed landfilled, resource available as landfill gas.
[3]billion cubic feet per year of biogas (60% methane).
[4]Gross resource refers to total estimated annual biomass produced. Technical resource refers to the amount that can potentially be supplied to utilization activities (see text).

Figure 3. Estimated gross biomass (BDT/y) by county in California, 2005. Shading indicates relative quantity in each county, increasing from light to dark.

3.1 Agriculture

California's agriculture generates products worth more than $27 billion from 350 different crops.[50] Five categories comprise the majority of agricultural biomass: orchard and vineyard prunings and removals, field and seed crop residues, vegetable crop residues, animal manures, and food processing wastes. Agricultural biomass is distributed throughout the state, but most heavily concentrated in the Central Valley (Figure 4).

- Approximately 2.6 million tons per year (all values are reported on a dry basis) of woody biomass are produced annually as prunings and tree and vine removals from orchards and vineyards (Table 3). Close to 1 million tons per year are currently used as fuel in direct combustion power plants, generally blended with other fuels such as urban wood and forest materials.
- California produces about 5 million tons per year of field crop residues, principally as cereal straws and corn stover. These materials are not currently used for power generation due to problems with ash slagging and fouling in combustion systems. Other conversion approaches are developing.
- Statewide production of vegetable crop residues amounts to 1.2 million tons per year but these are not generally considered for off-field utilization and are commonly incorporated into the soil.
- The agricultural animal population in the state is close to 280 million including 230 million broiler chickens. Total cattle population exceeds 5 million, with 1.7 million milking cows, 740,000 beef cows, and 2.8 million other cows including heifers and non-lactating dairy cows. Total manure production from animals is close to 12 million tons per year, with 8 million tons per year from cattle and nearly half of that from milking cows in dairies. The Dairy Power Production Program is currently supporting efforts to use manure from approximately 33,000 milk cows.
- Food processing operations in the state produce a variety of biomass feedstocks including nut shells, fruit pits, rice hulls, cotton gin trash, meat processing residues, grape and tomato pomace, beet residue, cheese whey, beverage wastes, and waste water streams containing sugars and other degradable materials. Cheese whey and waste sugars are responsible for the current in-state ethanol production of 9 million gallons per year.[51] Dry matter production is in excess of 1 million tons per year.[52, 53] A number of food processing residues are already used for power generation. At least 250,000 tons per year are presently used for power generation, mainly from rice hulls and shells and pits.

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[50] California Department of Food and Agriculture Resource Directory, 2002, http://www.cdfa.ca.gov/card/card_new02.htm

[51] MacDonald, T., G. Yowell, M. McCormack, M. Bouvier. 2003. Ethanol supply outlook for California. CEC 600-03-017F, California Energy Commission, Sacramento, CA.

[52] California Biomass Collaborative. 2004. An Assessment of Biomass Resources in California. PIER Consultant Report, California Energy Commission, Sacramento, CA.

[53] Matteson, G.C. 2005. Biomass resource assessment—food residues. Draft report, California Biomass Collaborative, University of California, Davis, CA.

Figure 4. Estimated agricultural biomass (gross BDT/y) in California, 2005.

3.2 Forestry

There are 40 million acres of forest lands in the state with an average standing tree biomass of 71 tons/acre.[54] Of the total acreage, 46% is national forest. Other public forests constitute 12% while forest industry and other private forests make up 42%. Trees 10 inches in diameter and less account for 88% of the total number of trees but only 15% of the total wood volume. Gross non-merchantable standing forest and shrub biomass is currently estimated at 1.3 billion BDT.[55]

The four main categories of forestry biomass are logging slash, biomass from forest thinning (stand improvement and fuels reductions operations), mill residues, and shrub or chaparral (Figure 5).[56] Forest biomass resources were estimated as part of a recent fuels supply assessment by the California Department of Forestry and Fire Protection (CDFFP).[57] Sawmill residues were estimated using a residue factor of 1.43 BDT/MBF[58] developed from year 2003 timber harvest and residue production data.[59]

- *Logging slash* comprises branches, tops, and other materials removed from trees during timber harvest. Slash excludes the tree stem or "bole," defined as from a one-foot stump to a four inch diameter top. Because the volume of slash is directly proportional to logging activity, slash has declined considerably in the state in recent years (Figure 6). Slash left on the ground after harvest can be a substantial source of surface fuels which can carry wildfire.
- *Forest thinnings* are non-merchantable components extracted during harvest activities and include understory brush, small diameter tree boles, and other material transported to the mill that cannot produce sawlogs. Thinning refers to silvicultural treatments designed to reduce crowding and enhance overall forest health and fire resistance. Thinning of forest and shrub lands by mechanical means (other than by prescribed fire) is often emphasized when the intent is to reduce the threat of catastrophic wildfire near houses or other vulnerable assets and where air quality is a concern. Thinning may or may not produce merchantable saw logs (close to half of which may end up as mill waste). The issue of mechanically thinning forests has been and remains controversial, but thinning is likely to increase, particularly in wildland-urban interface areas, due to

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[54] Shih, T.T. 2004. How much small wood do we have in California? Conference presentation, Smallwood 2004: Creating Solutions for Using Small Trees, Sacramento, CA, May 18-21, 2004.

[55] California Department of Forestry and Fire Protection, Biomass potentials from California forest and shrublands including fuel reduction potentials to lessen wildfire threat, Draft PIER Consultant Report, Contract 500-04-004, February 2005.

[56] Category definitions are adapted in part from California Biomass Collaborative, An assessment of biomass resources in California, PIER Consultant Report, California Energy Commission, Sacramento, CA, February 2004, and California Department of Forestry and Fire Protection, Biomass potentials from California forest and shrublands including fuel reduction potentials to lessen wildfire threat, Draft PIER Consultant Report, Contract 500-04-004, February 2005.

[57] California Department of Forestry and Fire Protection, February 2005, op cit.

[58] MBF = thousand board feet.

[59] Yang, P. and B.M. Jenkins. 2005. Wood residue generation from sawmills in California. Draft report, California Biomass Collaborative, University of California, Davis, CA.

new federal legislation[60] and increasing public concerns over the risk from wildfire. Estimates of the technical availability exclude forest reserves, stream management zones, coastal protection zones, coastal sage scrub habitats, national forest lands with slopes steeper than 35%, and private and other public forest lands with slopes steeper than 30%.

- *Sawmill residues* are a byproduct of the milling of sawlogs that consist generally of softwood tree boles with a diameter at breast height (dbh) of about ten inches. Sawmill and other forest products manufacturing operations generate a variety of wood residues including bark, sawdust, planer shavings, and trim ends. Resource quantities follow logging activity although imports and exports can also affect mill activity. Mill residue represents about half of saw log weight. A large fraction of this material is technically available for use, and about 1.3 million dry tons are already in use for power generation in the state[61] with additional amounts used for landscape and other products. Much of the power generated is used on-site at the mill and is not exported to the grid.
- *Shrub or chaparral* is comprised of mostly shrubby evergreen plants adapted to the semi-arid desert regions of California, especially in the south state. Shrublands range over a large area but so far there has been little development of this biomass for energy. Because shrub biomass has no current commercial value, it is only available as an energy resource through habitat improvement activities (such as thinning) or fuel treatment operations designed to reduce wildfire risks.

[60] Healthy Forests Restoration Act, 2003 (HR 1904).

[61] Morris, G. 2003. The status of biomass power generation in California, July 31, 2003. NREL/SR-510-35114, National Renewable Energy Laboratory, Golden, CO.

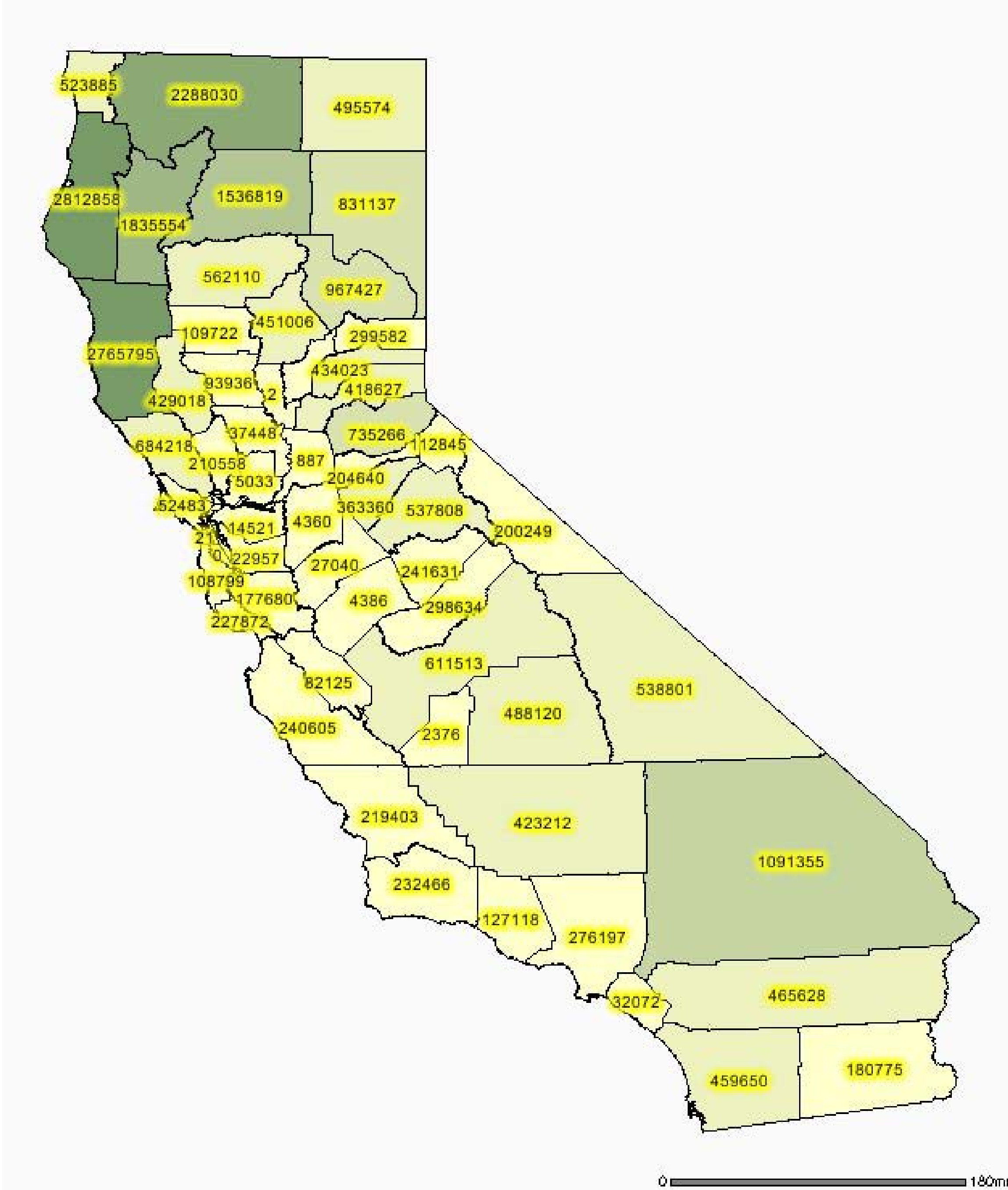

Figure 5. Estimated forest slash, thinning, mill, and shrub biomass (gross BDT/y) in California, 2005.

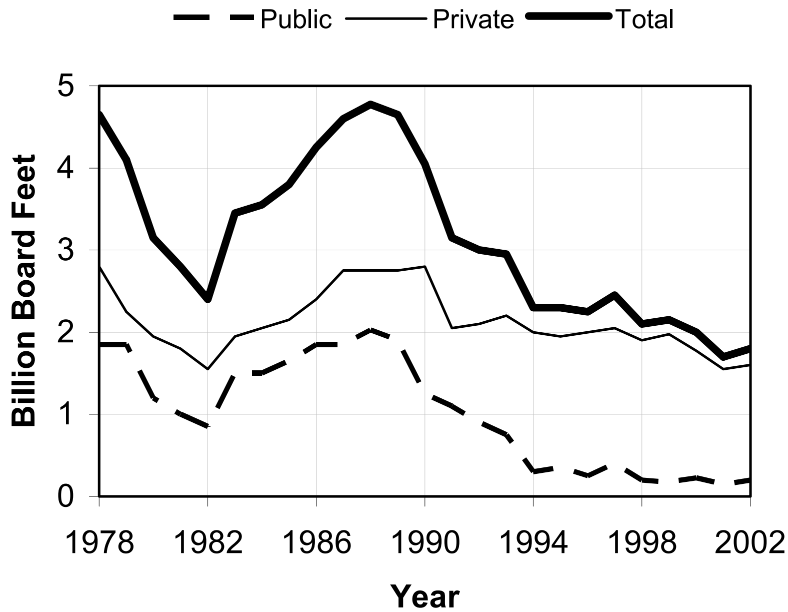

Figure 6. Volume of timber harvest (billion board feet) on public and private lands in California, 1978 – 2002.[62]

3.3 Municipal wastes

Californians produce more than two tons of municipal wastes per person per year. Municipal wastes, also referred to as post-consumer residues, include municipal solid wastes (MSW), municipal waste-water or sewage, and biosolids from waste-water treatment. Landfill gas generated from waste disposed in landfills and biogas from waste-water treatment are also included within this category.

- MSW is the single largest resource for biomass in the state. The biomass component of MSW totals 38 million dry tons per year including construction and demolition wood residue, paper and cardboard, grass, landscape tree removals, other green waste, food waste, and other organics, but not plastics and tires although some fraction of these may be from biomass. The generation rate is roughly 1 dry ton of biomass in MSW per person per year in the state. The 1989 Integrated Waste Management Act (AB 939) mandated that local jurisdictions divert at least 50% of generated wastes from landfill by 2000. Currently the state is just under this fraction. Remaining wastes are disposed in landfills and three mass-burn incineration facilities. Diverted wastes are used for compost, alternative daily cover (although this also contributes to landfill), recycling, and

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[62] California Department of Forestry and Fire Protection, The Changing California, Forest and Range 2003 Assessment, October 2003.
http://www.frap.cdf.ca.gov/assessment2003/Assessment_Summary/assessment_summary.html

energy. About 1.5 million dry tons per year of clean construction wood separated from the waste stream (referred to as urban woody biomass or urban wood fuel) is diverted to biomass direct combustion power plants.[63] Demolition residues are not permitted due to contamination from painted wood.

- There are more than 3,000 waste disposal sites in the state, most of them now closed to further disposal but more than 230 are actively receiving waste. Total waste in-place exceeds 1 billion tons.[64] The biomass portion of waste placed in landfills decomposes over time, albeit very slowly in conventional dry-tomb type landfills. The anaerobic conditions that largely prevail within the landfill result in the production of a methane-rich landfill gas that can be used for energy or chemical processing. The total landfill gas generation from more than 300 major landfills is estimated at between 118 and 156 billion cubic feet per year (BCF/y) for a methane concentration of 50%. The methane equivalent is 59 to 78 BCF/y. By comparison, natural gas consumption in the state is 6 BCF per day or 2,200 BCF/y. In the proper concentrations, methane is explosive in air. Methane is also a greenhouse gas having a global warming potential 21 times that of carbon dioxide. Emissions from landfills need to be controlled both for safety and environmental reasons. Landfill gas is already used for heat and power generation as well as being upgraded to pipeline quality. Landfill gas is also being used as transportation fuel. Even if the state acts to radically reduce future waste disposal, landfill gas will continue for decades to be produced from the waste disposed in previous years. Bioreactor landfills employing leachate recirculation and membrane covers have the potential to increase the rate of gas generation, as do high-rate in-vessel digesters. Proper design may allow storage of gas within the landfill to increase power generation capacity during peak electricity use hours. Gas storage can also be added to other digester systems to increase peaking capacity.
- More than 240 waste water treatment plants in the state treat sewage and other waste water prior to discharge. The organics in waste water are principally biogenic and some facilities use anaerobic digestion for sludge stabilization, producing a methane-rich biogas that can be used like landfill gas for energy or chemical processing. The total biogas resource from waste water treatment is currently 16 BCF/y for a methane concentration of 60%, or 9.6 BCF/y methane equivalent.
- Organic biosolids or sludge resulting from waste water treatment are another source of biomass. About 85% of biosolids are land applied or otherwise used. For example, biosolids have been used for NO_x control in cement manufacturing,[65] The remaining fraction of biosolids are landfilled.

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[63] Morris, G. 2003. The status of biomass power generation in California, July 31, 2003. NREL/SR-510-35114, National Renewable Energy Laboratory, Golden, CO.

[64] as-received wet tons.

[65] Battye, R., S. Walsh and J. Lee-Greco. 2000. NOx control technologies for the cement industry, Final Report, EPA Contract No. 68-D98-026, USEPA, Research Triangle Park, NC.

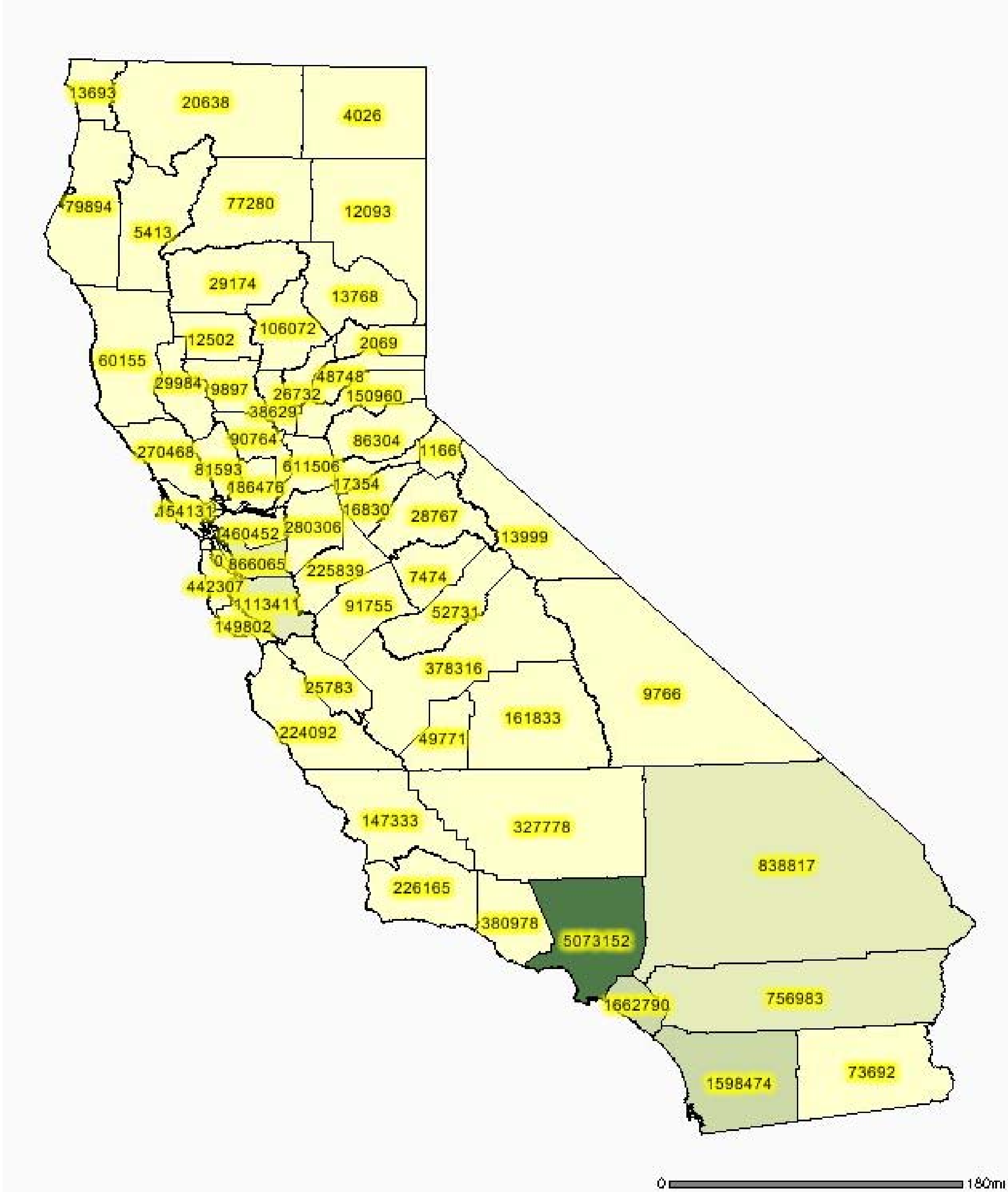

Figure 7a. Estimated biomass (gross BDT/y) in landfilled MSW, 2005.

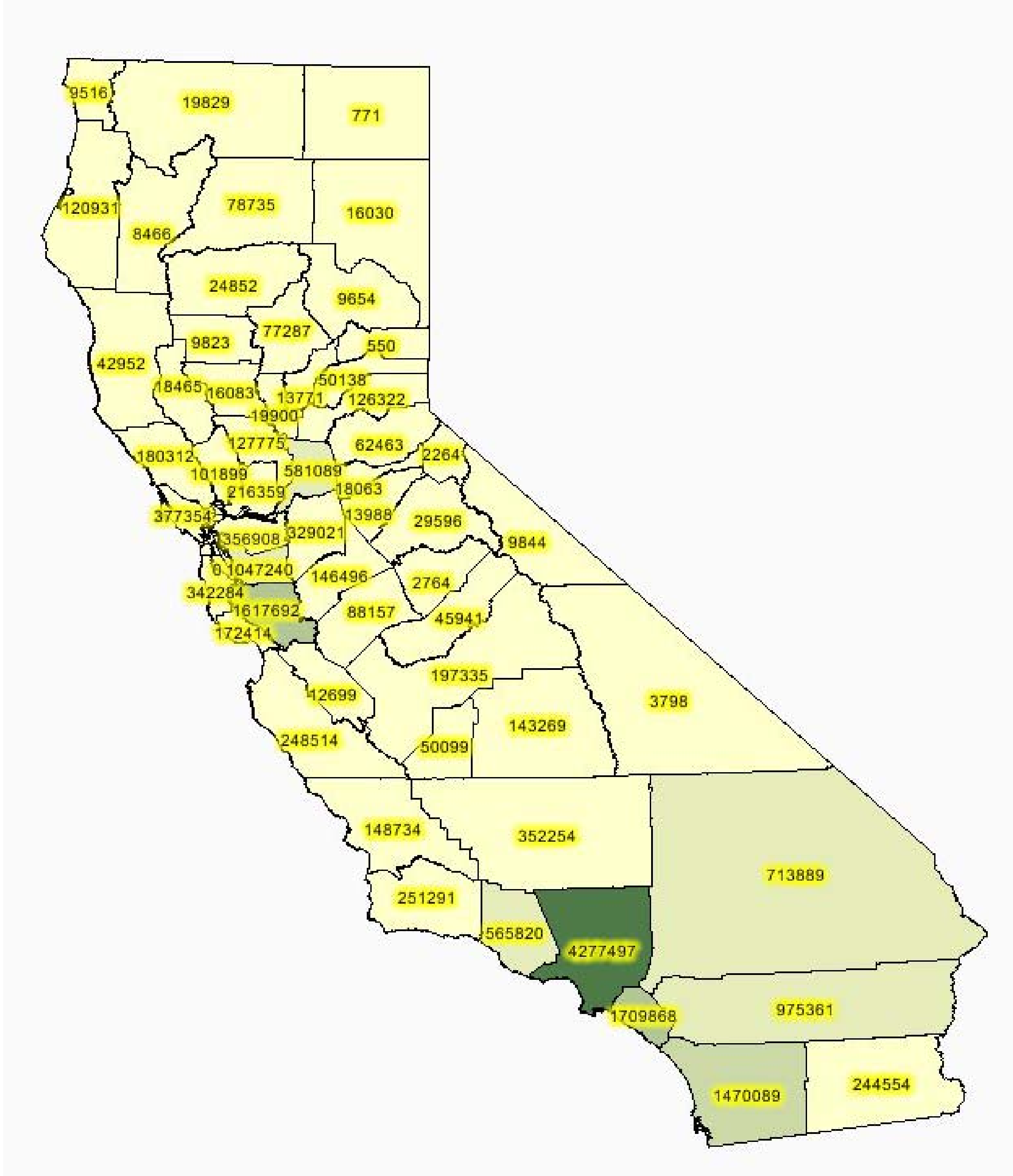

Figure 7b. Estimated biomass (gross BDT/y) in MSW diverted from landfill, 2005.

3.4 Dedicated biomass crops

Nationally, dedicated biomass crops, including herbaceous and woody crops, are targeted to supply large amounts of biomass for new biobased products and energy. Dedicated crop production has not yet emerged as a large scale agricultural enterprise in California, but there is increasing interest due to changes in the renewable fuels and biobased products markets, especially ethanol, and in green purchasing programs. Dedicated crops also have the potential to help solve a number of environmental problems including remediation of drainage impaired and salt affected soils.

- Elimination of MTBE from gasoline has created an expanded market for ethanol as a fuel oxygenate, although State challenges to federal fuel oxygenate requirements are still pending. Sugar and starch crops may develop over the shorter term, with cellulose conversion contributing over the longer term. Major candidate starch and sugar crops include corn, sweet sorghum, sugar beets, and sugar cane. Residues from these crops, such as corn stover, would provide additional biomass. About 12% of US corn is now used to produce ethanol. Woody crop production would offset agricultural crop demand. Developing successful hydrolysis and fermentation techniques for cellulosic biomass would greatly expand the resource base for ethanol and possibly lower costs of production. Recent efforts have been directed at radically reducing the costs of enzyme production. An alternative to acid and enzyme hydrolysis techniques includes thermal gasification to produce a gas from which ethanol or other chemicals can be synthesized. Corn is also being grown for use in the manufacture of polylactic acid (PLA) to make renewable biobased polymers and plastics.
- Oil crops for biodiesel production are currently in field trials within the state, principally sunflower and safflower grown on recycled drainage water. Canola (rapeseed) is another possibility, and a number of other crops, such as jatropha, are under consideration. Oil crops have long been grown in the state for edible oil production. These crops may be important elements of sustainable farm practices in addition to providing renewable liquid fuels and chemicals.
- Field trials are underway on a wide variety of salt tolerant species including trees, grasses, and halophytes that could be utilized for energy and products. These are largely being tested for phytoremediation of salt-affected soils in the San Joaquin Valley but plants can also be used to take up metals and other pollutants. Integrated farm drainage management (IFDM) systems being developed on the west side of the San Joaquin Valley sequentially reuse water to reduce the total volume of agricultural drainage water needing final disposal or treatment. Research is currently investigating the properties of biomass grown under highly saline conditions to determine the impacts on thermal and biochemical conversion processes.
- Marine and freshwater aquatic species have been investigated for industrial use and waterway maintenance operations, such as control of water hyacinth in the Delta, may provide additional biomass. Off-shore production of giant kelp

(*Macrocystis pyrifera*) was investigated for many years as a means of producing renewable methane but has not been deployed commercially. Algae have been widely investigated for photobiological hydrogen production.

- A wide range of crops are being considered for energy and new biobased products. Production practices for terrestrial crops are in most cases similar to other agricultural crops, although in both woody and herbaceous (e.g. grasses) crop production, the end use for the biomass can influence the management and cultural inputs and the practices employed to optimize the production system. The design of the production system considers soil preparation and preservation, species and variety selection, planting, weed and pest control, nutrients and fertilization, water and irrigation, harvesting, and post-harvesting operations. Switchgrass (*Panicum virgatum*), poplar (*Populus* spp.), and willow (*Salix* spp.) are principal crops considered as part of the national biomass development program for the east and midwest US under rainfed conditions. Eucalyptus is currently grown in California and is one species used in IFDM systems.

Dedicated biomass crop yields are variable and depend on the crop type and the availability of water and other inputs. Net energy yields also need to be considered, as for the case of corn grown for ethanol (see section on biofuels). Water is likely to be a limiting resource. On more marginal lands with limited water, biomass yields might average 5 dry tons per acre per year or less. Much higher yields can be obtained under better conditions. The integration of biomass crop production into more conventional agriculture may assist in improving overall sustainability, especially in the San Joaquin Valley. Biomass crops could help in sustaining many rural and agricultural economies. For dedicated crops to become a substantial component of the biomass resource in the state within the time frame of the RPS (2017) will take a concerted research and development effort. There will increasingly be near-term opportunities for high value crops in niche markets. State incentives for renewable fuels and products, such as ethanol, biodiesel, other fuels, polymers, solvents, and lubricants could help revitalize many agricultural sectors. Reductions in federal supports to some agricultural commodities would also provide incentives for new crop development, including energy crops.

One of the best opportunities for near-term dedicated crop development is on land retired from agriculture in the San Joaquin Valley. Agriculture in the valley relies on irrigation using both imported water as well as groundwater. Drainage systems that were integral to plans for agriculture on the west side of the valley through the state and federal water projects were never fully developed due to environmental and financial concerns. Discovery of wildfowl deformities and mortalities at the Kesterson reservoir in the early 1980's led to restrictions on drainage from farm lands. Growers and local water districts are faced with identifying other drainage management options, including on-farm or regional management systems and land retirement. More than 100,000 acres have now been retired due to shallow groundwater tables and salt buildup from inadequate drainage, and 1.5 million acres are considered drainage impaired. Dedicated biomass crops could be used to help remediate these lands and provide much needed economic relief to farmers and local communities. Dedicated crops would serve as biological pumps, lowering groundwater tables and reducing waterlogging of the soil. Biomass crops could be used to grow fuel for local power generation, reducing transportation costs and adding new capacity towards the goals of the RPS. Waste heat from power generation could also be used to purify drainage water, recovering clean water and extracting salts. The types of crops to plant, uses for the crops, irrigation requirements, and other impacts on the environmental quality of the valley, including air quality impacts, need further analysis. The production of biomass crops might, however, help overcome what has become a serious environmental and economic crisis for the state.

3.5 Future California biomass resource projections

Biomass from agriculture, forestry, municipal wastes, and dedicated crops could increase from the current 86 million dry tons to 100 million dry tons per year by 2017 (Figure 8).[66] Increases in MSW and animal wastes are projected to be responsible for about two-thirds of this 15 million ton growth, the rest projected to come mostly from dedicated crops. Biomass from conventional agricultural crops and from forestry will likely remain close to current estimated levels. The amount technically available may increase to more than 40 million dry tons per year by 2017 depending on contributions made by dedicated crops.

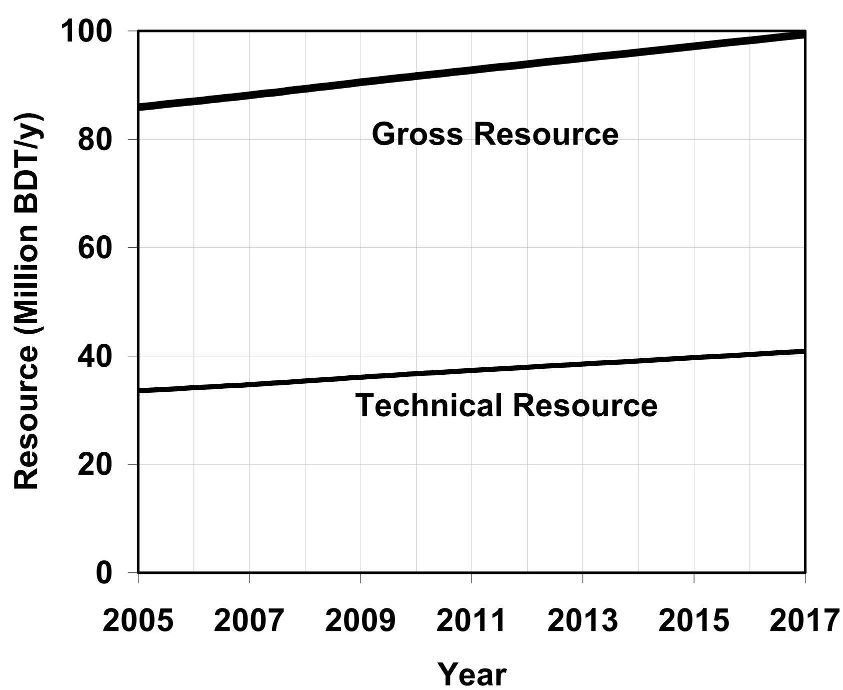

Figure 8. Growth projections for biomass in California through 2017. Does not include resource associated with landfill gas or biogas from waste water treatment facilities.

[66] California Biomass Collaborative. 2004. op cit.

Biogas from waste-water treatment operations will increase with population, but is also subject to waste management practices adopted by industry. Reductions in food processing waste-water disposal through municipal waste-water systems, for example, would reduce organic loadings and hence gas production from municipal digesters. This might be compensated by the food industry deploying on-site digesters to help meet its own energy requirements. Increasing adoption of anaerobic technologies by municipalities in place of aerobic treatment will increase biogas production. Landfill gas will similarly increase with population (Figure 9) unless the state acts to further reduce waste disposal. Even with radical waste disposal reductions, however, landfill gas from waste already in landfills will continue to be an important resource through 2017 (Figure 10). An immediate shift to bioreactor landfills might increase landfill methane generation rates 30% by 2017 (Figure 11), although these systems are still largely developmental. Total biomass resource availability will remain high over the coming decades and identifying improved management strategies will become increasingly important.

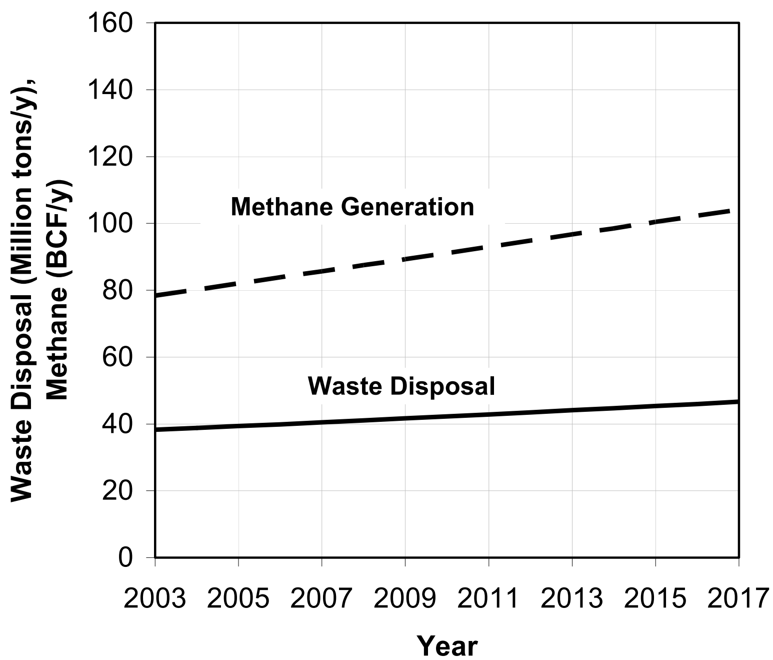

Figure 9. Projected waste disposal and methane generation from landfills, 2003-2017, assuming no change in per-capita waste disposal rates. Waste disposal is shown in as-received (wet) tons per year.

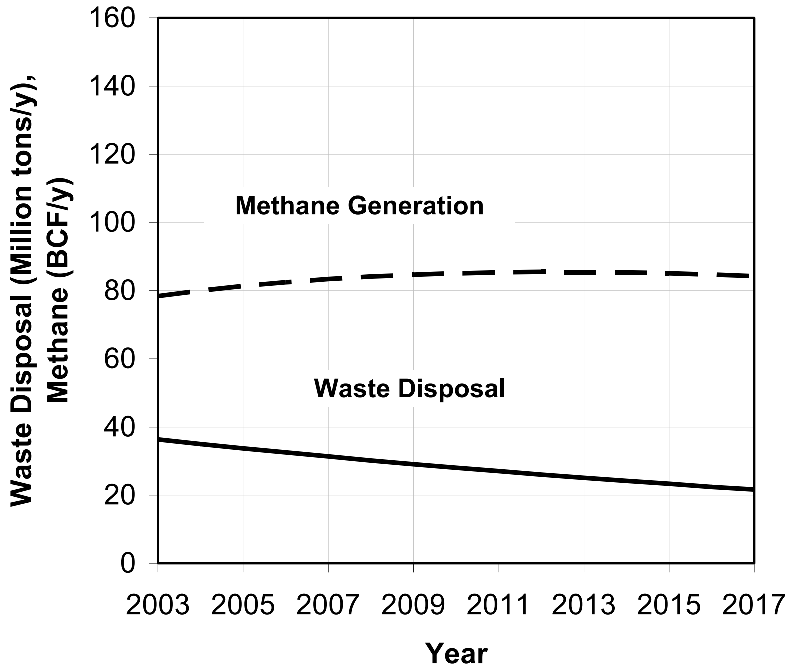

Figure 10. Projected waste disposal and methane generation from landfills, 2003-2017, assuming five percent per year reduction in per-capita waste disposal rates. Waste disposal is shown in as-received (wet) tons per year.

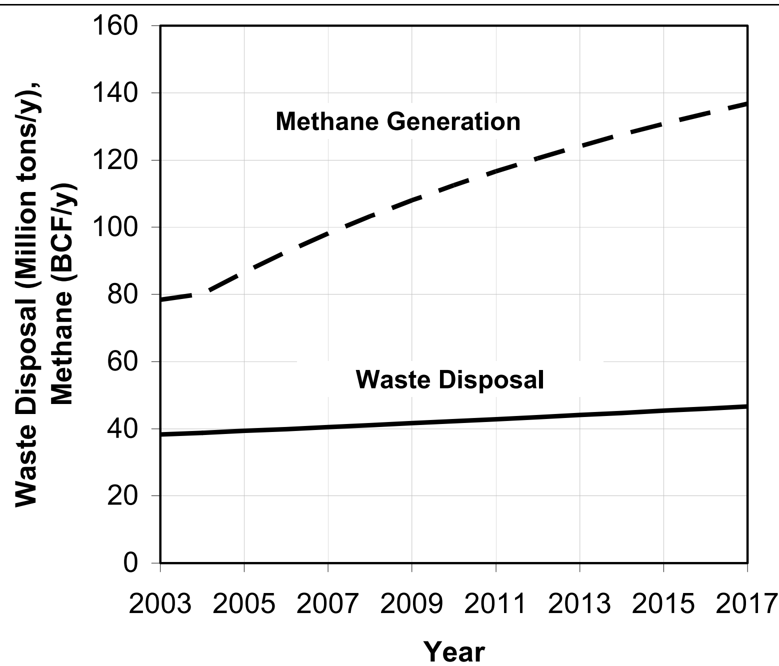

Figure 11. Projected waste disposal and methane generation from bioreactor landfills beginning in 2004 assuming no change in per-capita waste disposal rates. Waste disposal is shown in as-received (wet) tons per year.[67]

[67] California Biomass Collaborative, February 2004, op cit.

4. Biomass Conversion and Utilization Pathways

The multiple pathways that exist for generating energy and products from biomass resources offer significant opportunities for new economic development (Figure 12). Three principal routes exist for converting biomass: 1) thermochemical, 2) biochemical, and 3) physicochemical. In practice, combinations of these routes may be used.

Thermochemical conversion: Combustion, thermal gasification, and pyrolysis are classified as thermochemical conversion along with a number of variants involving microwave, plasma arc, supercritical fluid, and other processing techniques generally occurring at elevated temperatures. Products include heat, fuel gases, synthesis gases, ammonia, hydrogen, alcohols, Fischer-Tropsch hydrocarbons, other liquids, and solids. Thermochemical techniques tend to be high rate as compared with biochemical processes and relatively non-selective for individual biomass components in that the chemically complex biomass is substantially degraded into simple compounds. Thermochemical techniques are also being developed for the purposes of producing ethanol from cellulosic biomass such as wood and straw. Byproducts include ash, chars, and liquid effluents for disposal or recovery as commercial products.

Biochemical conversion: Conversion systems using biological processes include fermentation to produce alcohols, fuel gases (such as methane by anaerobic digestion), acids and other chemicals, and aerobic processes used for waste stabilization and composting. Anaerobic and other biological processes are also being explored for the production of hydrogen. Byproducts include organic solids and liquid effluents. Where feedstocks are uncontaminated by heavy metals or other toxic compounds not degraded by the process, byproducts can be recovered as commercial products for uses including animal feeds, fertilizers, and soil amendments. Proper handling and sterilization is required for byproducts from processes employing genetically modified or recombinant organisms.

Physicochemical conversion: Among the physicochemical methods are alkaline and acid processes, esterification, mechanical milling, steam and ammonia freeze explosion and other explosive decompression processes. Pressing and extrusion, many times in combination with a biochemical or thermochemical reaction process, are also included under this class. A major new industry is developing around vegetable and waste oils to manufacture biodiesel as a substitute diesel engine fuel.

Advances in thermochemical processing and biotechnology are allowing greater selectivity for higher value products. Biorefineries are a major research and development focus for extracting high value materials and energy from biomass in integrated processing facilities.

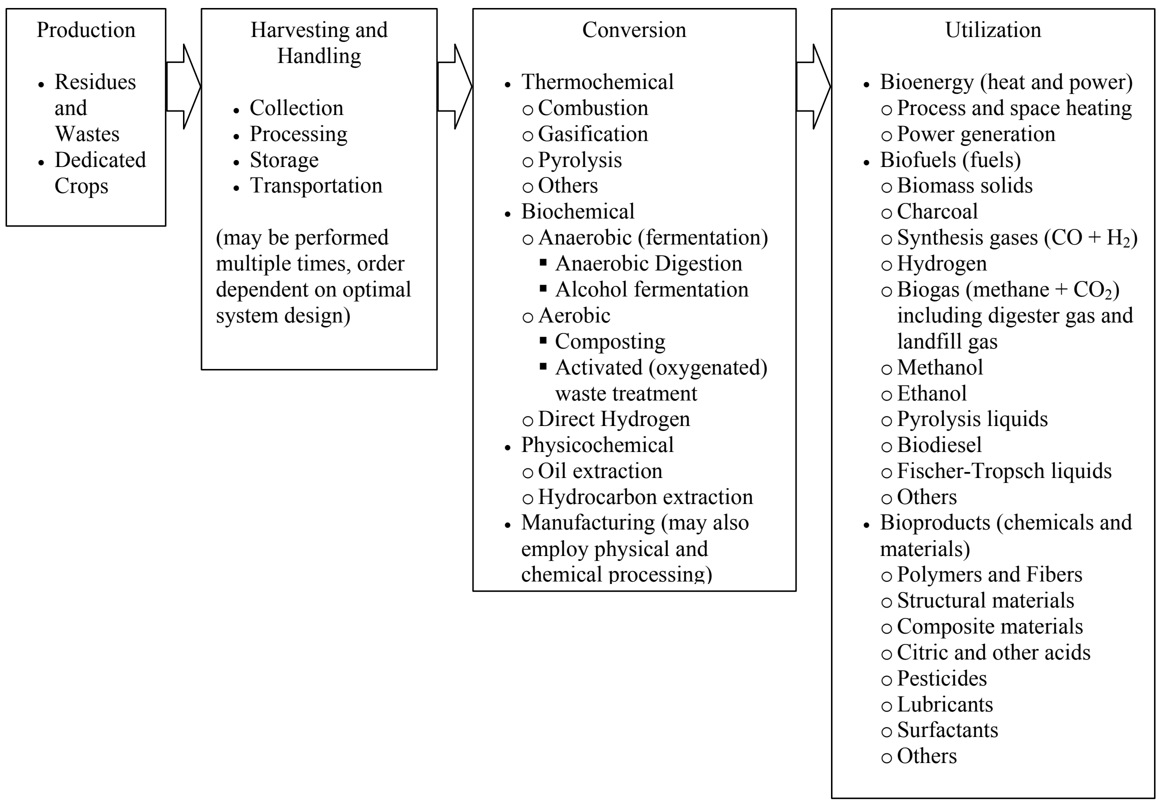

Figure 12. Production, handling, conversion, and utilization pathways for biomass to energy and products.

5. Potential Expansion of Electric Power Generation from Biomass

5.1 Potential generating capacity

The gross biomass resource in the state would be sufficient to generate in excess of 10,700 MW_e of electricity with more than 2,100 MWe from agriculture, 3,600 MW_e from forestry, and 5,000 MW_e from municipal wastes including landfill and sewage digester gas (Table 4).[68] Because not all of the biomass resource can or will be used for power generation, the current technical potential is substantially less, closer to 4,700 MW_e. This capacity could generate about 35,000 GWh of electrical energy, or roughly 12% of the 283,000 GWh of electricity currently used in the state.

Existing and near-term planned biomass grid generating capacity in California in 2005 was 969 MWe including solid-fueled combustion power plants and engines, boilers, and turbines operating on landfill gas, sewage digester gas, and biogas from animal manures (Table 4).[69] Total biomass capacity is about 2% of statewide peak power capacity.

In estimating the generating capacity, low moisture materials such as wood, paper and cardboard in MSW, and some field crop residues are more likely to be converted using thermal technologies, while high moisture materials such as dairy cattle manure, green waste, and food waste may more often be converted through anaerobic digestion or other biochemical systems. Moisture content is not the only factor to consider in selecting conversion technology, but it has a strong influence on whether to employ thermochemical or biochemical techniques. Improvements in both technology classes will lead to greater flexibility in fuel selection in the future. Co-firing with other fuels, such as natural gas and coal, also allows greater flexibility in fuel selection.

Net thermal conversion efficiencies for combustion power plants using biomass are in the range of about 20 to 28%, the higher values being associated mostly with facilities using circulating fluidized bed technologies. Advancements in integrated gasification combined cycle systems should enable efficiencies of 35% and above.

Bioconversion efficiencies depend on feedstock biodegradability and typically range from 13% to 22% when using newer, higher efficiency engines for generating electricity from biogas. Gas scrubbing and catalytic emission control devices added to comply with new air emission standards may cause net efficiencies to decline.

Average efficiency in the future will depend on the mix of small or distributed and larger, centralized facilities. To capture benefits associated with voltage support for the local electricity grid, reduced power transmission, decreased transportation, and better potential for waste heat utilization in combined heat and power (CHP) applications,

[68] California Biomass Collaborative. 2005, updated biomass resource database.
[69] Estimated gross installed capacity at the end of 2004 was 1,087 MWe, with 870 MWe net to the grid, see Aldas and Gildart. 2005. op cit.

smaller, distributed generation systems may be deployed. These systems will likely have lower electrical conversion efficiencies compared to larger centralized facilities, but overall efficiencies when CHP is included will typically be higher than power-only designs.

Incremental capacity additions exclusive of existing and near-term planned generation could exceed 3,600 MW_e based on the current resource (Table 4). With improvements in conversion efficiencies and resource additions through dedicated crops as well as corresponding growth in population and municipal wastes, sufficient resource should exist to achieve an incremental generation of 7,100 MW_e by 2017, the target date of the RPS for 20% renewable electricity (Figure 13). Without improving efficiencies, incremental capacity in 2017 would be closer to 4,800 MW_e. Due to the large amounts of waste already in place, landfill gas will remain an important contributor to power generation through 2017 and beyond even if the state acts to further reduce waste disposal. Electrical energy from biomass could reach 60,000 GWh by 2017 or 18% of projected statewide consumption (334,000 GWh).

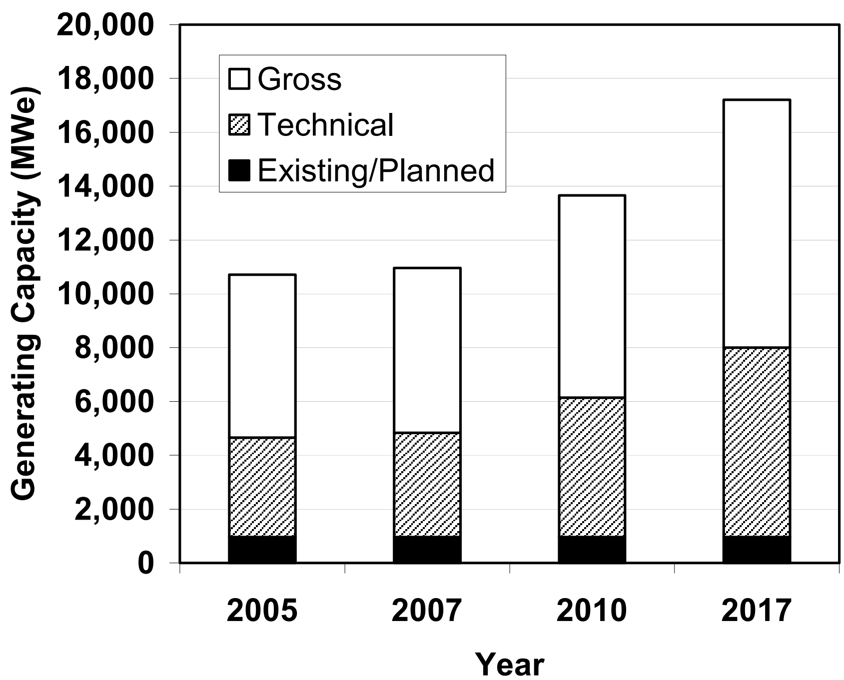

Figure 13. Projected potential electric generating capacity from biomass.

Table 4. Estimated electricity generating potential from biomass in California, 2005 resource base.

	Potential MWe		***Potential GWh***		***Existing/Planned***		***Net Technical***	
					MWe	***GWh***	***MWe***	***GWh***
	Gross	***Technical***	***Gross***	***Technical***				
Total Biomass	***10,711***	***4,654***	***79,757***	***34,650***	***969***	***7,216***	***3,684***	***27,434***
Possible Use by Thermal Conversion	8,536	3,671	63,561	27,337	644	4,796	3,027	22,541
Possible Use by Biochemical Conversion	2,175	982	16,196	7,313	325	2,420	657	4,893
Total Agricultural	***2,144***	***1,021***	***15,964***	***7,605***	***141***	***1,051***	***880***	***6,554***
Total Animal Manure	986	389	7,339	2,893	4	30	385	2,863
Total Cattle Manure	612	224	4,555	1,669	4	30	220	1,639
Milk Cow Manure	285	142	2,119	1,060	4	30	138	1,030
Total Orchard and Vine	346	242	2,573	1,801	93	694	149	1,108
Total Field and Seed	575	281	4,281	2,092			281	2,092
Total Vegetable	112	9	835	70			9	70
Total Food Processing	126	101	936	749	44	328	57	421
Total Forestry	***3,628***	***1,934***	***27,013***	***14,404***	***268***	***1,996***	***1,666***	***12,408***
Mill Residue	839	451	6,244	3,355				
Logging Slash	1,079	575	8,035	4,285				
Forest Thinning	1,088	583	8,103	4,345				
Shrub	622	325	4,631	2,419				
Total Municipal	***4,940***	***1,698***	***36,780***	***12,641***	***560***	***4,170***	***1,138***	***8,472***
Biosolids Landfilled	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Biosolids Diverted	61	49	454	363			49	363
Total MSW Biomass Landfilled	1,926	(1)	14,340	(1)	(1)	(1)	(1)	(1)
Total MSW Biomass Diverted	2,142	1,071	15,952	7,976	239	1,780	832	6,197
Landfill Gas (LFGTE)	694	500	5,171	3,724	258	1,921	242	1,803
Biogas from waste-water treatment plants	116	78	863	578	63	469	15	109

(1) Included in LFGTE. Technical generating capacity potentially higher by diverting from landfill to conversion technologies.
Totals may not add due to rounding.

Currently, biomass accounts for 24% of California net renewable system power, and 20% of gross renewable system power.[70] If in the future, biomass were to maintain a 20% share of net system power, then 660 MW_e of biomass capacity would need to be added by 2017—an average of approximately 50 MWe per year assuming an average capacity factor of 85%.[71] About a third of this could come from landfill gas and waste-water treatment facilities. To maintain a 20% share in each year, assuming other renewable additions remain on schedule, biomass additions would be needed as shown in Figure 14. The annual additions are projected based on retail electricity sales of 167,500 GWh in 2002 and 163,320 GWh in 2003,[72] escalating thereafter at a rate equal to the mean population growth rate of 1.4% per year assuming per-capita electricity consumption remains constant.[73] Capacity projections assume base-load facilities operating at an average 85% capacity factor. Renewable electricity is assumed to comprise 9% of sales in year 2001, increasing 1% per year beginning in 2002 until reaching 20%. Under these assumptions, the RPS goal could be achieved by 2013, prior to the required date in 2017. As additions at the level indicated will not occur through 2005, greater capacity additions will be needed in the latter part of the interval to sustain a 20% share. After meeting the RPS objective, an annual increment of 14-16 MW_e/y would be needed to maintain biomass share if electricity demand continued to increase at the same rate and the RPS remained at a target level of 20%.

If the state accelerates the implementation of the RPS to achieve 33% renewable electricity by 2020, annual capacity additions for biopower would need to increase more rapidly to maintain 20% share (Figure 15), with annual biomass additions ranging from 70 to 95 MWe per year and net cumulative additions through 2020 of 1,450 MW_e. Under these assumptions, total biomass generating capacity would be 2,400 MW_e. Although the actual share of biomass power under the RPS will be dictated by economic and market effects, sufficient resource is at least available to support development at a level equal to the current share. Such development would stimulate more intense competition for fuel and feedstock such as occurred during the growth stages of the biomass power industry in the early 1990s, although changes in waste management policy might open the market to large quantities of separated solid wastes. Given the current level of planned biomass development, additions of the magnitude projected are likely highly optimistic over at least the near term. Regardless of the actual annual additions, development of this kind will only occur when fuel or feedstock supplies can be assured and long term contracting is available for sales of facility output.

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[70] California Energy Commission, 2003 Net system power calculation, Publication 300-04-001R.

[71] A minimum average capacity factor of 69% can be estimated from the reported 2003 gross system power for biomass in California (CEC 300-04-001R) and the installed capacity of 924 MWe (California Biomass Collaborative, 2004). The actual capacity factor is higher due to self-generation not included in the gross system power calculation.

[72] California Energy Commission, 2002 Net system power calculation, Publication 300-03-002, and 2003 Net system power calculation, Publication 300-04-001R.

[73] California Energy Commission, 2003, Publication 100-03-014F.

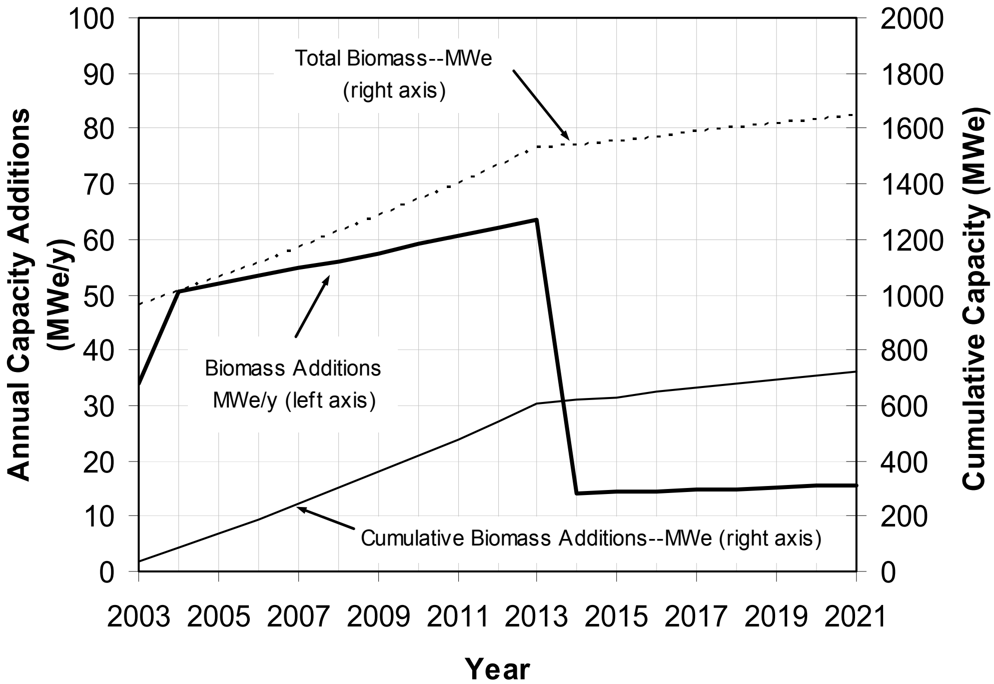

Figure 14. Projected annual biomass capacity additions (MW_e/y) and generating capacity (MW_e) under existing RPS with biomass maintaining a constant 20% share of renewables (based on retail electricity demand).

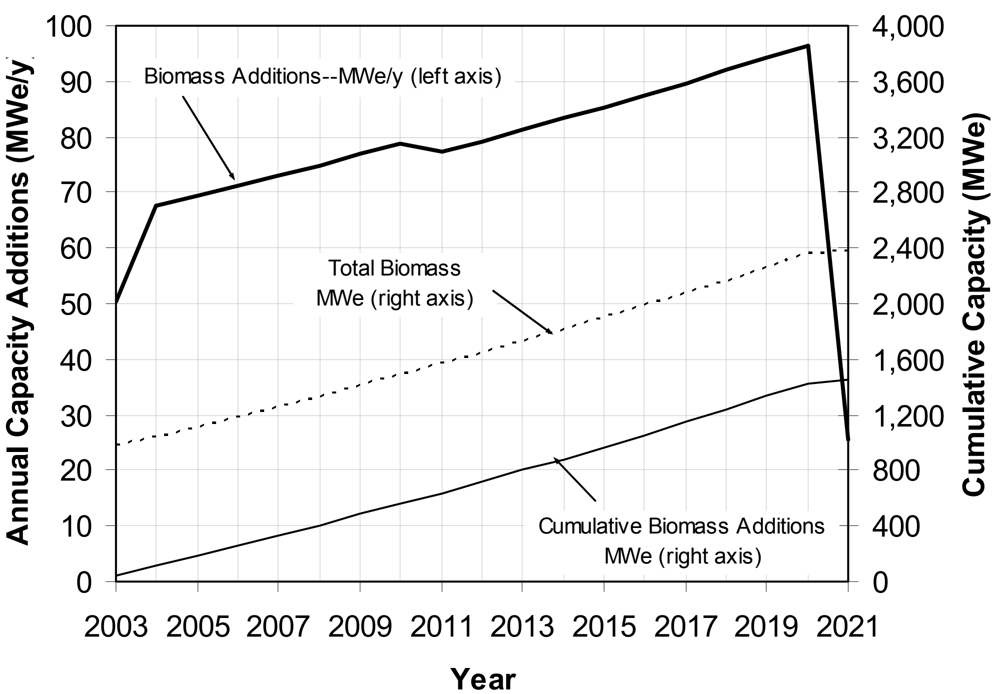

Figure 15. Annual biomass capacity additions (MW_e/y) and generating capacity (MW_e) under an accelerated RPS with biomass maintaining a constant 20% share of renewables (based on retail electricity sales).

5.2 Cost of electricity from biomass

The cost of generating electricity from biomass depends on capital, fuel, and non-fuel operating and maintenance expenses. Levelized cost of electricity (COE) from a new biomass power plant generating only electricity for sale lies in the range of \$0.06 to 0.08/kWh for installed capital costs of \$1500 to 3000/kW$_e$ (Figure 16). This estimate excludes return on equity (profit), and assumes a relatively optimistic base fuel cost of \$20/dry ton. The estimate also assumes 20% net efficiency, 5% interest on debt, 85% capacity factor, no capacity payments, 20 year economic life, straight line depreciation and 2.1% annual escalation in operating and maintenance costs but no escalation in fuel cost. Addition of 15% return on equity at an equity ratio of 25% adds \$0.015/kWh to the COE. The COE exclusive of fuel cost over the same capital cost range varies from about \$0.040 to 0.055/kWh. Sensitivity of COE at this efficiency is approximately \$0.001/kWh for each \$1/BDT change in fuel cost. Average biomass fuel cost for the solid-fuel direct combustion sector has ranged between \$22/BDT and \$40/BDT since 1986,[74] the latter sufficient to increase COE to \$0.10/kWh.

The capacity factor indicates what fraction of rated capacity a power plant achieves on average throughout the year. The value is typically lower than 100% because of scheduled and unscheduled shutdowns that occur for maintenance and repairs. Capacity payments are provided under some contracts by utilities to generators who can guarantee their facilities will operate with high reliability during the year, especially during times of peak electricity demand.

For power-only facilities and when the generator must pay for fuel, the cost of electricity increases rapidly as the conversion efficiency declines below 20% (Figures 16 and 17). If fuel is available at no cost, such as might be the case for certain waste fuels, the efficiency does not impact the COE as long as other operating and maintenance (O&M) costs remain fixed. The amount of fuel required to supply the facility and maintain the same capacity will increase with decreasing efficiency, however, so in general equipment and handling costs will increase.

COE is particularly sensitive to efficiency, capacity factor, capital cost, fuel cost, and rate of return on equity. Sensitivity to these and other factors is illustrated in Figure 17 showing the full COE as each parameter is varied over the indicated relative range, all other values held constant at their reference or base-case values. Complete elimination (-100% change) of capital charges reduces COE to around \$0.03/kWh (2004 constant dollars), while having fuel available at no cost decreases COE to around \$0.045/kWh as noted earlier. Imposing tipping fees (negative fuel costs) further reduces the COE.

For facilities operating in the vicinity of 20% efficiency, decreases in efficiency have more substantial impacts on COE than do increases in efficiency, all other factors constant. The economic incentives for improving efficiency are therefore substantially greater for low efficiency systems compared with those already operating at higher

[74] Morris, 2003, op cit.

efficiency. However, other benefits accrue from operating at higher efficiency, including generally lower environmental emissions per unit output and reduced fuel requirements for a given capacity.

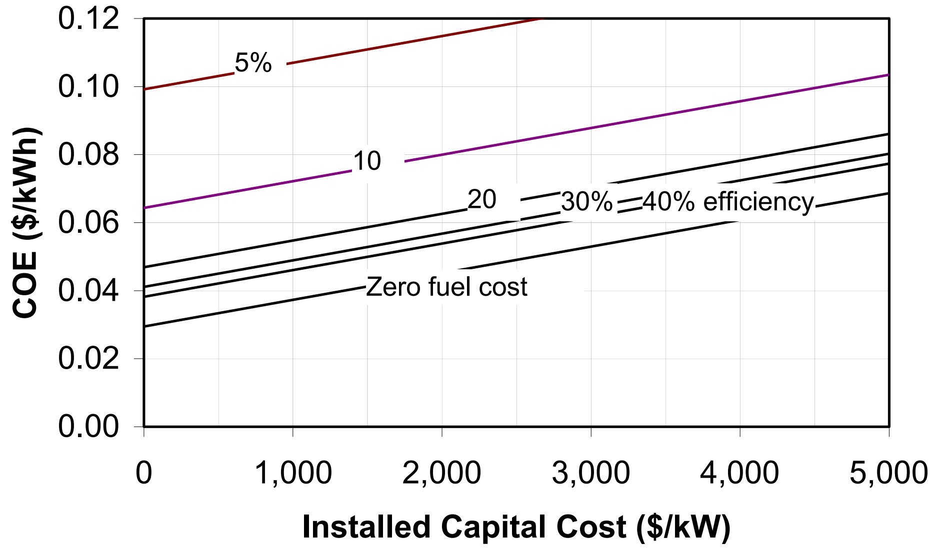

Figure 16. Levelized cost of energy (COE, $/kWh in constant 2004 dollars) for electricity from biomass. Fuel cost = $20/dry ton except as indicated. Assumes no return on equity (no profit) and no capacity payments. With fixed O&M cost, COE for zero fuel cost is independent of efficiency at any capital cost. Addition of 15% rate of return for 25% equity adds $0.015/kWh to the cost of energy.

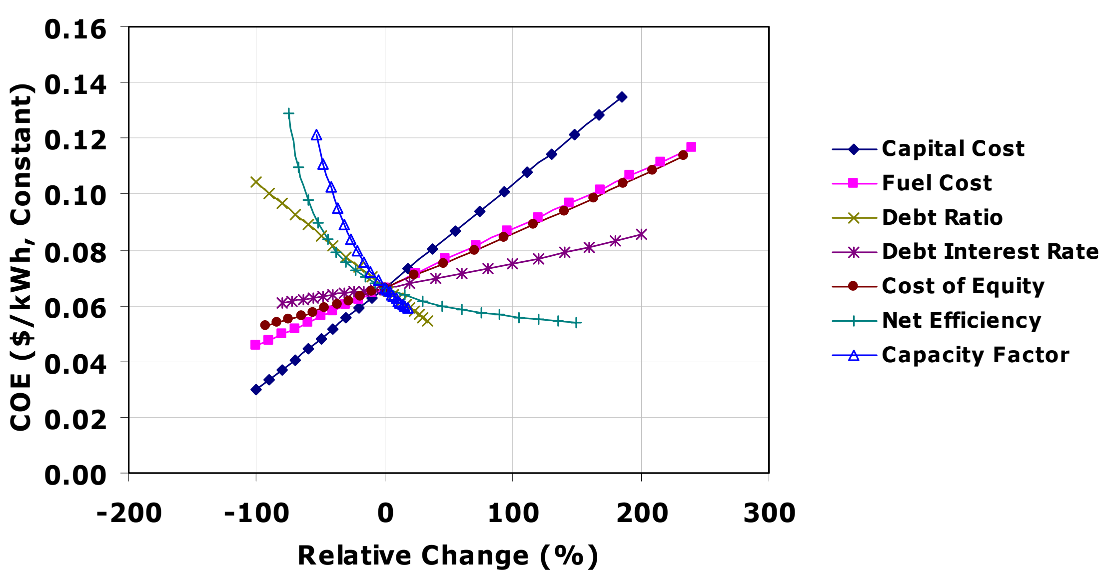

Figure 17. Sensitivity of COE (2004 constant $/kWh) to technical and financial factors for stand-alone power generation from biomass and assumptions as shown:

Capital cost = $2,800/kW$_e$	Net Efficiency = 20%	Capacity factor = 85%
Fuel cost = $20/ton	Debt ratio = 75%	Debt interest = 5%/year
Cost of equity = 15%/year	Capacity payment = $166/kW-y	PTC = $0.009/kWh
Straight line depreciation	General inflation = 2.1%/year	One year debt reserve

In comparison, the fuel cost contribution to COE from natural gas at current prices of $5 - 7/MMBtu[75] is $0.034 - 0.048/kWh for a modern, high efficiency natural gas fired combined cycle power plant (>50% efficiency). When used at efficiencies of 20 to 30%, natural gas at $5/MMBtu contributes $0.057 - 0.085/kWh to the COE. Biomass facilities can retain qualifying status[76] and still use up to 25% natural gas. At this level, natural gas adds $0.014 – 0.021/kWh to the COE when fired. Natural gas is primarily used in biomass facilities for startup and short term flame stabilization and to maintain capacity when burning high moisture fuels.

Biomass power generators in the state are mostly now operating under fixed price contracts for $0.0537/kWh. Some facilities also receive capacity payments amounting to an additional $0.02/kWh. Fixed price contracts begin to expire in 2006. Whether these facilities will continue to operate without renewal of these contracts at the same or higher price remains uncertain. The future of the fuel delivery infrastructure built to supply them is therefore uncertain as well. The market price referent (MPR) on which the contracts are based is currently under discussion by the CPUC, with a recent revision of the 2004 MPR to $0.0605/kWh reflecting a correction to current or nominal dollar basis from an inflation adjusted constant dollar basis.[77]

Anaerobic digestion systems employing principally reciprocating engine generating sets are typically installed with capital costs between $2000 to 6000/kW$_e$. The capacity of these systems tends to be small, ranging between 50 kW$_e$ and several MW$_e$. Feedstock costs are typically low. Incentives for the deployment of digesters for dairy manure management have been provided by the California Dairy Power Production Program and other state and federal programs. In most cases engine waste heat can be used either for digester heating to improve biogas yield or for industrial processes associated with the dairy operation, such as cheese production. Use of engine waste heat avoids expenses for fuels such as propane and natural gas otherwise needed to satisfy heat demand. Although some newly installed dairy digester systems include sulfur removal from the biogas to extend engine life, additional costs beyond those cited above would be incurred for catalytic or other NO_x emission reduction systems sufficient to meet more stringent air quality controls now proposed.

Installed capital costs for landfill gas-to-electricity (LFGTE) systems, including the cost of the gas recovery system, range from under $1000 to more than $6000/kW$_e$.[78] Attributing costs of landfill gas collection to the landfill operation and not to the energy conversion system can be a significant advantage for LFGTE systems.

Waste-to-energy facilities receiving municipal solid wastes charge tipping fees for waste disposal. Where tipping fees can be assessed, COE can decline with conversion

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[75] MMBtu = million British thermal units.

[76] as defined under the Public Utilities Regulatory Policy Act (PURPA) of 1978, see Appendix.

[77] CPUC, Assigned Commissioner's ruling issuing revised 2004 market price referents for the renewables portfolio standard program, 11 February 2005.

[78] Simons, G., Z. Zhang and P. Redding. 2002. Landfill gas-to-energy potential in California. CEC 500-02-041V1. California Energy Commission, Sacramento, CA.

efficiency if emission control and fuel handling costs do not increase as rapidly in compensation (Figure 18). For the same generating capacity, a lower efficiency implies greater fuel consumption, adding to plant revenue when tipping fees are charged. Such practice obviously needs to be discouraged from the perspective of resource use efficiency.

Wind and geothermal resources are currently viewed as being among the lowest cost renewable sources of electricity (Table 5). Anaerobic digestion of animal manure and landfill gas-to-energy (LFGTE) systems are projected to achieve lower COE when there are no costs associated with feedstock or fuel supply. Waste-water treatment facilities also avoid direct fuel costs for biodegradable constituents delivered in the waste water, but can increase biogas production and generating capacity by importing additional biodegradable feedstocks. Associating environmental and waste management benefits with biomass development to help defray fuel costs has significant economic advantages.

The amount by which larger biomass direct combustion systems exceed wind costs is roughly equal to the cost of fuel. Biomass direct combustion power generation exceeds geothermal costs by about half the cost of biomass fuel. More advanced biomass conversion technologies operating at higher efficiency would further reduce the fuel cost share of COE (see Figure 17), but higher capital costs may tend to offset this effect. In general, absent fuel costs, the cost of electrical energy from higher efficiency biomass power-only applications is equivalent to the cost of energy from wind or geothermal systems. Like geothermal, biomass facilities can operate as base-load units without intermittency in generation. Certain types of biomass systems in the future may also be able to schedule generation to operate on peak, reducing off-peak operation if needed to conserve fuel, and expanding the overall capacity available from biomass during periods of high electricity demand. However, base-load capabilities of biomass facilities allow for less reliance on base-loaded natural gas and other fossil fuel facilities that could be dispatched instead to help meet peak demand, thereby reducing the overall use of natural gas.

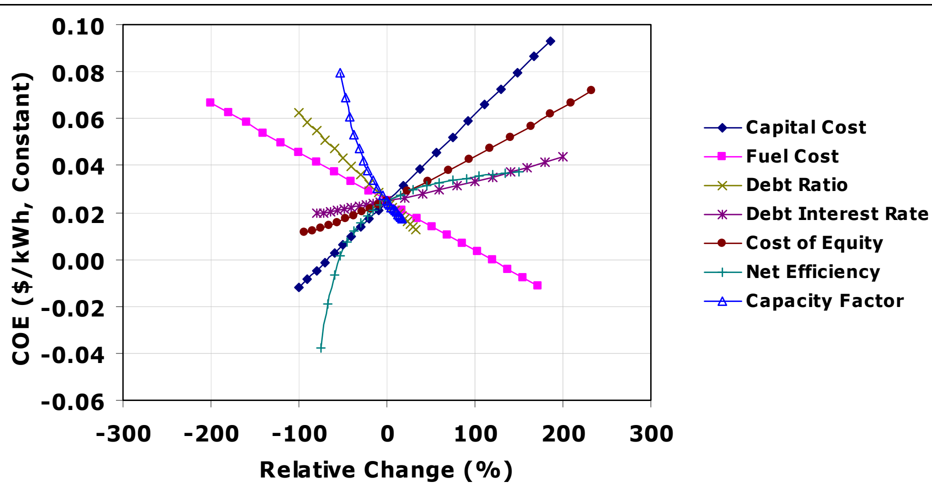

Figure 18. Sensitivity of COE (2004 constant $/kWh) for the same conditions of Figure 17 except for tipping fees charged on waste disposal (reference tipping fee of $20/ton).

Table 5. Estimated costs of renewable electricity.[79]

Resource	Scale (MW_e)	Levelized COE[(1)] (2003 constant $/kWh)
Animal Manure Digestion[(2)]	0.1 (100 kW_e)	0.043
Landfill gas	2	0.044
Wind	75	0.049
Geothermal[(3)]	50	0.054
Biomass Direct Combustion	20	0.066
Solar Thermal	100	0.120
Solar PV	0.003 (3 kW_e)	0.230

[(1)] In 2005. Listed in order of increasing cost, excludes production tax credit and other incentives.
[(2)] farmer or cooperative financed. COE is $0.069/kWh for developer financed.
[(3)] average of geothermal flash ($0.053/kWh) and geothermal binary ($0.055/kWh).

Valuing heat in biomass-fueled combined heat and power (CHP) systems can reduce the cost of electricity below costs for wind and geothermal. Direct combustion power generation from sawmill residues has long benefited from the on-site utilization of cogenerated heat in displacing natural gas, propane, and other fuels otherwise needed for kiln drying lumber. Matching power and heat applications is an important goal for improving economic competitiveness of biomass electricity systems. Distributed and smaller-scale generation systems have some advantage in this regard by having the potential to access a wider variety of heating and cooling applications. Integration of biomass conversion systems, such as in biorefinery concepts, may further improve economic feasibility due to better overall utilization of feedstock energy. Use of electricity at the site of generation (on-site power) also benefits from avoiding purchase of retail of electricity. Net-metering is advantageous in this regard, but is so far not available for all biomass generation classes, and as noted earlier, is currently scheduled to end in 2006 for dairy digester power systems.

Cost of electricity from a CHP system with the same reference conditions as the stand-alone power generation facility of Figure 17 would decline to $0.0120/kWh were heat valued at the equivalent price of $7/MMBtu in substitution for natural gas, exclusive of the added capital costs of heat recovery and distribution (Figure 19). Power plant cogenerated heat does not necessarily serve in direct substitution for premium fuels like natural gas, but heat utilization, even at lower economic value, can result in significantly lower revenue requirements for cogenerated electricity. For the example above, cutting heat value in half to $3.50/MMBtu and increasing overall capital cost by 50% to accommodate heat recovery costs still results in a cost of electricity that is 13% below the stand-alone COE, $0.0577/kWh instead of $0.0665/kWh for the assumptions used. Reliability of the biomass generation system is a key factor in the success of CHP systems to ensure heat is available when needed.

[79] California Energy Commission, 2003, Renewable resources development report, 500-03-080F, Sacramento, CA.

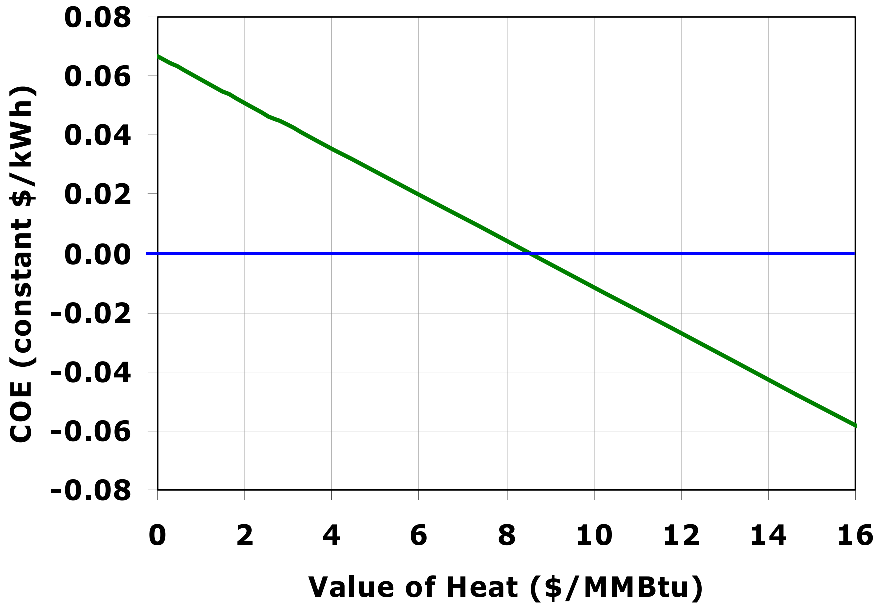

Figure 19. Impact of heat price on the revenue requirements for electricity (COE, 2004 constant dollars) from a combined heat and power facility (same conditions of Figure 17).

6. Potential Development of Fuels and Products from Biomass

Biomass resources will not be used solely for electricity generation. Other developing markets will compete for feedstock or provide opportunities for integrated processing through biorefineries, including animal feed, erosion control, green or renewable chemicals such as solvents and lubricants, polymers and plastics, and fuels. Among the latter category are transportation fuels such as ethanol, biodiesel, biogas or biomethane, Fischer-Tropsch liquids, and hydrogen.

6.1 Ethanol

Cost reductions in the manufacturing of ethanol from cellulosic biomass, either through improvements in enzyme manufacturing and fermentation technology, or through successful implementation of thermochemical conversion techniques could generate a market on the same scale as the power market with the capacity to accept large quantities of biomass. Current California demand for ethanol as a motor vehicle fuel oxygenate is approximately one billion gallons per year.[80] In the near term, in-state ethanol production would more likely come from starch and sugar crops including corn and sweet sorghum. Using corn imported from the Midwest for the production of ethanol with fermentation residues used as animal feeds is also being considered. Sugar and starch crops would at the same time produce cellulosic biomass (e.g. sugar cane bagasse, corn stalks or stover) that could be used for power generation, ethanol production, and other uses. Lignin produced as a residue of cellulosic fermentation could also be used for power generation or for the production of fuels and chemicals through thermochemical processes.

Ethanol accounted for 0.3 Quads[81] or 0.4% of US energy production in 2003.[82] By the end of 2004, ethanol production capacity exceeded 3.4 billion gallons per year, with another 0.7 billion gallons of capacity under construction. Over 90% is produced from corn grain. The current capacity amounts to 2.5 billion gallons of gasoline equivalent. The cost of ethanol production in the US is \$0.40 to 0.50 per gallon of gasoline equivalent more than the cost of gasoline production, exclusive of any incentives or external benefits. Supporting the manufacturing of ethanol are federal subsidies including a federal fuel tax exemption of \$0.51 per gallon ethanol under the American Jobs Creation Act of 2004[83] which replaced the previous tax credit, a small producer income tax credit, and annual incentive payments under the Bioenergy Program managed by USDA. Of some controversy has been the net energy benefit of ethanol production from corn grain, with some concluding that the fossil energy invested exceeds the equivalent energy obtained, in contrast to USDA estimates showing that mid-west corn ethanol production does achieve a net energy gain. If ethanol production increases in

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[80] MacDonald, et al., 2003, op cit.
[81] 1 Quad = 1 quadrillion Btu = 10^{15} Btu.
[82] Schnepf, R. 2005. Agriculture-based renewable energy production. Congressional Research Service Order Code RL32712, Library of Congress, Washington, D.C.
[83] PL 108-357.

California, demand for natural gas used in processing ethanol is also likely to increase. The net energy benefits will need to be carefully considered.

Ethanol from cellulosic biomass such as straw and other agricultural crop residues, the biomass fraction of solid waste, and potentially wood, may achieve substantially better net energy gains and lower cost, with a much larger resource base available compared to sugars and starch. The commercial technology to do so has not yet emerged, with acid and enzymatic hydrolysis processes limiting in their ability to economically produce the simple sugars for fermentation. Significant cost reductions have been achieved in the production of cellulase enzymes, and cellulose-to-ethanol pilot facilities are in operation. The future commercialization of these technologies remains uncertain, however, and developing thermochemical technologies may offer alternative routes.

The federal sugars platform program is aimed at the development of biorefineries employing biochemical technologies. A companion thermochemical platform supports research and development of mostly gasification-based biorefinery approaches to fuels production from synthesis gas. At an average yield of 70 gallons per ton, cellulosic resources could potentially support a production level of 1.5 billion gallons of ethanol in the state. To produce a similar level from corn grain alone would require 3 million acres, or somewhat more than a third of total irrigated agricultural acres in the state, with an input of 12 million acre-feet of water, but with production of another 10 to 15 million tons of residue biomass. Residual sugars, cheese whey, and other sources already support production of approximately 10 million gallons per year of fuel ethanol in the state, and development plans exist for much larger sugar- and starch-crop based facilities.[84]

6.2 Biodiesel

Biodiesel is a renewable diesel fuel substitute that can be produced from vegetable oils and animal fats, including waste oil sources such as yellow grease. Straight vegetable oils are not commonly employed as fuels due to the higher viscosity and injector and engine coking compared with biodiesels produced via transesterification of oils with alcohols using alkaline catalysts. Enzymatic approaches to biodiesel production are also in development. The facile transesterification reactions unfortunately do not lead to substantial control over fuel properties, so tailoring biodiesel to specific diesel engine requirements is difficult. Fischer-Tropsch liquids produced via thermochemical routes offer potentially greater selectivity in this regard. Biodiesel exhibits low toxicity and biodegradability than diesel fuel, and has better lubricity compared with low-sulfur diesel. Combustion emissions are lower for almost all species with the exception of NO_x for which small increases are generally observed compared with petroleum diesel. Higher NO_x emission constitutes a regulatory problem at present for biodiesel in California. US biodiesel production was 30 million gallons in 2004, about 0.05% of diesel fuel used in the nation. California consumption was 4 million gallons in 2002.[85]

[84] MacDonald, et al., 2003, op cit.
[85] California Energy Commission. 2003. Transportation fuels, technologies, and infrastructure assessment report, 100-03-013F.

Biodiesel can be blended with petroleum diesel, and is typically sold as a 20% blend (B20), but other blends are available including B2 blends in which small amounts of biodiesel are added to improve lubricity properties of low-sulfur diesel fuels. Current production costs for biodiesel from oil seeds are around $2.50/gallon or close to $20/MMBtu, with the largest share of the cost due to the cost of feedstock. A federal production excise tax credit for biodiesel in the equivalent amount of $1.00/gallon was enacted under PL 108-357, the American Jobs Creation Act of 2004. Biodiesel production also produces byproducts of oil seed meal and glycerol. Large scale biodiesel production would significantly increase the amounts of these materials in the market and drive down prices. Large scale production would also drive up demand for oil crops, increasing prices due to low elasticity of demand for food-grade oil. Nonetheless, opportunities exist for increasing biodiesel production in the state, including the use of oil crops in helping to manage saline drainage waters and remediate soils in the San Joaquin Valley. Net energy gains for biodiesel are greater than for ethanol, with a net energy ratio (output/input) of around 3.2 compared to 1.3 – 1.6 estimated by USDA for ethanol from corn.

6.3 Biogas and biomethane

Anaerobic digestion, including that occurring in landfills, produces a methane rich biogas that is most commonly used for power generation as discussed previously. Biogas can also be used as a transportation fuel, similar to compressed natural gas. Several European countries are already using it to this purpose. CO_2, the other major gas in biogas besides methane, can be removed to yield an enriched biomethane fuel substituting for natural gas. Sulfur can be removed, improving utilization for both transportation and stationary power generation, where catalysts employed for NO_x control on engines require the use of low sulfur fuel.

6.4 Fischer-Tropsch liquids

The production of synthesis gas or syngas containing CO and H_2 by thermochemical routes offers substantial opportunities for making diesel and gasoline substitutes and hydrogen. The Fischer-Tropsch (FT) process is capable of producing liquid hydrocarbons from syngas generated by biomass, coal, natural gas, or other feedstocks. A system to make FT liquids would include gasification of the biomass, generally using oxygen blown reactors although other configurations are possible. The syngas, after suitable gas cleaning, is reformed and shifted to manipulate composition and then reacted over a catalyst to form higher molecular weight compounds, including substitutes for conventional gasoline and diesel fuels. FT liquids are free of sulfur and therefore allow the use of catalytic control of combustion emissions, especially NO_x. FT systems are subject to significant economies of scale, and hence may be optimized for different technology configurations and sites.[86] Near-term production costs for FT diesel, naptha, and kerosene based on European studies are estimated to be in the range of $14—16/MMBtu, with longer term prospects to reduce the cost to about $9/MMBtu.[87] By comparison, crude oil at $50/bbl costs $8.62/MMBtu, while conventional diesel at $2.00/gallon is equivalent to $13.64/MMBtu although actual production costs are lower. Electricity at $0.05/kWh is $14.65/MMBtu. Power generation can be incorporated into the FT process facility to utilize byproduct gas and other residuals. Overall efficiencies are estimated for biomass to be in the range of 40-45%. FT facilities for biomass are conceptual at this time and subject to considerable research and development. The selectivity of these processes and the ability to utilize a diversity of feedstocks may make them attractive in comparison with other routes.

6.5 Hydrogen and Methanol

Thermochemical conversion can also be used in the production of methanol and hydrogen. Methanol as a fuel has previously been investigated in California. Hydrogen has a number of advantages in comparison with other fuels, particularly for reduced greenhouse gas and on-road emissions reduction. Production costs for hydrogen via gasification of biomass are estimated at $8 - 11/MMBtu, with longer term development possibly reducing these costs to $6 - 7/MMBtu.[88] Overall conversion efficiencies, including integrated power generation, are estimated at 52-61%.

6.6 Biobased products

Biomass can also provide raw materials for a diversity of biobased products. Plastics from biomass are already in production using polylactic acid produced from corn, and numerous other products are in development. A number of attempts have been made to manufacture straw-board panels and similar building materials in the state, with limited success to date although several projects continue in development. Future production levels within the state for biobased products are difficult to project. Federal programs and incentives including biobased product procurement programs are aimed at increasing production levels and providing new markets for agricultural products.

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[86] Hamelinck, C.N., A.P.C. Faaij, H. den Uil and H. Boerrigter. 2004. Production of FT transportation fuels from biomass; technical options, process analysis and optimization, and development potential. Energy 29:1743-1771.
[87] Tijmensen, M.J.A., A.P.C. Faaij, C.N. Hamelinck and M.R.M. van Hardeveld. 2002. Exploration of the possibilities for production of Fischer Tropsch liquids and power via biomass gasification. Biomass and Bioenergy 23:129-152.
[88] Hamelinck, C.N. and A.P.C. Faaij. 2002. Future prospects for production of methanol and hydrogen from biomass. Journal of Power Sources 111:1-22.

7. Costs of Biomass Acquisition and Resource Supply

7.1 Biomass acquisition costs

One of the primary constraints facing the increasing utilization of biomass is the cost of fuel or feedstock acquisition. Technical resource estimates (Table 3) do not specifically incorporate economic factors although in reality they are cost sensitive. Forest biomass on steep terrains excluded from the technical resource estimates might, for example, be harvested at high cost as long as erosion control and other compensating measures deployed at great expense accomplished equal ecosystem or resource management objectives. There would be little economic merit to such activity for the purposes of biomass utilization. Estimates of the statewide economic resource potential can be derived from general cost assumptions, but improved estimates require additional detailed assessments.

The optimal use of biomass implies a system integration that accounts for production, handling, conversion, product marketing, and environmental management over the full life cycle. For this reason, the economic feasibility is feedstock-, product-, and site-dependent. Exclusive of harvesting and downstream processing operations, production costs for agricultural and other biomass residues are typically allocated to the primary crop production system and not separately accounted. In contrast, dedicated crops grown for biomass assume full allocation of production costs, but may contribute other high value benefits, such as soil remediation, that can be used to offset high costs of production. Production costs for dedicated crops are quite variable and depend on species, production site, level of management, and resulting yield.

Biomass already collected at a potential site of use, such as certain food processing wastes, sawmill residues, and municipal wastes at transfer and material recovery facilities may be available at little or no additional cost. Facilities using these feedstocks do not incur additional collection and transportation costs, although there are typically still expenses for handling, processing, and storage. Tipping fees are charged at most landfills and waste-to-energy facilities and are an important source of revenue. Continuing development of waste conversion processes could lead to greater resource competition and changes in tipping fees. Longer term supply contracting is an advantage for most facilities in securing financing and ensuring reliable operation.

Collection costs for agricultural crop residues depend on the type of crop, yields, harvesting equipment, labor, in-field drying and other processing, harvesting losses, and nutrient export, the latter representing the nutrients taken off the field in the biomass that otherwise would have been retained and reincorporated into the soil. If not returned in the form of ash, sludge, or compost, nutrients will need to be replaced for the cropping system to be sustainable. Animal manure collection and handling costs are low for dairies where anaerobic digesters are integrated into on-farm waste management operations, but high for pastured animals. In the latter case, manure collection is generally considered infeasible.

Transportation costs may limit the size of facilities using more distributed biomass resources such as crop residues, dedicated crops, forest thinnings, and logging slash. The combination of increasing feedstock delivery costs offset by generally declining capital, operating, and product-marketing costs as the facility size increases can lead to an optimum facility size. Where collection and other feedstock acquisition costs are low or offset by tipping fees, such as in the case of urban wood fuels separated from municipal waste, longer transport distances are economically feasible. Due to the low density of some forms of biomass, especially straw bales, truck payload is frequently limited by volume and trucks do not carry the full weight allowed. In order to increase payload, the biomass can be densified, such as by making pellets. The cost of densification must be offset by reduced transportation costs, and is generally justified only for long hauls. However, densification may have other advantages in material handling and conversion, so transportation may not be the only determining factor. Densification is not used currently in the fuel supply infrastructure for existing biomass power plants. Bulk densities of wood chips are sufficiently high that trucks mostly operate near their weight limits.

Most facilities using biomass require storage due to the seasonal feedstock production characteristics and to enhance reliability in the case of feedstock supply disruptions. Grains are commonly harvested during the summer and fall, whereas orchards are pruned in the winter and spring. Harvest windows may be quite short. Rice straw, for example, can typically be collected dry only during a six- to eight-week period during the fall. Equipment access to the field following the first rains is often restricted and reentry is generally possible only in the spring after the fields have dried. The process of over-wintering rice straw in the field is actually beneficial in leaching potassium and chlorine to improve combustion properties and recycle nutrient to the field,[89] but unpredictable weather patterns lead to uncertainties in planning and risks for field preparation and planting in the spring.[90]

Orchard removals that supply a large fraction of current agricultural fuel used by the state's biomass power sector occur throughout the year. The composition of MSW, including the fraction of green waste, fluctuates according to season, and much of food processing waste is highly seasonally dependent. Equipment access to forest lands can be limited by weather conditions both during winter and under extreme fire conditions during the summer. Wood and woody materials are mostly stored uncovered in piles or windrows. Herbaceous materials such as baled straw generally require covered storage over winter to reduce losses. Storage under permanent cover, such as in metal barns,

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[89] Jenkins, B.M., R.R. Bakker and J.B. Wei. 1996. On the properties of washed straw, Biomass and Bioenergy 10(4):177-200.

[90] Bakker, R.R. and B.M. Jenkins. 2003. Feasibility of collecting naturally leached rice straw for thermal conversion. Biomass and Bioenergy 25:597-614.

tends to be of lower overall cost due to reduced losses compared with tarps and other more temporary shelter,[91] but system selection is scale specific.

7.2 Impact of fuel cost on cost of energy

Feedstock-cost per unit product-output depends on the conversion process efficiency. Fuel contributions to the cost of electricity (COE) for existing solid-fueled biomass power plants purchasing fuel at $20 to 40/dry ton are in the range of $0.02 to 0.05/kWh (Figure 20). The impact of conversion efficiency on COE is a primary driver for research into advanced conversion systems. As noted earlier, at 20% efficiency, each $1/dry ton increment in the cost of fuel increases COE by roughly $0.001/kWh. For comparison, each $10/ton increment in the cost of feedstock to an ethanol production facility adds between $0.07 and 0.14/gallon to the cost of ethanol. Research and development efforts are targeting total production costs below $1.00/gallon, therefore maintaining high conversion efficiency and low feedstock cost are critical.

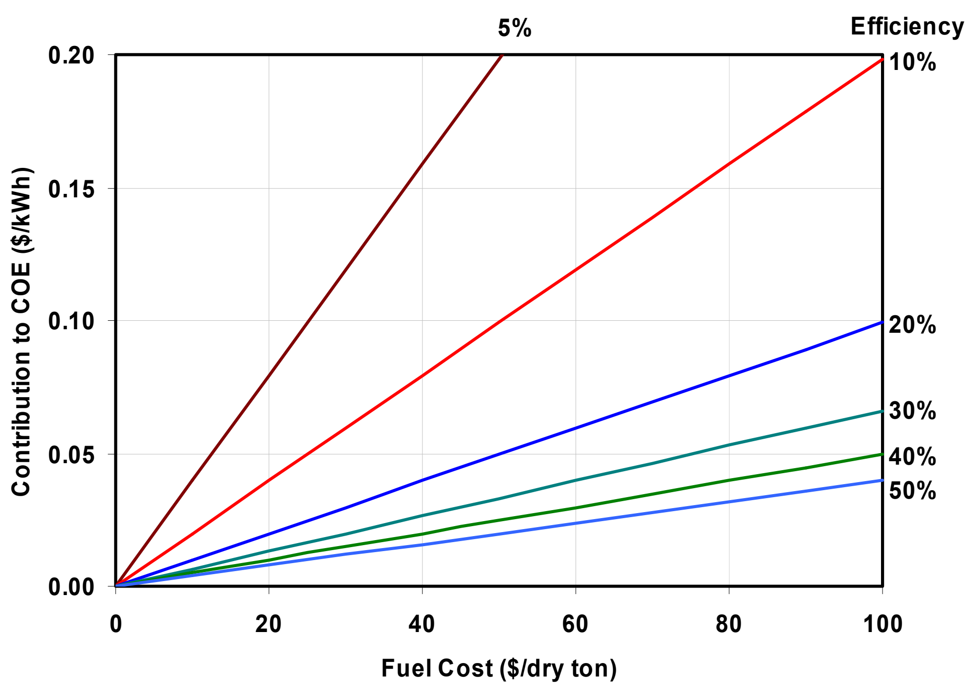

Figure 20. Impact of conversion efficiency on the fuel cost contribution to cost of electricity (COE) from biomass.

[91] Huisman, W., B.M. Jenkins and M.D. Summers. 2002. Cost evaluation of bale storage systems for rice straw. Proceedings Bioenergy 2002, Omnipress International, Madison, WI.

7.3 Cumulative resource supply costs

Overall, an estimated 33 million tons of the current technical resource might be obtained at average costs below about $40/dry ton including short-haul transportation but excluding storage and processing (Figure 21). Beyond this value, costs begin to increase sharply. This does not mean that the existing solid-fueled biomass industry, using approximately 5 million BDT/y, is able to procure fuel at low cost. Each fuel type has an associated collection cost that can be allocated to the utilization activity. For any single facility, fuel cost might range from zero to $40/BDT or higher depending on the resource available. The average fuel costs of $22 to $40/BDT for the solid-fuel direct combustion sector mentioned earlier are based on an assortment of fuels ranging from sawmill residues to forest thinnings. An example for a single facility using forest thinnings was analyzed through a detailed geographic information system (GIS) model for Plumas County showing how cost varies within a specific fuel class as a function of amount delivered (Figure 22).[92]

Total feedstock expense to supply the statewide technical resource estimate of 34 million dry tons would exceed $950 million (Figure 23). Landfill gas and biogas from sewage treatment are not considered in this analysis. The resource supply ranking is based on a least cost sorting across all categories of biomass and is only useful for the purposes of estimating the total statewide potential costs.

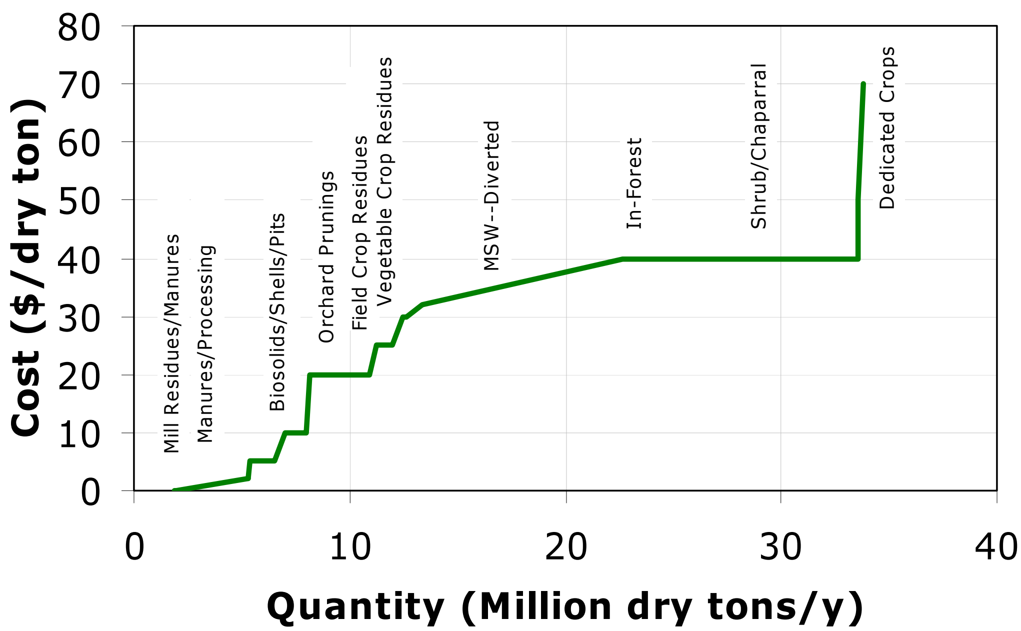

Figure 21. Estimated overall statewide biomass resource cost curve, 2005 technical resource base (excludes storage and on-site processing and handling costs).

[92] Chalmers, S., B. Hartsough, and M. De Lasaux. 2003. Develop a GIS-based tool for estimating supply curves for forest thinnings and residues to biomass facilities in California, Final Report, WRBEP Contract 55044.

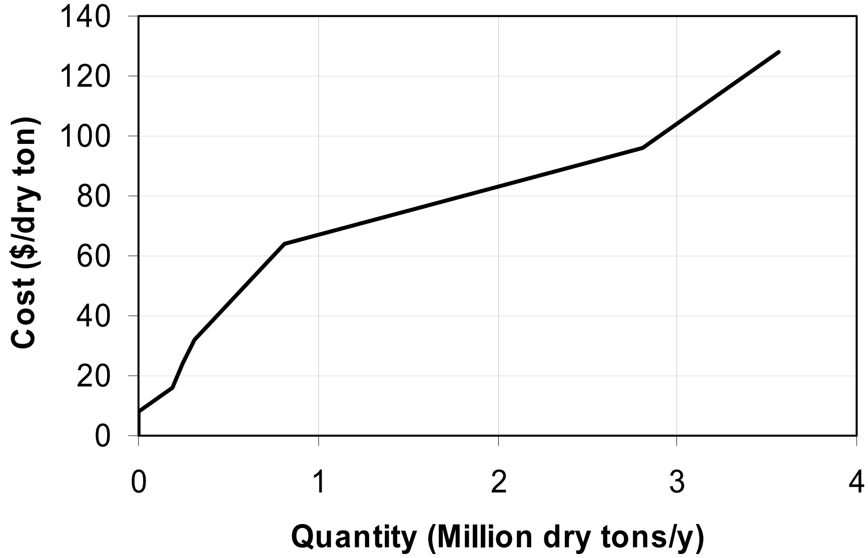

Figure 22. In-forest thinnings biomass resource cost curve for a single site location in California.[93]

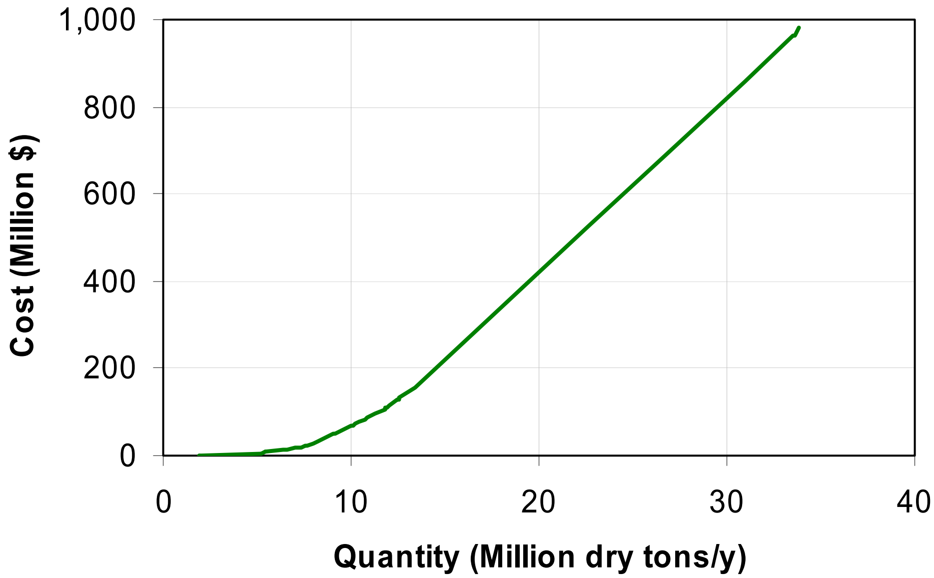

Figure 23. Cumulative estimated least-cost statewide feedstock costs, 2005 technical resource base.[94]

[93] Chalmers, et al., 2003, op cit.
[94] Based on California Biomass Collaborative, 2004, op cit.

8. Management and Development Needs for Biomass Resources in California

Of the 34 million tons per year of biomass presently estimated as technically available for use, only about 5 million tons are currently utilized. Environmental and social impacts of waste disposal, wildfire, and loss of economic opportunities for many communities will continue to worsen if improved strategies for biomass management are not adopted. Each of the major resource categories--agriculture, forestry, and municipal wastes--can contribute substantially more towards meeting the energy and material needs of the state, but ways to ensure sustainable use need to be addressed.

8.1 Agriculture

Many sectors of agriculture are in need of revitalization and can benefit from the opportunities biomass provides in new crops and new products. Production systems and markets are not well developed, however. Few direct incentives exist for development within this important economic sector. Elimination of open burning as a residue disposal practice provides much needed improvements in air quality but increases management costs to farmers. Increasing restrictions on animal waste disposal add costs to dairy and other operations, but also provide motivation for the development of new energy production facilities and improved treatment systems. Costs incurred in meeting new regulations may not be immediately made up through increasing commodity prices in competitive markets. As the state increases its use of renewable resources, agriculture will have an increasing role in producing biomass feedstocks, both as residues of conventional crops and from dedicated crops. Agronomic practices and management approaches may need to change depending on markets for biomass. Integrated systems, especially those in which biomass supplies soil and other environmental remediation as well as new commodities for economic development, will likely prove one of the major growth areas in the near term.

8.2 Forestry

Increasing urban development at the wildland interface is leading to greater risks from wildfire due to the larger number of people and structures in fire-prone areas. Wildfire suppression policies of the last century have resulted in densely stocked forests with large numbers of small trees and ladder fuels that can carry fire into the crown story of the forest with catastrophic consequences. Fires are increasingly intense and destructive. Fuel-reduction and stand-thinning operations can reduce risks and damage as well as supply biomass for energy and products but there remains controversy as to how or even whether these operations should be conducted. The federal Healthy Forests Restoration Act of 2003 is specifically intended to reduce the risks of wildfire on Federal lands and to address the development of energy and manufacturing processes using the biomass removed; however, opposition still exists to thinning and other fuel reduction activities due to concerns over logging and impacts to wilderness, old growth, and other forest areas and habitats. There does not appear to be a general consensus between environmental organizations and land management agencies that forests within wildland-urban interface (WUI) areas must be managed to reduce risks of wildfire. Without treatment, forests will be increasingly subject to catastrophic fires. At least in the near term, forest management will occur in an atmosphere of competing public needs and objectives primarily outside of WUI areas.

Markets must also exist for the biomass produced from forest management operations. The costs of biomass harvesting and removal should be reasonably allocated on the basis of the benefits obtained and to those who benefit from these activities. The issue of cost allocation, at least for public forests, will be a continuing issue for public policy, and may also be so for private lands. In addition to question of cost, reliable, long term supplies must be available to attract financing for new facilities that would use biomass.

8.3 Municipal Wastes

State policy is aimed at reducing disposal of waste in landfills but no clear consensus exists as to how to achieve this objective. Nor do state policies specifically limit total waste disposal, instead they only define the fraction of waste to be diverted from landfill. As waste generation increases, total disposal will increase as well unless higher diversion levels are required. Per-capita disposal in the state has remained relatively constant since 1995 while per-capita generation has increased.[95] The primary commercial alternative of using municipal solid waste as fuel in combustion power plants to generate electricity is now publicly and politically unacceptable due to perceptions regarding hazardous air emissions, particularly dioxin, and concerns over availability of material for recycling markets. Although combustion technology has improved and is widely deployed elsewhere outside the state, significant policy changes would be needed before this approach could see further development in the state beyond the three facilities now operating.

Non-combustion conversion technologies are receiving increasing attention worldwide. Gasification and related thermal technologies are being implemented for waste conversion, especially in Japan, but in Europe as well. The use of anaerobic digestion for processing solid waste is also increasing in Europe. The mixed waste stream is not entirely biodegradable, and pre-sorting of waste to separate biomass components for digestion is advantageous. There are also questions as to what portion of waste should be considered renewable with respect to RPS eligibility. Extended producer-responsibility programs and limitations on the total organic-carbon content and energy content of waste going to landfill have been implemented in the European Union. Adoption of policies such as these in California could significantly influence the amount of biomass disposed as well as the amount available for other uses.

Increasing use of landfill gas, improvements in landfill and waste handling technology, and greater separation of the waste stream could transform landfill practice into a

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[95] Williams and Jenkins, 2004, op cit.

competing commercial alternative for waste management in which the landfill is viewed as a biochemical reactor. Large scale experiments on landfill bioreactors are in progress with promising results but the technique is not fully developed and uncertainties remain regarding air and groundwater impacts and overall technical and economic feasibility.[96]

As noted earlier, existing regulations established under AB 939 (1989) for waste diversion from landfill do not allow full diversion credit for waste transformation and conversion technologies. For facilities attempting to locate within jurisdictions needing to increase diversion, the lack of diversion credit can prove a significant limitation in terms of long-term supply reliability and local economic incentives. Transformation is presently defined as incineration, pyrolysis, distillation, or biological conversion other than composting.[97] Composting and biomass conversion are not included. Pending regulations for non-combustion conversion technologies will move anaerobic digestion of MSW out of the transformation category, allowing it to receive diversion credit. Pending legislation is also attempting to remove other non-combustion conversion technologies from the transformation category to allow diversion credit.[98] The same legislation would repeal the existing and highly restrictive definition of gasification included under AB 2770 (2002) that no practical facility is likely to satisfy. California Public Resources Code Section 40106 defines biomass conversion to be the controlled combustion for electricity and heat of agricultural crop residues, certain types of green wastes, wood, and nonrecyclable pulp and paper when these materials are separated from other solid waste. This definition also does not encompass the broad range of biomass conversion technologies that exist. Regulating specific technologies rather than relying on performance-based standards may limit innovation and become more difficult as the complexity of conversion systems increases for the purposes of extracting higher value products. Limiting technologies by class, such as is done for combustion in the case of transformation, rather than applying environmental and life-cycle performance standards, may fail to achieve maximum benefits as technologies improve.

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[96] http://www.yolocounty.org/recycle/bioreactor.htm
[97] PRC 40106, http://www.leginfo.ca.gov/
[98] AB 1090 (Matthews), 2005.

9. Barriers to the Increased Use of Biomass in California

The greatest barriers to biomass development are cost, policy, and public perception and acceptance; however, these barriers do not apply equally to each of the principal resource categories. All three are interrelated, and within each are technical, economic, environmental, and institutional constraints, all affecting infrastructure for energy and products. The number and complexity of issues surrounding sustainable biomass management and use partly explain why, despite the many benefits of biomass industries in the state, no integrated state policy has so far been articulated or put in place to catalyze their development.[99] Barriers include:

- Cost Barriers
    - Cost of fuel or feedstock and security and reliability of supply
    - Cost of conversion
    - Competition with vested utility, fuel, and waste management infrastructures
    - Difficulty in obtaining long term contracts and power purchase agreements to secure financing
    - Lack of predictable state and federal management programs
    - Lack of stable long term economic and financial incentives and compensation for public benefits provided
- Policy
    - Siting and permitting
    - Uncertainties in environmental performance for new technologies
    - Lack of coordination among jurisdictional agencies
    - Utility interconnection for electric power generators
- Public perception
    - Lack of public awareness and advocacy
    - Limited training opportunities for skilled personnel needed for larger scale development

9.1 Cost

The sometimes high cost of biomass feedstock is viewed as a primary constraint to further biomass development in the state or even retention of the existing biomass industry. As demand increases, fuel costs for some types of biomass, particularly those from forestry and agriculture, will increase. Although fuel supply infrastructure has been developed in the state to support the existing industry, as new fuel or feedstock types are added and use increases additional infrastructure will be required, including new harvesting, handling, and processing techniques and equipment. Security of supply may

[99] California Biomass Collaborative Policy Committee Report, 2004.

also be an issue, as for the case of forest fuels in which wildfires may eliminate planned feedstock resource.

Once investments have been made, costs of power and fuels are not static, and increase over time with inflation of labor, feedstock, maintenance, and administrative expenses. Contract prices and supplemental energy payments used to support the existing biomass power industry in the state are not currently escalated to account for inflation. Efficiency improvements can be made to some extent to offset the effect, but for facilities already operating at efficiencies above about 25%, the rate at which cost of electricity declines is reduced relative to facilities operating at lower efficiencies (Figure 17). Shifts in technology to further increase efficiency will require concerted demonstration efforts and capital investment. Uncertainties in advanced technology performance and in long term policies and incentives make it difficult for the industry to identify financing for continued development of this sort.

Feedstock cost is not necessarily a primary issue with the use of municipal solid waste biomass. Tipping fees charged for waste disposal can offset the costs of fuel acquisition, reducing the overall cost of power generation or other utilization. Instead, public perceptions and state policy serve to limit the use of waste for power generation in combustion power plants, the major existing alternative to landfilling. Public perception will continue to be an important factor in acceptance of other technologies as well.

Power contracts created following the enactment of the federal Public Utilities Regulatory Policy Act (PURPA) of 1978 and the establishment of Standard Offer 4 for power generation in California created the necessary economic conditions to stimulate the growth of the biomass power industry in the state. Long term contracts are critical to obtaining financing for new facility development or retrofitting and repowering existing facilities. For renewable power generation, long term power purchase agreements (PPA) are available through the RPS for those winning bids in competitive solicitations. Projects that are not successful in the RPS process, but for which other benefits provide incentives for development, will also need long term contracts to secure financing. For power projects, the primary mechanism to obtain a PPA would be to qualify under PURPA and contract with a utility at the short run avoided cost (SRAC). The price paid for electricity is likely to be substantially below the price paid under the RPS, and differences in federal production tax credits further reduce incentives for biomass in comparison with other renewables. Contracts with municipal utilities would not allow supplemental energy payments from the Public Goods Charge fund. The lack of direct access in the state also limits the ability to recover generation costs. If biomass power projects are not competitive under RPS solicitations, securing long term contracts and financing may be difficult even if there are significant other benefits. This suggests both the need for policy addressing other public benefits provided by biomass projects, as well as possible alternative configurations and approaches by the industry that might lead to more competitive status within the RPS, such as CHP systems where feasible and strategically located facilities providing power and transmission benefits, especially if net metering is made more widely available.

Net metering is another economic incentive in renewable energy development. For biomass, net metering has been available only for biogas power systems and has not yet been applied equitably across all biomass generation technologies.[100] Legislation was enacted to establish the biogas pilot program because net metering was felt to facilitate implementation of energy efficiency programs to reduce energy consumption, reduce costs associated with energy demand, and reduce peak electricity demand. Loss of net metering would constitute a barrier to continued development of biogas systems. Extension of net metering to other biomass technology options would offer an economic incentive for other small and distributed systems. The application and compensation aspects of biomass net metering need further consideration in terms of equity among both the various biomass technologies as well as renewable energy systems in general, and in terms of the costs and benefits to customers and the public in general.

Biobased power, fuels, chemicals, and products in general must compete with mature industries that enjoy established fuel and feedstock supplies, technologies, markets, capital, and political influence at both the state and national levels. New technologies often have not been sufficiently developed or demonstrated and uncertainties exist regarding technical and environmental performance. Planning over the near term is hampered by a lack of credible data and uncertainties as to when new technologies will emerge, if at all. Technologies and products that have not been anticipated or fully evaluated by the current regulatory structure cannot always bear alone the cost of additional demonstration or testing. Developing adequate information can lead to delays in permitting and project implementation needed to verify technology performance.

Few programs exist for training the necessary skilled personnel to work in an expanding biobased industry. With potential jobs numbering in the tens of thousands for a fully expanded industry, education and training will become increasingly important. Universities and other schools do not generally have the financial resources or facilities needed to develop new programs to meet this need.

9.2 Policy

Fuel costs place biomass power generators at a disadvantage relative to wind and geothermal resources that do not use or pay for fuel. Production costs of biofuels are also higher than production costs for fossil fuels. Biopower is at some disadvantage relative

[100] Net metering for eligible biogas digester electrical generation facilities was established as a pilot program under AB 2228 (2002). The program was limited to individual system capacities of 1 MWe or less, and the total capacity was capped at 5 MWe per electrical corporation or 15 MWe statewide including the three major utilities. The law sunsets on 1 January 2006. Biogas net metering only nets out generation charges on a time of use basis and not full retail costs that include distribution and transmission charges and other surcharges, so no value is currently ascribed to the local or distributed generation aspect that may reduce overall utility transmission requirements. Additionally, excess energy in the year is retained by the utility without compensating the customer-generator. Recently introduced legislation (AB 728, 2005) would extend biogas net metering indefinitely, increase the generator size limit to 10 MWe, and eliminate the capacity caps. The compensation structure is unaltered, and the bill remains restricted to biogas digester systems.

to combined cycle natural gas power-plants operating at substantially higher efficiency. Although the state is placing heavy emphasis on natural gas for new power generation, it has not yet adopted a policy addressing the sequestration of the resultant CO_2, as needed to meet environmental goals contained in state policy for sustainable development,[101] although greenhouse gas emissions are beginning to be addressed through transportation policy, a climate change registry, and participation in developing REC trading markets. Based on the projected value of tradable carbon credits, adoption of such policies could result in incentives for power of $0.03/kWh or more.[102] Such a policy would still not provide specific incentives for biomass in competition with other, lower cost renewable technologies, as carbon credits would apply equally. Biomass, through photosynthesis, is the only renewable resource, however, that can be used directly to sink additional carbon from the atmosphere, if not permanently at least for long periods of time until renewable alternatives to fossil energy can fully implemented. No state policy currently exists to encourage sequestering of this sort, although it is already accomplished to some degree by landfilling wastes and by fixed-carbon additions to soils from biomass growth, burning, and decay (the potential loss of soil carbon when soils are disturbed is an important consideration in the overall carbon balance for biomass). Biomass conversion can also avoid uncontrolled emissions of methane from decomposition, reducing the global warming potential of the carbon emitted prior to recycling through new biomass growth.[103] The lack of policy to credit the distinct sustainability benefits of biomass or to require sustainable use of natural gas and other fossil resources makes the cost of biomass appear high.

The ability of landfills to adjust tipping fees in competition with other industries may still lead to difficulties in introducing new technologies without more specific policies to limit waste disposal. However, policies concerning landfill will need to be developed with careful attention to technology improvements that are now being investigated including bioreactor landfills and the management of landfills to allow for landfill gas storage and the operation of peaking power plants. These developments may essentially move landfills into the category of conversion technologies. Permitting landfill gas-to-energy and other biogas facilities remains an issue due to air emissions (e.g. NO_x) from generating equipment even though other emissions are in some cases reduced (e.g., uncontrolled methane emissions). Concerns over NOx in most regions of the state may lead to increased use of flares without energy recovery due to the lower emissions compared with internal combustion engines. Continued research, development, and demonstration coupled with public education will be critical to moving forward with improvements in waste management.

Permitting and siting processes are generally considered by technology developers to be complex, arduous, and sometimes unclear. Regulators and proponents have discussed streamlining these processes but no specific action has yet been taken. How or whether these processes can be streamlined while continuing to protect health and environmental

[101] Governor's Environmental Goals and Policy Report, Office of Planning and Research, Sacramento, CA, 2003.
[102] The value of RECs in some regions of the US exceed $0.05/kWh.
[103] Morris, 2000, op cit.

quality is subject to debate. Regulations attempting to define technologies and resources often create narrow or technically inaccurate definitions that inhibit application. Performance-based standards in general may prove more effective in achieving environmental objectives without inhibiting technical innovation.

Where access to the electric grid access is desired, utility interconnection can be difficult or expensive, and a single uniform statewide standard has not yet been implemented, although individual utility standards exist under Rule 21. Interconnection costs can be high owing to standby charges and exit fees. Net metering is an important means of valuing the benefits of biomass and other renewables but is available only to certain types of biomass facilities. Current caps on the capacity allowed for net metering significantly limit expansion.

Lack of more comprehensive policies leads in some cases to unintended consequences. Legislation (SB 705, 2003) eliminating agricultural burning in the San Joaquin Valley, for example, was enacted in complement with legislation providing subsidies for the use of agricultural biomass in power plants (SB 704, 2003). The subsidies were of only short duration and have since expired. The legislation had unintended consequences for permitting new facilities that might be deployed to use the biomass. By eliminating open burning, agricultural burning emissions were no longer surplus and could not be counted as emission offsets required to obtain air permits for new sources. The lack of offsets constitutes a significant barrier to technology development and deployment. The state will need further policy or legislation to overcome the barrier if the original legislative intent was to encourage such technologies. Without allowable emission offsets, permitting of new facilities is not likely to occur.

9.3 Public perception

Resolving policy and regulatory issues will require good coordination among the various agencies involved, as well as increasing public awareness. This is especially true of conversion technologies to utilize solid wastes. Although modern solid-waste power plants are designed to and do meet air quality standards and are deployed elsewhere in the US and around the world, public concerns over incineration have effectively eliminated the technology from consideration in California. These concerns extend in part to other waste conversion processes. Without good demonstration of alternatives, public acceptance is likely to remain low. Other concerns are associated with the potential for conversion technologies to draw resources away from recycling operations, although energy conversion also serves to recycle biomass resources through new biomass production by photosynthesis.

Despite present prices, renewable energy should be considered a high value commodity along with other renewable biobased products from biomass, including recycled products. There are also concerns that the availability of good conversion technologies will discourage the public from reducing waste generation. A similar argument might apply to recycling and other waste utilization. Public education and direct incentives aimed at reducing waste generation and disposal will be critical if total waste reduction is an objective. With both per-capita and total waste generation rates increasing, management alternatives of all types are urgently needed. No single alternative is likely to meet the objectives and needs of the state.

Information on the broad-based benefits of biopower, biofuels, biochemicals, and other biobased products is not widely disseminated in the general public, and as a result biomass industries have not so-far been assigned a central role in California's environmental and economic futures.

10. Capturing Benefits and Overcoming Barriers: Incentives for Development

Incentives, both at the federal and state levels, have been implemented to overcome many of the barriers and to encourage renewable energy development and the increasing use of biobased products and bioenergy.[104] A summary of incentives is provided in the Appendix. Although a number of incentives have been established, few at the state level are targeted specifically at biomass and there is no specific policy identifying the need for increased and improved utilization or to comprehensively address biomass as a resource.

Success of incentive programs is typified by the expansion of the biomass power industry in California following enactment of the federal Public Utility Regulatory and Policy Act (PURPA) of 1978. PURPA opened the electricity market to biomass and other qualifying facilities and created a contracting structure providing longer term stability in prices paid for electrical energy. This incentive attracted about $3 billion in financial investment for biomass power generation in California alone. Following restructuring of the state's electric industry in 1996, benefits captured under PURPA through the standard contracting agreements developed in its wake are no longer available. Project developers and financing entities that invested in alternative technologies under government encouragement through PURPA and then experienced the dismantling effects under deregulation may be less willing to risk new ventures in future.

The Renewable Portfolio Standard (RPS) created by SB 1078 in 2002 gives substantial motivation to further develop the state's biomass resources for renewable power generation, but contains no specific incentives for expanding biomass in competition with other renewable resources. The agricultural biomass-to-energy program established by AB 704 (2003) provided $10/ton payments for qualifying agricultural biomass but is now expired. The pilot net metering program for dairy anaerobic digesters established under AB 2228 (2002), the rice straw tax credit program administered by the California Department of Food and Agriculture, the rice straw utilization grant program established under AB 2514 (2002), and the dairy power production program administered through the California Energy Commission all provided direct incentives for biomass utilization. Biomass projects may be eligible for other programs and incentives, but these do not specifically target in-state biomass development.

Federal programs and incentives more specifically target enhanced utilization of biomass resources. The Biomass R&D Act of 2000 set policy to develop a comprehensive national strategy stimulating the development and use of bioenergy and bioproducts through research, development, and private sector incentives. The federal vision established goals for 2030 to double the biomass share of electricity and heat demanded by utilities and industry, increase transportation biofuels by 65 times, and expand the share of bioproducts by 5 times over current levels. Intermediate goals were also set for 2010 and 2020. Title IX of the 2002 Farm Bill established federal procurement and grants programs for biobased products. The biomass development levels included in the

[104] Further information on many of these incentives is available from the Database of State Incentives for Renewable Energy (DSIRE), http://www.dsire.org.

federal goals would be equivalent to an increase from the current 5 million tons to 23 million tons per year by 2030 in California, not including conversion of waste in landfills and in waste water. This quantity is about two-thirds of the technical potential estimated to be currently available (34 million tons, Table 3). Although resource appears to be available to do so, there is no inherent rationale for California to match federal targets and sustainable use in the state will need to be based on other influences.

Were the full 34 million tons per year of technical biomass resource potential used to generate electricity, the potential investment would reach nearly $14 billion while creating almost 14,000 primary jobs (Table 6). Fuel cost at an average of $28/BDT would total $952 million per year. Total generation cost for electricity at an average of $0.07/kWh would be $2.4 billion with a retail value roughly double that. CO_2 displaced from natural gas fired generation, assuming 95% net carbon balance for biomass (including fossil fuel used for biomass harvesting and plant operations), would be nearly 13 million tons CO_2 per year. At $33/ton, the carbon credits might eventually be worth more than $400 million per year.

By comparison, were this quantity of biomass used to manufacture ethanol, the total production would exceed 2.3 billion gallons per year, with an investment of $8.5 billion, creation of 3,600 primary jobs, and a CO_2 displacement of 18 million tons per year compared to gasoline, assuming the ethanol to be primarily produced from cellulosic biomass. Near term greenhouse gas reductions have been estimated on a well-to-wheel analysis for ethanol from cellulose to range from 79-118%.[105] Together, these values provide an estimate of the potential impacts for a mix of biomass utilization options. No single alternative will be used for all biomass. Greenhouse gas emission impacts could be more substantial if reductions compared to current management are included as well. These approximations give order of magnitude estimates of the potential impacts. More complete models are needed to assess the impacts in greater detail.

Incentives of different types have been developed to promote renewable energy and the sustainable use of biomass (Table 7). Strategic goals for biomass have been developed at the federal level but not at the state level with the possible exception of the zero waste goal adopted by the California Integrated Waste Management Board. Strategic goals have also been developed for biomass in Europe and elsewhere around the world, especially in countries that have ratified the Kyoto protocol and are attempting to make real and effective cuts in greenhouse gas emissions.

Various categories of incentives provide financial and economic support. Production incentives and support payments, tax credits, tax exemptions, procurement programs, green pricing, grants and loans, renewable energy and emission reduction credits, and infrastructure development rules and standards are all designed to increase competitiveness. Incentive programs are sometimes coupled to mandates, such as was the case of the Agricultural Biomass-to-Energy Program created under SB 704 (2003) and designed to complement the reduction in agricultural open burning mandated under

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[105] Wang, M., C. Saricks and D. Santini. 1999. Effects of fuel ethanol use on fuel-cycle energy and greenhouse gas emissions. ANL/ESD-38, Argonne National Laboratory, Argonne, IL.

the companion bill, SB 705 (2003). Many of the incentives developed to encourage renewable energy do not include specific provisions for biomass in competition with other renewable technologies and so may not stimulate much growth in the biomass industry. As a result, these incentives may fall short in meeting strategic goals that do apply, such as forest improvement and wildfire risk reduction and improved management of municipal solid wastes. A number of incentives targeted at biomass have been proposed but not addressed in state policy or only partially implemented without achieving the same particular benefits suggested.[106]

Table 6. Estimated impacts of power generation from biomass in California, 2005 technical resource potential.*

Category	Impact
Potential Biomass Utilization (Million tons/y)	34
Total Fuel/Feedstock Acquisition Cost ($ millions/y)	952
Investment ($ billion)	13.8
Generating Capacity (MWe)	4,601
Electricity Generation (GWh/y)	34,259
Primary Jobs Created	13,803
Cost of Energy ($ million/y)	2,398
Value of Electricity ($ million/y)	
Wholesale ($0.0537/kWh)	1,840
Capacity ($0.02/kWh)	685
Wholesale+Capacity	2,525
Retail ($0.12/kWh)	4,111
CO_2 Displaced (Million tons CO_2/y)	12.9
Value of CO_2 Displaced ($ million/y)	426

*Estimate is based on $3,000/kWe average installed capital cost, 3 primary jobs per MWe, average fuel cost of $28/BDT, 25% conversion efficiency, average generating cost of $0.07/kWh, 95% CO_2 displacement (fossil fuel used for biomass acquisition and facility operation), and CO_2 credits worth $33/ton CO_2.

Biomass is not addressed uniformly in all state green energy programs across the US, primarily because of air pollutant emissions associated with the conversion of biomass. Similar air pollutant emissions do not occur during the operation of other renewable technologies with the exception of certain emissions from geothermal systems. Emissions from biomass facilities can include criteria as well as hazardous air pollutants similar to other fuel converting activities. Emissions from biomass facilities need careful control and like any renewable energy process should be subject to life cycle assessments detailing environmental and other impacts. Modern biomass facilities are designed and permitted to meet air and water quality standards. Emerging technologies should result in reduced emissions. Overall, biomass conversion results in substantial reductions of pollutants emitted from open burning, prescribed fires, wildfires, and uncontrolled landfills.

[106] Morris, G. 2000. Biomass energy production in California: the case for a biomass policy inititative. NREL/SR-570-28805, National Renewable Energy Laboratory, Golden, CO.

European states and the European Union, largely as a result of commitments to reducing greenhouse gas emissions under the Kyoto protocol and energy tax policies designed to reduce energy consumption and increase energy use efficiency, have implemented a number of incentives affecting biomass. Among these are renewable portfolio standards, renewable fuel standards, production incentives, and tax credits similar to those implemented or proposed in the US and California.[107] Others include feed-in tariffs for renewable electricity in which producers are paid a guaranteed price for power. The German feed-in tariff for biomass, for example, provides approximately \$0.12/kWh for new installations with capacities below 500 kW_e and \$0.10/kWh for capacities over 5 MW_e.[108] Most such tariffs are designed to decrease the support price over time. The German tariff declines 1% annually over its 20 year duration.

Adopting a state greenhouse gas reduction policy would create a higher value market for renewable energy credits (RECs) that would substantially compensate for the present cost differential between biomass and natural gas in electric power generation. This would not alone create incentives for biomass conversion to electricity relative to other renewable resources that also benefit from higher REC values. Market demand for renewables would have to be large enough to accommodate any higher costs associated with biomass. Direct benefits would accrue to biofuels derived from biomass, particularly in the transportation fuels sector. Costs would generally be lower than producing fuels such as hydrogen from other renewable resources. A recent REC purchase by Commonwealth Energy of Tustin, California for renewable electricity generated by the Inland Empire Utilities Agency from dairy manure in Chino, California,[109] sold 12,000 MWh of RECs for \$18,000, the equivalent of only \$0.0015/kWh or \$4/ton CO_2. As noted earlier, RECs in other regions of the US are trading at much higher value. Enhancing the value of renewable energy and other environmental credits is an important policy goal affecting future biomass resource development in the state.

[107] European Commission, 1997, Energy for the future: renewable sources of energy. White paper for a community strategy and action plan, COM(97)599. Also, European Commission, 2001, Green Paper: Towards a European strategy for the security of energy supply, COM(2000) 769final. Also, European Union Directive 2001/77/EC.
[108] German Renewable Energy Sources Act, BGBI I 2000, 205.
[109] Inland Empire Utilities Agency, Chino, California, 2004, http://www.ieua.org/Home/news/Jun16PR.htm.

Table 7. Incentives applied to biomass.[110]

Type of Program	Incentive Programs
Strategic	Biomass R&D Act of 2000 National Bio-based Products and Bioenergy Initiative Federal Healthy Forests Restoration Act Western Governors' Association Global Warming Initiative President's Energy Plan Forest Service Energy Plan California sustainable development goals (Environmental Goals and Policies Report) California Hydrogen Highways Initiative California petroleum dependency reduction goals California Zero Waste goal
Production Incentive and Support Payment	California Renewable Resources Trust Fund Existing Renewable Facilities Program Tier 1: biomass and solar thermal New Renewables Program Emerging Renewables Program Consumer Education Fund California SELFGEN program California Dairy Power Production Program (SB 5X) California Agricultural Biomass to Energy Program (expired)
Tax Credit	Federal Section 45 production tax credits (extended under HR 4520, American Jobs Creation Act, 2004) California Rice Straw Tax Credit Program
Tax Exemption	Federal excise tax exemption for ethanol blended gasoline
Procurement	Federal Green Power Purchasing Goal (EO 13123) Title IX, 2002 Farm Bill procurement programs
Contract	California Standard Offer 4 (suspended 1985) and other standard offers
Green Pricing and Direct Access	Green-e certified energy Customer direct access for electricity supply (suspended in California, not currently available)
Mandates	Federal Public Utilities Regulatory Policy Act (PURPA) Federal Clean Air Act Oxygenated Fuel Requirements California Renewable Portfolio Standard California waste diversion from landfill requirements (AB 939) California vehicle greenhouse gas emission reductions (AB 1493) California ban on MTBE Phased reduction of rice straw open burning in the Sacramento Valley (AB 1378) Elimination of agricultural permit exemptions in the San Joaquin Valley (SB 700) Elimination of agricultural open burning in the San Joaquin Valley (SB 705)
Grants and Loans	California Energy Commission Public Interest Energy Research (PIER) program USDOE/USDA Bio-based products and bioenergy initiative USDA Value Added Producer Grant Program California Rice Straw Utilization Grant Program California Agricultural Biomass Utilization Account
Renewable Energy (RECs) and Emission Reduction Credits (ERCs)	California Climate Action Registry Kyoto Protocol (not ratified by US)
Infrastructure Development	Net metering (AB 58, AB 2228, AB 728) Interconnection standards (CPUC Rule 21)
Proposed	Federal Renewable Fuel Standard (proposed) Federal Renewable Portfolio Standard (proposed)

[110] see Appendix for additional details.

Appendix

Summary of Incentives

Federal incentives and policies

- The federal Public Utilities Regulatory Policy Act (PURPA)[111] of 1978 is a landmark for the development of an independent power generation industry in the US, including the biomass power industry. The Act authorized contracts between utilities and qualifying facilities for the purchase of electric power based on the concept of a utility's avoided cost of generating that power. In California, a total of almost 1,000 MW_e of direct combustion electricity generating capacity was installed with a peak operating capacity in 1990 of 770 MW_e using more than seven million tons of biomass.[112] These capacity additions were due to long-term Interim Standard Offer 4 (SO4) pricing contracts offered to qualifying facilities (QF) that allowed generators to operate at profit. Initially tied to short run avoided costs (SRAC) of power generation determined from the price of natural gas, SO4 prices were escalated at fixed rates for ten years. Declining energy prices after 1986, suspension of SO4 contracting, reversion to SRAC and low prices paid for electricity after the end of the favorable contract periods ("year 11 cliff"), and restructuring of the electric industry under AB 1890 (1996) caused operating capacity to decline. Offsetting this decline has been increasing generating capacity in the state using landfill gas so that overall the total generation from biomass has remained relatively stable. The decline in direct combustion capacity has increased landfill disposal, however, and has reduced the number of facilities able to accept increasing amounts of agricultural and forest biomass available in response to legislation restricting open burning and policies to reduce wildfire severity and risk and improve forest health. The lack of adequate biomass conversion capacity has proved to be a significant problem for managing fuel removed from the wildland-urban interface (WUI) areas of the San Bernardino and other south-state forests in response to drought-induced tree mortality and extreme wildfire. This will continue to be a problem for management of the other forests of the state.
- President Clinton's Executive Order 13134 of 1999 set policy to "develop a comprehensive national strategy, including research, development, and private sector incentives, to stimulate the creation and early adoption of technologies needed to make biobased products and bioenergy cost-competitive in large national and international markets." The order established the Interagency Council on Biobased Products and Bioenergy, the Advisory Committee on

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[111] PL 95-617, USC 16§2601.

[112] Morris, G. 2000. Biomass energy production in California: the case for a biomass policy inititative. NREL/SR-570-28805, National Renewable Energy Laboratory, Golden, CO.

Biobased Products and Bioenergy, the National Biobased Products and Bioenergy Coordination Office (now disestablished), set out duties of the Departments of Agriculture and Energy, and called for an annual strategic plan for the environmentally sound development and use of biobased products and bioenergy. Succeeding legislation, the Biomass Research & Development Act of 2000, Title III – Section 301-310 established the Office of Biomass Programs, the Biomass Research and Development Technical Advisory Committee, and the Biomass Research and Development Initiative to promote bioenergy and bioproduct research, development, demonstration, and deployment (RDD&D).[113] The federal Vision for Bioenergy and Biobased Products in the United States[114] published in 2002 established goals for 2030 to increase the biomass share of electricity and heat by 2 times, transportation fuels by 65 times, and bioproducts by 5 times over current levels. Intermediate goals were also set for 2010 and 2020. The goals amount to a tripling of biobased products and bioenergy by 2010 and a ten-fold increase by 2020.

- Executive Order 13123 (1999) established the federal green power purchasing goal and requires federal agencies to increase the use of renewable energy. The current goal is to obtain 2.5% of electricity from renewable sources by 2005. By 2003 agencies were at close to half the target.
- The Renewable Electricity Production Credit (REPC), also known as the production tax credit (PTC), applies to wind, cogeneration, closed-loop biomass, and poultry waste. The REPC was renewed under PL 108-357, the American Jobs Creation Act of 2004 in October, 2004. Geothermal, solar, wind, and closed-loop biomass are allowed \$0.018/kWh credit after indexing for inflation. Open-loop biomass, municipal solid waste, and small irrigation hydroelectric systems are eligible for half that amount, \$0.009/kWh. Refined coal is allowed a credit of \$4.375/ton. Wind, closed-loop biomass, and refined coal can apply the credit over ten years, all others for five years beginning 22 October 2004. Assets subject to the credit must be placed in service prior to 1 January 2006. The closed-loop biomass credit was intended for projects that produced dedicated biomass crops as feedstock for the energy conversion system. No biomass projects have so far met the closed-loop eligibility requirements.
- The Renewable Energy Production Incentive (REPI) provided incentive payments for electricity sold by new qualifying renewable facilities, including landfill gas, biomass, anaerobic digestion, and fuel cells employing renewable fuels. The REPI expired for new projects in December 2003. QFs were eligible for annual incentive payments of \$0.015/kWh indexed for inflation for the first ten years of the project. MSW combustion projects were ineligible for the program.
- The Farm Security and Rural Investment Act of 2002, Title IX – Energy Sections 9001-9010 (Farm Bill) established a number of programs on energy and biobased products including procurement standards, grant programs, and educational programs for biomass and biofuels. Also reauthorized and expanded funding for the Environmental Quality Incentives Program administered by USDA which

[113] http://www.eere.energy.gov/biomass/
[114] http://www.bioproducts-bioenergy.gov/pdfs/BioVision_03_Web.pdf

promotes agricultural production and environmental quality goals. May provide up to 75% of costs of conservation practices or cost-sharing up to 90%.

- Federal grants programs offer direct financial assistance to developers and producers. USDA in 2004 established a value-added producer grant program[115] for planning activities and working capital associated with marketing agricultural products and farm-based renewable energy. Other grants programs have included the Renewable Energy Systems and Energy Efficiency Improvements Program under the Rural Development Office of USDA.
- The Energy Policy Act of 1992 defines alternative transportation fuels to include ethanol, natural gas, propane, hydrogen, biodiesel, electricity, methanol, and p-series fuels. The latter is a blend of natural gas liquids, ethanol, and methyltetrahydrofuran (MTHF).[116] Ethanol, hydrogen, biodiesel, electricity, methanol, natural gas (biomethane), and MTHF can all be produced from biomass. Expanded goals towards increasing the renewable fraction of transportation fuels will likely lead to additional incentives for biomass.
- Excise tax exemptions of 5.4¢ per gallon of gasoline blended with alcohol fuels were initially established by the Energy Security Act of 1979. The federal fuel tax exemption for ethanol under section 301 of the American Jobs Creation Act (AJCA) of 2004 replaces the previous tax incentive. AJCA allows blenders a federal tax exemption of $0.51/gallon of pure ethanol. Blending level is no longer relevant. Under the AJCA, biodiesel receives a federal excise tax credit of $1.00/gallon of "agri-diesel," made from virgin oils and animal fats, and half that for non-agri-biodiesel (from waste oils).
- Healthy Forests Act of 2003, Title II – Biomass Sections 201-203 amended the Biomass Act of 2002 and provided research grants, funding for biomass technologies, and supports for purchase of biomass.
- The Sustainable Agricultural Research and Education (SARE) Program is administered by the USDA and assists farmers in adopting sustainable agricultural practices. The program administers grants including Producer Grant Projects and Research and Education Projects.[117]

State incentives and policies

- Renewable Portfolio Standard--California Senate Bill 1078[118] established the state's renewable portfolio standard (RPS) that mandates 20% of retail electricity sales to come from renewable resources by the year 2017. The utilities are required to hold competitive solicitations to procure the renewable power from eligible facilities. This is a major incentive for renewable energy development. More recent proposals are to accelerate implementation and increase the target share from renewable resources so as to achieve 20% by 2010 and 33% by

[115] http://www.rurdev.usda.gov/rbs/coops/vadg.htm
[116] 10 CFR 490
[117] www.sare.org
[118] SB 1078: http://www.leginfo.ca.gov/pub/01-02/bill/sen/sb_1051-1100/sb_1078_bill_20020912_chaptered.html

2020.[119] Although the RPS stimulates renewable energy development, it does not guarantee an increasing use of biomass in competition with other renewables such as wind and geothermal. SB 1038[120] (2002) set lower targets and was superseded by SB 1078.

- SB 1038 and SB 1078 both require production incentives or supplemental energy payments (SEP) to cover the above market costs of renewable resources selected by the investor-owned utilities (as retail electricity sellers) in fulfilling obligations under the RPS. The California Public Utilities Commission (CPUC), in consultation with the California Energy Commission (CEC), establishes a market price referent from which the above-market cost is determined. Eligible renewable energy facilities compete through the existing and new renewable facilities programs of the CEC. SEPs are paid to the extent funds are available from the Public Goods Charge established under AB 1890.
- The Renewable Resources Trust Fund is a Public Benefits Fund initially established in the amount of $540 million by AB 1890 in 1996 and extended through 2012 by AB 995 (2000) with an additional $1.35 billion. The trust fund manages four accounts including the Existing Renewable Facilities Program, the New Renewables Program, the Emerging Renewables Program, and the Consumer Education Program, all administered by the California Energy Commission. The Existing Facilities program is divided into two tiers, with biomass and solar thermal in Tier 1 and wind in Tier 2, and offers support through production credits, as does the New Renewables program. The Emerging Renewables program provides rebates for certain renewables to grid-connected utility customers within the PGandE, SCE, and SDG&E service territories. For biomass, the rebate would apply to fuel cells using renewable fuels. The program provides $3.20/W beginning 1 January 2005.
- Under the Public Interest Energy Research (PIER) Program (AB 1890, 1996), the California Energy Commission administers the Energy Innovations Small Grant (EISG) Program which provides up to $75,000 to small businesses, non-profits, individuals and academic institutions to conduct research that establishes the feasibility of new, innovative energy concepts. Research projects must target one of the six PIER program areas, address a California energy problem and provide a potential benefit to California electric ratepayers. Qualifying renewable energy sources include solar radiation, geothermal fluids, biomass, water, and wind. Technology applications include, but are not limited to: photovoltaic systems; solar thermal; wind turbines; hydropower; geothermal energy; and biomass energy. Roughly $2.4 million available annually.[121]
- California's hydrogen initiatives[122] will also encourage development of biomass. Hydrogen can be produced from biomass by both thermochemical and biochemical routes.

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[119] California Energy Action Plan, 2003, http://www.energy.ca.gov/energy_action_plan/

[120] SB 1038: http://www.leginfo.ca.gov/pub/01-02/bill/sen/sb_1001-1050/sb_1038_bill_20020912_chaptered.html

[121] PUC §381-384, PRC §25740, http://www.energy.ca.gov/research/innovations/index.html#275

[122] http://www.hydrogenhighway.ca.gov/

- AB 1493[123] requires the California Air Resources Board to develop and adopt, by January 1, 2005, regulations that achieve the maximum feasible reduction of greenhouse gases emitted by passenger vehicles and light duty trucks in the State. These regulations will apply only to motor vehicles manufactured in the 2009 model year and beyond. The bill also provided exceptions to certain data reporting by the California Climate Action Registry.
- SB 700[124] (2003) eliminates permit exemptions for agricultural equipment and requires air quality and air pollution control districts that are federal nonattainment areas to adopt and implement control measures to reduce emissions from agricultural practices, including confined animal facilities such as dairies and feedlots. The need to meet best available control technology requirements is a stimulus to biomass conversion systems, especially dairy manure digesters.
- SB 705[125] (2003) eliminates agricultural open burning within the San Joaquin Valley Air Pollution Control District after specified dates beginning in 2005. SB 704 was a companion bill intended to provide incentives for the alternative use of agricultural biomass no longer eligible for open burning. SB 705, in eliminating burning, also potentially eliminated emission credits applicable to open burning because the emissions are now no longer surplus. Means to allow emissions to count towards emission offsets are now under consideration.
- SB 704[126] (2003) established the Agricultural Biomass to Energy Program with funds up to $6 million redirected from the Renewable Resources Trust Fund. The program was coincident with restrictions on agricultural open burning imposed under SB 705 to improve air quality in the San Joaquin Valley. The program provided $10 per green ton subsidy for qualified agricultural biomass converted to energy between July 2003 and June 2004. The subsidy applied only to new agricultural biomass at least 10% above the five year average purchase amounts for the facility. SB 704 also repealed the former Agricultural Biomass-to-Energy Incentive Grant Program administered by the Department of Trade and Commerce through 2002.
- SB 38 (1996) established the Rice Straw Tax Credit Program. The program is administered by the California Department of Food and Agriculture and encourages the development of off-field uses of rice straw as alternatives to field burning or in-field disposal. Eligible purchases of rice straw can be made through 2007. The program is in effect until December 1, 2008. The aggregate amount of the tax credits granted to all taxpayers cannot exceed $400,000 per calendar year. Certificates are issued in order of receipt. The credit of fifteen dollars per ton of rice straw is allowed against net tax.[127]
- AB 2514 (2000) established the Rice Straw Utilization Grant Program to facilitate the development of off-field uses of rice straw by providing grants for processing, feeding, generating energy, manufacturing, controlling erosion and other

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[123] AB 1493: http://www.leginfo.ca.gov/pub/01-02/bill/asm/ab_1451-1500/ab_1493_bill_20020722_chaptered.html
[124] SB 700: http://www.leginfo.ca.gov/pub/bill/sen/sb_0651-0700/sb_700_bill_20030922_chaptered.html
[125] SB 705: http://www.leginfo.ca.gov/pub/bill/sen/sb_0701-0750/sb_705_bill_20030922_chaptered.html
[126] SB 704: http://www.leginfo.ca.gov/pub/bill/sen/sb_0701-0750/sb_704_bill_20030922_chaptered.html
[127] http://www.cdfa.ca.gov/exec/aep/aes/rstc_program/

environmentally sound purposes other than open-field burning. The program provides incentive grants at a rate of not less than $20 per ton with no single grant exceeding $300,000. Projects must also demonstrate environmental benefits and the ability to assist in developing a market for rice straw not dependent on government assistance.[128]

- California Health and Safety Code Section 39760 defines the Agricultural Biomass Utilization Account, a $2 million fund for using agricultural biomass as a means of avoiding landfill use, preventing air pollution, and enhancing environmental quality.[129]
- The Governor's Environmental Goals and Policies Report[130] issued in 2003 set a standard of sustainable development for the state. Embodied within state policy are the increasing development of renewable energy and sustainable habitat, reductions in greenhouse gas emissions, increasing attention to environmental justice, and overall improvements in natural resource management. Translating these goals into action will require incentives to biomass management and use.
- Net metering is a significant incentive to small and distributed renewable energy systems. Net metering credits customer-owned generation up to 1 MW capacity at the retail electricity price for solar and wind, and for the generation portion of energy from eligible biogas systems. Assembly Bill 58[131] of 2002 extended the state's net metering program indefinitely for solar and wind resources. The statewide limit is 0.5% of utility peak demand. AB 2228[132] of 2002 established a pilot net metering program for biogas digester electricity generation systems. The program was capped at 5 MW for each of the three large investor owned utilities (PGandE, SCE, and SDG&E) and is scheduled to sunset in January 2006. Legislation has been introduced under AB 728 (2005)[133] to extend net metering for biogas systems indefinitely, to increase the generator size limit to 10 MWe, and to eliminate the utility capacity caps.
- The CPUC self-generation incentive (SELFGEN) program[134] was launched to encourage customer-owned grid-connected renewable and distributed generation (DG) to help meet on-site energy needs. In 2003, the program was extended through 2007 by AB 1685.[135] Incentive payments are $1 to 4.50/W, depending on technology employed. Incentives for biomass are available for fuel cells, microturbines, small gas turbines, and internal combustion engines operating on renewable fuels up to a maximum capacity of 1.5 MW.
- The dairy power production program was established under SB 5X (2001)[136] and provides two support mechanisms: cost buydowns and incentive payments. The buydown option covers 50% of cost up to $2000/kW. The incentive payments

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[128] http://www.cdfa.ca.gov/exec/aep/aes/rs_grant_program/
[129] http://www.leginfo.ca.gov/
[130] Governor's Environmental Goals and Policies Report. 2003. California Governor's Office of Planning and Research, Sacramento, CA.
[131] http://www.leginfo.ca.gov/pub/01-02/bill/asm/ab_0051-0100/ab_58_bill_20020924_chaptered.html
[132] http://www.leginfo.ca.gov/pub/01-02/bill/asm/ab_2201-2250/ab_2228_bill_20020924_chaptered.html
[133] http://www.leginfo.ca.gov/pub/bill/asm/ab_0701-0750/ab_728_bill_20050217_introduced.html
[134] http://ora.ca.gov/distgen/selfgen/sgips/index.htm
[135] http://www.leginfo.ca.gov/pub/bill/asm/ab_1651-1700/ab_1685_bill_20031012_chaptered.html
[136] http://www.leginfo.ca.gov/pub/01-02/bill/sen/sb_0001-0050/sbx1_5_bill_20010412_chaptered.html

pay for energy at $0.057/kWh. The program is intended to reduce environmental impacts of dairies, particularly nitrates in groundwater and greenhouse gas and pollutant air emissions, and to increase peak electricity generation. The program has awarded 14 projects to date and $5.8 million. The program is administered by Western United Resources Development, Inc. for the CEC.

- AB 1002 (2000) required the CPUC to establish a surcharge on all natural gas consumed in the state to fund certain low-income assistance programs, cost-effective energy efficiency and conservation activities, and public interest research and development. Biogas which has been upgraded may be eligible for R&D funding under this program.
- Cooperative efforts with Oregon, Washington, and British Columbia through the Western Governor's Association Global Warming Initiative are aimed at identifying state and regional actions to mitigate climate change impacts.[137] Efforts such as this may lead to more regional incentives that may influence national policies affecting renewable resources including biomass.
- Elimination of MTBE from motor vehicle fuels has created a market for other oxygenates, most importantly ethanol. Current ethanol demand is being met mostly by Midwest corn ethanol and Brazilian ethanol through the Caribbean Basin Initiative, but a stimulus exists for increasing in-state production from sugar, starch, and lignocellulosic biomass. Annual ethanol demand in the state is now approximately one billion gallons.
- The CEC has recommended a goal to increase the use of non-petroleum fuels to 20 percent of on-road fuel consumption by 2020 and 30 percent by 2030.[138] Increasing renewable fuel demand will provide additional incentives for in-state production of fuels from biomass.
- The California Pollution Control Financing Authority provides low-interest loans to small businesses from a minimum of $1,000,000 up to $20 million for waste-to-energy, resource recovery and landfill projects through the Small Business Assistance Fund's tax-exempt bond program.
- SAFE-BIDCO provides low interest loans to small businesses of up to $250,000 for energy efficiency and renewable energy systems through the Energy Efficiency Improvements Loan Fund (Financial Code section 32900 et seq.).

Other influences

- International objectives relating to global climate change were agreed at the Earth Summit in Rio de Janeiro in 1992. This was followed by a protocol completed in Kyoto, Japan, in 1997 committing industrialized nations to specified, legally binding reductions in the emissions of six greenhouse gases. The treaty was opened for signature in March 1998. The treaty would commit the US to reduce greenhouse gases by 7% below 1990 levels between 2008 and 2012. The US has

[137] California Energy Commission. 2004. Staff proposal for scoping the 2005 Integrated Energy Policy Report, Sacramento, California.
[138] Integrated Energy Policy Report. 2003. CEC 100-03-019, California Energy Commission, Sacramento, CA.

not ratified the protocol and is delaying until developing nations also make commitments to participate. Based on the accounting for carbon sinks, actual levels the US would need to achieve are thought to be only 2-3% below 1990 levels. Emissions trading and joint implementation projects in which the actual reductions occur outside the US are viewed as providing a large share of the target, including clean development mechanisms for joint implementation between developed and developing nations.

- Extended Producer Responsibility (EPR) entails product manufacturers taking greater responsibility for the environmental impacts of their products downstream of disposal, and for selection of materials used and the design of their products. A primary function of EPR programs is to transfer costs and responsibilities for waste management and disposal from local governments and taxpayers to the producers. Environmental management costs would then be incorporated into the cost of the product and markets would reflect the true environmental impacts of the product. Adoption of EPR in Germany has had markedly increased the amount of packaging removed from the disposal stream and recovered for recycling or energy.[139]
- Limitations on the organic fraction and energy content of waste disposed in landfills have also been implemented outside the US. Germany has limited biogenic carbon and energy content of waste going to landfills to less than 18% and 2,580 Btu/lb (6 MJ/kg). Such limitations on waste in California might reduce disposal by more than 20 million tons and create incentives for waste reduction or greater biomass and organic waste utilization.
- In 1997, Oregon created specific standards for base load gas plants, non-base load (peaking) power plants and non-generating energy facilities that emit carbon dioxide.[140] The standard for base load gas plants applies only to natural gas-fired plants. The standards for non-base load plants and non-generating facilities apply to all fuels. For base load and non-base load plants the CO_2 emission is limited to 0.675 lbs/kWh, and for non-generating facilities the standard is 0.504 lbs/hp-hr. Facilities can also meet the standards through cogeneration, offset projects, or provide funds to the Climate Trust. To meet the generation standard, facilities would have to have a heat rate better than 5,770 Btu/kWh or an efficiency higher than 59%. At the time the standard was written, the best heat rate for a base load plant was 6,955 Btu/kWh (49% efficiency).

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[139] Williams, R.B. and B.M. Jenkins. 2004. Management and conversion of organic waste and biomass in California. Proceedings 2nd World Conference and Technology Exhibition on Biomass for Energy, Industry, and Climate Protection, 10-14 May 2004, Rome, Italy.

[140] http://www.energy.state.or.us/climate/climhme.htm