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PREFACE

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliability energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission, (Energy Commission), annually awards up to $62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Residential and non-residential buildings end-use energy efficiency
- Industrial, agricultural, and water end-use energy efficiency
- Renewable energy technologies
- Environmentally preferred advanced generation
- Energy-related environmental research
- Strategic energy research

What follows is a task report conducted by the California Biomass Collaborative. The report is entitled, "*A Roadmap for Development of Biomass in California*". The Energy Commission has funded this work pursuant to the PIER Program Contract Number 500-01-016 between the Regents, University of California at Davis and the Energy Commission. This project contributes to the Renewable Energy Program area.

For more information on the PIER Program, please visit the Commission's website http://www.energy.ca.gov/pier/reports.html or contact the Energy Commission's Publication Unit at (916) 654-5200.

ABSTRACT

In April, 2006, Governor Schwarzenegger issued his Executive Order S-06-06 proclaiming the benefits and potentials of bioenergy in helping to meet the future needs of the state for clean, renewable power, fuels, and hydrogen, and calling for actions by the state to meet targets for biofuel and biopower development:

- by 2010, producing 20 percent of its biofuels within California, increasing to 40 percent by 2020 and 75 percent by 2050, and
- by 2010, producing 20 percent of the renewable electricity generated from biomass resources within the State and maintaining this level through 2020.

Subsequently, the state's bioenergy action plan tasked the Energy Commission through the California Biomass Collaborative to prepare a roadmap for biomass research and development.

This document constitutes a preliminary summary of results and recommendations from the Collaborative board and staff and is intended to help focus public input and discussion on actions needed to achieve the targets of the governor's executive order and the broader vision of sustainable biomass resource management and development in the state.

The final roadmap is intended to inform and guide policy makers, law makers, regulators, investors, researchers, and developers involved with biomass and energy issues in California. It will be formalized following public discussions for which this document serves as a basis.

Recommended actions are identified and discussed within each of five priority areas:

- *Resource access and feedstock markets and supply,*
- *Market expansion, access, and technology deployment,*
- *Research, development, and demonstration,*
- *Education, training, and outreach, and*
- *Policy, regulations, and statutes*

Of the actions proposed, major actions are associated with

- *Carbon policy,*
- *Standards and best practices for sustainability,*
- *Financing and contracting,*
- *Permitting, and*
- *Research, development, and demonstration*

KEYWORDS: biomass, bioenergy, bioproducts, biopower, biofuels, sustainable development, roadmap, renewable resources, markets, RD&D, education, outreach, policy, regulation, planning

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EXECUTIVE SUMMARY

Background

In April, 2006, Governor Schwarzenegger issued his Executive Order S-06-06 calling for California to greatly increase its share of biofuels production and the generation of electricity from biomass.

The order stemmed from the following concerns:

- Intensifying public concerns over escalating fuel costs and heavy reliance on petroleum,
- Strong state agency advocacy and commitment for improving resource management and mitigating climate change,
- Legislative actions promoting growth in renewable energy and control of greenhouse gas emissions,
- Pronouncements at the federal level signaling greater support for bioenergy, and
- The promise of new technologies for stimulating economic development, improving environmental performance, and realizing the potential offered by biomass in meeting an increasing share of the state's energy demand.

The governor's executive order proclaimed the benefits and potentials of bioenergy in helping to meet the future needs of the state for clean, renewable power, fuels, and hydrogen, and called for the state to meet the following targets for biofuel and biopower development:

- By 2010, producing 20 percent of its biofuels within California, increasing to 40 percent by 2020 and 75 percent by 2050, and
- By 2010, producing 20 percent of the renewable electricity generated from biomass resources within the State and maintaining this level through 2020.

The order also specified certain actions by the agencies of the state in attempting to achieve the targets, including coordination on the development of research and development plans.

The executive order was followed in July by the release of the state's bioenergy action plan which reaffirmed the targets for biofuels and biopower, and set out actions for the state agencies in meeting the targets. Among the actions tasked to the Energy Commission through the California Biomass Collaborative was the preparation of a roadmap to guide future research, development, and demonstration activities. The Energy Commission was also to work with the Hydrogen Highway team to ensure the roadmap evaluated the potential for biofuels to provide clean, renewable sources of hydrogen. The roadmap effort was incorporated into a larger Collaborative strategic planning effort for biomass development.

Vision

Sustainable biomass resources energize a healthy and prosperous California through the environmentally beneficial production and use of renewable energy, biofuels, and bioproducts.

The draft roadmap has been prepared primarily by the executive board and staff of the California Biomass Collaborative and builds on efforts at both the national and state levels to increase the use of biomass for energy and products.[1,2,3,4] It is intended to inform and guide policy makers, law makers, regulators, investors, researchers, and developers involved with biomass and energy issues in California, but should be of interest to anyone concerned about environmental impacts, sustainable resource management, our current use of fossil fuels, and our future energy strategies.

Energy Potentials

By 2020, the state could triple its biomass-to-electricity generating capacity and increase its production of biofuels a hundred-fold, both from resources now considered feasible to use as feedstock and through at least a modest increase in dedicated biomass crops.

By 2050, as the state shifts to greater use of hydrogen in transportation and other energy sectors, biomass could be supplying a large amount of renewable hydrogen. Greater use of combined heat and power systems fueled by biomass could reduce demand for

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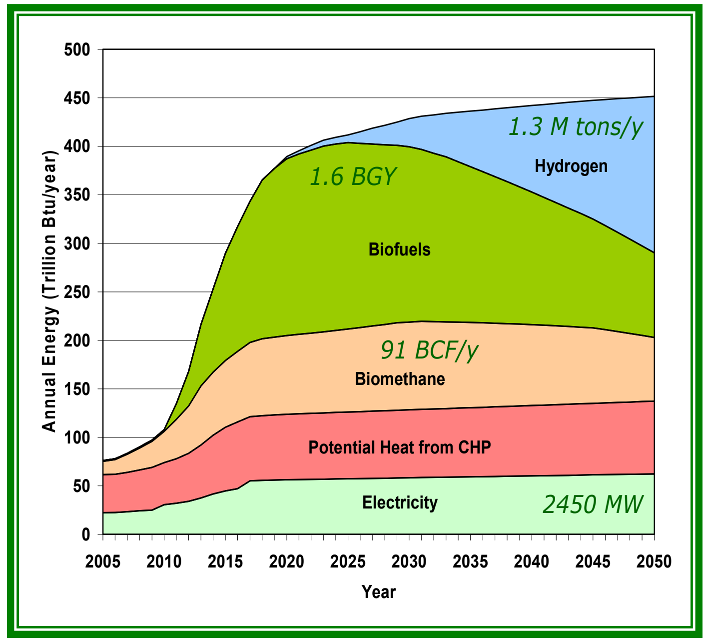
[1] California Biomass Collaborative, 2005, "*Biomass in California: challenges, opportunities, and potentials for sustainable management and development*", CEC-500-2005-160, California Energy Commission, Sacramento, California.

[2] "*Recommendations for a bioenergy action plan*", 10 April 2006, Final consultant report prepared for the California Bioenergy Interagency Working Group, CEC-700-2006-003-F, California Energy Commission, Sacramento, California.

[3] US DOE. (2002), "*Roadmap for Biomass Technologies in the United States.*" http://www.biomass.govtools.us/pdfs/FinalBiomassRoadmap.pdf

[4] Western Governors' Association, "*Biomass task force report, Clean and diversified energy initiative*", WGA, January, 2006.

natural gas in process and industrial heat and cooling operations, helping to increase overall energy efficiency and reduce carbon impacts of the state.



Major opportunities for in-state biomass development include: expansion to nearly 2,500 megawatts of electric power and 18 billion kilowatt-hours of electrical energy, one to two billion gallons per year of biofuels, 100 billion cubic feet of biomethane, and more than a million tons per year of hydrogen.

But California's energy appetite is huge—peak power demand in excess of 50,000 megawatts with annual electrical energy consumption of 300 billion kilowatt-hours, gasoline and diesel fuel demand approaching 20 billion gallons per year, and natural gas consumption of more than 2 trillion cubic feet per year. Potential contributions from current biomass resources are about five to ten percent of state demand in transportation with similar levels in the electricity and natural gas sectors. Improvements in energy use efficiencies would decrease fossil fuel use thereby increasing the biomass contribution from a fifth to a third of energy supply in selected sectors. Simultaneously, biomass can be augmenting supplies of high-value chemicals, structural materials, and other renewable bio-based products with improved environmental and consumer health attributes.

Critical path

The critical path to accomplishing these contributions from biomass involves stimulating the necessary capital investments to build production capacity and infrastructure, accessing markets for sales of products at prices justifying investments, maintaining sustainable supplies of feedstock, and having appropriate technologies and processes for meeting standards for environmental performance and environmental justice.

The intimate association of biomass production and use with other natural resource and waste management concerns means that there is not always consensus on how best to achieve the potential benefits offered by expanded development. A challenge for policy is to accomplish the compromise needed to satisfy the expressed goals of the state in increasing fuels and power from biomass.

Barriers and opportunities

Biomass resources can be used to generate renewable power, to produce renewable fuels such as ethanol, methanol, hydrogen, biodiesel, syngas, synfuels, and biomethane, and as feedstock for products such as plastics, solvents, inks, and construction materials. All of these can help meet the state goals to expand renewable energy, reduce petroleum dependency, provide economic development, and improve environmental quality.

Benefits of using biomass include:

- reducing the severity and risk of wildfire,
- improving forest health and providing watershed protection,
- improving air and water quality,
- restoring degraded soils and lands,
- reducing greenhouse gas emissions,
- improving management of residues and wastes,
- reducing dependency on imported energy sources,
- creating new economic opportunities for agriculture and other industries,
- improving electric power quality and supporting the power grid,
- creating jobs, and
- economically revitalizing many agricultural and rural communities.

Despite these benefits, there remain a number of barriers to development:

- biomass feedstock acquisition costs add to cost of production, reducing economic competitiveness,
- limited long term contracting opportunities make financing difficult,
- siting and permitting processes can be arduous and complex,
- utility interconnection processes can be difficult and expensive and net metering is not uniformly available for all forms of biomass generation within capacity limits,
- many new technologies remain to be fully demonstrated and commercialized,
- there is limited public awareness of the benefits and costs of biomass management.

Overcoming these and other barriers will take a concerted effort in technology and policy development as outlined in what follows.

Roadmap overview

This roadmap begins with an overview of opportunities, challenges, and constraints for biomass, discusses possible scenarios for future development, and introduces priority areas for future actions (Chapter 1). The present situation regarding energy and biomass in California (Chapter 2) is described along with projections (Chapter 3) of the state's future and implications for biomass development through 2050. Objectives for future actions are centered on the main goals for improving resource production and acquisition and increasing the use of biomass for power, heat, biofuels, and bio-based products (Chapter 4).

These goals include demonstrating and commercializing new technologies; supporting new bio-based industries that must compete with established conventional suppliers of energy, fuel, and products; recognizing the resource value of biomass in substituting for declining reserves of fossil fuels and reducing greenhouse gas emissions; conducting necessary research, and ensuring that the public is fully informed about the impacts and benefits associated with biomass.

Recommended actions (Chapter 5) are identified within each of five priority areas:

1. *Resource access and feedstock markets and supply:* Feedstock suppliers need access to biomass resources and must be able to deliver feedstock into biomass markets year round in sustainable ways and at acceptable prices.
2. *Market expansion, access, and technology deployment:* Power plants, biorefineries, and other biomass converters require access both to firm biomass feedstock supplies and to product markets. Market access in turn requires both physical capacity to deliver product through power lines, pipelines, trucks, and other transport systems, and the ability to price product competitively.
3. *Research, development, and demonstration:* New technologies need commercial demonstration and deployment to produce new fuels and additional renewable bio-based products. Continuing advances stemming from well supported basic and applied research should be sought in new product development, improved product quality, increased conversion efficiency, improved environmental performance, and better protection of public and consumer health and safety.
4. *Education, training, and outreach:* Supporting resource, market, and technology developments must be education, training, and public outreach to develop new information, crops, and technologies, provide skilled personnel, disseminate information and establish public dialog over the many issues of concern.

5. *Policy, regulations, and statutes:* The state's policies, regulations, and laws will influence public behaviors, technology implementation, resource management, and markets. These need to be comprehensive, allow for effective innovation, and have a vision of the long-term potential. They also need to provide a clear path for permitting new facilities while ensuring public health and safety and environmental quality.

Major actions

The diversity and breadth of topics addressed within this framework leads to many issues of concern and recommendations for future biomass development. However, a few major actions will have a large influence on motivating technical and economic changes that will be needed to achieve the roadmap goals.

Foremost among these are:

- *Carbon policy:* Implementing and expanding state carbon policies to meet or exceed greenhouse gas emission reduction targets and sending clear price signals to producers and consumers for encouraging more rapid adoption of higher efficiency technologies and renewable resources will be critical for meeting targets for biomass as well as overall state objectives in renewable energy. Through AB 32 and other legislation, California is already embarked on major initiatives to reduce greenhouse gas emissions and establish carbon markets that will provide needed economic support and stimulate increasing investment. California can take the lead in working with other states and at the federal level to ensure consistent national policy.
- *Standards and best practices for sustainability:* Establishing and employing independently certified performance standards and improving best management practices implemented through both state and industry enforcement will be necessary to build consensus and achieve compromise on environmental and public health and safety issues. Crediting suppliers and producers who meet sustainability standards will provide much needed economic support while avoiding other costs arising from fire suppression and mitigating environmental degradation.
- *Financing and contracting:* Ensuring the ability to finance and support biomass development by providing state-backed loan guarantees, government procurement programs, long-term contracting and other financial mechanisms supporting biomass projects commensurate with the benefits created is essential to stimulating the level of investment necessary to build the production capacity and infrastructure needed under the governor's executive order.
- *Permitting:* Improving communication among agencies and educating developers as to regulatory and permitting requirements will make the

permitting process less arduous. Consolidating permitting activity within interagency coordinating bodies or through master agency agreements where agencies work under one regulatory framework would likely expedite review, improve communication regarding cross-media impacts, and reduce permitting costs, both for developers and the agencies. Establishing a clearer permitting pathway will be important to stimulating the needed investment for new facilities to meet the state's objectives.
- *Research, development, and demonstration:* Ensuring adequately funded, long-term basic and applied research and conducting well monitored demonstrations are critical to bringing new technologies, resources, and products to commercialization and to improving technical and environmental performance while enhancing effective regulatory decision making and public policy.

Summary of Specific Roadmap Recommendations
Within each of the priority areas are recommended actions intended to help achieve the targets and realize the longer term vision of sustainable development. Actions are further detailed in the main text and in the tables appended at the end of the report.

Resource access and feedstock markets and supply:
Any long term, sustained use of biomass ultimately depends on sustainable acquisition practices to grow, collect, and store the resource and deliver it as feedstock to market.

Biomass feedstock supplies will expand due to policies and technological innovations resulting in greater competitive status in energy and product markets. Actions to secure access and long-term supply include:

- requiring the application of best management practices for resource development, production, and extraction allowing both industry and state enforcement of standards. Where standards do not yet exist, new standards should be developed;
- establishing processes for independent certification of sustainable practices including
    - land and water use,
    - environmental impacts,
    - environmental justice, and
    - resource and environmental monitoring;
- establishing a biomass commodity market and commodity board or commission to facilitate
    - biomass marketing,

    - development of production, collection, transportation, storage, and processing infrastructure,
    - and coordination of sustainable business certifications;
- crediting sustainable suppliers of feedstock through tax incentives or subsidies in recognition of other costs avoided;
- providing access to extensive biomass resource and market information.

Market expansion, access, and technology deployment:
For any new biomass capacity added, whether for power, fuels, or products, access to market is crucial. Providing adequate infrastructure for product delivery depends on:

- ensuring adequate physical infrastructure for
    - electricity transmission lines and interconnection,
    - gas pipelines and transportation fueling systems,
    - feedstock storage, transportation, and processing capacity;
- establishing policies and enacting necessary laws to monetize external benefits and stimulate needed investment through
    - new opportunities for long term contracting,
    - tax credits,
    - price supports and loan guarantees,
    - carbon markets,
    - environmental credits,
    - reopening direct access to electricity markets
    - and other financial incentives.

Market expansion can only occur if additional biomass capacity is installed. Near term deployment should target:

- upgrading or repowering existing power plants where needed,
- adding new power generation capacity including distributed generation,
- expanding landfill gas and other biogas systems to produce power and fuels including the adoption of bioreactor landfills,
- adding new source separation, waste-to-energy and other conversion capacity for biomass in MSW,
- expanding the use of biodiesel and other renewable diesel fuels including use as blendstock for conventional diesel,
- expanding E85 and other biofuel distribution and fueling capability,
- adding compressed and liquefied biomethane capacity,
- ensuring adequate feedstock collection, separation, and harvesting equipment.

Longer term deployment should be planned in concert with research and demonstration of new technologies and processes. Particular attention should be paid to:

- siting advanced integrated biorefineries incorporating both biochemical and thermochemical conversion and producing multiple value-added fuels such as ethanol and Fischer-Tropsch liquids, hydrogen, and products as well as electricity,
- replacing existing power facilities with more advanced systems such as biomass integrated combined cycles (BIGCC) and increasing use of combined heat and power (CHP),
- increasing renewable power capacity by creating a hybrid system to take advantage of stored energy in biomass in complementing intermittent renewable power from wind and solar systems,
- integrating specialized bioenergy and other biomass crops into agricultural systems,
- integrating crude biomass-derived fuel intermediates as feedstocks to conventional petroleum refinery operations,
- and expanding hydrogen distribution systems.

Research, development, and demonstration:
A substantially increased research effort will be needed as California develops and expands its use of biomass and implements renewable and low-carbon technologies to reduce reliance on petroleum and other fossil fuels. State research programs should build on and be coordinated with extensive strategic research plans developed at the national level while targeting specific areas of emphasis for California focusing on:

- conducting comprehensive life cycle assessments and health risk assessments systematically comparing waste and resource utilization alternatives;
- determining best management practices and monitoring environmental, health, and safety impacts from
    - feedstock production
    - feedstock handling and processing
    - conversion technology and manufacturing
    - product utilization;
- conducting basic bioscience, biotechnology, and biochemical research to
    - improve sustainability of biomass production systems
    - increase yields
    - reduce water and other agronomic inputs

    - increase disease- and pest-resistant of biomass crops
    - improve conversion processes and product quality;
- conducting applied research and demonstrating commercial scale biomass conversion and biorefinery techniques
    - biological, physical, chemical, and combined pre-treatment processes
    - lignocellulosic fermentation
    - advanced power generation including integrated gasification combined cycles and fuel cells
    - thermochemical biomass-to-liquids (BTL) processes employing Fischer-Tropsch and other techniques for making renewable diesels, gasolines, alcohols, and other fungible products
    - advanced high-rate anaerobic processes for biomethane production and integrated waste management
    - advanced integrated biochemical and thermochemical biorefineries for improved yields and cost;
- modeling, remote sensing, systems analyses, and systems optimization for
    - land use monitoring and evaluation
    - forecasting climate change impacts on biomass and bioenergy systems
    - assessing local and state economic impacts
    - improving feedstock production and acquisition logistics
    - siting and sizing conversion facilities and systems.

Greater coordination and facilitation of research and demonstration should be provided by focused efforts with access to state-of–the-art facilities and equipment. Research centers should be developed through state and industry support to provide enhanced laboratory and pilot capabilities for testing and development of advanced concepts.

Education, training, and outreach:
Informed citizens, consumers, and decision makers are crucial to the successful adoption of bioenergy and other biomass systems. Well trained professionals will also be needed to carry out the expansion envisioned. Greater effort and funding should be directed at:

- educating and informing the public and decision makers about biomass systems and issues in sustainable biomass development,
- informing investors about corporate social responsibility and environmental and social implications of investment decisions,
- conducting outreach to local, state and federal government decision makers, schools, non-governmental organizations (NGOs), and other public interest groups,

- providing outreach on biomass utilization and establishing early dialog with affected communities where facilities are proposed to ensure environmental justice and direct public involvement,
- holding general and specialized conferences, workshops, and onsite tours to increase information dissemination and encourage public, industry, and scientific interaction,
- conducting hearings and sponsoring field trips for policy makers and regulators to provide relevant information for policy, statutory, and regulatory proceedings,
- providing technical training by and for industry and expanding university curricula and programs to ensure the availability of adequate numbers of skilled professionals and technicians,
- augmenting existing cooperative extension programs to inform and educate farmers, producers, operators, investors, and others of results emerging from research and development efforts,
- building grade-level appropriate K-12 curricula and teacher training programs to enhance career preparation and public education.

Policy, regulations, and statutes:
California needs to establish an efficient process to address policy and regulatory issues in collaboration with the biomass industry. Only with a broad, overall approach will it be possible to address existing constraints and develop new policies, laws and regulations that promote the expanded use of biomass while protecting the state's environment. Addressing issues related to biomass may require state agencies to change existing policies or develop new ones. In addition, changes in existing laws or regulations may be required before some of the policies can be fully implemented. Meeting the targets as ordered will require support at the highest levels of state government agencies to develop policies, regulations, and statutes aimed at:

- accounting for externalities and establishing or augmenting financial incentives, including
  - expanding carbon markets and implementing carbon taxes if necessary to avoid excess leakage across state borders,
  - increasing the value of renewable energy credits and designating allowable emission offset credits,
  - providing equitable tax credits and production incentives for biomass production and use
  - facilitating long term contracting,
  - providing loan and other financing assistance;

- revising waste management policies and practices including
    - adding extended producer responsibility requirements
    - shifting to disposal-based regulations (e.g., reduce biodegradable material in landfills and reduce per-capita disposal amounts) from the current diversion-based regulations
    - amending laws to revise or eliminate technology and transformation definitions and require greater reliance on performance-based standards and results from comprehensive life cycle assessments
    - changing statutory definitions and permitting authorities to recognize the resource value of biomass in waste;
- requiring and enforcing best management practices where not yet applied;
- revising permitting requirements to enhance interagency communication and create a clear permitting pathway for applicants;
- establishing new or investing existing enterprise zones with responsibilities and opportunities to support biomass development including
    - siting assistance,
    - local government support,
    - environmental review,
    - and appropriate incentives;
- implementing environmental justice review,
- enhancing access to transmission lines, pipelines, and other infrastructure, providing equitable policies for net metering, opening direct access, and other incentives intended to stimulate markets.
- expanding the renewable portfolio standard (RPS) as needed
- establishing a renewable fuels standard (RFS).

Next Steps

This roadmap provides direction for government and industry action but does not fully address implementation of the recommendations. The state and other stakeholders will need to set priorities for actions to be taken over the near-, mid- and long-term and identify responsibilities for implementing the various elements. Some actions will require legislation; others may be handled by executive or administrative order. Some will require budgetary actions while still others must be accomplished by industry, local government, and/or academia. Realizing the vision for sustainable biomass development and achieving the state's bioenergy goals requires a continuing process focused on identifying and assigning responsibilities for implementing the roadmap recommendations.

1 INTRODUCTION

1.1 Purpose

A roadmap can serve many purposes. This one offers guidance and direction to policy makers, law makers, regulators, investors, researchers, developers, and the public on the sustainable development and use of biomass resources in California.

It builds on a number of other roadmaps, plans, and recommendations for bioenergy and biobased product development at both the national and state levels—most recently the governor's executive order S-06-06 on bioenergy and the state's subsequent bioenergy action plan, as well as the report of recommendations and the white paper on biomass on which the plan was based.[5,6,7,8] As such, this roadmap discusses many of the same issues that face biomass development everywhere, but views them over a longer term specific to California.

1.2 Opportunities, uncertainties, and constraints

Biomass is a chemically rich resource with potential application as feedstock to multiple processes and markets including power, heat, fuels, chemicals, and other products. It already is used in the state in all of these markets, most importantly at present to generate electricity and heat. But there is increasing emphasis on producing biofuels and bio-based products to substitute for or supplement supplies from petroleum and other resources. In the future, greater process integration across markets is likely to occur in order to obtain highest value from the resource. There is no single market driving biomass development. New markets will offer additional outlets for biomass, but will also increase competition and influence price for more readily available and higher quality supplies.

California's biomass resources offer a substantial opportunity for increasing production of clean and renewable energy and products to help meet the state's socioeconomic and environmental goals. Motivating the necessary investment in capital, technology, and resources to expand the sustainable use of biomass remains an important challenge.

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[5] Governor's Executive Order. EO S-06-06, 25 April 2006

[6] "*Bioenergy Action Plan for California.*" The Bioenergy Interagency Working Group, 13 July 2006. http://www.energy.ca.gov/bioenergy_action_plan/index.html

[7] "*Recommendations for a bioenergy action plan for California.*" CEC-600-2006-004-F, 10 April 2006.

[8] "*Biomass in California: challenges, opportunities, and potentials for sustainable management and development.*" California Biomass Collaborative, 2005, CEC-500-2005-160, California Energy Commission, Sacramento, California.

The clean-energy field, in total, faces many investment challenges. Unlike California's early dominance in high tech investments, today many other states and nations are competing for clean technology capital, including clean energy financing. From an investment prospective, biofuels, up 15 percent in the past year, are expected to grow from $15.7 billion in 2005 to $52.5 billion by 2015. Increased access to equity capital is essential for growing California's biomass industry.

In agriculture, forestry, and waste management, biomass utilization can improve stewardship of natural resources and provide economic opportunities for communities and new businesses. For example, forest thinning to reduce fuel loads can help to reduce the severity of forest fires and loss of life and property, while increasing supplies of renewable feedstocks and reducing costs of wildfire suppression. Collection of agricultural residues such as straw and tree prunings can reduce the need for open burning, help farmers comply with recent air-pollution regulations, and reduce incidence of plant disease. Animal manures concentrated at dairies, feedlots, and other production facilities can be processed to provide valuable fuel, electricity, and heat for use on-site or elsewhere, while providing opportunities to reduce odors and greenhouse gas emissions. Energy conversion and product manufacturing creates markets for municipal solid wastes and other residues that should no longer be considered wastes but rather as resources in improved management strategies. Purpose-grown or dedicated energy crops can increase renewable resource availability and in some cases help to improve marginal lands and lands degraded by unsustainable agricultural and industrial practices.

If this were the full story, there would be little concern over greater use of biomass. But almost every use involves one or more areas of controversy. Some forest thinning practices are opposed over concerns for protecting habitat and older-growth trees. Improved manure-management techniques such as the use of anaerobic digesters may be opposed on the basis of animal welfare, as such systems may encourage or support increased concentrations of animals. Improper harvesting of agricultural residues may decrease soil quality and increase erosion. Direct combustion and other waste-conversion technologies continue to be opposed due to worries over possible hazardous emissions and the potential for energy markets to negatively impact recycling, composting, and waste-reduction programs; this despite improvements in emission control and wide-scale acceptance elsewhere. Increasing dedicated energy crop production, which may help manage ground and waste water, can also compete for clean water supplies, potentially increasing costs to other agricultural enterprises. It may also transform landscapes, and – beneficially or adversely – alter biodiversity.

Although the need to develop in sustainable ways is generally accepted, there is not always a common perception as how best to do this. Conflicts arise from differing perceptions regarding the adequacy of information on health, safety, and environmental impacts, as well as from often profound differences in essential resource-management philosophies. Finding workable solutions to such issues will be important to the long-term sustainability of the state.

There are valid concerns over increasing biomass development. This is especially true for new approaches and technologies where extensive environmental performance data are not yet available and comprehensive life-cycle assessments have not been performed. Mitigating these concerns will require research, technologies, and policies supporting sustainable solutions.

1.3 Benefits

There are many environmental, economic, and societal benefits to be realized from greater use of biomass. As a renewable resource, produced sustainably and with attention to life cycle impacts, substituting biomass for fossil resources can generate global ecological benefits. Net greenhouse gas emissions can be lowered and help to stabilize or reduce atmospheric carbon dioxide concentrations. Changes in the way biomass is produced and managed can also reduce greenhouse gas emissions.

Proper biomass use can reduce local pollutant emissions from agriculture, waste management and forestry, including air emissions from wildfires and open burning of residues; emissions from animal manure handling; methane emissions from landfills, and salt and nutrient contamination of ground and surface waters. Local, regional, and state economies benefit from biomass industry development through direct and indirect employment, tax revenues, and by enabling the expansion of other commercial, residential, and industrial development. Imports of biofuels and products can similarly benefit economies outside the state. Such development, however, needs to be accomplished with proper regard to sustainability and environmental justice on all fronts.

1.4 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. 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. Lack of demonstrated commercial success can often make financing new technologies difficult. Concerted and coordinated action on the part of 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.

1.5 Critical needs in development

Feedstock suppliers need access to biomass resources and must be able to deliver feedstock into biomass markets in sustainable ways and at acceptable prices. Similarly, power plants, biorefineries, and other biomass converters require access both to firm biomass feedstock supplies and to product markets. Access to markets implies both physical capacity to deliver product through power lines, pipelines, trucks, and other transport systems, and the ability to price product competitively. New technologies will need commercial demonstration and deployment to produce new fuels and additional renewable bio-based products. Similarly, advances should continuously be sought in conversion efficiency and environmental and cost performance, to take best advantage of resource value.

Supporting these developments must be research, education, training, and public outreach, in order to develop new information, crops, and technologies, provide skilled personnel, disseminate information and establish public dialog over the many issues of concern.

Policies, regulations, and laws will influence public behaviors, technology implementation, and markets; they must be comprehensive and with a vision of the long-term potential.

1.6 Innovation and flexible policy

Any comprehensive long-range plan must be flexible and open to innovation. The chemical and biological complexity of biomass makes new discoveries and breakthroughs likely, but predicting future outcomes is difficult. Policies and regulations that are technology-prescriptive tend to inhibit development and innovation, often unintentionally. Setting environmental performance standards without attempting to prescribe specific technologies to meet them encourages innovation in all areas while providing necessary health and safety protections.

Similarly, objectives developed under today's standards may not endure as new developments emerge. However, encouraging needed investments will require long-term-contracting and a perception by the industry of a continuing role and market demand for those products generated through their investments. Because markets will not remain static, industry also needs to be flexible in adapting to market changes as new needs and technologies develop.

1.7 Mandates and targets

Stimulation of the market to encourage development should to be done through open processes and in ways that address policy objectives. The potential market influences of different strategies must be recognized. For example, statutory mandates to increase capacity such as setting future production targets for biofuels or generating capacity for electricity from biomass, will shift industry and financial resources to meet those objectives, shaping or distorting the market in specific ways. The more resource-neutral renewable portfolio standard (RPS) has not so far stimulated much biomass development as a result of competition from lower-cost wind and geothermal resources. Nonetheless, the process remains open to innovative designs that can directly compete with other resources. As targets are increased, higher cost alternatives will increasingly be selected in order to satisfy the mandate, thereby increasing prices. This will further stimulate innovation to reduce generation costs. At least over the near term, renewable-fuel standards, even if open to any resource type, will provide greater incentives for biomass development due to the limited ability of other renewable resources to provide products. Hydrogen, which can be produced from biomass and any other renewable resource, is the longer term exception.

1.8 Subsidies and taxes

Production mandates like the RPS are intended to influence supply. They do not necessarily directly influence demand. A common concern in seeking greater use of biomass is the lack of compensation in existing markets for environmental benefits such as greenhouse gas reductions, landfill diversion, local air quality improvements, wildfire risk reduction, and other externalities.

Across the country, demand for biomass has been stimulated through tax credits, renewable energy credits, and direct subsidies. But it can also be stimulated through cost penalties or taxes applied to other competing resources having undesirable environmental attributes, such as greenhouse-gas emissions. For example, fuel or carbon taxes applied to fossil fuel use or net emissions of greenhouse gases would increase fossil fuel prices and make renewable energy more competitive. Increased prices also send a direct signal to consumers: they encourage greater efficiency in use and stimulate demand for and development of more efficient vehicles, appliances, and other devices, critical to any successful economic transition. Means may also be needed to mitigate economic impacts on lower or fixed income individuals.

Other approaches include carbon cap and trade systems and mandated efficiency standards, such as the corporate average fuel economy (CAFE) standard applied to vehicle sales in the United States and California's appliance efficiency standards. The effectiveness of these approaches varies depending on governmental policy. European policy, for example, that now combines cap and trade systems with previously applied fuel taxes and greenhouse gas emission reduction mandates (Kyoto protocol targets) has achieved a less energy-intensive energy and transportation system than has the US with its primary reliance on CAFE. More time will be needed to assess the recently introduced federal Renewable Fuel Standard (RFS) and the renewable portfolio standards applied by various states. In practice, a combination of approaches is likely to better achieve current policy objectives for reducing petroleum demand and greenhouse gas emissions. California has recently enacted legislation (AB 32, 2006) calling for the development of market mechanisms to reduce greenhouse gas emissions. Other legislation (AB 1012, 2006) calls for increasing the number of fuel flexible vehicles capable of using renewable fuels. Through these and other actions, California is clearly oriented toward a more sustainable energy future.

1.9 Resource and market potential

The diversity of California's biomass resources makes for many opportunities. But it also makes for greater complexity in attempting to achieve large increases in energy and products. At present, the three principal resources are agricultural residues, forestry residues, and biomass from urban and industrial wastes. These resources are distributed variously throughout the state (Figure 1.1). Forest biomass is available mostly in the northern and central mountain areas, agricultural biomass in the Central Valley and coastal and southern valleys, and urban biomass in the main metropolitan regions of the Los Angeles basin, the San Francisco Bay area, San Diego, and the Bakersfield to Sacramento development corridor. A sizable number of facilities producing or utilizing biomass already exists (Figure 1.2).

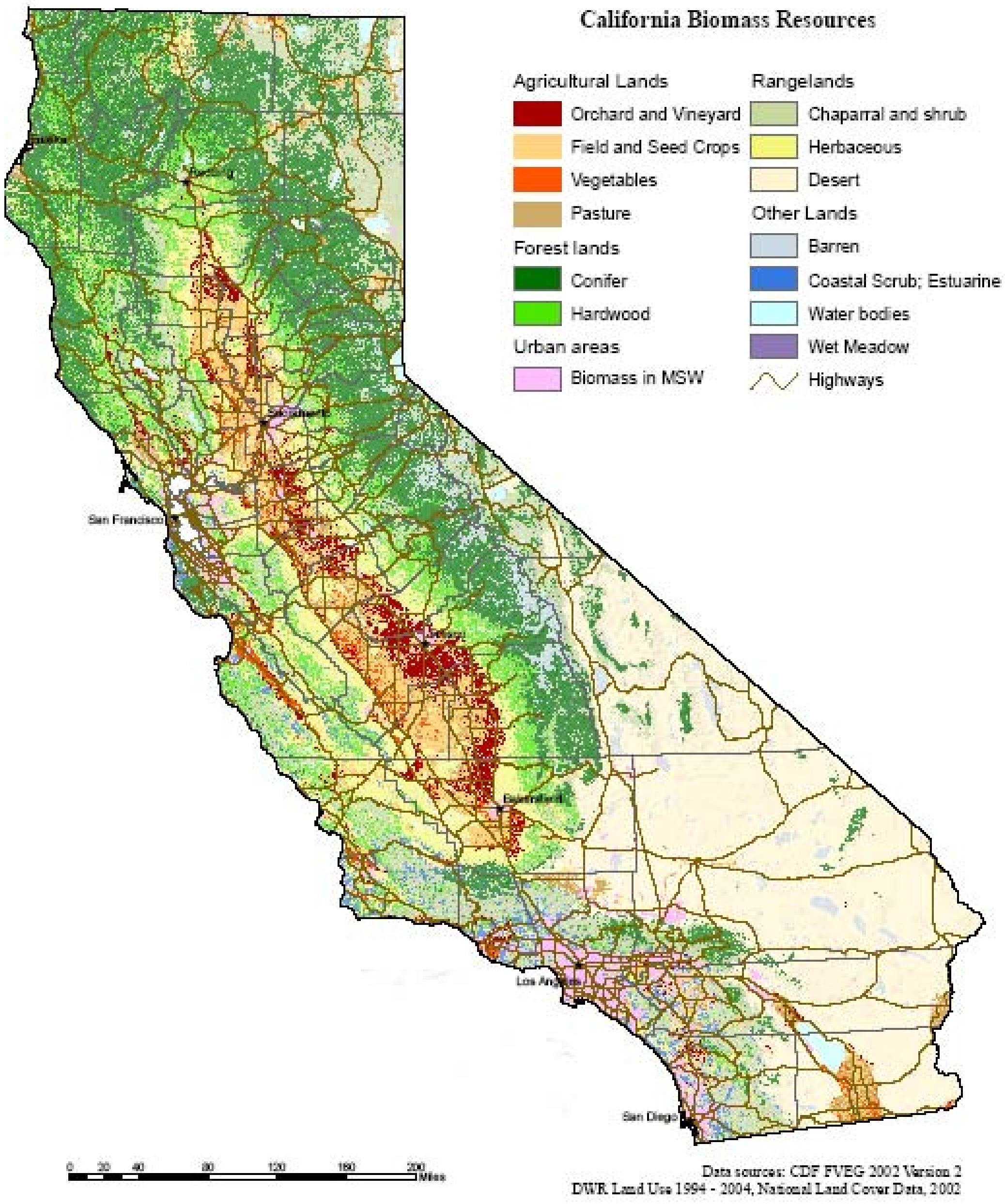

Figure 1.1. Land classification and distribution of biomass resources in California.

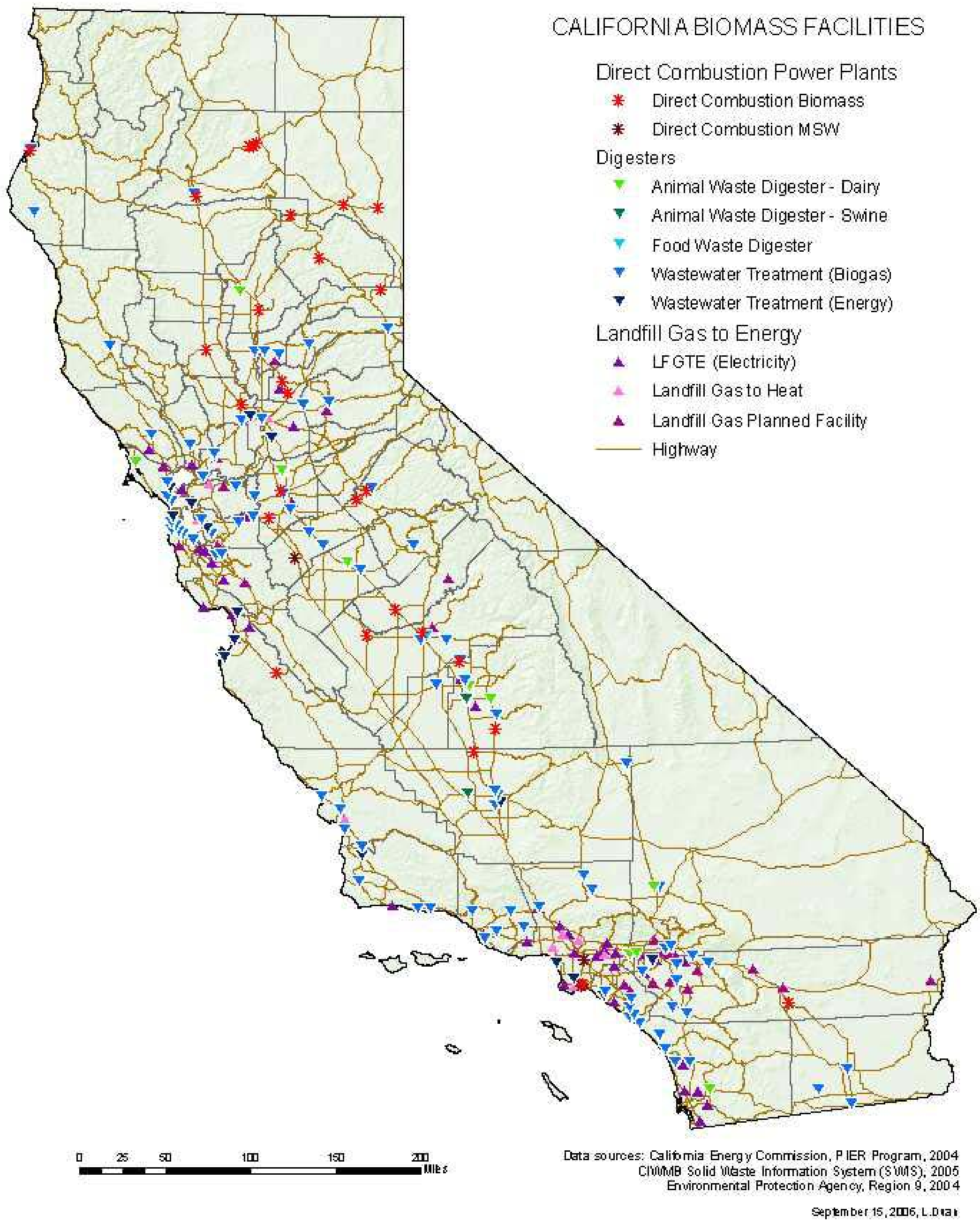

Figure 1.2. Biomass facilities in California.

Gross biomass production among all three primary categories amounts to 80 million dry tons currently (Figure 1.3). Increasing population and changes in agriculture, forestry, and waste management, along with possible future increases in dedicated crops, might result in annual generation of more than 100 million tons of biomass by 2050. Developments in plant biology might also markedly increase the resource potential.

The amount of biomass available under sustainable use practices is less than gross production. At present, estimates accounting for soil conservation, protected forest lands, performance of collection and harvesting technologies, and other factors suggest that about 32 million tons may be feasible for commercial and industrial use, expanding to 48 million tons by 2050. Excluding biomass associated with landfill gas and biogas generated during wastewater treatment, which represent a total potential of 137 billion cubic feet per year of biogas, annual biomass utilization in the state is presently about 5 million tons.

Although not all the biomass will be used for energy, the total energy contained in the biomass now considered to be available for utilization in California is large, exceeding 500 trillion Btu per year (Figure 1.4), or roughly 6 percent of California's primary energy demand.

Potential contributions to future electricity, heat, biofuels, and hydrogen supplies are significant (Table 1.1). Although biomass will be used for multiple purposes, maximum energy potentials within any one product category based on full use of the resources presently available are of the order of 10 percent of statewide demand in each of electricity and transportation sectors.

1.10 Future development scenarios

The future development of biomass will depend on many factors including state policies and technologies available for use. Starting from a current base of 5 million tons of biomass plus landfill gas and digester biogas, immediate actions to demonstrate, commercialize, and construct both thermochemical and biochemical biofuel production processes using cellulosic materials and to increase electricity generating capacity, both through separate facilities as well as integrated biorefineries, might result in production increases similar to those projected in Figures 1.5 and 1.6. This is only one conceivable outcome; many others are possible.

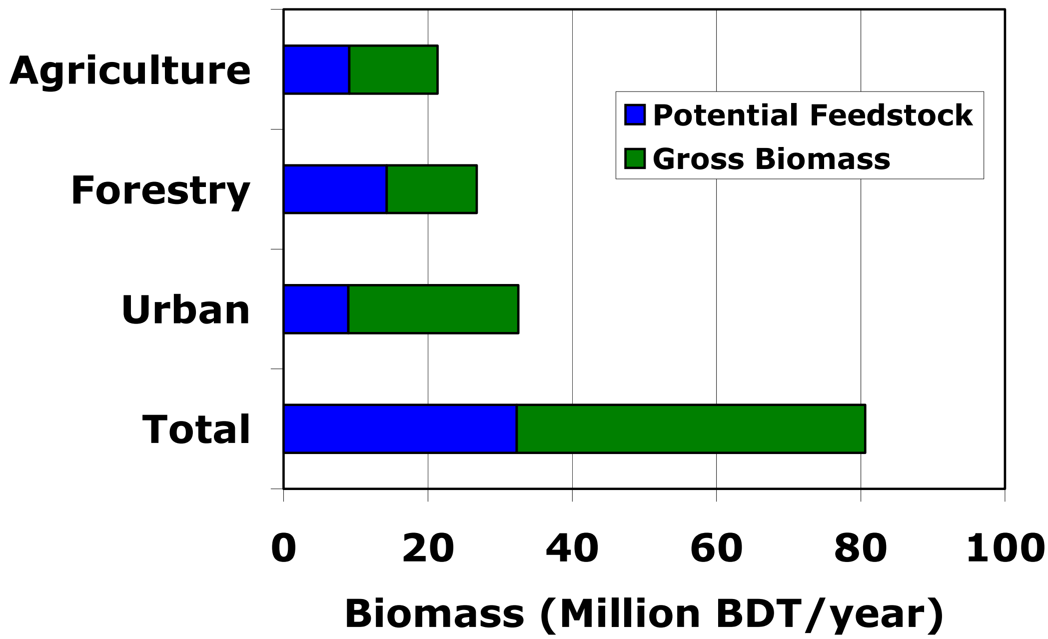

Figure 1.3. Gross annual biomass production in California (2005) and amounts estimated to be available for sustainable use (BDT = bone dry tons).

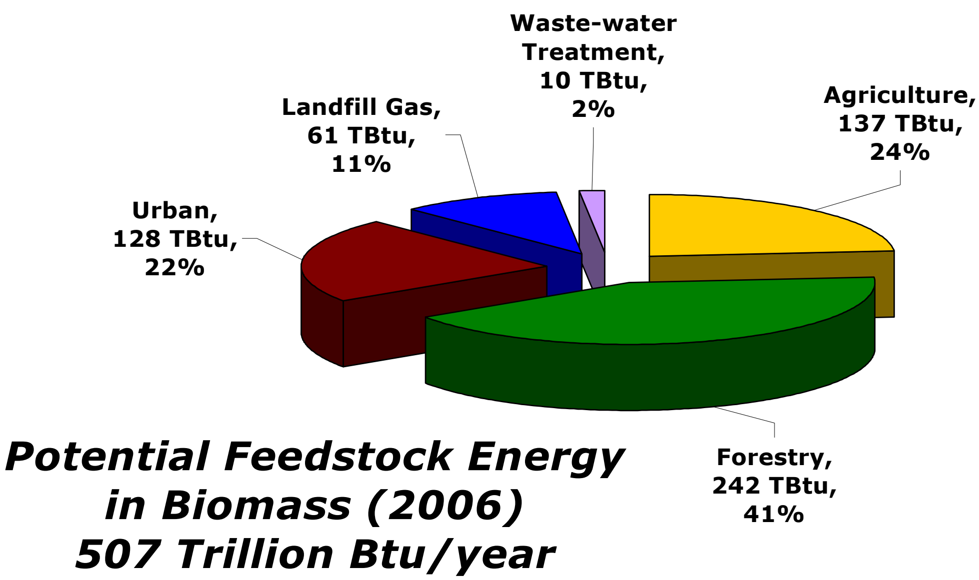

Figure 1.4. Energy potential in annual biomass considered to be available from agriculture, forestry, and urban wastes in California, 2006 (TBtu = trillion Btu).

Table 1.1. Total energy potentials for available California biomass feedstock by energy category (2006 biomass resource base).

Category	Biomass (Million BDT/year)	Energy in Product (Trillion Btu/year)	Total Capacity
Electricity CHP Heat	32	118 (35 TWh) 230	4,650 MWe 9,050 MWt
Heat	32	350	11,700 MWt
Biochemical Biofuel	32	188	2.3 BGY ethanol equivalent
Thermochemical Biofuel	27	250	1.7 BGY diesel equivalent
Biomethane	5 + Landfill gas and WWTP	106	106 BCF/y methane
Hydrogen (bio + thermal)	32	305	2.5 Million tons/y

BDT = bone dry ton. BCF = billion cubic feet. BGY = billion gallons per year. MWe = megawatt electric. MWt = megawatt thermal (heat). TWh = terawatt-hour (billion kWh). WWTP = wastewater treatment plant. 1 ton = 2000 lbs. Biochemical conversion is based on fermentation to ethanol. Thermochemical is based on gasification followed by Fischer-Tropsch synthesis. Biomethane is methane derived from anaerobic digestion of biomass. Biofuel capacities shown are based on assumed low yields for dedicated crops (see section 5.2.3 for more detail). Tonnage for thermochemical biofuel assumed to be constrained by moisture content.

Shown are quantities of in-state biomass used for electricity and heat through combined heat and power systems; biomethane; biofuels from both thermochemical and biochemical processes; and in the longer term, hydrogen. Feedstock supply includes increasing amounts from dedicated crops added largely by 2020.

Under the scenario illustrated, 1500 MWe of new electricity generating capacity are added through 2050, a peak production of 170 trillion BTU per year (roughly 1.6 billion gallons) of biofuels is achieved around 2025, and a peak production of 91 billion cubic feet of biomethane, including use of landfill and digester gas, is achieved by 2030. Biomethane could be used to generate electricity, in transportation markets, or pipelined with natural gas. Shifting production away from biomethane and biofuels to hydrogen after 2030 would result in net reductions in these two categories after the early development through 2020. Similarly, greater use of electricity in transportation might substantially alter the quantities of biomass used for biofuels and hydrogen.

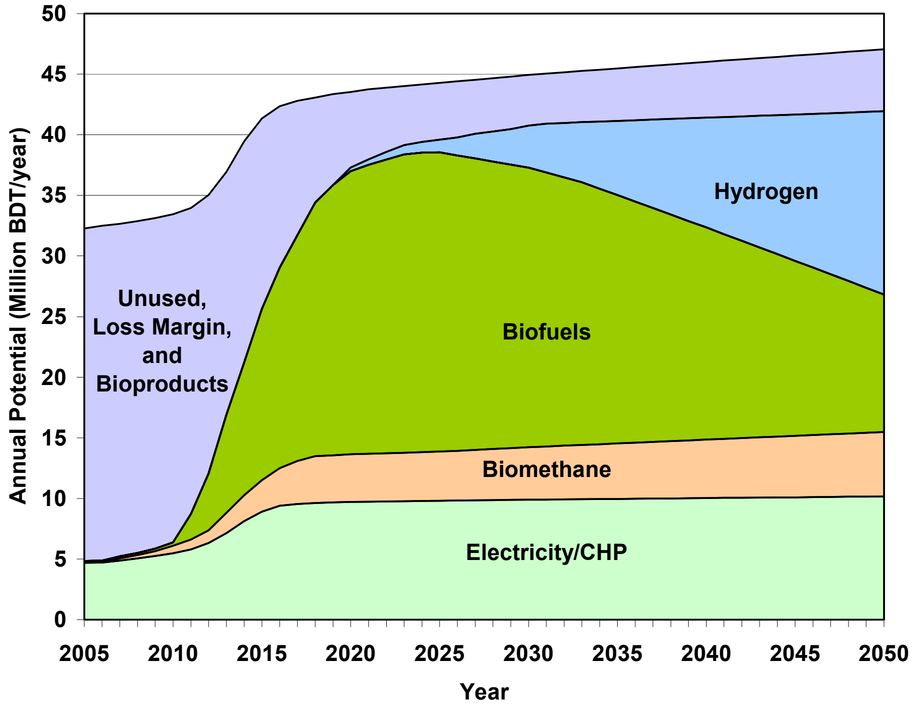

Figure 1.5. One scenario of in-state biomass development through 2050.

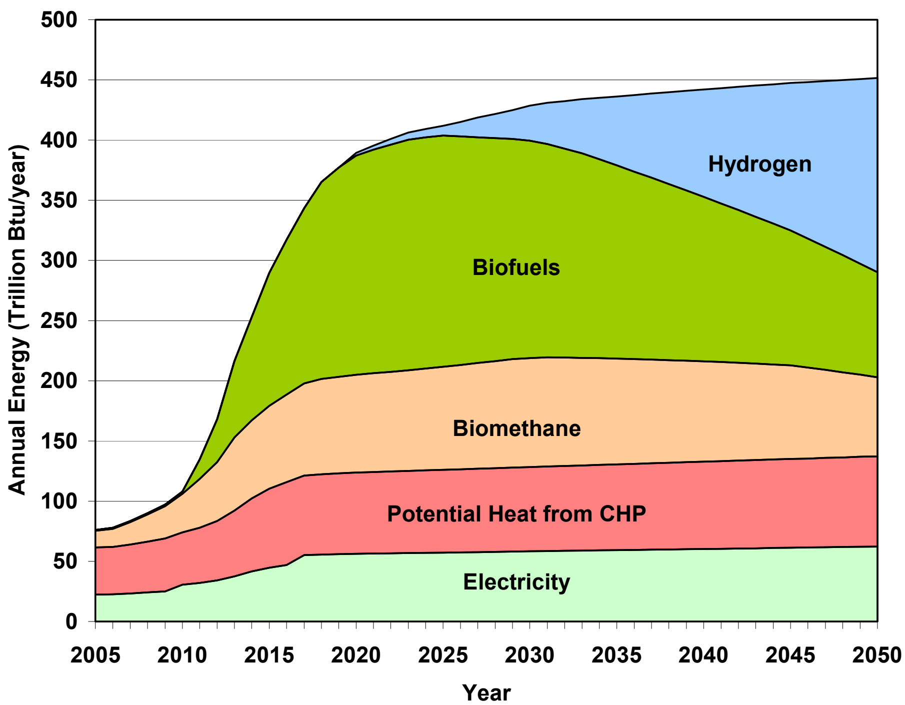

Figure 1.6. Energy associated with the biomass development scenario of Figure 1.5.

Included are landfill gas and digester gas from waste-water treatment not explicitly shown in the previous figure. Heat from combined heat and power (CHP) is potentially available, but little of this is used at present.

Not shown in the figures are imports of biomass, such as corn and other grains that at least in the near term will be employed to expand biofuel capacity. Continued research and development may lead to greater production of dedicated crop biomass. The capacity build-up indicated in Figures 1.5 and 1.6 include production of an additional 10 million tons from dedicated crops. Increasing production could also come from algae under high-intensity culture systems, and marine biomass crops.

A great deal of near-term activity will be needed to accomplish this development. Based on past and projected development costs, investment in conversion plants alone would approach $20 billion (2006 dollars) to process a total of 1.5 billion tons through 2050, or more than $12 per ton used. An equal investment might well be needed for feedstock production, harvesting, storage, and processing as well as for product distribution through electricity transmission and distribution, fuel pipeline, and other transportation infrastructure. Stimulating this investment while ensuring adequate profitability and sustainable practices is crucial to future development on this scale.

1.11 Roadmap process and priorities

Preliminary development of this roadmap was accomplished principally through input from the executive board and staff of the California Biomass Collaborative, representing industry, government, academic, and environmental community views. Additional public and expert stakeholder input was received at an environmental issues workshop held in November 2005, during which major issues and barriers were identified, along with possible solutions, as well as a public informational meeting held in September 2006.

Five major goals have been identified, each involving a number of principal objectives. These goals and objectives are explained in Chapter 4. The actions necessary to achieve these goals have been grouped under priority areas and set forth in Chapter 5.

Potentials for and barriers to biomass development have been identified in previous studies and reports, including the white papers on biomass prepared in preparation for this process.[9,10,11] Other plans and roadmap documents have also set out near-term actions and identified many areas for further development. From this preliminary roadmap process five key areas have emerged and constitute priorities for further action. Additional areas may be identified in future roadmap processes.

1.11.1 Resource access, feedstock markets and supply:

Stable supplies of biomass are critical to the long-term success of biomass conversion facilities. A common concern of industries seeking to invest in new or expanded capacity is the state of feedstock markets and the readiness of suppliers to enter into long-term contracts for particular feedstock types. Smaller scale, distributed, or portable conversion facilities may not require the same level of contracting, but they still require stable supplies with adequate storage. Fuel costs will remain a primary economic barrier to increasing use of agricultural, forestry, and dedicated crop biomass. Urban biomass, for which tipping fees can currently be charged by a separation and processing facility, may in the long term experience greater competition as resource, leading to higher prices to the end user.

Mobilizing the necessary resources leading to the expanded production outlined above while ensuring sustainable production, harvesting, and handling practices could lead to increasing costs of supply, mitigated by continuing research to improve equipment and handling techniques and reduce costs. To encourage and support feedstock development, incentives can be applied that reward suppliers who demonstrate sustainable practices. Such incentives could include state subsidies such as direct payments and tax credits to suppliers who can certify delivery of sustainably produced biomass. Such incentives have been applied occasionally in the past, but seldom for long enough to stimulate new plant investment. Developing a commodity market for biomass to allow broader access to feedstock by converters, and to conversion markets by suppliers, would also enhance stability of supply and potentially reduce price volatility as the market matures and expands.

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[9] California Biomass Collaborative, 2005, "*Biomass in California: challenges, opportunities, and potentials for sustainable management and development*" CEC-500-2005-160, California Energy Commission, Sacramento, California.

[10] Williams, R.B. (2006). "*Environmental Issues for Biomass Development in California-Draft.*" California Biomass Collaborative. University of California, Davis. CEC PIER Contract 500-01-016

[11] Williams, R.B. (2006). "*Biomass in California MSW-Draft.*" California Biomass Collaborative. University of California, Davis. CEC PIER Contract 500-01-016

1.11.2 Market expansion, access, and technology deployment:

The expansion of the biomass power industry after the enactment of the Public Utility Regulatory Policy Act (PURPA) in 1978 was due largely to its requirement for long-term contracts (most often Standard Offer #4) giving access to utility markets with favorable pricing based on the utility's avoided cost of production. In attempting to meet new targets for bioenergy, industry will similarly need appropriate investment opportunities. Electricity industry restructuring and the implementation of the existing California Renewable Portfolio Standard (RPS) have not yet provided the same incentives for bioenergy development. Higher costs of biomass power from stand-alone applications without CHP have so far limited access to utility markets through the RPS.

Increasing the mandated share of energy to come from renewables would likely increase access due to higher marginal prices to meet increased supply requirements. However, with additional development yet to come in wind and geothermal markets, biomass development may not occur to the extent desired to meet other environmental and resource management objectives. Implementing a renewable fuels standard would increase biomass use in the near term. Alcohols, diesel substitutes, methane, and other renewable fuels produced from biomass are not as readily produced from other renewable resources. Over the longer term, however, if hydrogen or electricity emerge as larger energy carriers for transportation, competition from other renewables will increase.

Another approach is to impose fuel or carbon taxes reflective of the actual external costs associated with the use of fossil fuels, thereby establishing a more accurate market for biomass and renewables of all types. Like existing fuel taxes, proceeds should be used to support improvements within the sectors targeted, such as transportation. Increased investment in new and improved technologies and methodologies would result in both reduced reliance on imported petroleum and increased efficiency. Improved vehicle fuel use economy, in turn would reduce the amount of fuel used by the consumer to accomplish the same number of trips. Along with renewable energy credits, environmental credits and carbon cap and trade systems, these mechanisms can motivate change in consumer behavior leading to much greater use of renewable energy. Expanded state and local government procurement programs can also be used to provide more secure markets for biomass products.

The amount of biomass presently available for conversion could be used with existing technologies to generate electricity and heat. Permits for new facilities will be increasingly difficult to obtain unless pollutant emissions can be reduced due to the limited availability and high costs of emission offsets. Advanced generation systems with reduced emissions and increased efficiency still need demonstration. Additional biomass in the form of starch, sugars, and vegetable oils could be produced to immediately increase supplies of ethanol and biodiesel. Imported biomass is already beginning to contribute to such fuel supplies in the state. Manufacturing biofuels from most of the biomass available in California will also require demonstration of new technologies.

Working together with federal programs and through public-private partnerships, the state can encourage development of conversion capacity by helping to fund demonstrations of emerging technologies, including thermochemical and biochemical approaches. Major technologies to be demonstrated in-state include biomass-integrated combined cycles for power generation (BIGCC); biorefineries for fuels and chemicals including cellulosic fermentation to ethanol, butanol, and other fuels and gasification with Fischer-Tropsch or other synthesis techniques to produce direct substitutes for gasoline and diesel. Commercial project implementation and technology deployment will also require effective permitting and contracting processes, and coordinated regulatory assistance to expedite environmental review and ensure compliance. Deployment of standardized technologies may be accelerated by building on new or existing enterprise zones leading to region-wide environmental and other reviews and approvals.

1.11.3 Research and Development:

California is one of several states with an active energy research and development program, but increasing funding will be required for both basic and applied research to make the transition to a more sustainable and renewable energy economy. Recent interest by industry in greater sponsorship of bioenergy research opens the possibility of leveraging increasing state support for research. Targeted research to meet state requirements, as well as more fundamental research, can be enhanced by establishing one or more biomass research centers to attract leading researchers working on the full range of bioenergy and bioproduct topics. Research should be supported in the areas of basic cellular and molecular biology, plant sciences, photosynthesis, enzymes, genomics, engineered systems, process integration, crop production systems, environment, life cycle assessment, economics and markets, and system optimization.

1.11.4 Education, training, and outreach:

Expanding the biomass industry to the levels identified above will require a skilled workforce, an educated business community, and an informed public. University programs offering advanced training in biomass systems should be expanded. K-12 educational programs should be developed to better inform our children about sustainable development practices and to motivate students to pursue careers in related fields. Teacher training programs should be established to help develop the K-12 curriculum. Professional training programs should be set up to provide skilled managers, regulators, operators, technicians, and other personnel who will be needed for permitting and operating advanced power plants, biorefineries, and other biomass systems. Outreach strategies will need to be developed for individuals engaged in public policy at the federal, state, and local levels. The financial community must also be engaged to ensure continued funding for new facilities and the upgrading of existing systems.

As biomass feedstock supply systems develop to meet the demands of a greatly expanded production capacity, cooperative extension programs will need to be expanded as well to help growers and feedstock suppliers address the challenges of the industry. Information clearinghouses and other information systems should be established to help the public understand the often complex issues in biomass resource management, environmental performance, environmental justice, and bioenergy and bioproduct market development.

1.11.5 Policy, regulations, and statute:

State and federal policies are primary influences on market development and transformation. Technology innovations and improved scientific understanding also influence policy and regulation. A number of state policy actions have already been identified through the governor's Bioenergy Executive Order and its companion Action Plan, as well as greenhouse gas and related legislation. Increasing legislative attention is likely to be directed toward this issue in the near future as energy costs, economic performance, international events, and environmental issues escalate public concerns. Numerous regulations apply to project development and operation, and improving consistency and coordination will be important, not just to ensure environmental quality and human health and safety, but to encourage investment. Clear processes are needed for permitting new facilities. Just a few major policy directives can do much to further these goals of the state and the more specific actions in this roadmap. Creating consensus around these directives will remain a challenge for the coming decades.

2 PRESENT SITUATION: Energy and Biomass in California

The sustainable management of biomass can provide environmental, social, and economic benefits far in excess of current practices, contributing to:

- A cleaner, healthier environment
- A prosperous and vibrant economy
- An economically and environmentally just society

The development and use of biomass in California can and must support these three principles. It must produce cleaner air and water and reduce greenhouse gas emissions. It must provide resources the state needs that are affordable and reliable. And it must provide jobs and economic development, especially in economically underdeveloped regions, distributing its economic benefits widely and not unfairly burdening disadvantaged areas with its environmental costs.

2.1 Energy and biomass supply and demand

California has a great demand for energy, and depends on out-of-state and international sources for a substantial proportion of it. The state has about 62,000 MW of electrical capacity within its borders. It uses about 288,000 GWh of electricity annually,[12] about 78 percent of which is generated in-state with close to half powered by natural gas. Most of the natural gas consumed here is imported, with only 15 percent produced in-state. Taking natural gas into account, more than half the fuel for in-state power plants comes from out of state. California generates 2 percent of its electricity from biomass and 9 percent from other renewables.[13]

The state's 28 million vehicles use about 16 billion gallons of gasoline and 3 billion gallons of diesel annually.[14] Another 1 billion gallons of diesel is used annually in

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[12] California Energy Commission. "*California Power Plant Database,*" August 2005. http://www.energy.ca.gov/database/index.html#powerplants. California Energy Commission. California Gross System Power for 2005. http://www.energy.ca.gov/electricity/gross_system_power.html

[13] California Energy Commission. "*California Gross System Power for 2005.*" http://www.energy.ca.gov/electricity/gross_system_power.html

[14] California Energy Commission. Fuels and Transportation Division. Accessed May 2006. http://www.energy.ca.gov/transportation/index.html

applications other than vehicle transportation.[15] In-state petroleum production accounts for 37 percent of consumption.[16]

Biomass is defined by 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."[17] In general, biomass is biologically derived renewable material. Although much of fossil fuel is biologically derived from ancient plants, our rate of current consumption does not classify it as a renewable resource.

Cellulose and hemicellulose are two of the three main structural components of the great bulk of biomass resources. They are polymers of sugars and can be broken down to component sugars for fermentation to ethanol and other valuable fuels and chemicals. Lignin is the third main component of biomass; it can be extracted and used to generate heat and electricity or converted to other chemicals and products. Cellulose, hemicellulose, lignin, and other biomass components can also be processed to fuels and chemicals through thermochemical means, and both biological and thermal processing can be combined in advanced refining processes to produce value-added products and energy.

In California today the three primary sources of biomass for energy are agriculture, forestry, and municipal wastes. Of the 81 million gross tons of biomass produced annually, it is believed to be technically feasible to collect and use about 32 million tons in producing renewable electricity, biofuels, and biobased products. Not quite half the technically feasible supply comes from forestry, with roughly a quarter from each of agriculture and municipal wastes. There is a further potential energy contribution from biogas released by landfills and wastewater treatment plants.[18] Only about 16 percent of the technically feasible biomass resource is currently used.

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[15] U.S. Department of Energy, Energy Information Administration. "*Sales of Distillate Fuel Oil by End Use, 2004, California.*" http://tonto.eia.doe.gov/dnav/pet/pet_cons_821dst_dcu_SCA_a.htm

[16] California Energy Commission. "*California's Major Sources of Energy, 2005.*" http://www.energy.ca.gov/html/energysources.html

[17] California Energy Commission. "*Biomass in California: Challenges, Opportunities, and Potentials for Sustainable Management and Development*." June 2005. Page 1.

[18] California Energy Commission. "*Biomass in California: Challenges, Opportunities, and Potentials for Sustainable Management and Development.*" June 2005. Page 15.

Biomass electricity generated in-state contributes close to 2 percent of California's electricity generating capacity and more than 2 percent of its electrical energy supply.[19] Largely due to the end of Standard Offer #4 Contracts, biomass electricity generation has declined about 20 percent from its peak in 1992.[20]

Table 2.1 indicates the electrical capacity and generation from California's biomass facilities.[21] Biomass fuel used in direct combustion power plants includes forestry material, mill residue, agricultural residue, and urban wood. Urban wood is about 10 percent of this category.[22]

Table 2.1. California Biomass Electricity Capacity and Annual Generation

Type of Facility	Capacity (MW) existing and planned	Generation (GWh) estimated gross annual production
Direct Combustion	602	5,827
Landfill Gas*	305	2,109
Wastewater*	65	480
Animal and Food Waste	3	24

*actual values uncertain due to unknown use of supplemental natural gas and other fuels.

Ethanol from biomass contributes close to 6 percent of California's gasoline supply by volume, and about 4 percent by energy content. Total usage is nearing 1 billion gallons annually.[23] Roughly 25 million gallons is produced in state from corn, cheese whey and reject sugars; perhaps 100 million gallons of capacity is under construction or in

[19] California Energy Commission. "*2005 Gross System Electricity Production*." http://www.energy.ca.gov/electricity/gross_system_power.html

[20] California Energy Commission. "*California Electrical Energy Generation, 1995 to 2004. Total Production, By Resource Type*." http://www.energy.ca.gov/electricity/electricity_generation.html, http://www.energy.ca.gov/electricity/index.html#generation.

[21] California Energy Commission. "*Biomass in California: Challenges, Opportunities, and Potentials for Sustainable Management and Development*." June 2005. Page 35.

[22] California Energy Commission. "*An Assessment of Biomass Power Generation in California: Status and Survey Results*." January 2005, page 31.

[23] California Energy Commission. "*Ethanol as a Transportation Fuel in California*." Accessed May 2006. http://www.energy.ca.gov/ethanol/index.html

development to produce ethanol from imported corn.[24] The bulk of the ethanol is imported from out of state, and will likely be for many years.

Biodiesel derived mostly from soybeans, along with other oil seeds, waste vegetable oil, cooking oil, animal fats and trap grease, is a smaller contributor to California's energy supply. About 4 million gallons per year are being used.[25] This amounts to about 0.1 percent of California's diesel usage. However biodiesel production has been steadily increasing nationwide, and attempts have been made recently in California to enact requirements for biodiesel and other renewable diesel blending in conventional diesel fuels.

Biogas, a fuel gas produced by the biological decomposition of biomass at landfills, wastewater treatment facilities, and increasingly from animal manures, food wastes, and other degradable wastes is a medium-Btu gas usable for heat and electricity generation. Biomethane, renewable natural gas made by purifying biogas, is a transportation resource opportunity that is under development. Currently one landfill in Southern California is using biomethane as a transportation fuel in trucks converted to run on compressed natural gas (CNG).[26]

Currently biofuels make little or no contribution to rail, aviation, or ship transportation, although research efforts are underway targeting these uses.

2.2 *California's commitment to biomass energy*

Many policy initiatives from the governor, the legislature, the California Public Utilities Commission, and the California Energy Commission have recommended or mandated increasing the use of biomass for electricity and biofuels to increase fuel diversity, reduce dependence on petroleum, and reduce greenhouse gas emissions.[27]

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[24] Perez, Pat. Ethanol in California. Presentation for Platts Ethanol Conference, May 2005. http://www.energy.ca.gov/2005publications/CEC-999-2005-014/CEC-999-2005-014.PDF. Communication with Steve Shaffer, June 6, 2006.

[25] California Energy Commission. "*Biodiesel as a Transportation Fuel Factsheet*." Accessed May 2006. http://energy.ca.gov/afvs/vehicle_fact_sheets/biodiesel.html

[26] Sanitation District of Los Angeles County. Puente Hills Gas-to-Energy Facility. Accessed May 2006. http://www.lacsd.org/swaste/Facilities/LFGas/PHGTE.htm

[27] For an extensive policy review see Jenkins B.M. (2005). "*Biomass in California: Challenges, Opportunities, and Potentials for Sustainable Management and Development.*" California Biomass Collaborative, University of California, Davis. CEC PIER Contract 500-01-016. Page 58-74

California's electricity policy is defined in the Energy Action Plan II, a collaborative effort of the California Energy Commission and the California Public Utilities Commission, and in the Energy Commission's 2005 Integrated Energy Policy Report.[28] The Energy Action Plan defines the "loading order," or sequence of priorities, for types of future resource additions. These include not just new physical facilities, but additional *non-use* of electricity, achieved through various measures. Energy efficiency and demand response are the first two preferred types of "additions." Renewable resources are next on the list. Under renewables, a key action in the Energy Action Plan II is to "develop and implement forestry, agriculture, and waste management policies to encourage the generation of electricity from landfills, biomass and biogas."[29] The plan also calls for significant reduction in gasoline and diesel use and increases in the use of alternative fuels.[30]

In 2002 California established its Renewable Portfolio Standard (SB 1078). It requires the state to generate 20 percent of its electricity from renewable resources by 2017. The Energy Action Plan II increased the goal to 20 percent by 2010 and 33 percent by 2020, a goal previously endorsed by Governor Arnold Schwarzenegger in the letter he sent to the California Energy Commission on August 23, 2005 in response to the Integrated Energy Policy Report as required under SB 1389.[31]

The governor's August 23 letter supported the reinvigoration of the Bioenergy Interagency Working Group, led by the California Energy Commission. The Working Group issued Recommendations for a Bioenergy Action Plan in April 2006,[32] listing four main policy goals and a series of action recommendations. In Executive Order S-06-06 the governor endorsed the general thrust of the report and several specific recommendations. In that order, Governor Schwarzenegger established targets for biomass to contribute 20 percent of the goal for renewable electricity generated in the

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[28] California Energy Commission and California Public Utilities Commission, Energy Action Plan II, Implementation Roadmap for Energy Policies, September 2005. California Energy Commission, "*2005 Intergrated Energy Policy Report.*" November 2005.

[29] California Energy Commission and California Public Utilities Commission, "*Energy Action Plan II, Implementation Roadmap for Energy Policies,*" September 2005, page 7.

[30] California Energy Commission and California Public Utilities Commission, "*Energy Action Plan II, Implementation Roadmap for Energy Policies,*" September 2005, page 10.

[31] Governor Arnold Schwarzenegger Press Release August 23, 2005. http://www.governor.ca.gov/state/govsite/gov_htmldisplay.jsp?sFilePath=/govsite/press_release/2005_08/20050823_GAAS37505_EnergyPolicy.html&sCatTitle=Press %20Release

[32] California Biomass Interagency Working Group, "*Recommendations for a Bioenergy Action Plan for California,*" April 2006. http://www.energy.ca.gov/2006publications/CEC-600-2006-004/CEC-600-2006-004-F.PDF

state under the RPS. In the same order he stated that 20 percent of biofuels should come from within California by 2010, 40 percent by 2020, and 75 percent by 2050.[33]

The Western Governor's Association Clean and Diversified Energy Initiative Biomass Task Force concluded that biomass electricity could supply 15,000 MW to the Western states by 2015, and 10,000 MW would be available for 8 cents/kWh or less. It made ten policy recommendations to reach that goal.[34]

By Executive Order S-03-05 Governor Schwarzenegger established greenhouse gas emission reduction targets for California: by 2010, reduce such emissions to 2000 levels; by 2020, reduce emissions to 1990 levels; by 2050, reduce emissions to 80 percent below 1990 levels.[35] The target for reaching 1990 levels has now been codified through AB 32 (2006).

2.3 Biomass benefits for California

Sustainably managed biomass energy resources make a unique and vital contribution to California today and will make an even more important contribution in the future. They will be key to achieving the vision of California in 2050 described in Chapter 3.

Large supplies of renewable energy and biofuels can be produced from ample domestic feedstocks.[36] Biomass resources contribute a variety of feedstocks. Each of these in turn can be used for a variety of renewable energy, renewable fuel, and non-energy products. They can be used to generate baseload and in some cases peaking electricity and heat. They can be used to create liquid and gas transportation fuels. They can be used as a renewable feedstock for hydrogen. They can replace fossil fuels as a feedstock in the production of valuable chemicals, polymers, fertilizers, structural and composite materials, and other products. This varied-use aspect of biomass feedstocks means that the mix of energy and products can be adjusted over time in response to market conditions.

Replacing imported energy with domestic biomass resources enhances the nation's energy security. It stimulates the domestic economy, especially the rural agricultural

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[33] Executive Order S-06-06 by the Governor of the State of California, April, 2006.

[34] Western Governor's Association, Clean and Diversified Energy Initiative, Biomass Task Force Report, January 2006.

[35] Executive Order S-3-05 by the Governor of the State of California, June 2005.

[36] Oak Ridge National Laboratory. "*Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply.*" April 2005.

economy, and helps rural communities near forests and wildlands. The dispersed nature of the feedstock encourages dispersed production facilities--an additional contribution to energy security and rural development, but also leads to increasing costs associated with transportation where capital cost economies of scale favor concentration to increase production capacity.

For forest biomass, the use of residue for the production of energy (electricity or fuels) is now the lowest value product from solid wood or chips. Colocating small (< 5MW) biopower plants with the manufacturing of other forest products (poles, sawn wood, fire wood, posts, and other niche markets), will likely be a viable economic model. In essence, these sites will become biomass market centers. This allows transportation costs to be minimized by locating processing plants close to the supply. If transmission access is opened up, it could also add to the reliability of power supplies to the more remote communities.

Biomass decomposing in landfills produces a methane-rich gas that is both a flammability hazard for nearby houses and other buildings, and a potent greenhouse gas. Requirements to control methane migrating from landfills resulted in the development of landfill-gas collection systems; these evolved from simply flaring the gas to using it for heat and power generation and even vehicle fuel. This has provided operators a new source of revenue from sale of electricity, heat, or fuel gas while reducing methane emissions to the atmosphere.

Biomass energy can be produced sustainably, without increasing greenhouse gas emissions. Substituting biomass for fossil fuels eliminates the greenhouse gases that would have been emitted by combusting the fossil fuels. Biomass is the only renewable resource that can also sequester carbon and restore depleted soils by incorporating plant-derived materials into the ground, although our ability to accomplish this in practice remains uncertain.

Biomass energy production provides a number of other environmental benefits. Purpose-grown biomass energy crops can make marginal croplands more productive. These crops may also perform some soil restoration and improvement, capturing metals and salts and helping to lower water tables in drainage-impaired lands. Where perennial crops are grown there is an addition to the carbon sequestered in the soil with increased root volume and reduced soil erosion. Costly disposal and conventional landfilling of wastes can in many cases be avoided, and any waste that does go to landfills makes an energy contribution when the biogas generated there is put to use.

Landfills, wastewater treatment plants, and anaerobic waste lagoons produce methane, a greenhouse gas. Collecting these gases and using them to generate energy reduces emissions, which would otherwise enter the environment. Sustainably managed bioenergy production can contribute to improved forest health and watershed protection, along with the reduced risk of dangerous, polluting, and costly catastrophic forest fires.

2.4 Obstacles to the increased utilization of biomass

As noted earlier, despite its benefits, increased use of biomass for energy in California faces a number of obstacles.

Currently most bioenergy products are more expensive than the fossil fuels they replace. Even where biofuels now have an economic advantage due to the rapid escalation in the cost of petroleum, the potential for external control of petroleum prices leads to longer term uncertainties for investors in new biomass facilities. Many biomass resources are dispersed or seasonal, or both. For dispersed feedstocks such as forestry residues, the cost of collection and transportation is a major impediment. These costs limit the economies obtained with increasing scale of conversion facilities. While some biomass resources such as municipal solid waste and landfill gas are available year-round, others like crop and food processing residues are seasonal. Seasonality incurs storage costs or plant downtime, or the expense of using alternative feedstocks. However, bioenergy products are becoming more competitive as petroleum and natural gas prices rise.

Bioenergy would likely be less expensive than fossil fuels if energy users had to pay the short- and long-term costs of air and water pollution and greenhouse gas emissions that result from the use of fossil fuels. It would also be less expensive if the environmental benefits of bioenergy products were reflected in the price. If external costs and benefits were properly allocated and priced, bioenergy use would likely expand dramatically. Some estimates of the external value of bio-based energy reach as high as 11 cents per kWh (Morris, 1998),[37] other estimates are in the range of 5 to 6 cents per kWh.[38] Additional research and analysis is needed to provide a more concrete number.

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[37] Morris, G. (1999). "*Value of the Benefits of U.S. Biomass Power.*" Subcontract Report. NREL SR-570-27541. http://www.nrel.gov/docs/fy00osti/27541.pdf

[38] Williams, R.B. (2006). "*Environmental Issues for Biomass Development in California-Draft.*" California Biomass Collaborative. University of California, Davis. CEC PIER Contract 500-01-016.

There are significant institutional barriers to the use of distributed electrical generation. The transmission grid and transmission policies were not designed to facilitate distributed generation or smaller generators. Gaining access to the grid is expensive and time consuming for biomass projects, even the largest of which are small compared to central station power plants, and the financial benefits are often too low to encourage this generation. And in common with other energy projects, the permitting process for biomass energy plants is complex, time-consuming and expensive.

Further, the public has had a negative perception toward some bioenergy plants. Combustion of biomass has been seen as a source of air pollution and combustion of municipal solid waste as an environmental hazard. Such perceptions reduce public support for policies that would encourage biomass electricity generation. On the other hand, public perception of biofuels such as ethanol and biodiesel is largely positive, even given continuing debates regarding the energy benefits of corn-based enthanol production.

In lieu of full costing of environmental harms and benefits, the government has set in place various policies and incentives to encourage renewable energy. Unfortunately the policies change periodically and the incentive programs are not always funded. This uncertainty causes investors to demand a higher risk premium that often makes it hard to raise the capital to get projects built.

Another obstacle to increased use of biomass is that there is a limited infrastructure for the use of some biomass-based alternative transportation fuels. Ethanol can be used as an additive to gasoline to a level of 10 percent in existing vehicles and gas pumps. The use of a more concentrated formulation (E85) requires pumps devoted to it, and flexible-fuel vehicles to run it. Engine conversions may also be required when biodiesel is added to petroleum diesel in concentrations higher than about 20 percent (B20). Biomethane will work only in vehicles designed to run on compressed natural gas (CNG) or liquefied natural gas (LNG), and requires a CNG or LNG fueling station, which is entirely different from a liquid fuel station. The distribution infrastructure for hydrogen is an even larger challenge.

A recent study indicates that the presence of ethanol in fuel blends has been found to reduce the decomposition rate and increase the persistence of petroleum-derived compounds in contaminated soils[39].

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[39]Mackay et al. (2006). "*Impact of Ethanol on Natural Attenuation of Benzene, Toluene, and o-Xylene in a Normally Sulfate-reducing Aquifer*", Environmental Science and Technology article 10.1021 09/01/06

Finally, there are concerns about some air pollutants for some of the alternative transportation fuels made from biomass. According to the California Air Resources Board, the presence of ethanol in low concentrations blended with gasoline can increase hydrocarbon emissions. It also may cause higher nitrogen oxide (NOx) emissions.[40] Biodiesel use brings major reductions in volatile organic compounds (VOC), an ozone precursor, particulate matter (PM), and carbon monoxide (CO). Whether biodiesel results in higher NOx emissions is still unresolved. In contrast to previous evaluations showing a slight increase in NOx emissions with biodiesel compared to conventional diesel fuel, more recent tests with newer vehicle models suggest no net increase in NOx. Variability in feedstocks used in the production of biodiesel can also yield varying test results. The National Renewable Energy Lab[41] in conjunction with the Air Resources Board are currently conducting joint and independent studies to investigate this issue further.

[40] California Air Resources Board, "*A Summary of the Staff's Assessment Regarding the Effect of Ethanol in California Gasoline on Emissions*", Draft Report, February 2005. Page 1. http://www.arb.ca.gov/fuels/gasoline/meeting/2005/030105etohrpt.pdf

[41] http://www.nrel.gov/docs/fy06osti/39538.pdf#search= percent22NREL percent20Biodiesel percent22 http://www1.eere.energy.gov/vehiclesandfuels/resources/proceedings/index.html

3 A SCENARIO FOR CALIFORNIA'S FUTURE

What will California be like in 2050? The sections that follow offer projections and predictions. But it is important to remember that positive statements – "California's strong environmental ethic will continue in mid-century," for example – however likely they may seem, are still only predictions.

3.1 A Vision for California in 2050—Society

In a demographic study required by Assembly Bill 910, the University of California Berkeley Center for the Economics and Demography of Aging says that the most likely state population is 52 million by 2050. Noting that population growth is related to the state of the economy, the study forecasts replacement-level birth rates and moderate domestic emigration, with population growth driven by international immigration.[42] The highest rates of population growth will be in Southern California's Inland Empire and, especially, in the Central Valley.

The predicted population growth is based on the assumption that California will continue to have a strong economy. Housing prices and land values will remain high. Service jobs will continue to replace manufacturing jobs.[43] Agriculture will continue to be vital, though it will be a smaller share of the economy than it is today. Some acreage currently devoted to farming will be sold to developers and given over to housing. This economic growth will increase the demand for and cost of energy services. Demand for residential fresh water will grow, while agricultural demand may decrease due to less acreage under irrigation. A predicted decline in snowpack will reduce supply and increase the cost of water transportation and storage. Higher prices will encourage recycling and much more efficient use of fresh water.[44]

Population growth will produce problems relevant to biomass policy. As farmland and water become more expensive, farmers will grow only the most profitable crops. More

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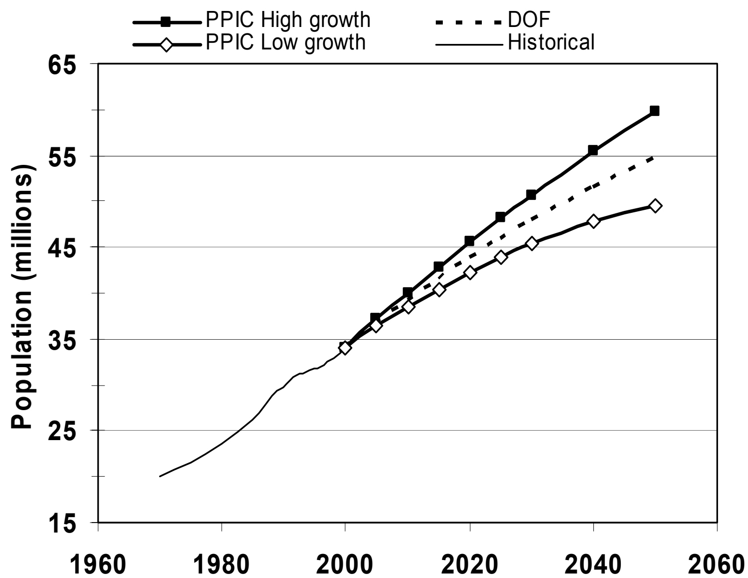
[42] Lee, Ronald, Timothy Miller and Ryan Edwards. "*Special Report: The Growth and Aging of California's Population: Demographic and Fiscal Projections, Characteristics and Service Needs.*" UCB Center for the Economics and Demography of Aging, 2003.
http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1006&context=iber/ceda

[43] Public Policy Institute of California, "*Californians 2025: Taking on the Future.*" Page 80.
http://www.ppic.org/content/pubs/report/R_605MB2R.pdf

[44] Pacific Institute. "*California Water 2030: An Efficient Future.*" September 2005.
http://www.pacinst.org/reports/california_water_2030/ca_water_2030.pdf

homeowners will find themselves living near or next to farms, increasing pressure on farmers to mitigate odors, flies, dust, noise and other nuisances. More homeowners will live closer to forests, increasing the costs of suppressing many forest fires.



By 2050, California population is estimated to be between 48 and 60 million people. The rate of increase is predicted to decrease from the current 1.4 percent per year to about 0.6 percent per year.

PPIC = Public Policy Institute of California
DOF= California Department of Finance

Figure 3.1 California population projections .[45, 46]

Assuming California's strong environmental ethic continues in mid-century, the resulting political pressure will require more stringent regulation, making the state's environmental regulations stronger and more effective than today, taking all media impacts into account and possibly necessitating sensible tradeoffs among media.

Economics of environmental management will be dramatically different. By 2050 public policy will require producers to incorporate the costs and benefits of environmental externalities into the pricing of all products. Policies relating to greenhouse gas emissions and other international issues will be more commonly agreed upon. Greater competition for dwindling supplies of petroleum and natural gas resources will strengthen public support for domestic renewable energy solutions.

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[45] State of California, Department of Finance, "*Population Projections by Race/Ethnicity, Gender and Age for California and Its Counties 2000-2050,*" Sacramento, California, May 2004. http://www.dof.ca.gov/HTML/DEMOGRAP/whatsnew.asp

[46] Hanak, E. & Baldassare, M. (2005). "*California 2025 - Taking on the future.*" Public Policy Institute of California. http://www.ppic.org/content/pubs/report/R_605MB1R.pdf

Material disposal costs will increase, and improved technologies and policies will reduce packaging, improve material separation, increase reuse and recycling, and convert more organic materials to useful products and energy rather than going to disposal. When wastes are disposed they will be pre-treated or better contained in bioreactor landfills, landfills designed to recover a larger percentage of the energy in biomass while protecting the environment from releases of harmful gases or leachates.

Despite efforts in the intervening years to mitigate them, the problems caused by climate change are likely to become more apparent. Higher temperatures, rising sea levels, shifting vegetative land cover, and more erratic and extreme weather patterns will be among the most significant.[47] The social disruption and expenses that result will prompt increasing efforts to slow, mitigate or even reverse the accumulation of greenhouse gases in the atmosphere.

3.2 California in 2050—energy and fuel

With a growing population, a robust economy, technological development, and increasing demand for residential fresh water, especially in the south of the state, the demand for electricity and heat will be much higher than today. This will be partially offset as more energy services are provided per unit of energy consumed, due directly to higher energy efficiency and indirectly to higher prices.

Continued high energy prices, declining supplies of fossil fuels, and potential carbon-control policies will produce dramatically higher end-use energy efficiency in all applications, allowing energy services to grow faster than energy demand. Demand growth will be further moderated as energy-intensive manufacturing jobs decline as a proportion of the state's economy, and less energy-intensive service jobs increase.[48]

In this vision, public policy in 2050 will make the costs of environmental externalities part of the price of energy, particularly energy derived from fossil fuels, increasing the price of all energy, especially from fossil sources, while reducing their use and increasing the use of clean renewable electricity and fuels.

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[47] Hayhoe, K. Dan Cayan, et. al. "*Emissions pathways, climate change, and impacts on California.*" Proc. Natl Acad Sci, USA. 2004 Aug 24;101(34):12422-7. Epub 2004 Aug 16.

[48] Public Policy Institute of California, "*Californians 2025: Taking on the Future.*" Page 80. http://www.ppic.org/content/pubs/report/R_605MB2R.pdf

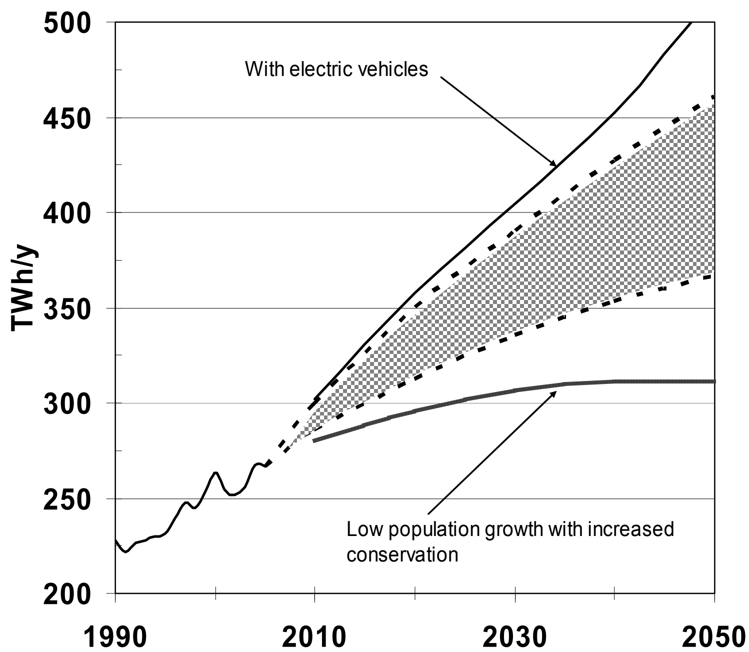
Demand-response technologies and time-of-use pricing will smooth electrical demand and reduce the premium earned by peak electricity generation.

Renewable energy from biomass, wind, solar, the oceans and tides, geothermal, and perhaps other sources will provide a much larger proportion of the energy mix. In response to concerns for energy security, a larger proportion of energy will be produced domestically, and generation facilities will be smaller and more dispersed, with greater integration of mobile power sources and stationary demand.

North America's conventional supplies of natural gas are predicted to decline and natural gas will be more expensive. New sources of methane will be developed, but they will be more expensive and will require extensive efforts to prevent environmental degradation. LNG imports will replace some North American gas, but will be limited by environmental and security concerns, and competition from other buyers. Unless there are significant technical improvements nuclear energy will continue to be limited by public opposition and limited options for waste handling and disposal. Coal with carbon capture and storage will be more important, not necessarily within California but for electricity and possibly coal-derived fuels imported from outside the state.

Improved conversion technologies will increase the energy generation efficiency. Energy yields will also rise due to an increasing focus on combined heat and power applications.

Energy conversion in 2050 will have a much lower environmental footprint. Facilities will be sited in and out of state according to principles of environmental justice. Better technologies to control emissions and effluents will reduce air emissions and water pollution.

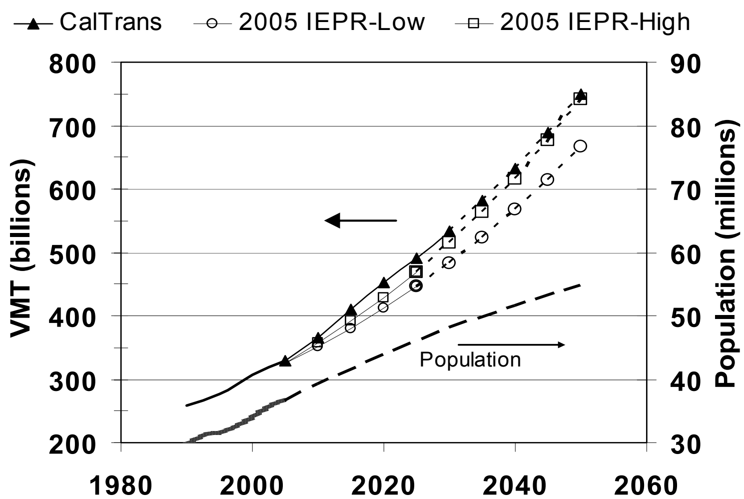


Projected electricity demand combines the high and low per capita demand from the September 2005 CEC Staff Energy Demand Forecast (7400 to 7700 kWh per person per year) with the high and low population scenarios developed by the PPIC. These assumptions predict electricity demand by 2050 to be between 365 and 460 TWhr/year (an increase of 27 to 60 percent in demand compared to 2005).

In addition, the effect of a successful plug-in-hybrid vehicle (PHEV) market is modeled using simple assumptions on use and grid energy requirement per vehicle. Fifteen million PHEVs by 2050 could add another 12 percent - 15 percent to state electricity demand.

Low population growth and decreasing per capita usage by 15 percent by 2050 could result in 311 THh/y total demand in 2050.

Figure 3.2. Projected electricity demand for California including a hypothetical plug-in hybrid vehicle scenario. [49,50]



Total vehicle miles traveled (VMT) on state roads is about 330 billion. VMT has been increasing roughly at the same rate as population for the past 15 years. CalTrans as well as the Energy Commission predict VMT increases that are higher than population growth rate. VMT on California roads is predicted to increase 60 percent by 2030 (to more than 500 billion miles). Extrapolating to 2050, VMT could be as high as 700 billion miles, more than twice what it is today.

Figure 3.3. Vehicle miles traveled (VMT) and population [51 52]

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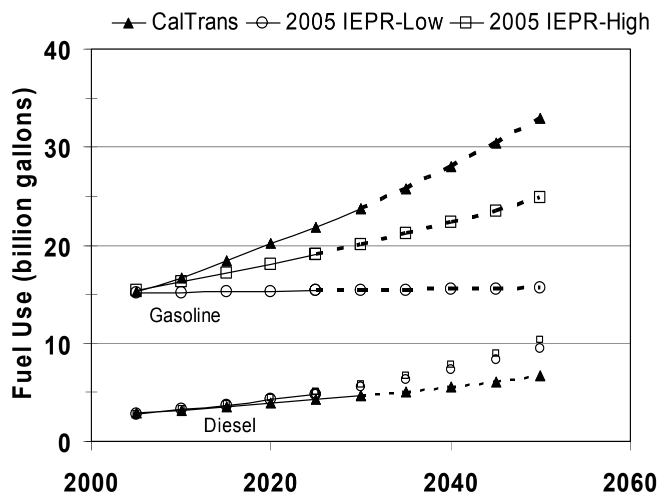
[49] California Energy Commission (2005). "*California energy demand 2006 – 2016.*" Staff energy demand forecast, September revision. Accessed at: http://www.energy.ca.gov/2005publications/CEC-400-2005-034/CEC-400-2005-034-SF-ED2.PDF

[50] "*2005 Gross System Power*" was 288 TWh. See http://www.energy.ca.gov/electricity/gross_system_power.html



Gasoline usage in California is nearly 16 billion gallons per year. CalTrans estimates gasoline usage to grow to 24 billion gallons/year by 2025. The CEC forecasts gasoline usage will be between 15.5 and 19 billion gallons by 2025 (the low estimate assumes strong greenhouse gas regulations in effect). Extrapolating to 2050, gasoline usage could be between 16 and 33 billion gallons/year.

California uses about 3 billion gallons/year of diesel. The CalTrans and CEC diesel forecasts are similar (4-5 billion gallons/year by 2025). Extrapolating to 2050, diesel usage could be between 6 and 10 billion gallons/year.

Jet fuel usage and forecast amounts in California are similar to diesel.

Figure 3.4. Petroleum fuel usage projections [53] [54].
Note: Dashed lines are extrapolations beyond reference study time scales.

A robust and reliable transmission system will be designed to fully utilize renewable resources. No significant resource will be stranded or bottlenecked because of limitations in the transmission system, although ways will need to be found to reduce land-use and other impacts. Security needs will also be important in the design of the transmission system.

Regulation and market structure will encourage the use of renewable energy resources and distributed generation. Interconnection rules will facilitate the use of distributed generation.

The growing population and strong economy will produce an increased demand for transportation, even as declining supplies and higher costs make current transportation modes much more expensive.[55] Urban population densities will be higher and public

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[51] CalTrans Forecast (2005 MVSTAFF)
http://www.dot.ca.gov/hq/tsip/otfa/mtab/MVSTAFF/MVSTAFF05.pdf

[52] California Energy Commission (2005). "*Forecasts of California Transportation Energy Demand," 2005-2025.*" IEPR 2005 Support Document. http://energy.ca.gov/2005publications/CEC-600-2005-008/CEC-600-2005-008.PDF

[53] CalTrans (2005). op. cit.

[54]California Energy Commission (2005). op. cit.

[55] Hirsch, Robert L., "*Peaking of World Oil Production: Impacts, Mitigation, and Risk Management.*" February 2005.

transportation will be more available. Fuel efficiency will increase in all forms of transportation (e.g. automotive, rail, aviation, and ships).

There will be a wider choice of transportation fuels and technologies, including hybrid technologies. These choices will include electricity, liquid fuels made from coal with carbon sequestration and storage, and renewable fuels such as ethanol from cellulosic feedstocks, biodiesel from esterified oils and other bio-oils, Fischer-Tropsch gasolines and diesel fuels, biomethane, and hydrogen. Transportation technologies will be cleaner.

3.3 Biomass in California in 2050

3.3.1 General factors affecting biomass supply

If this vision comes to pass, biomass resources will contribute substantially to California's energy supply for electricity, heat and transportation fuel. Agriculture, including dedicated energy crops, forestry, urban waste, and aquatic biomass will be used. Transforming technologies in plant and synthetic biology and nanoengineering will produce many new technologies that will enhance the production and use of bioenergy.[56]

By 2050 population growth in the Central Valley will reduce farming acreage by about 15 percent[57] although more remote farming areas may not see this reduction. Impacts from climate change will affect crops and yields. Farm income will be maintained by more intensive agriculture and new agricultural practices. Higher prices for water will increase the cost of irrigation, potentially driving further improvements in efficiency of use. Under current conventional agricultural approaches, these factors would combine to make bioenergy crops less attractive, but in the future practices will change, and these crops will earn far higher returns than they do now.

Biomass crops will increasingly be used for remediation of degraded or impaired lands. This and higher costs for energy will expand opportunities to increase supplies of biomass through drought- and salt-tolerant species and other low-input crops that can stabilize soils and reduce the costs of production.

Sustainable forest management will help preserve the forest ecosystem and keep the watershed healthy. Forest biomass collection will reduce the risk of catastrophic forest

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[56] Lawrence Berkeley National Laboratory, "*Future Energy Sources, Helios, a New Proposal for Solar Energy Research*", website accessed May 2006. http://www.lbl.gov/pbd/energy/research.html
[57] Teitz, Michael, Charles Dietzel, and William Fulton. "*Urban Development Futures in the San Joaquin Valley.*". Public Policy Institute of California, 2005. Page ix. http://www.ppic.org/content/pubs/report/R_205MTR.pdf

fires and the collected material will be used for energy and products. Biomass from forest sources will help replace some of the expected losses of biomass crop production from agricultural lands. More use of distributed generation in rural communities will reduce gathering and transportation costs of forest residue and increase its use in energy production. The cost of harvesting and gathering forest biomass will decrease as advances are made in necessary equipment. As the average forest age class increases and the average annual growth increases, the harvest of traditional sawlogs will grow. The increased timber harvest will in turn result in a greater amount of forest mill residue as a source of biomass.

Economics will of course continue to affect the production of biomass. Farmers will grow crops that are most profitable. In response to full environmental cost pricing of energy for users, biomass energy will become more cost competitive. This will have the effect of increasing the production of biomass energy crops and crop residues. The risk will be that biomass energy resources become so valuable that crop shifting will raise the price of food, feed, and fiber.

Environmental regulation and urban/rural interface pressures should improve the economics of biomass. This will happen as an indirect result of requiring farmers to manage their crop residues and animal waste in an environmentally responsible way. Farmers unable to use residues, or dispose of them on site, will have to remove them from the farm. If the farmer pays to haul them to a biomass energy generator, it will substantially reduce the cost of collecting this energy resource.

Many biomass resources can be used as feedstocks for a variety energy products, so market forces and technological development will determine the mix of end products, and they may be quite different from the mix predicted below.

The public will have a better understanding of the benefits of bioenergy, and this will lead to public policies that promote a larger supply of biomass resources for energy, more research and development funding, and the adoption of new technologies.

3.3.2 Biomass for renewable electricity and heat

Research and technological innovation will lead to higher electrical conversion efficiencies and lower generation costs with biomass. After 2025, advances in plant biology and biotechnology will produce new energy products with substantial benefits.

Tipping fees, emission reduction credits, carbon credits or charges, environmental regulations, and other policies that charge the user for the environmental costs of energy will make biomass electricity economically competitive with other energy sources

Open-field burning will be heavily restricted or no longer allowed. All appropriate agricultural and food-processing residues will either be processed on site or separated, collected and transported to be used as energy resources and other useful products. This will eliminate not only the need for open burning but also the need for landfilling.

If proper policies are enacted and markets permit, municipal solid waste will be source-separated to maximize energy production and drastically reduce the material that will be landfilled. By 2050 most products will be designed to be reused and per-capita waste generation will decline. Recyclable elements will be collected and reused. Organic waste will be used through a variety of processes for energy or to produce valuable products such as fertilizers and organic soil amendments.

3.3.3 Biomass for renewable transportation fuel

By 2050 all forms of transport will be much more fuel-efficient. Vehicles, ships, trains, and aircraft will be fueled by a variety of products using combustion engines, fuel cells, and other prime movers. Fuels will include gasoline, diesel, ethanol, biodiesel, Fischer Tropsch liquids, natural gas, biomethane, electricity, and hydrogen. A new distribution infrastructure and a network of fueling stations will be in place to dispense these new fuels. A much more extensive public transportation system, more efficient vehicles and transport-use patterns will all contribute to reductions in the transportation energy intensity (energy/ person-miles).

Biomass, including imported resources, will contribute increasing amounts of liquid transportation fuel. There is significant potential for use of biomass feedstocks if biofuels facilities are located near where the biomass is already gathered, such as in a landfill or a municipal recycling facility. Forestry and agricultural residues are also large sources of cellulosic biomass. These include plant stalks, leaves, husks, and straw in addition to starch grains and oil seeds. In the longer term, the biomass industry could support dedicated energy crops specifically grown for energy use, such as switchgrass, poplars, willow, with research conducted over the near term to determine preferred crops. Sustainable yields will increase with improved and new varieties.

In 2025 cellulosic biofuels, including ethanol produced from biomass grown on marginal cropland, will be an important source and perhaps the largest source of renewable transportation fuel. Bioengineering advances will decrease production costs and increase energy yield. Biodiesel from purpose-grown crops and from food processing waste will be another major fuel, substituting for diesel. Biomethane from the anaerobic decomposition of organic wastes may be another fuel. After 2025 renewable hydrogen from biomass can make a major contribution to transportation fuel and might supplant ethanol as the largest contributor by 2050.

3.3.4 Biomass for bioproducts

Technologically advanced biorefineries will produce valuable chemicals and polymers that were previously produced from petroleum, coal, and natural gas. Advances in bioengineering will revolutionize these processes.

Compost and soil amendments produced as byproducts of anaerobic digestion and other bioconversion processes, along with bioengineered products, will replace fertilizer produced from natural gas.

In rural communities near forests and wildlands there will be an increase in the number of wood marketing centers. Small trees harvested from fuel-hazard-reduction projects will be sent to these centers, sorted and used to produce the highest value-added products. If energy purchase commands a higher value, a greater percentage of this material will be used for the production of energy.

Residues from food and fiber production not used for energy generation will be used in other applications and products. Together, product and energy markets will provide stable, economic outlets for the great diversity of biomass produced in the state.

4 GOALS AND OBJECTIVES

4.1 *Goal 1 Increase sustainable production and improve acquisition of biomass*

We need to enhance our understanding of the direct and indirect impacts of growing and harvesting biomass on the state's air, water, soils, and ecosystems. Balancing competing land uses is critical to the overall sustainability of biomass systems. In agricultural applications, soil quality, erosion, nitrogen and other nutrient demand, plant uptake rates, and fertilizer use and characteristics must all be analyzed to determine what production rate is sustainable for any given crop. Soil amendments must minimize phosphorus, other salts, and nitrogen transport from the field to surface and ground waters and greenhouse gases to the atmosphere. In forests, sustainable rates of removal must balance harvest levels against the limitations of biomass growth while maintaining a balanced age structure. In addition, the impact on wildlife habitat and surface and ground water movement must be considered.

Better techniques must be developed for removing biomass from the point of generation, processing it into a useful feedstock, transporting it to an end-use, and producing useful energy or commodities - ones that are financially viable in the long term to drive down costs.

Objective 1. Develop sustainable and cost effective growing, harvesting, collection, and processing techniques including new crops and cropping systems

Current techniques of planting, irrigating and harvesting agricultural crops must be evaluated as to their energy demands, environmental impacts and economics and, where necessary, improved so as to become sustainable. Impacts on air, water, and soil quality from fertilizer use, equipment emissions, and other factors must be assessed and, where necessary, mitigated. Conservation tillage, cover crops, and other low-impact practices can improve agronomic sustainability. Biomass residues can be processed into soil amendments such as mulch or compost as a substitute for petroleum-based fertilizers. Collection, transport and processing infrastructure and increased storage capacity must be developed that are also economically viable. Establishing cooperative commodity agreements could support regional and interstate distribution of feedstocks. Use of remote sensing including satellite imagery, aerial photography, ground-based systems, and ground-truthing could establish a near real-time land-use inventory for surface crops, residues, and forest extent.

Objective 2. Evaluate competing land uses for food or fuel crops

As California grows, competition for resources will increase. Land suitable for agriculture is increasingly being lost to urbanization, making demands on the remaining farmland ever greater. To determine appropriate crops for farmland, the interactions of soils, crops, climate, and water must be studied. The competing needs for food, fuels and fiber production must be evaluated to determine best crops.

Objective 3. Accommodate seasonality of production

Agricultural production is seasonal and a source of liquid and solid residues and food-processing wastes; dedicated crops are also seasonal in nature. Any biomass system must be able to handle these seasonal surges in supply, either by handling multiple feedstocks or through expanded processing and storage capacity. Storage sites must meet a number of criteria including control of leachate, odors, regulated air and water emissions, and fire prevention. In some cases, storage can be on the same site as the source of the feedstock. In others, the economics demand volumes that can only be achieved by combining the feedstock from a number of nearby sources. Density of feedstock is important both for handling throughout the system as well as in storage. Costs of handling, storage, and conversion interact in ways that lead to optimal scales of use.

Objective 4. Remediate contaminated or impaired soils by growing biomass

Dedicated biomass crops offer one of the best opportunities to help remediate contaminated lands and provide needed economic relief to farmers and local communities. Biomass crops can help control water tables, serving as biological pumps to reduce waterlogging of soils, and to help filter nutrients, heavy metals, and other contaminants from ground and surface waters.

Objective 5 Increase separation of biomass from the urban waste stream

Creating a clean feedstock of material currently disposed in landfills can be accomplished through separation of materials either at the point of generation or by improved processing techniques for mixed materials. Source-separation will result in higher quality feedstocks. Waste wood, cardboard and tree removals from construction sites; packing material such as waxed or otherwise contaminated cardboard and wood pallets and boxes; and tree trimmings and yard wastes can be source-separated for use in conversion technologies.

4.2 Goal 2. Increase production of biopower, heat, and cooling

Using biomass sustainably to produce energy in any of its many forms can improve California's environment and economic health. Such use can be achieved in many ways: by increasingly substituting biomass for fossil fuels in electricity generation, process heat applications, and in transportation; capturing digester gas from sewage treatment plants and other digesters where such practice is not already employed for raising heat used in treating wastewater and manures; and by increasing the conversion of the organic fraction of municipal solid waste to electricity, fuel, soil amendments, and other products. These are already being done, but much more is possible; they can be carried out profitably while protecting the environment and reducing the generation of greenhouse gases.

Objective 1. Expand electricity generating capacity from biomass

Technologies that can produce electricity from biomass are in various stages of development or commercialization. Expanding capacity to help meet the Renewable Portfolio Standard (RPS) and other targets will require eventual upgrading or repowering existing units and deploying more advanced technologies to meet environmental requirements.

Use of biomass in the generation of electricity can be carbon-neutral. The growing biomass takes up the CO_2 that is released to the atmosphere when it or products derived from it is burned. Use of biomass displaces the burning of fossil fuels and the emission of CO_2 from carbon stored underground for millions of years. Burning biomass also prevents the release of other greenhouse gases such as the methane released during the uncontrolled anaerobic decomposition of organic waste, providing opportunities for biomass conversion to be a net negative greenhouse gas emitter.

Objective 2. Generate useful heat from biomass

Biomass fuels can also be used to generate heat for thermal applications in industrial boilers or for commercial or district heating. Solid biomass fuels, liquids, or gases derived from biomass may all be combusted.

Objective 3. Increase the use of Combined Cooling, Heat and Power Systems

Significant improvement in efficiencies can be achieved by installing systems that generate both useful power and heat (combined heat and power – CHP). Where there is a need for cooling, heat energy can be used to drive the cooling cycle. The increased efficiencies reduce both fuel input and overall greenhouse gas emissions compared to separate systems for power and heat, and also realize improved economics for power generation where expensive natural gas and other fuels are displaced.

Objective 4. Improve and expand the use of distributed generation (DG) technology

Many applications exist for smaller, distributed generating equipment. Only limited development of commercially successful systems has occurred to date, and expanded research and development is needed.

4.3 Goal 3. Increase production and improve environmental performance of renewable biofuels

Biomass feedstocks can be converted to liquid or gaseous transportation fuels, displacing petroleum, natural gas, and other fossil fuels. The biomass can be either residue from primary production of food, feed, or fiber or from purpose-grown energy crops such as grain corn, switchgrass, cereals, oil seed crops, sugar cane, sweet sorghum, other high yielding grasses, sugar beets, and numerous other crops. Some of these can be grown on marginal cropland and can be used to remediate high-salinity soils, although much further research is needed to identify suitable crops for California.

Objective 1. Establish and expand long-term markets for renewable transportation fuels

Adopting a state renewable fuels standard, developing greater flexibility in regulations, and expanding the fueling infrastructure can all help to improve market access for biofuels. To stimulate markets, government purchase programs should be expanded for biofuels and biofuel-capable vehicles.

Objective 2. Encourage investment in renewable fuel production facilities

Investments in biofuel production can be stimulated in a number of ways including loan guarantees and public-private partnerships to demonstrate commercial readiness.

Objective 3. Increase production of ethanol and other gasoline substitutes

Demonstrate and continue to develop technologies that advance ethanol production and reduce costs of production from lignocellulose. Distribution and fueling infrastructure for E85 and other alcohols will need to be created. Government fuel and vehicle purchase programs for state agency fleets could provide ready markets for biofuels. Loan guarantees, insurance premiums, guaranteed payment supports, and development grants can all accelerate development.

Objective 4. Increase production of biodiesel and other renewable diesels from biomass

Develop distribution and fueling infrastructure for biodiesels, establish or expand biorefinery capacity, encourage lipid-ester deployment, evaluate direct addition of lipids to current oil-refining operations, and develop FT and other renewable diesels and jet fuels and new synthesis techniques.

Objective 5. Increase production and use of biogas and biomethane

Biogas, a mixture primarily of methane and carbon dioxide, is produced from the decomposition of biomass through anaerobic digestion, a natural bacteriological process that breaks down organic material in an oxygen-free environment. Biogas is now used to generate electricity, with superior performance and reduced emissions when gas treatment is performed to reduce contaminants, especially sulfur. By removing hydrogen sulfide, moisture, carbon dioxide, and other contaminants biogas is upgraded to biomethane, a product equivalent to natural gas which typically contains more than 95 percent methane. The process can be controlled to produce biomethane that meets a pre-determined standard of quality and can be introduced into natural gas pipelines for distribution. Biomethane can also be handled as compressed natural gas (CNG) and liquefied natural gas (LNG). Extending alternative fuel incentives to include biomethane can increase its use in California.

Objective 6. Develop hydrogen production systems

Hydrogen is a clean-burning fuel currently produced in small amounts from mostly hydrocarbon sources such as natural gas. Biomass has the potential to accelerate the realization of hydrogen as a major fuel of the future. Hydrogen can be produced from biomass by thermochemical, biochemical, and direct biological means as well as by use of biomass derived electricity for electrolysis.

4.4 Goal 4. Increase production of bio-based products

A variety of chemicals including lubricants, adhesives, solvents, and polymers, as well as construction and other materials can be produced from biomass. Integrated biorefineries are being developed to produce a number of value-added products and energy from single or multiple feedstocks. Biomass can also be used to displace petroleum, natural gas, and coal as manufacturing feedstocks. The economics of bioenergy conversion may often depend on developing bio-based co-products.

Objective 1. Increase production of chemicals from biomass

Development and demonstration of biorefineries can provide multiple bio-based products in addition to biofuels and power. Future biorefineries can be based on biochemical or thermochemical technologies, or both in combination.

Objective 2. Produce more construction products, composites, packaging materials, textiles, absorbents and other green products

Already commercial products made by converting biomass include lubricants such as castor oil; solvents such as tetrahydrofuran or THF from corn byproducts; polymers and plastics (polylactic acid or PLA from corn or soy); soaps and cosmetics (jojoba, aloe); and others. The state can also build on existing or establish new enterprise zones co-locating bio-based energy and manufacturing facilities, including biorefineries.

4.5 Goal 5. Improve knowledge and disseminate information

Much greater research effort will be needed as California develops and implements biomass technologies to reduce reliance on petroleum and other fossil fuels. Consistent, coordinated and focused research, education, training and public outreach are required to expand sustainable use of biomass in California.

Objective 1. Support innovative research to advance science, refine existing approaches, and develop new technologies

Research will need to be directed at developing biomass to power systems that have higher efficiency with lower environmental emissions and impacts. Integrated gasifier combined cycle (IGCC) systems for solid biomass fuels, for example, will have efficiencies that are 40 to 100 percent better than the current fleet of biomass power plants. IGCC systems fueled by biomass are still developmental but have been demonstrated in Europe.

Biomass-to-liquid (BTL) fuel systems based on gasification followed by catalytic synthesis and similar techniques have theoretically high yields and very low life-cycle carbon emissions. Such facilities might be integrated into California's existing refinery infrastructure or into advanced biorefinery operations.

Cellulase enzymes are being developed worldwide to decrease cost and increase yields of alcohol fuels from lignocellulosic biomass. This work needs to continue with an emphasis on enzymes or sets of enzymes that can function on the range of feedstocks available in California (e.g., forest and orchard woody material, rice and wheat straw, waste paper and urban wood waste as well as purpose grown crops).

Cropping systems for sustainable production of energy crops in California will also need to be developed. This includes investigating the potential of marginal and impaired lands for use in energy-crop cultivation.

Plant breeding and genomics for improved yields or enhanced characteristics can lead to lower impacts and costs in the fuel-crop-to-product life-cycle and provide for novel products with high potential value. Research is needed to enhance plant expression of valuable chemicals, fuel compounds, and cell-wall modifying proteins which reduce downstream processing requirements.

Full life-cycle analyses (LCA) of biomass resources through product utilization are needed for California-produced as well as imported bio-products. Net environmental impacts (including life-cycle carbon emissions) are dependent upon feedstock type and the production and conversion process. As California is among the leading states in the US with respect to greenhouse gas accounting and policy, including recent legislation such as AB 1007 and AB 32, a full understanding of bioenergy and bioproduct LCA is necessary in order to properly value biomass benefits and to inform public policy. Substantially more data will be needed to fully characterize performance of many new approaches. Development is also needed for new and bio-engineered crops to produce fuel, food, and fiber with less water, fertilizer, and other inputs.

Objective 2. Establish dedicated renewable energy and biomass research and development center(s) of excellence

Establishing biomass research centers would foster development of innovative technologies and lead to greater understanding of environmental consequences and development of mitigation measures where needed. Biomass centers located at universities can train engineers, scientists, and other professionals to meet the needs of an expanding bioenergy and biotechnology industry. These "centers of excellence" will develop and maintain deep institutional knowledge and can contribute to public outreach through conferences, workshops, certificate training programs, and speaker bureaus. Centers can also be proving grounds where technologies and ideas from elsewhere are evaluated and demonstrated.

Objective 3. Support research and demonstration projects outside of dedicated centers

Whether or not biomass research centers with technology demonstration facilities are created, there will always be a need to support research, demonstrations, and pre-commercial pilot facilities. To move forward with new ideas and technologies, some form of public financial support is almost always necessary because of the high financial risk, and, in some cases, potential environmental risk associated with new technologies.

Objective 4. Educate and inform the public and decision makers on the need for, and value of, biomass systems and their role in providing sustainable energy and products

Ensuring good institutional knowledge on newly developing technologies and approaches to managing biomass increases the need for and the value of educational outreach to decision makers. With rising energy costs and heightened public awareness of climate change and other issues, there is an increasing need to educate the public on the value and capabilities of biomass systems, how bioenergy fits in a carbon constrained world, and the choices that will be available to the public.

Objective 5. Provide industry and other training in biomass systems and enhanced opportunities for community involvement

Industry leaders, advocates and employees will need training in the capabilities and operation of biomass systems, but can also provide training in the community to help increase the skills base and job opportunities in the state to support a growing and diverse industry. Greater opportunity for community interactions in project planning can also help in realizing the environmental and economic benefits associated with biomass development.

Objective 6. Provide information and funding for consumer education

As systems and choices become available, consumer education will play a key role in successful adoption of bioenergy and other renewable systems. Early involvement of an informed public in policy, project planning, and market development will be important to sustained economic feasibility.

Objective 7. Enhance professional education in biomass, bioenergy, and bioproducts

Education must be available for the professionals who will create, innovate, and lead in the development of biomass systems and products. Scientists, engineers, analysts, and others who will work in biomass related fields in industry, academia, education, state and local government, and beyond, need a solid background and training in the field. Many will require in-depth knowledge and specialization.

These goals and objectives define areas where additional actions by the state are needed. The following section describes priorities for actions to be taken in achieving the vision for biomass management and development.

5 ROADMAP ACTIONS

Actions to achieve the biomass roadmap goals are described below and divided among five priority areas:

- Resource access, feedstock supply and markets;
- Market access, expansion, and technology deployment for energy and products from biomass;
- Research, development, and demonstration needed to advance knowledge and technology;
- Education, training, and outreach; and
- Policy, regulation, and statutes.

The recommended actions are also listed in five tables and distributed across a timeframe of recommendations spanning immediate implementation to longer term needs for 2020 and beyond.

5.1 Resource access – feedstock supply & market

5.1.1 Standards and best practices for sustainable feedstock supply

Any long-term, sustained use of biomass ultimately depends on sustainable practices to grow and collect the resource and deliver it as feedstock to a market. In some instances, short-term harvesting rates may exceed sustainable production rates to correct past deficiencies in management such as have occurred in forests where fire suppression practices have allowed the build up of large stocks of vegetation that fuel more intense and destructive fires. Even in such cases, however, effective practices will be needed to provide adequate environmental protection and avoid damage to soils, watersheds, and other ecosystem attributes that might inhibit eventual sustainability.

Agricultural Biomass

Sustainable practices for agriculture have been widely investigated and these practices will need to be more widely applied as harvesting of residue increases and production of dedicated energy crops expands. As with other agricultural operations, biomass feedstock supply systems will need to apply best knowledge of soil structure and fertility to protect soil health over the long-term. As with other agricultural sustainability concerns, standards should address the compatibility of soils and various crops, agronomic production rates, crop rotations, residue removals and impacts on erosion and soil nutrients, organic matter, and microflora, fertilizers, greenhouse gas emissions, soil compaction, water use, salinization, and other factors influencing the long-term performance of the agricultural system.

Conservation tillage and cover crops are increasingly being used by California farmers for a variety of reasons, including to improve soil tilth, water use efficiency, and weed management, and to reduce tillage requirements, labor and fuel, and fertilizer inputs. The wide diversity of crops and commodities requires that these practices be demonstrated in a variety of cropping systems, soil types, irrigation regimes, and climate conditions. This diversity also makes it especially difficult to quantify both carbon emissions and potential carbon sequestration benefits from implementing conservation tillage and cover crops.

Forest Biomass

Harvesting of solid wood products from timberland within California is regulated by the Forest Practice Act. One component of the Act requires sustainable production levels (sustained yield) and limits harvest not to exceed growth over a 100-year planning period. The Board of Forestry and Fire Protection is the regulatory lead agency and can review and consider regulatory modifications that will reduce harvesting costs of biomass.

California is currently growing more forest biomass than it is harvesting. The problem is greater on federally-owned lands than on private lands as, on federal lands, only a small portion of their annual growth is harvested allowing mid- and understory trees to become a fire threat. Removal of these "ladder fuels" is needed on so large a number of acres that, at the current rate of treatment, a return treatment is anticipated only every 50 or so years. Private lands are now harvesting at rates in excess of growth in order to reduce fuel loads, but will later need to reduce harvest rate to sustainable yield (Figure 5.1).

The California Department of Forestry and Fire Protection, in contract with the California Energy Commission, has also recently completed an initial analysis of the sustainability of forest and wildland biomass.[58] However, additional work is needed in this area. Because harvest-to-growth ratios vary throughout the state, the Governor's Bioenergy Action Plan calls for establishing "biomass zones" that reflect more locally

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[58] California Department of Forestry and Fire Protection. (2005). "*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.

reliable sustainability estimates. The technical ability to gather and analyze the necessary data exists but needs to be augmented, such as through the existing Fire Resource and Assessment Program, to provide an ongoing monitoring and assessment capability.

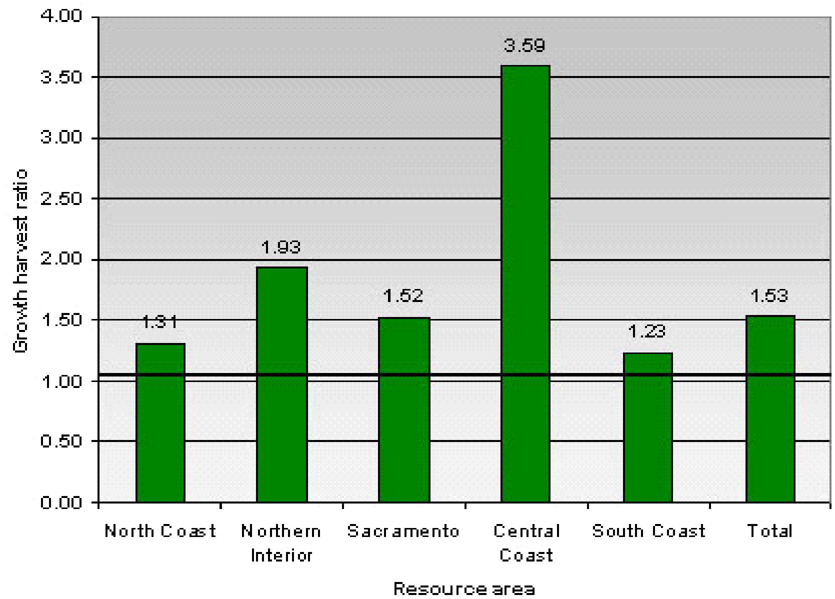

Figure 5.1. Harvest relative to growth on private timberlands by resource area, 1984-1994[59]

stand basis through the California Forest Practice rules for Silviculture (14 CCR, 913 -913.11; Division 1.5). The Forest Practice Rules (FPR) will result in a distribution of age classes that tends to center between 60 and 80 years Unless markets for biopower and alternative fuels change dramatically, Public timberland management is generally guided by land management plans prepared under the National Forest Management Act of 1976 (NFMA), and site specific environmental analyses prepared under National Environmental Policy Act of 1970 (NEPA). Land allocations, desired future condition of the land base, and resource-management standards and guidelines are contained within the NFMA documents. All public lands projects are subject to public input, challenge, appeals and possible litigation. Sustainable yield rates of public lands are theoretically determined in NFMA assessments; however, actual yields are the product of a complex interaction between local forest planning teams, the interested and affected public and the judiciary.

Ownership of forest lands in California is concentrated in national forests, forest industry, and other private holdings. National forests are the largest timberland owner in the state. The U.S. Forest Service holds 8.8 millions acres (53 percent) of timberlands

[59] FRAP, 2003 Assessment, "*Timberland Inventory Characteristics.*"

while the forest industry holds 4.2 million acres (25 percent). Other private owners also have a large share of timberlands holding over 3.2 million acres (19 percent).

The balance of age structure on forest industry and other private lands is an outcome of the current regulatory process for private forest lands and is accomplished on either a single tree or the largest source of biomass from private forest industry lands will come through forest thinning of the 10 to 40 year old stands (Figure 5.2). Much of that will be the yield from fuel-hazard-reduction projects (residue).

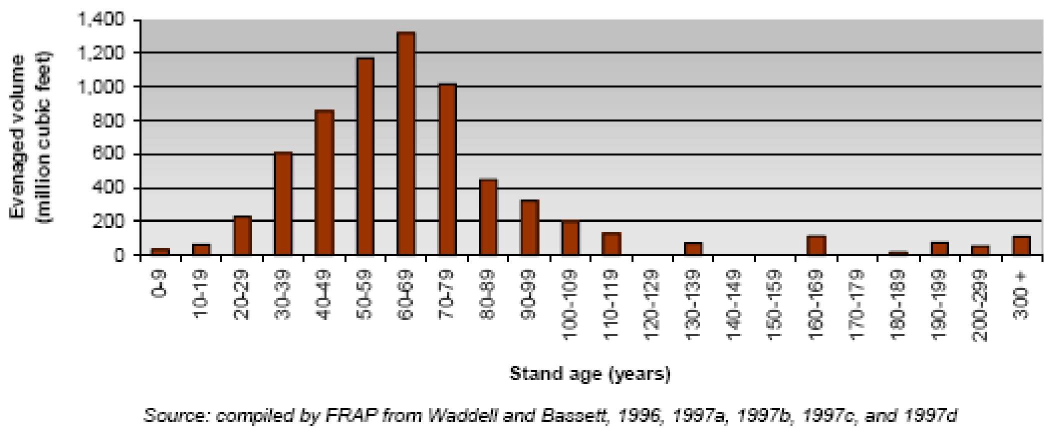

Figure 5.2 Volume of even-aged growing stock by age class, private land. [60]

National forest lands have a much greater portion of their volume of standing biomass (depicted in board-foot volume) in older stands (Figure 5.3). This is also indicative of the amount of stands in the older age classes. Even though these stands are older, a significant acreage requires fuels treatment to remove understory material that has accumulated over time through effective fire suppression in a previously fire-driven ecology.

The age differences between national forests and private industry forests are due to their differing management objectives. Public lands have not in the last few decades been managed for timber production, hence the age distribution has shifted heavily to older stands. That management, together with aggressive fire suppression, has also resulted in stands with a great deal of understory vegetation that poses a significant fire hazard.

[60] California Department of Forestry and Fire Protection

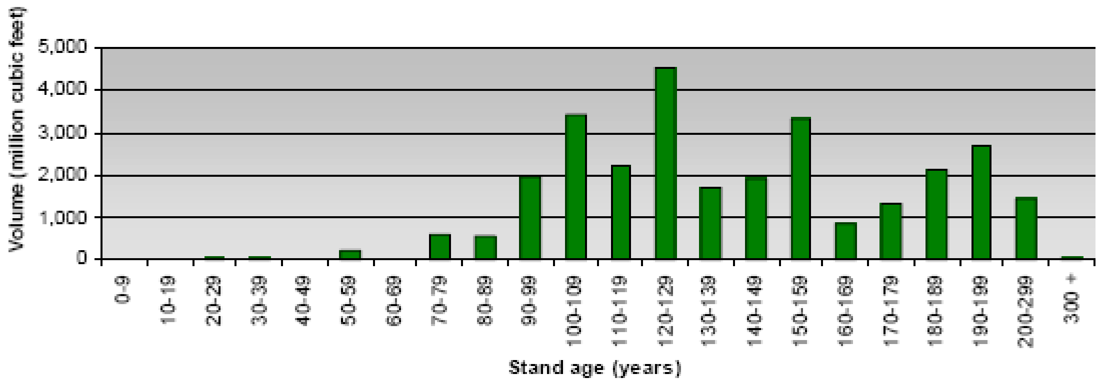

Figure 5.3 Volume of even-aged growing stock by age class, national forest. [61]

The 3.2 million acres of other private forest land include farms, ranches, small non-industrial family forests and forest land being lost to development. Age class distribution on these lands tends to vary greatly as each smaller owner has his or her own purpose of ownership. Many of the family-owned parcels tend to be near the 80 to 100 year age class, while those owned by developers tend to be in the 60 and under age classes. Again, these ownerships have the same characteristic of being overstocked with understory trees and vegetation and susceptible to large damaging fires.

Items that remain to be addressed in the maintenance of stand structure revolve around the policy objectives of the land owner and managers. One common factor is the necessity to treat the lands so that they are resistant to large damaging fires. A healthy balance of species, age, and size distribution is necessary to maintain a healthy forest and to protect investments as well as to meet the public policy objectives for each ownership class.

Regardless of the ownership and the constant risk of large fires, one factor could lead to a major shift in age distribution at the landscape level: the loss of a viable forest industry in California. If present trends continue, the ability may not exist in California to harvest and process forest-related products, including energy-related products. A healthy forest cannot be maintained solely through public funding; a forest industry to treat the state's 16 million acres of timberland is also required.

High-risk forests are a priority for treatment for most forest landowners. Rates of treatment are determined by stand economics, individual landowner objectives, state

[61] California Department of Forestry and Fire Protection

and federal program budgets, and achieving consensus with the public on public lands. Federal forests have developed five-year plans for managing vegetation and fuels, and identifying the highest priority areas for treatment within the planning period.

Several programs currently in place at the state and federal levels provide cost assistance to landowners for thinning or brush removal. These programs target areas where development has occurred in or near forested or wildland areas. They include Proposition 40, the California Forest Improvement Program, Wildland Urban Interface Grants, the Vegetation Treatment Program EIR, Bureau of Land Management Fire Safe Grants, and others. In addition to efforts on private lands, the Healthy Forest Initiative under the Forest Service is providing additional funding to treat federally-owned forest lands. Over 100,000 acres of public and private land have been treated to reduce fuel hazard and improve forest health. Much of the biomass from those treatments has been returned to the forest floor as chips, or open-burned as the air-quality permitting process allowed.

The current protection of these overstocked high-risk forests continues to come through fire suppression. A record keeping system to document treated acres across all ownerships needs to be established so progress can be documented. Also, because there are examples of fuel-treatment projects assisting fire-suppression efforts in gaining control of a fire that otherwise would have grown to catastrophic size, a record keeping system needs to be developed to show the return on investment. This would help further public confidence in the value of a viable biomass market.

The California Forest Practice Act and the rules of the Board of Forestry provide guidance on harvesting practices that prescribe fire-hazard reduction treatments and protect the environment. The act and the rules address silvicultural practices, water quality protection, wildlife protection, and old-growth forest protection, as well as standards for reforestation following harvest. This system, in place since 1975, has undergone constant change to adapt to public perception. The result is a set of rules that make it difficult to harvest biomass where the resource removed has small economic value. Various revisions have been made by the Board of Forestry and Fire Protection within the statutory mandate to assure that harvesting practices protect environmental values. The need for additional standards to ensure sustainable harvesting practices will need to be carefully evaluated as larger amounts of biomass are removed.

Urban Biomass

Californians produce more than two tons of municipal wastes per person per year. Municipal wastes 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 derived from biomass materials and are included in this category.

The biomass component of all MSW generated totals more than 38 million dry tons per year including construction and demolition wood (also referred to as urban wood fuel), paper and cardboard, grass, landscape tree removals, other green waste, food waste, and other organics, but not plastics and tires. 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) with an average methane concentration of 50 percent, yielding a methane equivalent of 59 to 78 BCF/y. The total biogas resource from over 240 waste water treatment plants is currently 16 BCF/y with an average methane concentration of 60 percent, or 9.6 BCF/y methane equivalent. By comparison, natural gas consumption in the state is 6 BCF per day or 2,200 BCF/y.

The Integrated Waste Management Act of 1989 (IWMA) set forth policy to reduce California's reliance on landfills. The IWMA required local jurisdictions to implement diversion programs that would help achieve the goal of 50 percent reduction in solid waste disposal by 2000. The current statewide diversion level is estimated to be 52 percent, but achieving the target has largely been the result of increases in waste generation while quantities disposed have remained unchanged. Even with a plethora of diversion programs, 42 million tons of material is still being disposed. Of the amount disposed in landfills, approximately 80 percent is organic material and can be retrieved for use (paper, wood, green waste, food waste, plastics, etc.), although the non-biogenic component cannot properly be classified as renewable. Some countries in the European Union have instituted producer responsibility programs and a restriction of the landfilling of organic material as a method to comply with aggressive greenhouse gas reduction goals set forth in the Kyoto Protocol.[62]

Waste management alternatives instituted throughout the European Union and elsewhere can serve as potential models for future California waste management practices, especially in light of California's new greenhouse gas emission reduction law. Various measures to consider include additional bans on landfilling certain types of materials, such as limiting total organic matter content in landfill disposal, restrictions on diversion allowances for alternative daily cover, and elimination of the transformation category from California statute that inhibits the use of combustion and some other technologies in waste-to-energy systems. These issues are controversial and

[62] Williams, R.B. (2006). "*Biomass in California MSW-Draft.*" California Biomass Collaborative. University of California, Davis. CEC PIER Contract 500-01-016

landfill bans should not be instituted without having working alternatives to disposal. Reductions in landfilling will also adversely impact the existing landfill gas-to-energy industry by reducing the production rate of landfill gas over time. Additionally, advanced landfilling techniques using landfill bioreactors and other containment systems may function as well to meet sustainability standards as some other conversion technologies. These more advanced techniques may more properly be viewed as alternative conversion technology design concepts. Standards for the implementation and operation of these various technologies will need to be developed.

Separating the biomass fraction from other waste could help ensure a cleaner feedstock for conversion technologies. Separating food residuals from other solid waste, for example, especially by the food service industry, would provide cleaner feedstock for anaerobic digestion systems. Such material is now being used to augment digesters at some waste water treatment plants. Separation of construction wastes (as opposed to demolition waste which can be highly contaminated) at the job-site diverts clean wood for fuel, mulch, or feedstock for other products. Better separation of greenwaste can similarly improve feedstock properties.

Sorting mixed municipal wastes at material-recovery facilities often results in a sizeable fraction of organic wastes too contaminated for use by traditional recycling businesses. Improving mixed-waste separation processes would add value to this stream. Reducing the content of toxic or hazardous materials, such as batteries, would also improve access for urban biomass to conversion markets. Increased producer responsibility for reclaiming or recycling such products should be considered. California's e-waste program is one example where increased responsibility reduces disposal and enhances recycling of used electronic components.[63] Better enforcement will also be needed, including curbside inspection and the imposition of fines for violations.

Existing definitions in the Public Resources Code that pertain to solid waste management and the biomass fraction of solid waste have not evolved as quickly as biomass conversion technologies have evolved. Legislation has been proposed that would change statutory laws to distinguish conversion from disposal. Until changes are made in statute, it is difficult for the principal regulatory body, the California Integrated Waste Management Board to provide clear permitting pathways for the operation of biomass conversion facilities that meet environmental standards. In particular, facilities using biomass that has been separated from municipal wastes

[63] California PRC § 42460

should not be labeled as waste facilities and should not be required to obtain waste management permits.

5.1.2 Land use

As California grows, competition for resources will increase. Land suitable for agriculture is increasingly lost to urbanization, making demands on the remaining farmland ever greater. Maintaining a viable agriculture producing food, feed, fuel, and fiber will require careful matching of needs, location, and availability.

Population growth also impacts the availability of working forests. Between 30,000 and 40,000 acres of forestland are lost annually to other land-uses including development and agriculture. Additional forest lands are subject to production limitations through the establishment of forest preserves. Local government land-use practices need to establish a high priority on the maintenance of working landscapes for agriculture and forestry and to counter urban sprawl.

5.1.3 Environmental impacts

As use of biomass expands, there is increasing need to understand the full life cycle impacts for air, water, and land quality, greenhouse gases and carbon cycling, biodiversity and other effects.

Agriculture

Principal environmental impacts from agricultural operations relating to biomass production and use largely center on harvesting of residues, impacts from animal operations, and increasing cultivation of dedicated energy crops. Changes to food and other agricultural processing operations can also result in new environmental impacts. Residue harvesting must be done with careful consideration of soil sustainability but can reduce the air quality impacts of field burning the residue. Emissions from harvesting and use, including those from equipment, are generally well below emission levels from open burning for most pollutants, NOx and SOx being the principal exceptions although most emissions controls on conversion systems are sufficient to reduce these pollutants as well. Incorporating energy conversion such as biogas power generation systems into animal operations will generally reduce odors, particulate matter, and VOC emissions but may increase NOx emissions due to the use of combustion engines, turbines, and boilers. Land application of digester residue may also lead to increased ammonia emissions compared with spreading of fresh manure, but has offsetting benefits from greater nutrient availability and reductions in odors when applied appropriately.

Increased production of dedicated energy crops will result in changes in crop types, cropping patterns, pest and weed management, cultivation techniques, fertilization, irrigation, harvesting, and processing. Net effects compared to prior agricultural or other land use will need to be assessed in addition to the over-all system level effects due, for example, to fossil fuel displacement. In many cases the production of dedicated energy crops will also be done in conjunction with other environmental improvement efforts, such as land remediation or nutrient management. More extensive field trials are needed.

Forestry

Harvesting projects for forest biomass must adequately consider air quality, water quality, wildlife habitat, and other environmental values. As noted earlier, forestry accommodates this need through the Forest Practice Act. The State Water Quality Control Boards, Department of Fish and Game, and the various Air Quality Management Districts have separate regulatory structures for resources over which they have jurisdiction, but each has a specific authority in the evaluation of timber harvesting projects. This is done through an interdisciplinary environmental review process. These agencies are also specifically included in the development of rules adopted by the Board of Forestry and Fire Protection.

Nutrient cycling is impacted by the amount and type of material removed from the stand and how often this is done. Nutrients exists in the duff and organic layers of the forest floor and with proper harvesting techniques should largely be preserved under current practices addressing the removal of excess small trees and shrubs. A sufficient crown canopy for continued recycling and capture of nutrients should be be retained. After an initial entry for fuel reduction, a significant time will pass before a second entry or commercial harvest is feasible.

Stand health will improve with a appropriate biomass harvest. Removing excess stems will provide a greater quantity of nutrients, light, and moisture for the remaining stems. This will increase individual tree resistance to insect and disease infestations. The increased light favors regeneration and growth of shade-intolerant tree species such as the white pines, ponderosa pine, and Jeffery pine.

There is little conclusive research on the question of wildlife disturbance and biomass harvesting; however, work with the Department of Fish and Game in traditional timber harvesting has resulted in some common practices to address this concern. Using partial stand harvest (individual tree selection), a balance of tree species and size classes are retained to provide roosting, foraging, and nesting habitat for birds. Small pockets of brush and understory are retained for use by deer and other species as cover for offspring during migration periods. Retention standards are in place for snags to accommodate cavity-nesting birds, and small mammals as prey for owls and other raptors. Hardwood components of natural stands are retained to provide bird habitat, as well as acorn and other food crops for foraging species such as deer and elk. Where these common steps are not sufficient, individual mitigations are developed by involved agencies. Additional standards are needed in the area of impact determination and mitigation development.

Soil scarification during harvesting is a concern for establishment of shade-tolerant species such as true fir. Increased light entering the stand following thinning should create more favorable conditions for pine and cedar regeneration. Once a forest stand has the excess vegetation removed, a secondary treatment with prescribed fire will also help maintain a species balance, as true fir are more susceptible to mortality with cooler understory burns. Standards addressing cumulative impacts from biomass harvesting need to be developed.

The single largest impact on water quality from forest harvesting comes from roads; this has been well documented.[64] Practices have been developed that reduce actual and perceived water quality impacts from forest road systems. For biomass harvesting there will be little need for new roads, as most harvesting will be in areas previously harvested for sawlogs. The Board of Forestry and Fire Protection provides an extensive set of standards for the use of existing roads and for erosion control as well as road abandonment. These rules are enforced by a cadre of inspectors employed by CDFFP. The Regional Water Quality Control Boards also have responsibility, through the Porter-Cologne Water Quality Act, for preventing impacts on the beneficial uses of water. Further action will be needed in this area as the board continues to review and develop standards for forest roads. The Regional Water Quality Control Boards will also need to review and revise the individual Water Quality Control Basin Plans.

Fugitive dust and direct emissions from the harvesting and transport equipment need to be considered for air quality impacts. Dust can be suppressed by road watering through the summer when soils are dry and dust is easily raised. Positive benefits to air quality will come through reduced smoke from open burning of residues and fewer forest fires. Under current regulations slash and debris from logging may be open burned. Although this must be done under air quality permits, it does not address

[64] Lewis, J. and Rice, R., 1989, "*Site conditions related to erosion on private timberlands in northern California: Final Report: Critical Sites Erosion Study*," California Department of Forestry and Fire Protection, Forest Practices Section

actual emissions. Air quality permits primarily address the public nuisance aspect of open burning for slash disposal.

Urban Biomass

Emissions from MSW conversion are subject to existing regulation; however, concerns remain over emissions from certain types of conversion technologies, particularly thermal systems. Municipal solid waste feedstock, unlike biomass, is very heterogeneous and may contain items that increase the toxicity of the feedstock (e.g. household batteries). One method to reduce the quantity and toxicity of materials from entering the waste stream is to provide enhanced collection methods for materials such as household batteries.

Another method to reduce the quantity and toxicity of material entering the waste stream is instituting producer take-back programs whereby materials that would typically enter the waste stream would instead by sent back to the manufacturer for proper management. In any case, permitting requirements will continue to need review and updating as more waste is diverted for conversion to energy to ensure acceptable environmental standards are met.

5.1.4 Resource monitoring

Better monitoring of resources is needed to ensure sustainable use and to forecast future development. Greater use of remote sensing technologies would prove especially helpful in determining biomass inventories and providing good spatially resolved information for project planning and feedstock supply.

State forestlands are assessed by CDFFP every five years. To accomplish this, the Fire and Resource Assessment Program (FRAP) maintains data bases on forest inventory, harvest, growth, and change over time. A unique aspect of the FRAP is the change-detection analysis it applies to existing data bases. This identifies changes in land use and land cover over the last five-year period. Including this step in assessing the data provides an estimate of changes needed to existing inventories.[65] FRAP works closely with the US Forest Service on inventory analysis, using federal growth data, state vegetation data bases and the change-detection methodology to produce final estimated growth.

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[65] The most current assessment was prepared and published in 2003 [http://www.frap.cdf.ca.gov/assessment2003]

Remote sensing and other inventory assessment techniques should be developed to give more rapid estimation of changes in biomass and to allow better overall management of agricultural and forest biomass resources. Improved resource estimates will be important for ensuring sustainable practice as well as providing accurate feedstock supply data to existing and planned biomass facilities.

5.1.5 Dedicated biomass crops

Dedicated biomass crops can serve a variety of purposes in addition to supplying feedstock for biomass conversion. Soil remediation, groundwater and nutrient management, and new local economic development opportunities may all be objectives associated with biomass production systems.

A number of crops could supply promising new markets:

Biodiesel: Promising oil crops for producing biodiesel include canola, sunflower and safflower. The California Department of Water Resources in partnership with growers and public agencies has funded projects to demonstrate feasibility.

Alcohols: Sugar beet is an established salt-tolerant crop that can be grown in drainage-impaired lands and used in the production of ethanol and higher alcohols. The material left over after sugar extraction is high in protein and is used for animal feed at local feedlots and dairies. Commercialization of cellulosic fermentation and other alcohol production techniques will also provide opportunities from many other crops.

Biomass electricity: Retired lands could be used to produce biomass for electricity production. A number of suitable tree species such as eucalyptus can grow with little irrigation, tapping brackish shallow groundwater. Suitable trees can be grown in large areas to provide a continuous stream of feedstock for existing and new biomass power plants. Composition of these materials need to be carefully evaluated to ensure feasibility of use. Active accumulators of salts, for example, may have high concentrations of alkali metals that will adversely affect their suitability in many combustion power plants.

Other biofuels: Many of the same crops used to produce biomass for electricity generation can be used for making biofuels through hydrogenation/ hydrotreating/ hydroformylation and thermochemcial processes such as gasification and Fischer-Tropsch synthesis.

Biomass products. Certain grasses, trees, and other crops can be grown under saline conditions to produce biomass for composite construction materials, pallets, containers, sound proofing panels, and other applications. The tree, *prosopis alba*, for example, is now being planted at selected locations to demonstrate this use. It needs little irrigation and grows by tapping into local shallow brackish groundwater aquifers.

Production of corn and other starch and sugar crops can also be expanded to increase or alter feedstock supply. Double- and other multiple-cropping systems can extend use of agricultural lands and existing irrigation and transport systems to increase biomass production. Imported grains are already contributing to in-state energy production, and can continue to support state biofuel demand, but questions of best land and resource use remain.

5.1.6 Biomass collection and transport

Greater use of biomass and larger-scale conversion systems will require a larger-scale feedstock handling and delivery infrastructure. Existing equipment can often be used, but more equipment will be needed to expand access and reduce costs. Development of new types of equipment will also be needed. To accommodate expansion in feedstock collection and transportation, production centers can be established where smaller quantities of biomass are consolidated, stored, and transferred to long-distance transportation systems, in much the same way that transfer stations are used in municipal waste handling. Pre-processing equipment may be used to densify biomass, increasing truck payloads and reducing transportation costs over longer haul distances.

Substantial work has already been done on biomass harvesting and handling systems. The capacity to convey much larger amounts of biomass can be developed if adequate markets are provided. Supporting this development will be important as the industry expands, as will ensuring that the feedstock supply system operates in sustainable ways.

Incorporating the use of biofuels and biomass products into biomass industry practices can further enhance biomass markets. Such practice would also improve life cycle performance by reducing consumption of petroleum and other non-renewable inputs.

5.1.7 Seasonality and storage

Increasing storage for biomass will be needed to accommodate seasonality of production. With the expansion in biomass use envisioned, storage capacity will need to grow and more innovative and compact storage technologies developed to reduce costs and improve quality. The types of storage will depend on the properties of the biomass, especially moisture content. For high-moisture biomass intended to be used wet, such as in fermentation and anaerobic digestion systems, wet-storage systems can be used, with storage times closely controlled to avoid excessive degradation of feedstock. Storage systems typically used with wood chips, baled straw, and similar materials need to protect against spontaneous combustion and excess decomposition, and the maximum storage moisture depends on the type of storage employed. Different storage systems are needed for food-processing residuals than for agricultural and forest-based materials.[66]

Storage sites must meet a number of criteria. Leachate must be controlled to avoid contaminating land surface and groundwater. Moisture limits must be observed to avoid spontaneous combustion and the emission of regulated compounds. Emissions are also of concern when transferring biomass or products, such as the potential VOC emissions associated with the use as animal feed of wet distillers grains from ethanol fermentation. Cost of storage is important to the overall feasibility of the biomass enterprise. In some cases, the storage can be on the same site as the source of the feedstock. In others, necessary volumes can only be achieved by combining the feedstock from a number of relatively close sources. Typically, delivery within about 50 miles is economic,[67] but longer-range transport is sometimes acceptable, especially when disposal fees can be reduced.

Storage of Low-Moisture Biomass

Agricultural residues such as wheat straw, rice straw, and corn stover are usually spread or windrowed behind the grain harvesters for later baling and roadsiding. Typically these residues are left in the field to air dry to moisture levels below about 14 percent preferred for bales in stacks or large piles of loose material. Following collection, biomass may be stored in the open or protected from the elements by tarps or various structures. Pelletizing, although adding $10-15/dry ton to feedstock cost, may be employed to increase bulk density and reduce storage and transport volume and cost. Recent studies of tarps, fabric structures, and more permanent metal storage structures have shown economic advantages for the latter in higher capacity, longer term use.[68]

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[66] US DOE. (2002) "*Roadmap for Biomass Technologies in the United States.*" http://www.biomass.govtools.us/pdfs/FinalBiomassRoadmap.pdf

[67] Jenkins, B. M., J.F. Arthur and P.A. Eibeck, (1983) "*Selecting optimum biomass utilization sites.*" American Society of Agricultural Engineers, Transactions of the ASAE, page 1551-1556, 1560

[68] 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.

Forest operations are highly limited between mid-November and mid-April. Forest thinnings and logging residues are typically handled in stages, first processing at a landing in the forest and then transporting chipped or densified material to the site of use or a centralized processing facility. Woody materials are commonly stored in open piles, and at most larger facilities are stacked and handled through a combination of automatic conveyors and driver-operated front-end loaders. European straw-handling facilities use on-line microwave moisture detection and other sensing systems to improve control of boilers, furnaces, and other processes.

Storage of Seasonal High Moisture Biomass

Seasonality is also a major issue for food-processing residuals and other types of high-moisture biomass (Figure 5.4). For example, most of the grape crush occurs between mid-August and mid-September and most tomato processing occurs over the two months of August and September. About half the food and food-processing residuals in California flow from vegetable crop production and from food processing and handling facilities. The remaining half is found in municipal solid waste streams going to landfills or diverted to compost facilities that will come under increasingly stringent air emission regulations. Food and food processing residuals in California amount to more that 4 million tons per year.[69]

Solving the seasonality issue in managing residual streams for food processors may require partnerships among several companies, bagged storage facilities, or integrated biomass-to-energy product conversion systems using multiple feed streams. Air, land and water-quality protection requirements being placed on the food processing industry are closing off many of this industry's waste-management options. As described later, additional research on storage will be needed as utilization of residues advances.

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[69] Matteson , G.C. and B.M. Jenkins, 2005 "*Food and processing residues in California: resource assessment and potential for power generation.*" Paper No. 056018, ASAE, St. Joseph, MI 49085.

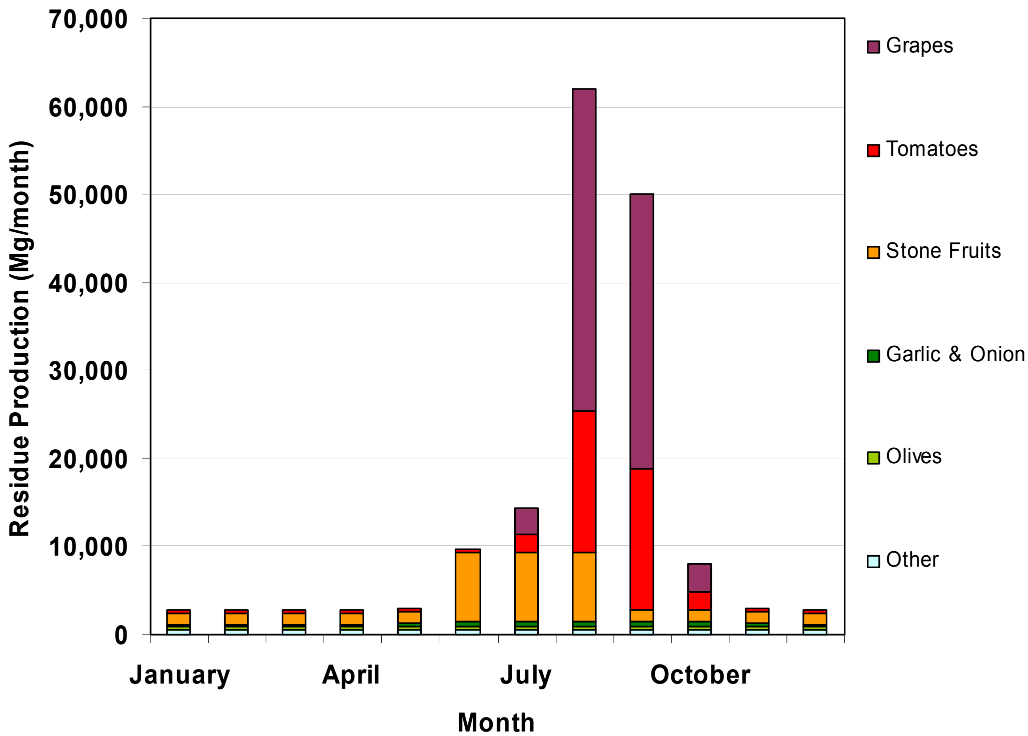

Figure 5.4. Seasonal production levels (metric tons per month dry weight) for selected food processing residuals from surveys of operators in California.[70]

5.1.8 Biomass commodity markets

A commodity can be an agricultural product that investors buy or sell, usually as commodity futures contracts, or agreements to purchase or sell a commodity for delivery in the future: (1) at a price that is determined at initiation of the contract; (2) that obligates each contracting party to fulfill the contract at the specified price; (3) that is used to assume or shift price risk; and (4) that may be satisfied by delivery or offset from alternative sources.

Unlike agricultural commodities, a biomass commodity market does not yet exist except for select materials used as animal feed. To improve marketing of biomass, regional collection and distribution centers could be established to help broker materials between suppliers and users. Biomass commodity markets could also help shift some residue biomass from the status of waste to resource. Agricultural cooperatives could be formed to help farmers produce, collect, and process biomass for sale, and to cultivate sustainable feedstock supplies through partnerships among farmers, ranchers,

[70] Matteson and Jenkins, 200 Op Cit.

foresters, and food processors. Tax credits and other incentives could help move residue into these markets.

5.1.9 Biomass enterprise zones

California currently has 42 enterprise zones operating across the state. The purpose of the California Enterprise Zone Program is to stimulate business and industrial growth in depressed areas of the state and to create higher paying, higher skilled job opportunities for local residents.[71]

Within these zones local governments administer economic development programs including local and state incentives. Many local governments offer permitting assistance, expedited environmental reviews, and fee waivers. State incentives include lender income tax credits, accelerated depreciation schedules, and income tax credits against sales and use taxes paid on certain capital expenditures. Establishing biomass incentives within enterprise zones could reduce the cost of business and industry development and expedite the development of biomass markets.

The zones would bring together users of common feedstocks with the producers or pre-processors of the biomass material. Local governments would have the opportunity to provide services and utilities (garbage, water, sewer) at reduced rates, as well as offer new job opportunities to area residents. By addressing the development of new biomass facilities within a comprehensive economic development strategy, communities have an opportunity to better share in the benefits, potentially also alleviating many environmental justice concerns in the future.

5.2 Market access, expansion and technology deployment for energy and products from biomass

Increased use of biomass requires competitive access to energy and product markets. In some cases this will occur spontaneously without incentives due to clear economic advantages. The increase in electricity generating capacity from biomass after 1978, for example, was largely due to enhanced access to utility markets created by the Public Utilities Regulatory and Policy Act and long-term standard contracts at favorable prices, especially Standard Offer #4 (SO4).

[71] California Government Code Section 7071

The sudden expansion of the California ethanol market between 2003 and 2005 was due to the elimination of MTBE as an oxygenate in gasoline and the limited availability of acceptable alternatives other than ethanol. Recent increases in the price of motor fuels have stimulated greater interest in biofuels. Many of the fuels that can be made from biomass become competitive when conventional fuel prices are above about $3 per gallon; however, the fuels market is still subject to considerable price volatility in the supply of crude oil, and investors will be more reluctant to invest in new biofuels capacity without greater market security through long-term contracts, loan guarantees, taxes, regulated price floors for petroleum, or other incentives and control mechanisms.

Higher costs of generating electricity from biomass, compared with wind and geothermal resources, have resulted in fewer winning bids for biomass under Renewable Portfolio Standard (RPS) solicitations. Because the RPS is the primary mechanism by which long-term contracts for new capacity can be secured, building biomass capacity may require increasing RPS goals to expand the total market for renewable electricity thereby increasing marginal cost for new capacity added, incentives that reward certain attributes such as base-load operation and allow biomass to compete against other renewables, or reducing the cost of generation from biomass such as through combined heat and power operations.

Access to market is a key consideration for any new biomass capacity, whether for power, fuels, or products. For this reason, attention must be given to providing adequate physical infrastructure and equitable incentives, including necessary transmission and pipeline capacity, infrastructure for transportation fuel distribution, parity among technologies for net metering and tax credits, and means to internalize environmental costs and benefits not captured by the existing markets. Procurement mandates, caps on carbon emissions from fossil fuels, carbon trading allowances, carbon taxes, waivers of certain fuel taxes for renewable fuels, low interest loans, loan guarantees, direct subsidies, and other mechanisms, can all contribute to opening up markets for greater use of biomass.

5.2.1 Funding and incentive mechanisms

Tax Mechanisms

a) Carbon taxes: Taxing the use of non-renewable carbon-based fuels provides a price incentive for renewable energy. Carbon taxes are nominally justified on the basis of penalizing net atmospheric greenhouse gas emissions, principally carbon dioxide released from fossil fuel conversion. Carbon taxes have not so far emerged as a preferred strategy for carbon management in comparison with regulated caps on emissions and carbon trading systems, although each method has advantages and disadvantages. State policy is now expressly defined in favor of a carbon market system through Assembly Bill 32 (2006).

Carbon emission caps, carbon trading systems, and carbon taxes are all mechanisms designed to help control the undesirable release of carbon dioxide and other greenhouse gases to the atmosphere. Caps are direct mandates that place limits on emissions. Carbon trading, which may be permitted as a way of optimizing reductions under a cap, and carbon taxes are both economic instruments attempting to affect corporate and public behaviors in limiting emissions. When cost and benefit functions are known, price-based systems such as taxes and quantity-based systems such as tradable permits are equivalent in economic efficiency toward reducing emissions.[72] Both approaches provide for the use of least expensive abatement methods. Practically, cost and benefit functions are not well known, and the implications of trading systems and tax systems are therefore uncertain and may have different effects.

Tax systems provide a fixed incentive per unit of emission regardless of the quantity; permit trading provides a variable incentive to achieve a fixed quantity of emission. The cost of implementation in a trading system can be high or low depending on anticipated future abatement costs and level of emissions. Such costs under a tax system are likely to vary less. If each unit of emission (e.g. ton of carbon dioxide) is equal in climate change impact, a fixed tax per unit of emission is appropriate. If a known climate change threshold exists beyond which catastrophic damage occurs, a quantitative cap ensuring emissions do not exceed such a threshold is appropriate. Taxes cannot guarantee that the threshold is not exceeded. As Holtsmark[73] has noted, the stock of greenhouse gases, not just annual emissions, is responsible for climate effects. Quantitative limits on emission rates therefore do not amount to control of climate change.

Taking into account the costs of regulation and long-term damage, tax regimes appear to offer much higher economic efficiency than quantitative targets. Despite this, cap and trade systems have been the preferred choice among policy makers and are the basis for international carbon management under the Kyoto protocol (although the U.S. remains outside its authority). Similarly, a market-based approach utilizing an

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[72] Holtsmark, J.H. og Bjart, 2005. "*Cap-and-trade or carbon taxes?*" Discussion Papers No. 436, Statistics Norway.

[73] ibid

emissions cap with emissions trading, auctioning, or offsets is the recommended strategy for California in meeting emission reduction targets.[74]

Carbon taxes are direct and publicly transparent. They are a way to influence public behavior to reduce fossil resource consumption and shift to other resources, improve efficiency, provide for carbon capture and storage if it can be shown to be sustainable, or most appropriately some combination of these. Permit trading systems are typically less transparent and economic costs of the policy are often concealed. Tax systems are considered less susceptible to corruption[75] and avoid the need to maintain emission baselines. The only relevant baseline for a tax system is the emission level resulting in zero tax. A successful tax system will result in tax revenues declining over time as consumption shifts away from the taxed commodity. A problem may arise if the revenues are used to fund unrelated social programs that then experience a loss of funding. Any carbon tax system therefore needs to be properly designed so that the intended shift in behavior results in the public eventually freeing itself of the tax.

Both tax and trading systems are difficult to enforce. Costs of a carbon tax might be offset through reductions in other taxes or increased incentives and subsidies elsewhere so that the environmental cost is not fully internalized. Measurement of net carbon tax thereby becomes a key element of enforcement.[76] Trading systems suffer from the possibility of making inaction legitimate so that overselling and underbuying can undermine effectiveness. Tax systems do not suffer the same problem of inaction and non-compliance. Enforcement may, therefore, be even more important for cap and trade systems.[77]

A frequent argument against carbon or energy taxes is that they place a disproportionate burden on lower-income earners by increasing prices. Market-based systems, if properly functioning, will also increase costs, however. Missing from many arguments is the potential to increase unit costs without proportionally increasing total cost of fuel or energy, which is the relevant concern. Adding tax to shift consumption while using tax revenues to improve efficiency can result in restricting the increase in total costs to consumers. Income-based subsidies provided from tax revenues can help overcome the difficulty of improving access for lower-income earners to higher

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[74] California Environmental Protection Agency, 2006. Climate Action Team report to Governor Schwarzenegger and the California Legislature, March. See also AB 32 (2006).

[75] Nordhaus, W.D, 2001, "*After Kyoto: Alternative mechanisms to control global warming.*" Presented American Economic Association and Association of Environmental and Resource Economists, Atlanta, Georgia, January.

[76] Ibid.

[77] Holtsmark, op cit.

efficiency vehicles and other energy products. Higher energy costs are thereby translated into high system efficiency with a declining need for subsidy as tax revenue diminishes over time.

b) Value-added taxes: Taxes on wood and selected agricultural products to finance the proper handling of these residuals can also provide incentives for reducing disposal and improving utilization. Specifically, funds collected from taxing the sales of such products would be directed to finance the sustainable collection and transportation of biomass residues from point of generation to a biomass facility. Funds collected through additional surcharges on garbage disposal could subsidize biomass users in proportion to the biomass consumed or biogas recovered for beneficial use.

c) Production tax credits: Providing the user of a biomass feedstock with a credit against taxes on earnings helps to offset costs of feedstock acquisition. At the federal level, the Production Tax Credit (PTC) available for residue or so-called 'open-loop' biomass lacks parity with credits available to wind and solar generators and users of dedicated energy crop or 'closed-loop' biomass both in value and duration of the credit. Parity among credits should be provided when sustainable use, even for open-loop biomass, can be demonstrated.

Loans

a) The creation of a renewable-energy or green-product insurance fund, a loan loss reserve fund, or a subsidized loan program could lower the cost of borrowing for developers and reduce the risk to funding sources of making loans. Another option is to bundle projects into resource portfolios or packages. By pooling capital-intensive emerging technologies with more mature, less expensive technologies into a resource package, the overall blended risk may be more acceptable to lenders and investors.

b) Loan Guarantees: Government loan guarantees represent a commitment by the government to pay part or all of the loan principal and interest to a lender in the event the borrower defaults. A loan guarantee would enable a biomass business to obtain a term loan, line of credit, or letter of credit when it would not otherwise qualify for a loan. A state-backed program could provide the lender with the necessary security, in the form of a guarantee, to approve a conventional loan to a facility. Loan guarantees could be important for introducing into the market new technologies for which extensive production experience does not yet exist.

Contracts

a) Long-term contracts: Demonstrating to bondholders an ability to repay debt service, such as through long-term contracts, is critical to the issuance of debt instruments.

Long term contracts such as SO#4 established between utilities and qualifying facilities after PURPA (1978) were important in attracting investment capital. Providing new opportunities for long term contracting is one of the more important policy considerations for the state in increasing the supply of renewable energy.

b) Net metering: Net metering is not universally available to all biomass generating technologies. At present, net metering is available only for certain biogas facilities. Net metering policies should equitably treat all types of biomass facilities delivering equal service. Under biogas net metering, when a customer-generator is producing more power than it needs the excess is exported to the grid. That energy can then be imported without generation charges at times when the customer-generator's usage exceeds its generation. The account is zeroed out annually and the customer generator receives no compensation for excess exports. Net metering should be revised to provide for compensation to the customer-generator for excess exports up to defined limits.

Pricing Structure

a) Commodity Market: As noted under resource access, establishing a commodity market for biomass feedstock could bring stability to the sale of biomass feedstock and help reduce price volatility, especially during periods of rapid industry expansion.

b) Greenhouse Gas Market: Through AB 1493 (2002) and AB 32 (2006), the state has enacted legislation restricting greenhouse gas emissions and providing for the development of a greenhouse gas market. Establishing a market-system to allow trading of surplus reductions in green-house gas (GHG) emissions first requires enacting caps on the emission of GHG and establishing a baseline against which any reductions are to be measured. AB 32 has set a baseline of 1990 emissions. Potential categories for control of GHG are the electric generation sector, oil and gas extraction and refining, automobile and transportation sector, landfills, cement production, and others. Capping emissions from specific sources would allow any reductions beyond those levels to be tradable in a market. Biomass-based generation and fuels could reduce emissions in such a manner as to allow specified entities to claim those reductions and sell them. In addition, GHG reductions achieved through capture of CO_2 during plant growth cycles could create tradable credits if proven to be real, permanent, and convertible. Such a system is in effect in some regions; the Chicago market currently trades GHG offsets at $3 to $5 per ton of CO_2 reduction. Much higher values are likely to develop in the future as emission caps are set lower to reduce emissions.

c) Direct Access: Direct access allows retail customers to purchase electricity directly from wholesale markets rather than from a distribution utility. Direct access in California was initiated under AB 1890 and implemented in 1998. It was suspended by the Public Utilities Commission in 2001 during the state's electricity crisis. The suspension was to assist in the issuance of investment grade bonds by the Department of Water Resources which was given authority to purchase electricity on behalf of utility ratepayers. The suspension was also intended to give DWR a stable customer base from which to recover the cost of power purchased. Reinstating direct access could be important for increasing the market share of renewable biomass electricity by allowing companies to directly contract with generators for delivered energy.

d) Increase Government Procurement: Using the purchasing power of government to build demand for biomass products and technologies by requiring government purchases can also expand markets. Federal requirements already exist, such as those under Title IX of the Farm Bill and the Federal Biobased Products Preferred Procurement Program (FB4P)[78]. Similar programs at the state, county, and municipal levels would further expand the market. In the private sector, revising or modifying building standards to provide more flexibility for use of "green" materials for construction would also support increased use of biomass. The federal government has also undertaken a program that provides funding for facilities to install biomass technology to reduce energy from fossil fuels - the Federal Energy Management Program. Assistance is provided to help agencies decide whether to fund energy improvements through energy savings performance contracts, utility energy service contracts, efficiency and renewable energy incentive programs, or some combination. A similar program could be implemented at the state level.

e) Target prices and supplemental energy payments: The California Energy Commission, within the Existing Renewable Facilities Program provides production incentive payments to biomass generators for amounts above a target price for electricity. Funding for the program is collected from ratepayers of the state's investor-owned utilities and was collected from 1998 through 2001 pursuant to Assembly Bill 1890, and from 2002 through 2011 pursuant to Assembly Bill 995 and Senate Bill 1194. Senate Bill 90 and Senate Bill 1038 authorized the California Energy Commission to expend these funds from 1998 through 2006. Senate Bill 1250, which is currently going through the legislative process, would authorize the expenditure of funds collected from 2007 through 2011 although shifting funds from the existing to the emerging renewables account which provides for rebates to grid-connected customers. Biomass is not clearly delineated as an eligible technology class within the emerging renewables

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[78] http://www.biobased.oce.usda.gov/public/index.cfm

category. Changes in the distribution and disbursement of funds under these support programs will influence the competitive pricing of biomass energy.

Regulatory incentives

Emission Offsets

The lack of emission offsets is a significant barrier to technology development and deployment. Policy development or legislation may be needed to overcome this barrier. Without recognition that biomass facilities can reduce overall emissions, permitting of new facilities is not likely. Emission reduction credits (ERCs) are available for purchase in a few areas of the state; availability in amounts necessary to offset the potential growth of the industry are particularly limited in the central valley and Southern California. Mechanisms to provide offsets, such as trading between mobile and stationary sources where reductions can be certified and allowances for emissions avoided from wildfires will be important to future industry development under existing national air quality standards.

Renewable Energy and Environmental Credits

A renewable energy credit (REC) is produced when a unit of renewable energy is generated in substitution of a unit of non-renewable energy. Within the RPS, renewable energy credits are bundled with the sale of the energy so that renewable energy generators are not able to take separate advantage of the economic value of the credit. Unbundling constitutes the financial separation of the RECs from the underlying electrical energy. Were RECs to be unbundled from the sale of energy to utilities under the RPS, further economic incentive would be provided for the development of biomass and other renewable resources. Disaggregation of specific attributes from RECs may also enhance economic value but requires additional tracking.

The function of an REC tracking system is to track renewables purchases, to verify compliance with the RPS mandate, and to ensure that credit for each renewables purchase is only counted once. This is important from both a compliance and environmental standpoint, as it would ensure that environmental benefits of renewable generation are not counted by multiple power sellers to meet their RPS targets. Credits within California will be tracked under the Western Renewable Energy Generation Information System (WREGIS), scheduled for operation in mid-2007. Until adequate tracking is in place, REC values will remain low. Ensuring timely deployment of WREGIS will be important to the near-term expansion of the industry.

Other environmental credits pertain to the generation of renewable biomass energy, such as the capture of methane that would otherwise enter the environment, and local reductions in criteria pollutants. These benefits should not be bundled into the RECs, which should capture only the substitution benefits common to all renewable energy sources. Access to greenhouse gas markets and to markets for environmental credits would provide further economic incentives for biomass development.

5.2.2 Infrastructure improvements and access

Transmission Access

The state's present electric transmission system will need to be both expanded and upgraded to meet growth in consumer demand for power and the increasing diversity of dispersed renewable generation. To maintain a 20 percent share of renewable power within the RPS as called for by the Governor's Executive Order S-06-06 and the bioenergy action plan, biomass capacity additions will need to total approximately 700 MW by 2017, or 1500 MW by 2020 under an accelerated RPS.[79] If electricity emerges as a major transportation energy source even greater transmission capacity will be needed, because feedstock for much of this capacity is in regions with limited transmission infrastructure at present. Greater investment in electricity transmission and distribution will need to occur to provide generators access to power markets.

The difficulties in building new transmission hampers access to geographically dispersed generation, and decreases system reliability. To invest in new transmission lines requires long-term contracts for the energy that will be transmitted over these lines – but long-term contracts for energy are difficult to acquire without assurance that there will be a transmission system to carry the energy to the consumer. Upgrading the transmission system will not only benefit biomass projects, but in many cases will also provide capacity for transmission of other renewable power from wind, solar, and geothermal sources, thereby enhancing the ability of the state to increase the share of electricity from all renewable resources.

a) Uniform interconnection standards: Interconnection guidelines in California are standardized under California Public Utilities Commission (CPUC) and Federal Energy Regulatory Commission (FERC) processes. The CPUC applies its Rule 21 to the interconnection of CPUC jurisdictional facilities. The California Independent System Operator (ISO) reflects FERC tariff, including large and small generation interconnection processes. By and large, the RPS-eligible power should be interconnecting through California ISO tariff. Another viable option for interconnection

[79] "*Biomass in California: challenges, opportunities, and potentials for sustainable management and development.*" California Biomass Collaborative, 2005, CEC-500-2005-160, California Energy Commission, Sacramento, California.

could be at distribution level, under the wholesale distribution tariff. These processes specify the timeline and costs for interconnections. In addition, they have standards for certification of the generator-set interface.

The investor-owned electric utilities must adhere to standardized interconnection guidelines, CPUC Rule 21, to connect with distributed generation, defined as plants under 20 MW. Most municipal utilities have willingly adopted these standards as well. Rule 21 specifies the timeline and costs for three types of interconnection: simplified interconnection; interconnections requiring supplemental review; and interconnections requiring a full interconnection study. Reciprocating engines, typically used for small (under 1 MW) biomass distributed generation systems, usually require a supplemental review by the utility. Some biomass-to-energy systems will not have the option to interconnect with a local transmission grid because an extension to their location would be prohibitively expensive. In such cases, power would need to be used on-site or distributed only locally. Other biomass power systems have four options: 1) the power can be used only on-site, 2) the power can be used on-site and surplus power exported to the grid, 3) the entire generation of the plant can be exported to the grid, and 4) power can be exported to the grid with on-site loads also being served by the grid. Issues regarding timeliness and cost in interconnection should be resolved over the near term.

b.) Equipment Certification: Rule 21 now includes standards for certification of the generator-set interface. To certify equipment, it must be shown to comply with IEEE Standard 1547, which references testing required under a nationally recognized testing laboratory such as Underwriters Laboratories (UL). UL 1741 is the standard for 'Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources.' Use of equipment that is listed under UL 1741 is more readily accepted by the electric utility, which may then require fewer protective relays and may reduce the testing requirements necessary for inspection and approval of the interconnection. Development or use of UL-certified equipment, which would reduce the time and cost of interconnection should be a priority for biomass developers.

c.) System Capacity: On occasion, utilities need to make improvements to their distribution systems to receive small (<1 MW) distributed generation power. If upgrades are necessary, the cost is usually borne by the generator. Larger generators (>10 MW) can exceed the available transmission capacity, making upgrades necessary. Again, the cost is usually borne by the generator unless the utility has additional reasons to upgrade transmission to the area, making the transmission system improvement an important cost consideration. In-depth utility system studies can be done to identify optimal sites for distributed generation that would require no system upgrades. In some cases distributed generation can save expenses for utility system upgrades by reducing the need for increased transmission. Many forms of biomass are mobile and can be transported to a preferred site, allowing a match to be made between biomass resources and the distribution system, thereby reducing cost for system upgrading. Attempts have been made to identify such areas, such as the strategic value assessment conducted by the Energy Commission.[80]

Biofuels Production Potential and Infrastructure

Biomass feedstocks can be converted to liquid or gaseous transportation fuels, displacing petroleum, natural gas, and other fossil fuels. To increase market share, production capacity must be increased. Under optimistic estimates of conversion rates, potential ethanol production from in-state feedstocks may be as high as 3 billion gallons annually, although as noted earlier, shared use of available resources is likely to result in lower volumes.

In-state biofuel production potential

In-state biofuel production can be estimated using goals articulated in Executive Order S-06-06 and the Bioenergy Action Plan (i.e., by 2010, 20 percent of state's biofuel consumption should be produced in-state, increasing to 40 percent by 2020, and 75 percent by 2050), projected demand for gasoline and diesel fuel from the 2005 IEPR, and possible RFS or biofuel blend-rate scenarios,

California gasoline currently contains about 5.7 volume-percent ethanol (E5.7), creating demand for approximately 900 million gallons. Proposed legislation that would have required all diesel fuel in the state to contain at least 5 percent renewable content if systems emissions are found acceptable by CARB (SB 1675, Kehoe)[81] was not passed. Had it passed, it would have created a near-term demand for about 150 million gallons of renewable diesel, including conventional monoalkylesters commonly referred to as biodiesel. No specific recommendation for a renewable fuels standard (RFS) has otherwise been made although greenhouse gas benefits are widely acknowledged.[82] A legislative resolution supports a goal of 20 percent displacement of petroleum fuels by the year 2020 using some combination of biofuels, electricity, hydrogen, and other

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[80] Tiangco, V., P. Sethi, and Z. Zhang. (2005). "*Biomass Strategic Value Analysis*." Draft Staff Paper. California Energy Commission. CEC-500-2005-109-SD. http://www.energy.ca.gov/2005publications/CEC-500-2005-109/CEC-500-2005-109-SD.PDF

[81] As amended 8 August. http://www.leginfo.ca.gov/pub/bill/sen/sb_1651-1700/sb_1675_bill_20060629_amended_asm.html

[82] See: http://www.climatechange.ca.gov/climate_action_team/reports/index.html

alternative fuels.[83] CARB's update of the gasoline-vehicle emissions predictive model to include analysis for a range of ethanol blend-rates and potential adjustments of gasoline volatility parameters to accommodate ethanol is expected to be complete by January 2007. Results from the predictive model update should give insight into ethanol-gasoline blends and emissions tradeoffs.

For this analysis, three biofuel blend-rates for ethanol in gasoline are assumed; continuation of the current 5.7 percent statewide average (E5.7); a 10 percent RFS which assumes some combination of ethanol-gasoline blends such that the overall average is E10; and a 20 percent RFS (or E20 overall average). For diesel, four scenarios are modeled; renewable diesel blends of 2 percent, 5 percent, 10 percent and 20 percent (B2, B5, B10 and B20 [20 percent RFS], respectively).

Table 5.1 and Figures 5.5 A, and 5.5 B. show the results of the analysis. For ethanol, by 2010 about 325 million gallons/year (gpy) of in-state production is needed for the E10 scenario, increasing to between 390 and 1,430 million gpy by 2020 and between 900 and 3,250 million gpy by 2050. For renewable diesel, in-state production goals would vary from between 30 and 130 million gpy in 2010, to between 150 and 1,490 million gpy by 2050 for the B2 through B20 blend scenarios.

Table 5.1 Instate biofuel production goals for several blend rate scenarios

Instate biofuel goals (million gallons per year)

Year	Ethanol			Biodiesel			
	E5.7	E10	E20	B2	B5	B10	B20
2010	183	325	675	13	32	65	130
2020	390	700	1430	35	85	170	345
2050	900	1,570	3,250	150	375	750	1,490

[83] ACR 167 (Pavley) - As Introduced: August 15, 2006. http://www.leginfo.ca.gov/pub/bill/asm/ab_0151-0200/acr_167_bill_20060815_introduced.html

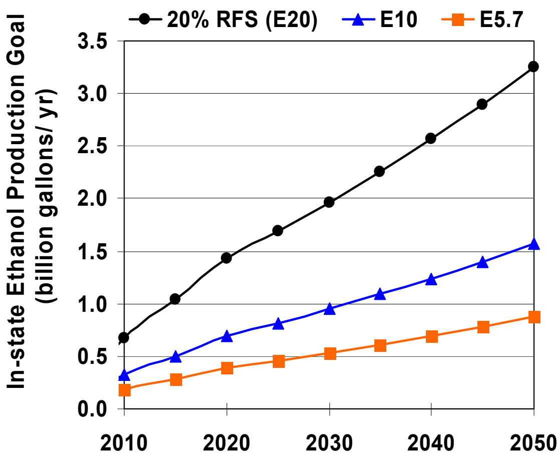

Figure 5.5.A. In-state production goals for renewable gasoline (ethanol) for three blend scenarios

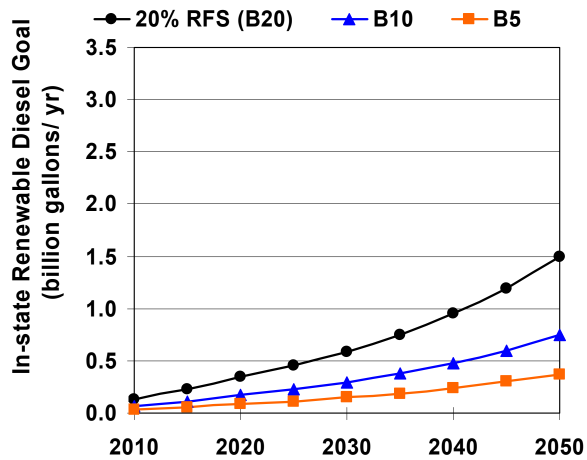

Figure 5.5.B. In-state production goals for renewable diesel for three RFS scenarios

Number of in-state ethanol facilities

Assuming an average production capacity of 50 million gpy for ethanol facilities, four in-state facilities will be needed by 2010 for the E5.7 scenario and fourteen facilities for the 20 percent RFS case (See Figures 5.6.A and 5.6.B). By 2020, eight and twenty-nine facilities will be needed for the E5.7 and 20 percent RFS scenarios respectively. By 2050, between 18 and 65 in-state bioethanol facilities will be needed (more for higher in-state goals or higher RFS standards). After 2010, the E5.7 scenario will require an additional 100 million gpy capacity every 5 years and about 300 million gpy new capacity will be needed every 5 years for the E20 case.

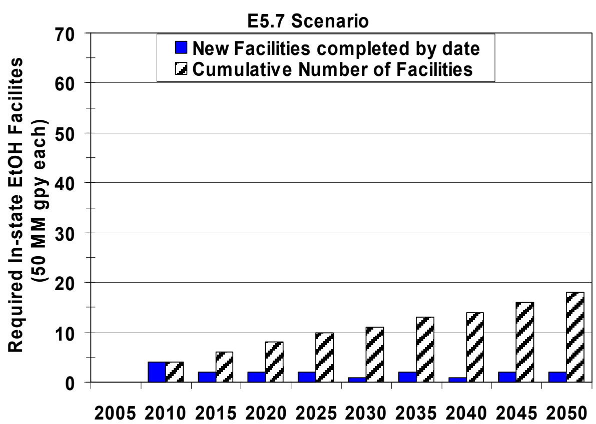

Figure 5.6.A Number of in-state 50 M gpy ethanol facilities for the E5.7 scenario

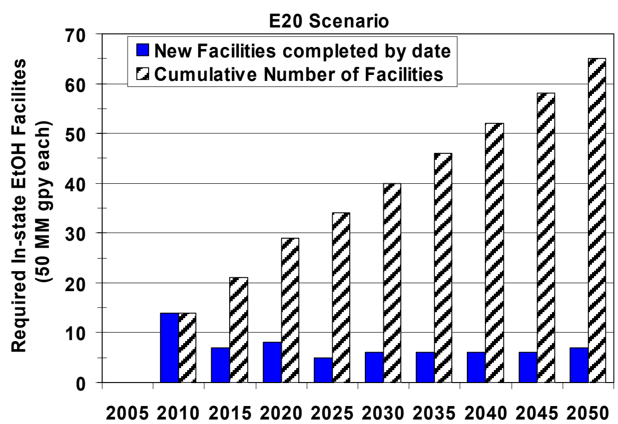

Figure 5.6.B. Number of in-state 50 M gpy ethanol facilities for the E20 scenario (20 percent RFS)

In-state starch and sugar crops

California's diverse agricultural sector includes many starch and sugar crops that could be used for bioethanol feedstocks. Grown currently for food and feed (and driven by markets in the long-term), rice, wheat, corn, barley, sorghum, oat and sugar beets have the largest potential for conventional bioethanol production. These crops together accounted for more than 1.1 million acres harvested in 2005, or about 12.7 percent of all irrigated cropland in the state.

The potential ethanol production represented by the 2005 California harvest from these crops is about 360 million gallons (Table 5.2). With the exception of rice, these grain and sugar crops had been cultivated in much larger amounts at one time or another since 1950. In 1954, 1.9 million acres of barley were harvested and 1.3 million acres of wheat were harvested in 1981; however, crop rotations and crop shifting imply that maximum acreages were not necessarily concurrent.

Table 5.2 -.California starch and sugar crop yields, acres harvested, and ethanol potentials.

	Product Yield (tons/acre)	Ethanol Yield		Acres Harvested in 2005 (1000s)	Max. Acres Harvested post 1950		Ethanol Potential (million gallons)	
		(gal/ ton)	(gal/ acre)		Acres (1000s)	Year	2005 Crop	Historical Max. Crop
Rice	4.0	90.0	355	526	593	1981	187	211
Wheat	2.3	93.3	210	369	1345	1981	78	283
Corn	4.8	96.4	459	110	375	1984	51	172
Sugar beets	35.0	24.8	870	44	354	1964	38	305
Barley	1.4	58.3	84	60	1915	1954	5	161
Sorghum	2.4	96.4	230	10	424	1967	2.3	97
Oats	1.3	58	75	20	223	1957	1.5	17
Totals				**1,139***	**5,229***		**360**	**1,250**

*There are about 9 million irrigated acres in production in California.[84]

Sources : California crop yield and harvest data from NASS[85], Ethanol yields from Dale, B.E. (1991)[86], and Shapouri et al., (2006)[87]

[84] Gildart, M., Jenkins, B. M., Williams, R. B., Yan, L., Aldas, R. E., and Matteson, G., C. (2005). "*An Assessment of Biomass Resources in California."* CEC PIER Contract 500-01-016, California Biomass Collaborative.

[85]California yields from USDA National Agricultural Statistics Service (NASS). Available at: http://www.nass.usda.gov/

[86] Dale, B. E. (1991). "*Ethanol production from cereal grains.*" Food Sci. Technol. Handbook of Cereal Sci. and Technol. K. J. Lorenz and K. Kulp. New York, Marcel Dekker, Inc.: 863-870.

[87] Shapouri, H., Salassi, M., and Fairbanks, J. N. (2006). "*The economic feasibility of ethanol production from sugar in the United States.*" USDA.
Available at; http://www.usda.gov/oce/EthanolSugarFeasibilityReport3.pdf

Crop acreage requirements

Traditional food and feed crops are currently used for biofuel and bioenergy production. The vast majority of US ethanol production comes from Midwest grain corn . In 2005, about 14 percent of the US corn harvest was used to produce some 3.9 billion gallons of ethanol-equivalent or about 1.8 percent of US gasoline demand.[88] The non-fermentable solids, or distillers' grains, from corn ethanol fermentation is used for cattle feed and is an important source of income for the US bioethanol industry. Coproduct credits are important to the overall economic feasibility and energy balance of corn ethanol facilities in the US. Midwest facilities commonly dry distillers grains prior to marketing. In California, feeding of wet distillers grains is more commonly proposed. Controlling ethanol and other VOC emissions from these feedstuffs will be important to the success of these operations.

In Europe, cereal grain crops and sugar beets are used in bioenergy production., primarily for production of biogas from anaerobic digestion which is used for renewable electricity and renewable compressed natural gas vehicle fuel. France and a number of other countries are beginning to expand ethanol production.

According to Hill et al., (2006), the US corn harvest could yield about 28 billion gallons of ethanol (about 13 percent of US gasoline demand). To supply all of the US gasoline demand from corn-derived-ethanol, about 575 million acres would be required, well in excess of available land[89].[90]

California crop acreage requirements for ethanol production

If the current grain and sugar crops in the state were diverted from food and feed production to conventional ethanol production, they could meet the 2010 in-state goal for ethanol for the E10 scenario (about 360 million gallons of ethanol potential from 1.1 million acres harvested).

To meet in-state production goals for ethanol using only corn from California would require between 845,000 and 3.1 million acres by 2020 and between 1.9 and 7.1 million acres by 2050 for the E5.7 and E20 scenarios respectively (See Table 5.3.). Note that there are about 9 million acres of irrigated crop land in California.

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[88] Hill, J., Nelson, E., Tilman, D., Polasky, S., and Tiffany, D. (2006). "*Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels.*" PNAS, 103(30), 11206-11210.

[89] 303 million harvested acres in 2002 – USDA NASS Op cit

[90] USDA NASS. Op. cit.

Table 5.3 .Starch/sugar crop area requirements for in-state ethanol production goals
(thousand acres)

Year	Corn			Corn + Stover			Sugar Beet		
	E5.7	E10	E20	E5.7	E10	E20	E5.7	E10	E20
2010	398	709	1,468	231	411	851	211	375	776
2020	845	1,504	3,116	489	871	1,805	447	795	1,647
2050	1,919	3,416	7,076	1,112	1,979	4,100	1,015	1,806	3,742

For the same scenarios and goals, sugar beet acreage would be about half of that required for corn. In the case of an integrated biorefinery that utilizes corn grain as well as the lignocellulosic portions of the plant (the stover), required land area would be about 60 percent of that for an industry that utilizes only the corn grain.

California crop acreage requirements for biodiesel production

Crop acreage requirements to meet in-state goals for conventional biodiesel production are higher than those for conventional ethanol.[91] The oil crop acreage required varies from about 130,000 to 1.3 million acres for the 2010 goal, between 340,000 and 3.4 million acres for the 2020 goal, and from 1.5 to 14.9 million acres by 2050 depending on blend-rates varying from B2 to B20 [See Table 5.4]. Biodiesel crop acreage is based on oil-seed yield of 2000 lbs/acre, with a 40 percent oil content, and about 94 percent oil extraction efficiency. This gives a biodiesel yield of about 100 gallons per acre.

Table 5.4 . Oil seed crop requirements to meet in-state production goals for conventional biodiesel
(thousand acres)

Year	B2	B5	B10	B20
2010	130	324	648	1,295
2020	343	857	1,713	3,427
2050	1,488	3,719	7,438	14,875

California lignocellulosic ethanol potential

Lignocellulosic-derived ethanol offers several advantages over ethanol produced from sugar-starch feedstocks. These include the potential for higher-per-acre ethanol yields and lower agronomic inputs for purpose-grown energy crops; improved product-life-cycle environmental performance, GHG balances and net-energy ratios; the potential to utilize marginal and idle lands - which reduces competition with food crops; and the

[91] Conventional biodiesel means a biofuel from transesterification of plant oils suitable for use in compression ignition (diesel) engines. Conventional ethanol production means bioethanol fermented from starch and sugar crops. Advanced biofuels will be produced from lignocellulosic components of plant material through thermochemical and biochemical processes.

potential to use the large and diverse existing lignocellulosic biomass-residue-streams found in urban waste, forest thinnings, and agricultural residues. As the US will not be able to make enough biofuels (e.g., bioethanol) from conventional feedstocks (starch and sugar sources) to substantially reduce petroleum imports or lower GHG emissions from the transportation sector, lignocellulosic routes to biofuels will be needed.[92, 93,94]

The existing lignocellulosic resource in California that could be used for production of fuel alcohol is composed of forest-operation and wood-product residues, urban mixed paper-, wood-, and green-wastes that are currently landfilled, and certain crop and agricultural residues, about 24 million BDT/y in this estimate (Table 5.5). Dedicated energy crops, such as switchgrass,[95] grown specifically for ethanol feedstock on 1.5 million acres of idle or marginal lands could add another 7 to 13 million BDT/y. Potential ethanol production from these cellulosic residues in California could be as much as 1.7 billion gallons.[96] Energy crops could add another 600 million to 1.3 billion gallons of ethanol potential depending on crop and ethanol yield. Total ethanol production from in-state lignocellulosic feedstock material, therefore, could approach between 2.3 and 3 billion gallons (between 1.5 and 2 billion gallons of gasoline equivalent or 10-13 percent of current gasoline use[97]; see Table 5.5).[98]

In summary, assuming biofuel blends in gasoline and diesel of 10 percent by volume, in-state production goals for ethanol would be 325 million gpy by 2010, 700 million gpy

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92 Farrell, A. E., Plevin, R. J., Turner, B. T., Jones, A. D., O'Hare, M., and Kammen, D. M. (2006). "*Ethanol can contribute to energy and environmental goals.*" Science, 311(5760), 506-508.

93 Perlack, R. D., Wright, L. L., Turhollow, A. F., Graham, R. L., Stokes, B. J., and Erbach, D. C. (2005). "*Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply* " TM-2005/66, Oak Ridge Natl. Lab, Oak Ridge, TN.

94 Hill et al. (2006). Op cit.

95 Switchgrass is used as an example and may not be the preferred crop for California. Other potential dedicated (cellulosic) energy crops include miscanthus, bermuda grass, short-rotation willow or eucalyptus. Crops such as sweet sorghum producing sugar and cellulosic biomass can also be grown. The best mix of energy crops that are agronomically sustainable in California's agricultural regions is the subject of on-going and proposed research.

96 Assumes a conservative ethanol yield of 70 gallons per dry ton of field and seed crops, orchard and vine prunings and removals, forest and range thinnings, and landfilled paper and woody/green wastes considered to be available for utilization. Nearly 70 percent of the state estimate is due to the large potential for forest and rangeland thinnings. The estimate assumes no competition for the resource such as biopower, mulch, compost, etc.

97 Current gasoline usage in the state is approaching 16 billion gallons. http://www.boe.ca.gov/sptaxprog/spftrpts.htm

98 Ethanol is not the only biofuel that can be made from lignocellulosic biomass. Fischer-Tropsch synthesis following thermochemical conversion of biomass is another pathway (sometimes called the 'biomass to liquids' or BTL route) and can produce gasoline and diesel hydrocarbon substitutes.

by 2020, and 1.6 billion gpy by 2050 if hydrogen or other energy forms do not emerge to displace gasoline. For renewable diesel, the goals would be 65, 170, and 750 million gpy by 2010, 2020, and 2050 respectively and twice these amounts for a 20 percent RFS.

The required land-area to grow conventional starch and sugar crops for ethanol feedstocks could reach from 1 to 7 million acres in-state depending on RFS targets and combinations of crops. Land area required for oil-seed crops for conventional biodiesel production could grow to more than 14 million acres by 2050 for a 20 percent RFS scenario.

Table 5.5. California Lignocellulosic Ethanol Potential[99]

Biomass Source		Technical amount * (million dry ton/yr)		Potential Ethanol (million gallons/y)
Field and Seed		2.3		160
Orchard/Vine		1.8		125
Landfilled Mixed paper		4.0		280
Landfilled wood & Green		2.0		140
Forest thinnings		14.2		990
Totals: Current California		**24.2**		**1,695**
1.5 Million Acres Dedicated Energy Crop				
Low Yield (5 BDT/acre, 80 gallons/ton)		7.5		600
High Yield (9 BDT/acre, 100 gallons/ton)		13.5		1,350
State potentials w/ 1.5 M acres energy crop	**Low Yield**	**32**	**Range**	**2,295**
	High Yield	**38**		**3,045**

* Gildart et al. (2005) [100]

California currently harvests around 9 million acres of cropland. Competition for land will arise to meet high biodiesel demands if only oil-seed crops are proposed to meet in-state production targets. Use of lignocellulosic resources will be needed to satisfy the long-range targets. Biofuels (alcohols and renewable diesel) from in-state lignocellulosic resources (current residues plus 1.5 million acres of energy crops) could supply 2 – 3 billion gpy ethanol (1.3 – 2 billion gallons gasoline equivalent).

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[99] Williams, R. B. (2006). "*Central Valley and California Lignocellulosic Ethanol Potential: Summary Analysis.*" California Biomass Collaborative. University of California, Davis.

[100] Gildart et al. (2006). Op cit.

Biofuels Infrastructure
In addition to increasing production capacity, a convenient distribution and fueling infrastructure must be established. These requirements vary depending on type of fuel.

a) Ethanol and other alcohols: As described above, the primary market for ethanol currently is as blendstock in gasoline. Increasing market share in helping to meet state petroleum reduction targets will require blending at higher concentrations. Ethanol blended in gasoline reduces the emissions of particulate matter, carbon monoxide, and hydrocarbons. To achieve these air quality benefits, and to meet octane and supply requirements, bioethanol is added into almost all gasoline in California at 5.7 percent of volume. Blends up to 10 percent ethanol by volume (E10) can be used without adversely affecting automotive fuel or engine control systems. Beyond this level, flexible-fuel vehicles (FFV) designed to accommodate higher ethanol concentrations are required. The maximum commercial ethanol concentration is likely to be 85 percent (E85).

E10 is not currently marketed in California because refiners have not chosen to adjust gasoline formulations to accommodate it under California reformulated gasoline blendstock for oxygenate blending (CARB-OB) requirements. Price differentials between ethanol and gasoline may influence this decision, as may results due in early 2007 from the latest predictive model used by the California Air Resources Board (CARB) to predict emissions from fuels under reformulated gasoline specifications.

An E85 market in California could greatly expand demand for biomass. Substituting E85 for current gasoline usage would require about 23 billion gallons per year, well above the potential for in-state production from existing biomass resources, and close to five times the current national production capacity. Currently E85 is dispensed at three locations in California. Two of these are reserved for use by vehicle fleets and only one is for retail sales. The state has nearly 300,000 flexible-fuel vehicles.[101] Pending legislation (AB 1012) would require CARB to adopt regulations ensuring that by 2020 half the vehicles sold in the state are clean alternative vehicles, including FFVs, plug-in hybrids, CNG, LPG, and hydrogen fuel cell vehicles. For FFVs to operate on clean alternative fuels as defined in the legislation, substantial increases in biofuel production capacity will be needed.

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[101] MacDonald, T. (California Energy Commission), 2005. "*Alcohol Fuel Flexibility – Progress and Prospects*". Fifteenth International Symposium on Alcohol Fuels, September 26-28, 2005, San Diego, CA., 8pp.
- CEC, Staff Report (CEC-600-2005-020), May 2005. "*Alternative Fuels Commercialization*", 41pp.,
- The Associated Press, Sunday, June 11, 2006. "*Alternative Fuel Station May Be Future*". By Tim Molloy. http://www.washingtonpost.com/wp-dyn/content/article/2006/06/11/AR2006061100504.html

As a low blend, E10 can be distributed by the current ethanol fueling infrastructure. New infrastructure will be required for the use of high blends like E85. Experimental programs are currently in development to evaluate E85 fueling systems. Fuel production and fueling infrastructure will need to be developed concurrently in order to stimulate and maintain consumer demand.

Other alcohols from biomass, such as n-butanol, are more readily distributed through existing infrastructure and may not need the same level of infrastructure development to bring them to market. Butanol has a higher volumetric heating value compared to ethanol, and because it is less hygroscopic does not suffer the same problems of phase separation when blended with gasoline the way ethanol does.

b) Hydrogen: Hydrogen is currently used primarily in refinery operations and is produced from natural gas, petroleum, coal gasification, and electrolysis. For hydrogen to be used as a transportation energy source, an extensive distribution infrastructure will need to be developed. Biomass is a source of renewable hydrogen. Hydrogen can be produced from biomass thermochemically through gasification, biochemically through microbial fermentation, and biophotolytically by green algae and cyanobacteria. There are not yet any completed large-scale technology demonstrations. In this regard, programs targeting the advancement of biomass-to-hydrogen technologies need to be closely integrated with other hydrogen development programs. Hydrogen enriched fuel can also contribute to emissions reductions from stationary power plants.

c) Biogas, a mixture primarily of methane and carbon dioxide, is produced from the decomposition of biomass through anaerobic digestion, a natural bacteriological process that breaks down organic material in an oxygen-free environment. Biogas is typically 50-70 percent methane. The remainder is almost all carbon dioxide along with much smaller quantities of hydrogen sulfide, ammonia, water, and various other compounds. By removing moisture, carbon dioxide, and impurities, biogas can be upgraded to biomethane, a product equivalent to natural gas which typically contains more than 95 percent methane. Production of biogas and biomethane can be expanded through greater use of anaerobic digestion systems for animal waste, food waste, and other biodegradable waste management.

Biomethane can be used interchangeably with natural gas for power generation, heating, cooling, or as vehicle fuel. When sufficiently purified, it serves as a renewable natural gas and can be distributed through natural gas pipelines. Impurities, especially vinyl chloride, in landfill gas tend to limit this option, but biogas from animal manures, separated food wastes, and other higher quality feedstocks generally can meet pipeline quality standards. High pressures can be used to store and transport it as compressed biomethane which is analogous to compressed natural gas (CNG), or it can be liquefied to produce a product analogous to liquefied natural gas (LNG).

Biomethane production requires a willing buyer such as a fueling station, industrial customer, or a gas utility. Fortunately fuel standards do not need to be developed, since natural gas standards already exist and biomethane plants can be designed to meet them.

In addition, a physical distribution infrastructure has to be established. If the biomethane is to be used as a fuel, more natural gas fueling stations and more natural gas vehicles have to be in place. Piping, or storage and trucking must be set up to get it to the fueling station. If it is to be used in a transmission pipeline then piping needs to be built to get it to the transmission pipeline. Trucking can be a temporary alternative but is expensive.

Central Valley cities such as Tulare, Visalia, Hanford or Modesto would be good sites for a biomethane vehicle fuel project because they are in a non-attainment area for ozone, and each has many dairies near existing CNG filling stations. To make such projects feasible these cities would need to enlarge their natural gas fleets and expand or reconfigure their filling stations.

Other buyers would include industrial customers and gas utilities. At least one investor-owned utility is actively investigating the purchase of biomethane from dairies to put in its natural gas pipeline which could be very helpful, as some local regulations specify that permits for underground pipelines carrying gas can only be granted to public utilities.

A biomethane industry along California's Highway 99 could serve as the infrastructure for a future "hydrogen highway," providing a renewable fuel for the on-site manufacture of hydrogen for vehicle fuel.

d) Biodiesel and other renewable diesel fuel: Biodiesel typically refers to the monoalkylester produced by reaction of a triacylglyceride with an alcohol, such as reacting vegetable oil or animal fat with methanol or ethanol. These esters can be used in place of conventional diesel fuel in diesel engines and many other applications. Esters are not the only form of diesel fuel that can be made from biomass, however. Renewable diesels can also be produced by gasification to produce a synthesis gas containing carbon monoxide and hydrogen that is then converted catalytically to hydrocarbons. Fischer-Tropsch synthesis is a well known synthetic fuel production route that is now used to produce gasolines, diesels, and many other compounds from natural gas and coal. FT synthesis can also be used with biomass to produce fuels that have properties similar to or superior to those of conventional liquid hydrocarbon fuels. The process is still developmental for biomass, however.

Biodiesel esters can be produced from a wide variety of lipid sources, including a number of oil seed crops already grown in California such as safflower, sunflower, and others. Biodiesel can be blended with conventional diesel for distribution. Legislation has been proposed to require blending of biodiesel at levels of 2 to 5 percent (B2 and B5), although a recent bill (AB 1675) with this purpose was not passed. To distribute B100, or pure biodiesel, will require separate pumps and delivery systems. This is not the case with FT liquids which should largely be fungible in the existing infrastructure.

Other biofuels and refining options: Other fuels can be produced from biomass including pyrolysis bio-oils, and possibly catalytically refined oils to produce aviation grade fuels. In the near term, biodiesel and ethanol can be marketed separately or blended. Over the longer term, integrating crude biomass oils and fuel intermediates into petroleum refining operations, in addition to the use of biomass for electricity and hydrogen generation, may be feasible in order to produce standard fuels that can be handled together without the need for separate infrastructure.

5.2.3 Technology deployment

Market expansion can only occur if additional biomass capacity is deployed. Near term deployment should target upgrading or repowering existing power plants and adding new power generation capacity including distributed generation, expanding landfill gas and other biogas systems to produce power and fuels including the adoption of bioreactor landfills, adding new waste-to-energy and other conversion capacity for biomass in MSW, expanding the use of biodiesel as a blendstock for conventional diesel, expanding E85 fueling capability, adding compressed and liquefied biomethane capacity, and ensuring adequate harvesting equipment, truck transportation, feedstock storage, and electricity transmission and natural gas pipeline capacity exist to meet the needs of a roughly seven-fold increase in biomass utilization within twenty years.

Longer term deployment should be planned in concert with research and demonstration of new technologies and processes. Particular attention should paid to siting advanced integrated biorefineries incorporating both biochemical and thermochemical conversion and producing multiple value-added fuels, hydrogen, and products as well as energy, replacing existing power facilities with more advanced systems such as BIGCC and increasing use of combined heat and power, increasing hybrid system capacity to take advantage of stored energy in biomass in complementing intermittent renewable power from wind and solar systems, integrating specialized bioenergy and other biomass crops into agricultural systems, integrating crude biomass-derived fuel intermediates as feedstocks to conventional petroleum refinery operations, and developing hydrogen distribution systems.

5.3 Research, development, and demonstration

A substantially increased research effort will be needed as California develops and implements renewable and low-carbon technologies to reduce reliance on petroleum and other fossil fuels. Consistent, coordinated and focused research, education, training and public outreach are required if the state is to realize its vision for biomass.

Biomass materials are composed of organic compounds that can be broken down into various chemical constituents and reformed into new chemical-based products. Biomass can be the raw material or feedstock for many energy products that currently come from hydrocarbon resources. Many biomass materials have a cellular structure with the mechanical and physical properties needed to manufacture fiber-based consumer products, from paper and fabric to building materials.

An adequately funded research program and infrastructure must be created at the state level if California is to make best use of its agricultural, forest and urban biomass resources, as well as crops grown specifically for conversion to energy and products.

Innovation and high productivity are key components of California's global competitiveness. In the field of biomass and other low-carbon technologies, California has strong competition from other states and regions in the world. As the renewable energy and low-carbon industrial sector matures, regions that come to dominate will have more access to investment capital. Early adopters will develop technologies and systems which will be exported to late adopters. Increased levels of biomass research will allow California to compete in biomass and bioenergy technology and products markets. Additionally, research and technology development may allow farm businesses to develop new crops and products to sell into sustainable biofuels markets. A profitable biofuels production sector will help sustain the economic viability of farmers, and provide them a means of directly contributing to global sustainability by reducing carbon emissions from farming.

5.3.1 Resource base, sustainability and access

Best Practices

Management, cultivation, and utilization of biomass resources should employ practices that provide long-term availability of the resource while minimizing impacts to the environment and local communities. Depending on the crop or biomass resource, these best practices may or may not already be established. Where acceptable practices are not yet in place, investigation and research are needed to determine them. Because techniques and environmental understanding change over time, best practices will also evolve. There needs to be ongoing attention to development of sustainable practices for all biomass resource types, and certification, monitoring, and enforcement to ensure they are followed.

Agricultural and dedicated energy crop sustainability

Estimates of agricultural residues available for biomass may not always adequately account for the long term sustainability of the agricultural system. Agronomic effects such as loss of organic material and nutrients from soils, soil carbon and nitrogen cycles, water- and wind-borne soil erosion, irrigation water infiltration into soils and habitat, and effects of weed control need to be considered in relation to crop residue removal and new crop production. Adding or removing crop residues can have long-term effects on soil quality and productivity, and may have secondary, more complex effects on soil ecosystems and crop health. Sustainable agricultural residue removal rates need to be determined and are part of the agricultural reside best practices determination.

In energy-crop production, maximum usable biomass is a primary goal. But measures to maximize production will have correlated environmental effects. For example, maximizing production through fertilization and irrigation will affect non-CO_2 greenhouse gases (e.g. nitrous oxide and methane). Consequently, in addition to understanding the agronomic requirements of a set of energy crops suitable for California, a full greenhouse gas balance should be included when selecting or improving potential energy crops. Empirical research and modeling need to be integrated in order to scientifically and cost-effectively address these issues.

The College of Agricultural and Environmental Sciences at UC Davis maintains the only field scale research project in the state focused on the long-term effects of critical management practices like irrigation, fertilizer use and crop residue recycling in arable farming systems in California. This facility, the Long Term Research on Arable Farming Systems (LTRAS) project can be used to study and predict the consequences of long-term energy crop production in California. The LTRAS experiment is part of the Center for Integrated Farming Systems, which focuses on a systems-level, long-term approach to management of California's diverse farming systems.

Long-term field research allows for the assessment of slowly changing but important processes sustaining farming and for unanticipated phenomena to emerge over time. Such knowledge can be incorporated into improved models to predict future trends and otherwise not easily measured agroecosystem functions such as greenhouse gas mitigation. Long-term research on the production of bioenergy crops in California can be linked to the further development and calibration of models that simulate changes in productivity, soil quality, and greenhouse gas fluxes; this in turn helps evaluate the sustainability of alternative biomass production strategies and provide guidance to decision makers.

Improve agronomic techniques

Information developed from long-term field research of energy cropping systems can be used to improve agronomic techniques. Techniques that reduce water, petroleum-fertilizer, and other inputs are needed to enhance economics and sustainability of energy crop production, for example, minimum tillage, integrated pest management, microirrigation, and precision agricultural practices.

Dedicated biomass crops

A systematic approach to the evaluation of energy crop production potential and sustainability should also include consideration and testing of advanced plant genetics and crop breeding techniques to develop suitable or improved cultivars. For example, wheat, barley, and triticale crops with greater starch content and less protein might be better suited than current types for ethanol production, and may require less nitrogen fertilizer. An earlier maturing wheat crop would work more efficiently in a relay or multiple cropping system with corn sorghum or other warm season biomass crops grown in the same season.

There are several types of potential energy crops that California farmers might produce profitably. These are cereals, oilseeds, sugar crops, forages or forage-type crops and woody crops produced in plantations. Because of the state's long growing season, high-quality soils and potential available acreage, a wide array of biomass crops and strategies may prove feasible. Water will in some cases be a constraint but there are some areas where biomass production will be important in managing ground water regimes. These crops and strategies require systematic assessment based on available data, and research on plant genetics and plant improvement through biotechnology will be needed to improve candidate energy crops in order to take full advantage of their potential. Also needed are field trials for selected species and novel cultivars with significant potential but where little data are available for California conditions. Results should be integrated into simulation models to estimate the magnitude of correlated effects, the direction of change in cropping system properties, and greenhouse gas effects.

<u>Cereals</u>

Cereals have several advantages for the production of ethanol and other fuels. Both grain for direct fermentation and straw or other stalk residues for cellulosic fermentation, thermochemical conversion, or fuel for process energy are produced. Cereals are generally easy to grow, harvest, store and transport. Some are winter crops and can make efficient use of rainfall, and some are salt tolerant, so could be produced on lower quality land and/or with poorer quality water. The world's major, and many minor, cereals are currently produced in California. These include rice, wheat, barley, triticale, corn, and sorghum.

Wheat, barley and triticale are winter cereals. For the most part they are grown without irrigation in the Central Valley and elsewhere in the state, and several hundred thousand acres are in crop/fallow systems linked with livestock grazing. Diseases and pests are generally controlled through plant breeding, so they are low-input crops in general and very suitable for no-till production. It may be possible to modify these crops for energy purposes using molecular biotechnology and traditional plant-breeding once the needed characteristics are identified.

Corn is widely grown in California, particularly in association with dairy farms for silage, but also in the Delta and Sacramento Valley for grain. Yields here are high in comparison to the Midwest with mostly rainfed production. Increased demand due to diversion of corn for ethanol may improve profitability. Some insecticides are used in corn production. The crop must be irrigated and is not salt tolerant. It is responsive to and requires N fertilizer or livestock manure for high yields

Sorghum is hardier than corn and can be grown with less water but still must be irrigated. It tends to be lower yielding, in part because it tends to be grown under less ideal conditions than corn.

<u>Oilseeds</u>

Safflower is the only significant oilseed in California. It is grown throughout the Central Valley, where it is very well-adapted. It is essentially disease- and pest-free. In the northern Central Valley on deeper soils it can be produced without irrigation. It produces an oleic fatty acid dominant oil (monounsaturated-18:1) which has excellent properties as feedstock for biodiesel. It is moderately salt tolerant and because it is deep-rooted it can be used in farming systems to reduce overall leaching losses to ground water. It is planted in spring and harvested in summer.

Canola is a mustard-family crop (a low eruric acid type of rapeseed) and is grown similarly to winter wheat. It can take advantage of winter rainfall but may need late spring irrigation. It is susceptible to some insect pests, particularly aphids. It, too, produces a high-quality oil and grows well in California. UC researchers and private companies, using molecular methods, have successfully increased the salt tolerance of canola.

Residues from oilseed crops would be more limited than from cereals. Both canola and safflower can be produced in no-till systems in California. Other novel oilseed crops may also develop as legitimate biomass sources here. Flax is well adapted to the inter-mountain and coastal regions and was produced as a winter crop in the Imperial Valley at one time. Jojoba is a native desert shrub that produces seeds high in waxes and oils , but production is adequate only when produced under agricultural conditions. Jatropha curas, a tree grown in India for oil, is also being studied for biodiesel production.

<u>Sugar crops</u>

The highest average sugar beet yields in the world occur in California. Sugar beets are adapted to lower quality soils and are salt tolerant. At one time they were grown throughout the state, but they are only produced in the San Joaquin and Imperial Valleys at present. There is unused potential for sugar beet production for ethanol in the Sacramento Valley and Delta regions. Besides sugar, beets produce a primarily cellulose byproduct now used as animal feed but that may have potential for energy feedstock. Annual dry matter yields of 18 to 25 tons per acre are possible.

Sugar cane trials have been carried out in the Imperial Valley in the last several years. Sugar cane grows well there and might be used for ethanol production, particularly in combination with sugar beets, as the two have different harvest periods. Sweet sorghum grows well in California but for economic reasons has not been widely produced.

<u>Forages</u>

A large number of forages are grown in California. *Alfalfa* is the most common because of its value in the dairy industry, but grass hays are also widely produced. Perennial forages like switchgrass will grow but switchgrass has not yet been seriously evaluated as a biomass source here although work on this crop in California is now beginning. *Bermuda grass* and *Jose tall wheat grass* are two highly salt-tolerant forages that can be produced on poorer quality land using waste waters. Many other grass species might be suitable for energy crops but need evaluation over a range of California environments. New crops introduced into California need also be considered in terms of their invasive potential.

Woody biofuel crops:
In the past poplars and eucalyptus trees have been produced successfully on non-salt-affected soils for biomass in California. These and other sources of woody biomass such as short rotation willow deserve additional attention.

Inventory assessment and monitoring
Biomass resources in California have been assessed in a number of studies.[102,103,104,105, 106, 107] In addition, the California Biomass Collaborative has issued updated and comprehensive resource estimates by compiling information from the California Department of Forestry and Fire Protection, California Department of Food and Agriculture, the USDA National Agricultural Statistics Service , the California Integrated Waste Management Board, and the California Energy Commission.[108] There remains a need to develop more routine assessment methods providing higher resolution spatial and temporal data supporting biomass utilization.

Improve factors used for gross and technical agricultural residue estimates
Agricultural residues comprise about 25 percent of the gross biomass resource. These residues are estimated based on crop-specific, per-acre residue yield factors many of which are decades old or are only estimated from similar crop types. These factors need to be updated or measured.[109]

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[102] Springsteen, B. (2000). "*Assessment of California Waste Resources for Gasification*", GE-EER. EER - SDV Contract No. 500 - 98 - 037

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

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

[105] California Energy Commission*, 1991, " Biomass Resource Assessment Report for California,"* Draft; P500-94-007,

[106] California Energy Commission, (1999). "*Evaluation of biomass-to-ethanol fuel potential in California,*",A report to the Governor and Secretary of CalEPA; Executive Order D-5-99.

[107] Burnes, E. I., Koehler, N., Koehler, T., and Sebesta, P. (2004). Ethanol in California - a feasibility framework, Great Valley Center.

[108]California Biomass Collaborative: (2005). "*An Assessment of Biomass Resources in California;*" CEC PIER Contract 500-01-016.

[109] Ibid.

Expand models for estimating economically available resource

Current biomass resource inventories, including estimates of amounts technically feasible to harvest are not yet based on full economic assessments using production, collection, and other acquisition costs. GIS and other more detailed models are needed to provide better resource information for developers and planners.

Develop statewide biomass resource models to facilitate industry siting

Using improved resource recovery factors and economic models, a comprehensive GIS-based resource model can be developed to help industry, local governments, and others with facility siting.

Develop and/or adapt remote sensing technologies, techniques and systems for biomass inventory assessment and monitoring of sustainable practice.

Remotely sensed data have become the primary source for biomass inventory assessment in forested lands. Remote sensing is used to estimate mass of above-ground carbon, vegetation type, density, health, and other conditions. However, a review of the literature[110] indicates biomass estimation remains a challenging task, especially in areas with complex forest stand structures and environmental conditions. Research is needed to focus on the integration of optical and radar data, the use of multispectral, multisource data, and the selection of suitable variables and algorithms for biomass estimation at different scales. Light detection and ranging (lidar) is increasingly being used to develop predictive models of forest biophysical variables. However, before this technology can be adopted with confidence for long-term monitoring, robust models must be developed that can be applied and validated over large and complex forested areas. [111, 112, 113, 114, 115, 116]

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110 Lu, D. S. (2006). "*The potential and challenge of remote sensing-based biomass estimation.*" International Journal of Remote Sensing, 27(7), 1297-1328.

111 http://www.isprs.org/commission8/workshop_laser_forest/DANILIN.pdf

112 http://www.affa.gov.au/content/output.cfm?ObjectID=79623470-FEF5-4453-8D97FCBAAB5C737C

113 Lu, D. S. (2006).Op Cit.

114 Lucas, R. M., Cronin, N., Moghaddam, M., Lee, A., Armston, J., Bunting, P., and Witte, C. (2006). "*Integration of radar and Landsat-derived foliage projected cover for woody regrowth mapping, Queensland, Australia.*" Remote Sensing of Environment, 100(3), 388-406.

115 Nelson, R., Parker, G., and Hom, M. (2003). "*A portable airborne laser system for forest inventory.*" Photogrammetric Engineering and Remote Sensing, 69(3), 267-273.

116 Thomas, V., Treitz, P., McCaughey, J. H., and Morrison, I. (2006). "*Mapping stand-level forest biophysical variables for a mixedwood boreal forest using lidar: an examination of scanning density.*" Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere, 36(1), 34-47.

Infrastructure and biomass scale limitations
Because ethanol is hygroscopic, blending it with gasoline presents challenges due to phase separation. This is because most gasolines are pipelined or transported "wet," that is with some water that later is gravity-separated in tanks at the fueling station. For high ethanol blends (e.g., E85) 'splash' blending at the retail outlet is most commonly proposed. Finding interchangeable alternatives to reduce costs of fuel marketing is an important area for research and development which should be pursued in cooperation with fuels industry. Alternatives to ethanol that are less hygroscopic, such as n-butanol, are proposed, but other solutions should also be investigated. Because pipelines are used to handle multiple fuel types, there is potential to contaminate when transporting incompatible fuels, such as aviation fuel following biodiesel.

Other cooperative investigations include biomass and fossil fuel co-firing for electricity generation. Co-firing in fossil-fueled systems, predominantly coal, can increase the overall efficiency of biomass use, as adding small fractions of biomass to the fuel blend does not generally impair overall system efficiency. Although there is limited in-state coal-fired power generation, opportunities include biogas/natural gas systems, solid biomass combustion in 'hybrid' boilers that use natural gas for superheating, and biogas or biomass producer gas used as a re-burn fuel to reduce NOx in existing boilers. [117, 118, 119, 120, 121]

Biosciences and Biotechnology
Bioscience and technology research refers to development and improvement of genome sequencing, genetic engineering, understanding of cellular and molecular biology, plant biochemistry and enzymes, development of desired traits in plants such as enhanced yield of energy feedstock, higher cellulose:lignin ratio, reduced resistance to hydrolysis and fermentation treatments, improved enzymes, development of in-plant enzymes, new or increased hydrocarbon expression/production, reduced agronomic inputs, and other control over specialized plant and organism function. Results from such research can ultimately lead to lower biomass costs, with impacts across all bioproduct types.

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[117] Williams, R.B., "*Technology assessment for advanced biomass power generation*" - Final Report for SMUD ReGen program, in. (2005), University of California, Davis. CEC PIER Contract 500-00-034.
[118] Rizeq, G., and Zamansky, V. (2004). "*Utilization of waste renewable fuels in boilers with minimization of pollutant emissions.*" California Energy Commission contract no. 500-98-037, GE Global Research, Irvine
[119] Harding, N.S. and B.R. Adams, (2000) "*Biomass as a reburning fuel: a specialized cofiring application.*" "*Biomass and Bioenergy.*" 19(6): p. 429-445.
[120] Maly, P.M., V.M. Zamansky, L. Ho, and R. Payne, (1999) "*Alternative fuel reburning. Fuel.*" 78(3): p. 327-334.
[121] Dagaut, P. and F. Lecomte, (2003) "*Experiments and Kinetic Modeling Study of NO-Reburning by Gases from Biomass Pyrolysis in a JSR.*" Energy Fuels. 17(3): p. 608-613.

Public concerns relating to genetically modified organisms and inadvertent transfer of genetic material influence how modified plants can be incorporated into agricultural practice and this will remain an important policy issue. [122]

The USDOE federal biomass roadmap and the Genomics-to-life (GTL) program roadmap address critical biotechnology research needs in these areas and so a full listing of research areas is not repeated here.[123, 124] USDOE is already funding some of the federally roadmapped biotechnology research needs. California industry and academies can more fully participate in and contribute to the federal activities especially if leveraging state research funding. Results from the federal activities should be built upon for solutions to California biomass feedstock and product needs.

Substantial intellectual and physical biotechnology research infrastructure already exists in California and should be enlisted to address California-specific bioenergy biotechnology needs. Within the state are the UC Biotechnology Research Program,[125] the UC Davis Genome Center,[126] the DOE Joint Genome Institute,[127] the Synthetic Biology and the Helios Project at Lawrence Berkeley National Laboratory,[128] the USDA Agricultural Research Service Western Regional Center,[129] the recently organized Joint Bioenergy Institute, and numerous biotechnology companies, many of which have major interests and major capabilities in biomass research and development. In addition, recent industry and government announcements have targeted greater research into basic plant and organism sciences to further the aims of more sustainable biomass use and greater production of fuels and products.

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[122] Sticklen, M. (2006) "*Plant genetic engineering to improve biomass characteristics for biofuels.*" Current Opinion in Biotechnology, 17, 315-319.

[123] US DOE. (2002). "*Roadmap for Biomass Technologies in the United States*;" http://www.biomass.govtools.us/pdfs/FinalBiomassRoadmap.pdf

[124] GTL- Cellulosic Ethanol Roadmap; http://www.doegenomestolife.org/biofuels/

[125] UC Biotechnology Research Program; http://ucsystembiotech.ucdavis.edu/

[126] UC Davis Genome Center: http://genomecenter.ucdavis.edu/index_html.html

[127] Joint Genome Institute, USDOE, Walnut Creek, CA; http://www.jgi.doe.gov/index.html

[128] Helios Project, LBNL; http://www.lbl.gov/pbd/energy/research.html#helios

[129] USDA ARS Western Regional Center, Albany, CA; http://www.ars.usda.gov/Main/docs.htm?docid=5819

Federal goals in basic plant biology

The Genomics:GTL ('Genomes to Life') is a research program headed by the USDOE Office of Science. Its purpose is to develop technologies to understand and use the diverse capabilities and potential of plants and microbes for energy and environmental solutions.

The goal of the GTL program is to develop methods and concepts that "achieve a predictive, systems-level understanding of plants and microbes" to enable bio-based energy and environmental solutions.[130]

To achieve this goal the GTL program proposes to build on and continue genomics and DNA sequencing, develop improved analytical measurement techniques for cell molecular components as well as for systems-level analysis of microbial communities, develop biological systems modeling and computational methods, and establish national facilities dedicated to GTL activities.[131]

Bioscience and Biotechnology challenges

Challenges for biotechnology related to biomass production and conversion include developing a better understanding of the biosynthesis, structure, and disassembly of the plant cell wall and complex assemblage of cellulose microfibrils, hemicelluloses, pectins, and lignins. The lignin in plant cell walls imparts stability and resistance to enzymatic attack, properties that favor survival of the plant but which may need to be reduced or overcome so that the plant cell wall polysaccharides can be converted to simple sugars and ultimately fermented to ethanol and other products.

Molecular biology and genetic regulation of cell-wall synthesis can play a crucial role in developing the understanding needed for improved biomass conversion. An important research area is in modification of the plant cell wall to reduce the ratio of recalcitrant lignin to more readily convertible polysaccharides.[132] This would involve both molecular biology and plant breeding to develop crops with improved bioenergy and bioproduct traits. Other possibilities include modifying the cell wall to include new enzyme systems that begin tissue degradation to fermentable sugars as the plant ages, or at other stages of the plant's cycle that can be controlled or triggered by external stimuli, such as spraying with an activator, to maximize the yield of energy or other

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130 'About the GTL Program'. Accessible at: http://www.doegenomestolife.org/program/index.shtml
131 Ibid.
132 Sticklen, M. (2006) "*Plant genetic engineering to improve biomass characteristics for biofuels*." Current Opinion in Biotechnology, 17, 315-319.

components. Such modifications have already been incorporated into sugar cane to expedite pretreatment and fermentation.[133]

Microbiology and enzymology will be called upon to create new enzymes by such techniques as directed molecular evolution, which can substantially increase rates and conversion yield, and do so at or near ambient conditions for a variety of biomass substrates. These processes should be scalable to commercial production levels using mostly standard fermentation equipment. Cellulase enzymes are being developed worldwide to decrease cost and increase yield of alcohol fuels from lignocellulosic biomass. This work needs to continue with an emphasis on enzymes or sets of enzymes that can function over the range of feedstocks available in California, such as forest and orchard woody material, rice and wheat straw, waste paper and urban wood waste, as well as purpose-grown crops.

Increasing yields by improving the plants' water-use efficiency, salt tolerance, and disease and pest resistance are other areas under investigation. As with most agricultural crops, improved yield can lead to improved profitability in production, although inputs must be carefully managed and sustainable practices employed. Realizing substantially greater yields with dedicated crops could greatly increase the overall biomass resource of the state, thereby increasing the power, fuel, and product potential well above that identified previously. Greater productivity could also mean greater opportunities for system integration to take better advantage of the stored solar energy in biomass; through hybrid direct solar-biomass power systems, for example.

Improved biomass harvesting handling, and processing

Biomass is generally considered an expensive feedstock for energy, especially if produced as dedicated feedstock rather than as a multipurpose crop (e.g. use of residues for energy or products). This is due to several factors including the distributed nature of the resource, cost of production inputs, equipment access for harvesting, relatively low energy density, feedstock processing, separation, and preparation requirements, and the seasonality of the resource. Although this area has been widely studied, improvements and innovative solutions continue to be needed in the areas of harvesting, handling, transport, and storage. For example, improved harvest systems for small diameter wood and shrubs are needed for forest fuels reduction activities which increase economical and ecological access to biomass. Similarly, improved harvest systems for dedicated biomass crops and agricultural residues are needed. Better processing techniques that increase density and extend storage life are needed. Innovative or improved separation and processing techniques are needed for access to

[133] http://www.farmacule.com/

MSW biomass. Finally, there is the need to optimize logistics for feedstock harvest, transport, preparation/processing and storage.

5.3.2 Biomass conversion systems

Research will need to be directed at developing biomass-to-power systems with higher efficiency and lower environmental impacts. Two-thirds of California's installed biopower capacity consists of solid-fueled steam boilers. These have overall net station efficiencies from 15 percent to about 27 percent.[134] Furthermore, the last major solid-fueled biomass power plant was commissioned in 1992.[135] In the meantime, the U.S. EPA has adopted more stringent federal ambient air quality standards for ozone and particulate matter. As a result more air basins have been declared 'non-attainment and more stringent air quality regulations apply. Permitting new sources has become more difficult due to limited or expensive pollution offsets, which are required as a condition of new-source air permits. With distributed generation (DG) systems required by California statute[136] to meet 'central powerplant' emission levels, there will be increasing pressure to reduce emissions from units not now considered to be DG. RPS regulations in other states such as Massachusetts and Connecticut, which require emissions and/or efficiency standards for biopower to be RPS-eligible, may act to put pressure on California biomass power as well.

Thermochemical conversion systems

Integrated gasifier combined cycle (IGCC) systems for solid biomass fuels, for example, should have efficiencies 40 to100 percent better than present biomass power plants. With appropriate gas cleanup and post-turbine emissions controls, biomass IGCC systems will require less feedstock and have lower emissions per unit output (i.e., per MWh) than conventional steam Rankine cycle power plants. IGCC fueled by biomass is still developmental, but has been demonstrated in Europe. Demonstration of BIGCC (biomass integrated gasifier combined cycle for power generation) in California (at a scale of 10 to 20 MW) is necessary to enable commercialization of advanced biopower systems.

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[134] Williams, R.B. (2005). "*Technology assessment for advanced biomass power generation*" - Final Report for SMUD ReGen program. University of California, Davis. CEC PIER Contract 500-00-034.

[135] This is primarily due to economic reasons such as discontinuance of SO #4 contracts, increased price or reduced availability biomass fuel as a consequence of shrinking forest products industry,etc.

[136] SB1298 (Chapter 741, Statutes of 2000);
http://www.arb.ca.gov/energy/dg/sb1298bill20000927chaptered.htm

Massachusetts RPS

The Massachusetts Renewable Portfolio Standard – RPS – declares renewable facilities operating before 1998 not eligible for the RPS, and further requires eligible biomass power be generated by 'low emissions advanced technology'. Because of lack of clarity in the legislation on the meaning of 'low emission advanced technology', the Massachusetts Division of Energy Resources, with stakeholder involvement, has issued draft guidelines for 'RPS Eligibility of Biomass Generation Units'.[137] These guidelines define low emissions to mean units greater than 25 MW having a NOx limit of 0.065 lb NOx/MMBtu of fuel input, and units less than 1 MW are limited to 0.3 lb NOx/MMBtu.

The meaning of 'advanced technology' has been interpreted in the Massachusetts RPS eligibility guidelines by setting conversion efficiency requirements for eligible biomass. For stoker-boilers, the efficiency requirement ranges from 22 to 27 percent (heat rate of 15,500 to 12,500 Btu/kWh) and for fluidized-bed combustors required efficiency ranges from 21 to 25 percent (heat rate of 16,500 to 13,500 Btu/kWh).

. . . and Connecticut

Connecticut's RPS defines three classes of eligible renewable energy. Class I includes solar, wind, landfill gas to energy, run-of-river hydro less than 5 MW (post-2003), and sustainable biomass facilities. Class II includes solid waste to energy, high emissions biomass, and run-of-river hydro (pre-2003). Class III is heat from CHP or energy saved from conservation or load management.

By 2010, Connecticut electricity usage must contain at least 7 percent Class I, 3 percent Class II, and 4 percent Class III renewables. For biomass to meet Class I eligibility, NOx emissions must be less than 0.075 lb NOx/MMBtu. Class II biomass facilities must have been operational before July, 2003 and have less than 0.3 lb NOx/MMBtu emissions.[138, 139]

Environmental performance of biopower systems

For new solid-fuel combustion of biomass, advanced reburning should be considered as part of the original plant design, using gasified biomass for the reburn fuel or other reburning techniques such as direct biomass injection. For existing facilities, unanswered questions remain regarding the viability of retrofit reburn systems using biomass gasification. These questions likely will not be answered without a full-scale demonstration.

137 http://www.mass.gov/doer/rps/rps_biom_guideline.pdf

138 http://www.cga.ct.gov/2006/sum/2006SUM00074-R02SB-00212-SUM.htm

139 http://dep.state.ct.us/air2/SIPRAC/2006/ctrenportfolio09feb06.pdf

Selective catalytic reduction (SCR) technology for controlling NOx emissions in biomass-fueled boilers is difficult to implement because of catalyst de-activation, and is considered developmental. Research is ongoing both in the U.S. and Europe. California should monitor and actively pursue SCR-biomass research.

Regenerative SCR (RSCR) may offer an improvement over the current non-selective catalytic reduction (NSCR) method for NOx reduction. RSCR treats flue gas after gas cleaning by re-heating the gas to a level required for the catalyst to function. Due to the expense and energy required for re-heat, RSCR systems do not necessarily operate at the optimal temperature for the catalyst. Therefore, NOx reduction from RSCR is expected to be less effective than standard SCR. Performance information from two biomass facilities in the U.S. Northeast recently retrofitted with RSCR should be pursued.[140] Whether RSCR is suitable and sufficient for California's needs should be determined.

Low-temperature ozone injection (also called low-temperature oxidation) should be investigated as a candidate NOx control technique for installation at new biomass combustion facilities as well as for retrofit use.

Small modular or distributed biomass-to-energy systems can be located closer to the source of biomass feedstock, possibly moved from one locale to another as seasonal biomass availability changes. Modular and small gasifier-engine generator systems are in development in the US and overseas. Performance and emissions of these systems need to be demonstrated for California applications, with continuing emphasis on improving efficiency, emissions, availability, and economic performance.

Improved gas-engine emissions (most importantly, NOx) and more efficient small gas-turbine systems are needed to increase the desirability of each prime mover type in power from biogas or producer gas applications. NOx emissions from engines can be reduced by catalytic aftertreatment of exhaust gas, and, in some cases, treatment or removal of nitrogen compounds in the fuel gas. However, catalyst deactivation can occur when sulfur, alkalis, and metals are present in the fuel gas.

H_2S in biogas is a source of SO_2 emissions and leads to catalyst deactivation in systems used to control other pollutants such as NOx. Fuel-gas cleaning in association with catalytic emissions control should be investigated in more detail. Fuel-gas cleaning has other benefits as well, including reduced corrosion rates in gas handling and power generation equipment, and as a technique to permit the use of biogas as clean vehicle

[140] These are the Whitefield, NH (16 MWe) and the McNeil Generating Station, Burlington, VT (50 MWe)

fuel or for injection into natural gas pipelines. Biofilters are an important research area for biogas systems as well as a number of other technologies.

For reciprocating engines powered by gasified biomass, the fuel gas is usually cleaned and cooled before use. This results in condensation of alkali and metal vapors onto particles or aerosols. For integrated gasifier combined-cycle systems employing gas turbines, hot gas filtration, which provides both particle and alkali metal control, is commonly proposed. Sulfur is less of an issue with producer gas or syngas because of the low sulfur content of most biomass, although advances in thermal processing of animal manures and sludges may lead to the need for sulfur removal. Clean syngas will also be required for downstream chemical or fuel production such as Fischer-Tropsch synthesis. Providing adequate gas cleaning to enable effective catalyst system operation remains a key research need for biomass gasification and other gas handling systems.

Gasification of biomass releases fuel-bound nitrogen, predominantly as ammonia and HCN in the fuel gas. When the fuel gas is combusted (in a boiler, gas engine or gas turbine), these nitrogen compounds primarily transform to NOx. It is difficult to remove ammonia by condensation in hot-gas cleaning systems. Cold gas cleaning removes ammonia; and catalytic means to reduce ammonia to N_2 for hot gas cleanup systems need further study.

Hydrogen enrichment or blending with syngas and biogas extends the lean-burn flammability range for internal combustion engines, and this offers greater opportunity for NOx control. The effect of increased hydrogen in the fuel gas of small engine-based biopower systems should be studied. Improved methods of hydrogen co-production from anaerobic digestion and gasification of biomass should be linked with emissions improvement for power systems as well as for its fuel value.

Anaerobic Digestion

Power and fuels can be created from anaerobic fermentation gases (biogas). These include biogas from anaerobic digestion of animal manures, food and other organic residues, purpose-grown feedstocks, waste water treatment processes, and landfill gas. Additional research is also needed on bioreactor landfills which could substantially increase the amount and efficiency of recovery of landfill gas.

The state has supported development of manure digesters for power production in recent years (e.g., the Dairy Power Production Program administered by the California Energy Commission). Ten dairy biogas systems supported under the Dairy Power Production Program are now operational. Follow-up information for these systems that were financed with public money is needed, specifically, environmental, engineering, and economic performance data.

Research data on coefficients needed for the kinetic models to accurately predict dynamic response of methane yield vs. temperature for manure digesters are still lacking. Dynamic models that fully integrate microbial kinetics and system mass and energy balances during ambient temperature or transient anaerobic digestion with thermal feedback have not been performed. Economic optimization analyses for anaerobic digestion systems are still needed as well. Compared with lagoons, significantly higher digester capital costs may be justifiable for attached growth and similar systems when reducing retail electricity purchases. Additional detailed experimental and operating data should be obtained to assess these results.[141]

Optimization of manure collection and handling systems on farms with digesters is needed to improve yields. For example, reducing the amount of water used in manure collection could allow greater use of thermophillic digestion.

More research is needed to develop effective processes and technologies to treat the effluent of anaerobic digester effluent for nutrient and water recovery and salt management. Innovative approaches for effective management and utilization of anaerobic digester effluent will help improve the economics of anaerobic digestion systems.

Co-digestion of manure and other feedstocks (e.g., food and food industry wastes) is a promising opportunity for biogas production combined with waste management.[142] [143] [144] In order to better utilize co-digestion opportunities, better information on the amount, availability and location of substrates for co-digestion is required. Efforts are needed to understand the suitability and performance of other substrates when co-digested with manures using computer models and expert systems followed with development of lab

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[141] Jenkins, B.M. & Zhang, Z. (2004) "*Thermal Analysis and Comparitive Performance of Anaerobic Digestion Systems for Dairy Manure Management.*" In "*2nd World Conference and Technology Exhibition on Biomass for Energy, Industry and Climate Protection.*", pp. 2147-2150, Rome, Italy.

[142] Shang, Y., F. Soroushian, E.J. Whitman, & Z. Zhang. (2006) 'Co-digesteion – Potential increase of renewable energy production from waste for Califonia'. Presentation at Pacific Southwest Organic Residuals Symposium. 12 July. Sacramento, CA.

[143] Braun, R., Brachtl, E., & Grasmug, M. (2003) "*Codigestion of Proteinaceous Industrial Waste.*" Applied Biochemistry & Biotechnology, 109, 139-154.

[144] Braun, R. & Wellinger, A. (2003). Potential of Co-digestion. IEA Bioenergy, Task 37-Energy from Biogas and Landfill Gas.

and pilot scale systems, and finally by demonstration and implementation of best solutions in full scale digesters.[145] [146] [147]

Increased understanding of the microbiology and spatial distribution in biofilms are needed to improve anaerobic degradation and gas yields. Reactor design improvements for better heat and mass transfer, handling systems for high solids feedstocks, application of improved low cost real time sensors, and improved cleaning and upgrading technologies also are needed. For digestion of municipal wastes, better understanding of the fate of metals and micropollutants, as well as processes to increase biodegradeability of the substrate is needed.[148]

Further work is needed to optimize AD systems and processes to make them more robust and less sensitive to upsets and perturbations. Better monitoring and control tools are needed to improve the performance and stability of anaerobic digesters. Ideal monitoring methods should be on-line, robust and give early indications of imbalance in the microbial status of the system.[149] Most waste waster treatment plants and European organic residuals digesters rely on manual sampling and data collection with subsequent manual and ad hoc feedback system operation. [150] [151] There is recent progress in developing real time monitoring techniques for high-strength waste and co-digestion systems in Europe. [152] [153] [154] [155] [156] At least one biogas facility supported under

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[145] Minnesota Department of Agriculture, Agricultural Resources Management and Development Division, (2005). "*Opportunities, Constraints, and Research Needs for Co-digestion of Alternative Waste Streams with Livestock Manure in Minnesota.*"

[146] Murto, M., Bjornsson, L., & Mattiasson, B. (2004) "*Impact of food industrial waste on anaerobic co-digestion of sewage sludge and pig manure.*" Journal of Environmental Management, 70, 101-107.

[147] Fernandez, A., Sanchez, A., & Font, X. (2005) "*Anaerobic co-digestion of a simulated organic fraction of municipal solid wastes and fats of animal and vegetable origin.*" Biochemical Engineering Journal, 26, 22-28.

[148] Mata-Alvarez, J. (2006). "*Anaerobic Digestion Needs.*" Presented at the Workshop on Research in the Waste Area, Towards FP7. 31 January, Brussels. Available at: http://cordis.europa.eu/sustdev/environment/ev20060327.htm

[149] Bjornsson, L., Murto, M., Jantsch, T.G., & Mattiasson, B. (2001) "*Evaluation of new methods for the monitoring of alkalinity dissolved hydrogen and the microbial community in anaerobic digestion.*" Water Research, 35, 2833-2840.

[150] Olsson, G. (2006), "*Instrumentation, control and automation in the water industry - state-of-the-art and new challenges CD.*" Water Science and Technology, 53, 1-16.

[151] Spanjers, H. & van Lier, J. (2006), "*Instrumentation in anaerobic treatment - research and practice*." Water Science and Technology, 53, 63-76.

[152] Jantsch, T.G. & Mattiasson, B. (2004) "*An automated spectrophotometric system for monitoring buffer capacity in anaerobic digestion processes.*" Water Research, 38, 3645-3650.

[153] Liu, J., Olsson, G., & Mattiasson, B. (2004) "*A volumetric meter for monitoring of low gas flow rate from laboratory-scale biogas reactors.*" Sensors and Actuators B-Chemical, 97, 369-372.

the Dairy Power Production Program employs automatic influent sampling, but there is a continuing need for in-line instrumentation that, among other things, assesses actual loading and system capacity and links new on-line sensors with advanced control algorithms. [157]

Bioreactor Landfills

Bioreactor landfills can enhance the rate of degradation compared with conventional sanitary landfills by providing containment and allowing water addition and leachate recirculation promoting greater microbial activity. Research on basic design requirements is still needed, including lining techniques, pressure monitoring and control, slope stability, timing and placement of temporary covers, selectively permeable membranes allowing water transfer but not gas, and whether bioreactor landfills are, in fact, superior in safety or environmentally preferable to conventional landfills. Reactor control also needs investigation, including whether the reactor can be shut down once started. Many other issues in bioreactor landfill operation remain to be investigated and are important for the development of this technique as an alternative conversion technology.[158]

Biohydrogen Production

The primary biological processes that can be utilized for hydrogen gas production include biophotolysis of water by algae, dark and photo-fermentive and two stage dark/photo fermentive production.

Advantages of biohydrogen include sourcing from 'low cost' and renewable organic feedstocks. The major problems are the low rates and yields of hydrogen formation, requiring large reactor volumes. Advances are needed in increasing yield through reactor designs, advances in microbiology, and process and environmental optimization. Metabolic engineering for improved biohydrogen yields is still in its infancy.[159] [160], [161], [162]

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[154] Liu, J., Olsson, G., & Mattiasson, B. (2004), "*On-line monitoring of a two-stage anaerobic digestion process using a BOD analyzer*." Journal of Biotechnology, 109, 263-275.

[155] Liu, J., Olsson, G., & Mattiasson, B. (2004) "*Monitoring and control of an anaerobic upflow fixed-bed reactor for high-loading-rate operation and rejection of disturbances*." Biotechnology and Bioengineering, 87, 43-53.

[156] Liu, J., Olsson, G., & Mattiasson, B. (2006). "*Extremum-seeking with variable gain control for intensifying biogas production in anaerobic fermentation*." Water Science and Technology, 53, 35-44.

[157] Spanjers, H., Bouvier, J.C., Steenweg, P., Bisschops, I., van Gils, W., & Versprille, B. (2006). "*Implementation of in-line infrared monitor in full-scale anaerobic digestion process*." Water Science and Technology, 53, 55-61.

[158] http://www.epa.gov/nrmrl/pubs/625r01012/625r01012.htm

[159] Hawkes, F.R., Dinsdale, R., Hawkes, D.L., & Hussy, I. (2002), "*Sustainable fermentative hydrogen production: challenges for process optimisation*." International Journal of Hydrogen Energy, 27, 1339-1347.

Efficient hydrogen-producing microorganisms need to be found. Development and demonstration of stable biohydrogen production systems using multiple substrates are important for making biohydrogen become a significance fuel source.

Hydrogen can also be produced from reforming of biomethane. As noted earlier, biogas cleaning and upgrading methods need to be improved as well as efficiencies and costs of small or decentralized reforming systems.[163] [164] [165]

Biorefinery technologies and systems

Biorefineries need to be demonstrated using California feedstocks and under California environmental performance standards. Advanced biorefineries will likely include both biochemical and thermochemical techniques to convert biomass or biomass-derivatives into final products. Many of the research areas for biorefineries are similar to those discussed for individual unit operations, but process integration and optimization are important to technical and economic feasibility.

Biomass-to-liquid (BTL) fuels systems using gasification followed by Fischer-Tropsch or other catalytic synthesis, have theoretically high yields and very low life-cycle carbon emissions. These types of facilities might be integrated into California's existing refinery infrastructure or implemented independently.

Systems and components are needed to adapt or improve thermochemical technologies for liquid fuels production (feedstock handling, gas cleaning, syngas conversion catalysts, etc.) for integration with biochemical platform refineries. This should be followed with projects that demonstrate thermochemical biomass to liquids technologies. Additional research effort should be directed at syngas fermentation techniques as alternatives to more traditional catalytic refining. There is also a need to demonstrate advanced integrated biorefineries using a range of feedstocks. Many

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[160] Kapdan, I.K. & Kargi, F. (2006) Bio-hydrogen production from waste materials. "*Enzyme and Microbial Technology*", **38**, 569-582.

[161] Yang, P., 2006 unpublished PhD dissertation, University of California, Davis

[162] Hawkes, F.R.; Dinsdale, R.; Hawkes, D.L. and Hussy, I. (2002). "*Sustainable fermentative hydrogen production: challenfes for process optimization.*" International journal of hydrogen energy 27:1339-1347

[163] Ferreira-Aparicio, P., Benito, M.J., & Sanz, J.L. (2005), "*New trends in reforming technologies: from hydrogen industrial plants to multifuel microreformers.*" Catalysis Reviews-Science and Engineering, **47**, 491-588.

[164] Van herle, J., Membrez, Y., & Bucheli, O. (2004), "*Biogas as a fuel source for SOFC co-generators*." Journal *of Power Sources*, **127**, 300-312.

[165] Trogisch, S. and Baaske, W.E., eds.; Trauner Verlag: Wien, (2004) "*Biogas Powered Fuel Cells.*" Case Studies for their Implementation.

biorefinery operations show good economies of scale in capital cost and can be designed for large capacities in order to reduce cost of production. Guaranteeing feedstock supply will be a critical issue and having multi-feedstock capability will make these systems more robust to supply disruptions.

Bioproducts

Biomass has the potential to be used for many different products. Commercial tree species are the feedstock for nearly all solid-wood-based consumer products (paper, cellulose-based fibers and fabrics such as rayon, tencel®, etc.) and many wood fiber/polymer composite products (wood-based panels, plastic/wood lumber, fiber/cement building materials such as shingles and siding). As demand for these products increases and availability of the primary feedstocks diminishes, opportunities will be created for the use of other biomass materials as feedstocks. Non-woody or herbaceous biomass may also realize increasing potential . For example, rice straw has been used to produce fiber and polymer composite panels and has been densified into bales for use as a construction material, but these markets have not yet developed to accept large quantities of feedstock.

The potential for converting biomass into various chemicals and chemical-based products is generally accepted, but many processes remain to be commercialized. Biochemical and thermochemical techniques can produce intermediate chemicals and compounds as well as secondary chemicals and final products. Continued research to develop alternative pathways that either lower the cost of production or raise the quality of the product are needed.

5.3.3 Systems analysis

Systems analyses are important to optimizing facility scale and ensuring full life cycle impacts are properly assessed. The latter is particularly important for developing informed policy and regulations.

Life-cycle assessments of biomass and bioenergy systems

Full life-cycle analyses (LCA) accounting for impacts and benefits of biomass management and utilization from production and acquisition through final product utilization are needed for in-state resources as well as imported resources and products. Life cycle analyses are also needed to assess impacts of exporting California resources for further processing, such as paper and other recyclables. Net environmental impacts, including life-cycle carbon emissions, are dependent upon feedstock type, production and management practices, and conversion process. As California is among the leading states in greenhouse gas accounting and policy, a full understanding of bioenergy and bioproduct LCA is necessary to properly value biomass benefits and inform public policy.

Research to establish, value and document the external benefits of sustainable biomass use continues to be needed for proper cost internalization, including assessing REC values. Assessments of the value of the externalities associated with California biomass power, for example, have returned variable results, although values are higher than available for any trading on California facilities conducted to date.[166,167] Environmental impacts from forest fuels treatments for use in biopower in California and the Western US are currently undergoing more comprehensive review,[168] and at least two US-based power generation externality studies address biopower.[169, 170] There is more extensive information on valuing externalities from studies done in Europe and Asia.[171,172,173,174,175,176,177,178,179,180,181] Current EU 'Community Guidelines for state aid for

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166 Morris, G. (2000). "*Biomass Energy Production in California: The case for a biomass policy initiative.*" NREL/SR-570-28805, NREL/SR-570-28805, Golden, CO.

167 Williams, R.B. (2006). "*Environmental Issues for Biomass Development in California-Draft.*" California Biomass Collaborative. University of California, Davis. CEC PIER Contract 500-01-016.

168 See: http://www.fs.fed.us/psw/biomass2energy/

169 Roth, I.F. & Ambs, L.L. (2004), "*Incorporating externalities into a full cost approach to electric power generation life-cycle costing.*" Energy, **29**, 2125-2144.

170 Swezey, B.G., Porter, K.L., & Feher, J.S. (1995), "*The Potential Impact of Externalities Considerations on the Market for Biomass Power Technologies.*" Biomass & Bioenergy, **8**, 207-220.

171 Faaij, A., Meuleman, B., Turkenburg, W., van Wijk, A., Bauen, A., Rosillo-Calle, F., & Hall, D. (1998). "*Externalities of biomass based electricity production compared with power generation from coal in the Netherlands.*" Biomass & Bioenergy, 14, 125-147.

172 Saez, R.M., Linares, P., & Leal, J. (1998), "*Assessment of the externalities of biomass energy, and a comparison of its full costs with coal.*" Biomass & Bioenergy, **14**, 469-478.

173 Soderholm, P. & Sundqvist, T. (2003), "*Pricing environmental externalities in the power sector: ethical limits and implications for social choice.*" Ecological Economics, **46**, 333-350.

174 Freppaz, D., Minciardi, R., Robba, M., Rovatti, M., Sacile, R., & Taramasso, A. (2003), "*Optimizing forest biomass exploitation for energy supply at a regional level.*" Biomass & Bioenergy, 26, 15-25.

175 Sundqvist, T., 2002,. "*Power Generation Choice in the Presence of Environmental Externalities.*", Ph.D. Dissertation, Division of Economics, Luleå University of Technology, Sweden

176 Sundqvist T. and Söderholm P., 2002. Valuing the environmental impacts of electricity generation: a critical survey. *Journal of Energy Literature* **8** pp. 3–41.

177 European Commission, 1995. Externalities of fuel cycles. European Commission, DG XII, Science, Research and Development, JOULE, ExternE Externalities of Energy, Vol. 2, Methodology. European Commission, Luxembourg, EUR 16521

178 Krewitt, W. (2002). "External costs of energy--do the answers match the questions?: Looking back at 10 years of ExternE." *Energy Policy*, 30(10), 839-848.

179 Reijnders, L. (2006) Conditions for the sustainability of biomass based fuel use. *Energy Policy*, **34**, 863-876.

180 Bergmann, A., Hanley, M., & Wright, R. (2006) Valuing the attributes of renewable energy investments. Energy Policy, 34, 1004-1014.

environmental policy' recommend a 5 Euro-cent/kWh or about $0.06/kWh adder for renewable electricity to compensate for external value.[182] Life cycle or well-to-wheels assessments have also been conducted for biofuels of various types, but as new systems are commercialized more detailed impact studies should be conducted.

Economics of biomass management and development

Additional research and analysis on economic impacts of biomass management and conversion to products is needed to support or inform investment, policy, and regulatory decisions. Research must assess the impact of feedstock competition on food, feed and fiber markets as well as the impacts on employment, tax revenues, and social issues due to increased or new biomass usage.

Land, water, and climate effects

Larger scale development of biomass will increase competition for land and water resources The issue of crop land adequacy must be addressed as competition increases among dedicated biomass crops, traditional agricultural crops, and urbanization. Potential impacts of climate change on the state's biomass resources also need to be better understood in terms of long term feedstock supply, available inputs such as water for feedstock production, soil carbon, and greenhouse gas emissions. Predictive models should be developed that specifically address biomass related outcomes.

Research centers

Biomass research centers would foster development of new technologies and lead to greater understanding of environmental consequences, and the development of mitigation measures where needed. Biomass centers at universities can train engineers, scientists, and other professionals to meet the needs of an expanding bioenergy and biotechnology industry. Centers should also develop and maintain institutional knowledge and contribute to public outreach through conferences, workshops, certificate training programs, regular extension activities, and other means. Centers can also be proving grounds where new technologies and ideas can be evaluated and demonstrated. The possibility of federal and industry co-funding should be explored.

Biomass research centers should support the full range of research from basic biosciences to long-term crop production trials and integrated processing techniques and systems. Centers should include expertise in economics and systems analysis, public policy, environmental review and permitting, and technical training. However,

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[181] Sasao, T. (2004) An estimation of the social costs of landfill siting using a choice experiment. Waste Management, 24, 753-762.

[182] Community guidelines on state aid for environmental protection, OJ C 37, 3.2.2001. http://europa.eu.int/eur-lex/pri/en/oj/dat/2001/c_037/c_03720010203en00030015.pdf

regardless of whether biomass research centers are created, there will continue to be needs for demonstration and pre-commercial evaluation of new biomass facilities. To move forward with new ideas and technologies, some form of public financial support is almost always necessary because of the high financial risk, and, in some cases, potential environmental risk associated with new technologies.

5.4 *Education, training & outreach*

Biomass is not as widely recognized by the general public as a renewable energy alternative as are wind and solar energy. The many competing uses and issues associated with the use of biomass often lead to confusion or conflict among policy makers and regulators. The recycling of CO_2 and the implications for greenhouse gas emissions and climate change are also less well understood by the public.[183]

Documentation on public perceptions and attitudes regarding biomass is limited; most recent literature is from Europe. Some of these reports indicate that public perceptions of bioenergy are best in countries with a long tradition of biomass use and high environmental concern such as the Scandinavian countries. Where bioenergy has not been as widely used, public knowledge about its potential in meeting resource needs is limited.[184, 185, 186] Consumer and other education will play a key role in biomass development. Actions should be taken to

- educate and inform the public and decision makers about biomass systems and issues in sustainable biomass development,
- conduct outreach to local, state and federal government decision makers, schools, non-governmental organizations (NGOs), and other public interest groups,
- provide outreach on biomass utilization and establish early dialog with affected communities where facilties are proposed for development

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[183] Dobson, L. (1993). Biomass Energy- State of the technology, present obstacles & future potential, Report No. DOE/EE/15425-H1. Northern Light R&D, Seattle, WA.

[184] Rohracher, H., Bogner, T., Spath, P., & Faber, F. (2004). Improving the public perception of bioenergy in the EU. European Commission - Directorate-General for Energy and Transport, Brussels

[185] (2001). Comparison of public acceptability of energy from waste and energy from biomass residues in 5 EU states. Technical Report P1-404. AEA Technology for the UK Environment Agency.

[186] (2004). European Research Area Bioenergy Strategy - Short-term measures for bioenergy research and development, Rep. No. Enk5-CT-2001-80526. European Commission.

- hold general and specialized conferences, workshops, and onsite tours to increase information dissemination and encourage public, industry, and scientific interaction,
- conduct hearings and sponsor field trips for policy makers and regulators to provide relevant information for policy, statutory, and regulatory proceedings,
- provide technical training by and for industry and expand university curricula and programs to ensure the availability of adequate skilled professionals and technicians.

5.4.1 Public education and outreach to decision makers

Better choices are made when current and accurate information is at hand. Term limits in the California legislature have decreased institutional knowledge because average time in office has decreased. This increases the need for and the value of educational outreach to decision makers.

With increased energy costs and heightened public awareness of climate change and other issues, there is an increasing need to educate the public on the value of bioenergy and products in a carbon-constrained world, choices that will need to be made, and other issues involved in increasing biomass utilization and changing biomass management strategies.

5.4.2 Consumer information and education

Keeping consumers well informed on biomass production chains and product performance will be important in gaining public acceptance and support and engaging communities in sustainable development activities. Additional industry and public resources should be put into widely accessible information clearinghouses, public workshops, speakers bureaus, adult education and lifelong learning courses and curricula, and mass-media communication such as video, radio, virtual education, and others. Accurate product labeling and greater use of utility and other service mailings can also help provide objective, high quality information.

5.4.3 Environmental justice

Communities and the public should be brought into project discussions early in the development process. Opportunities need to be provided to air and alleviate environmental justice concerns. Some standards for involving community participation already exist, but past experiences show the need to enhance this in the future, and clear guidelines should be established.

5.4.4 Industry training and professional education

To ensure adequate numbers of skilled technicians and industry professionals, training programs in biomass systems will need to be expanded. Industry expertise can be extended through industry-sponsored programs or joint programs with academic and other institutions. Specialized instruction can be provided in facility permitting, best practices, and regulations, as well as facility operations, codes, and standards.

There is a growing awareness of corporate social responsibility among investors and financial institutions. Fiduciary counsel are increasingly recommending investors and upper management of publicly held companies consider the environmental and social impacts of financial practices. Companies are also being engaged by the public on environmental justice issues. Industry training on environmental justice can build on the foundation of existing policies within state government and elsewhere.

5.4.5 K-12 curricula and university degree programs

Key in developing the knowledge base and disseminating information is the education of students and professionals who will create, innovate, and lead in developing, managing, and researching future biomass systems and products. Scientists and engineers who will work in biomass-related fields in industry, academia, education, state and local government, and beyond need a solid background and training in the field. Some will require in-depth knowledge and specialization. University curricula at both the undergraduate and graduate levels should be expanded to include greater coverage of topics in biomass technology, systems, and policy. Further training at the graduate level will be needed to accomplish the research and development objectives in basic plant and microbial biology and advanced biomass conversion processes.

Similarly, education beginning in the early grades and continuing throughout a student's academic career will enhance qualifications for scientific, industry, and government employment opportunities and bring greater innovation and expertise. Formal education at all levels also helps provide more general public education through extramural school and home activities.

5.4.6 Research extension and technical interaction

Effective extension and outreach programs will need to be developed to inform and educate farmers, producers, operators, investors, and others of results emerging from research and development efforts. Formal outreach programs can be built through existing Cooperative Extension mechanisms as well as through programs developed in association with biomass research centers created as part of an expanded statewide research effort. Extension of research results affecting the industry can be provided through short courses and similar activities targeting specialized as well as generalized programmatic needs. Technical conferences and workshops, international and teacher exchange programs, student and teacher internships with industry, government, and other organizations and institutions should be routinely supported for the purposes of improving communication and providing greater dissemination of specialized information and instruction.

5.5 Policy, regulations, and statute

5.5.1 Policy, law, and regulation

Government agencies establish policies to recognize and encourage desired actions while discouraging undesirable outcomes. These policies may include goals and prohibitions that agencies impose on themselves, other agencies, and/or the public. Often an agency need only use a rulemaking process to adopt a policy; however, in some cases, new laws and regulations must be created.

Issues related to laws and regulations are often collectively referred to as "regulatory issues." But there are significant differences between "laws" and "regulations."

Laws

Laws are established by the state constitution and by statutes. The state legislature usually enacts statutes, but the people of California can also enact statutes and constitutional provisions through the initiative process. Most of California's laws appear in 29 codes that cover various subject areas.[187] Some laws are broad in affecting many industrial activities including some applicable to biomass.

Regulations

The California Constitution and the statutes enacted by the legislature create and empower the various agencies, departments, offices, commissions, boards, etc. (collectively referred to as "state agencies") to implement and enforce the laws in statute. The powers of state agencies often include "rule making" by which they can make rules and regulations to carry out their duties. California's regulations are presented in various titles in the California Code of Regulations (CCR).[188]

[187] http://www.leginfo.ca.gov/calaw

[188] http://ccr.oal.ca.gov/linkedslice/default.asp?SP=CCR-1000&Action=Welcome.

5.5.2 Policy and regulatory issues and recommendations

California's biomass industry is composed of producers (e.g., farmers, foresters, agricultural processors, and urban waste facility operators), providers (e.g., companies that collect, process, and transport biomass), and end users (e.g., power plants, landscape companies, and manufacturers of fuels and other products). Each segment of the industry has different interests and faces different regulations that make it difficult for industry representatives to address common issues or speak uniformly on regulatory issues.

A number of federal, state, and local agencies have jurisdiction over various aspects of biomass development and use, and often have overlapping and conflicting regulations and policies. Dealing with California's complex permitting process has often been cited by project proponents as a significant barrier to development of new bioenergy facilities.

State Agency Authorities, Overlap and Barriers

<u>California Department of Forestry And Fire Protection</u>

The Department of Forestry and Fire Protection and the Board of Forestry and Fire Protection (i.e., the "Department and Board") coordinate programs of fire protection, fire prevention, pest control, and forest and range maintenance and enhancement. To accomplish their goals, the Department and Board establish management practices for private timberlands and forest lands within the state. Specifically, for biomass, it provides the authority to declare a public nuisance and mandate corrective actions in areas where removal of excessive vegetation is needed to reduce fire hazard.

The Z'Berg Nejedly Forest Practice Act established the authority for the Board to adopt regulations setting standards for the harvest of forest products from non-federal timberlands within the state. Permits authorized for harvesting of forest products under this regulatory process are Timber Harvesting Plans, Non Industrial Timber Management Plans, Programmatic Timber Environmental Impact Reports, Programmatic Timber Harvesting Plans, and Timberland Conversion Permits (required for converting timberland to a non-timber growing use).

The PRC, Division 4, Part 2 also mandates the Board and the Department conduct a forest resource assessment every five years. The most recent assessment was completed in 2003. Part of this assessment is the potential resources available from the state's forest, range, and timberlands, including an assessment of biomass available for bioenergy and biomass products.

Also mandated are programs to remove vegetation for watershed protection; improve and maintain wildlife habitat and grazing conditions, improve forest health; and reduce fuel-hazards. Under the Urban Forestry Program, the Department provides technical assistance and other resources for establishment, maintenance, and management of urban forests in California, in conjunction with local government agencies. The maintenance of urban forests requires periodic pruning, removal, and replanting activities that result in the production of biomass. The biomass that is produced needs to be evaluated relative to biomass use opportunities.

California Air Resources Board (ARB)

The ARB is the state agency responsible for protecting public health and the environment from the harmful effects of air pollution. Air pollutants may be generated in the production, harvesting, or processing of biomass and by the operation of facilities that use biomass to produce energy and the use of biomass-derived fuels and products.

The ARB oversees all air pollution control efforts in California, including the activities of 35 independent local air pollution control districts ("districts"). State law vests ARB with direct authority to regulate pollution from motor vehicles, fuels, and consumer products, and toxic air contaminants from all sources. Primary responsibility for controlling pollution from business and industry (i.e., stationary sources) rests with the districts. ARB works in cooperation with the districts and the U.S. Environmental Protection Agency on strategies to attain state and federal ambient air quality standards and reduce air toxics.

The majority of biomass facilities in California are required to obtain district permits, typically an Authority to Construct followed with a Permit to Operate. The permit is essentially a legal authorization to emit pollutants under specified conditions. This authorization often restricts emissions so that district-wide emissions do not exceed state or federal air quality standards.

A key regulatory requirement governing allowable emission levels for new and expanding facilities is New Source Review (NSR). The California NSR permit program is derived from the California Clean Air Act, and NSR requirements are codified in the California Health and Safety Code, Division 26. NSR is a preconstruction permitting program in areas that do not meet ambient air quality standards ("non-attainment areas"). Most of the more heavily populated metropolitan areas of the state are non-attainment areas for one or more state or federal standards. NSR has two main components—best available control technology (BACT) and offsets.

BACT

A principle of BACT is that the most cost-effective time to control a source is at the time of its installation or when it undergoes a significant modification. BACT is determined for a "class or category of source" and is the most stringent emission level within the following three minimum requirements: (1) the most effective control achieved in practice, (2) the most stringent emission control in any approved State Implementation Plan (SIP), or (3) any more stringent emission control technique found to be both technologically feasible and cost effective.

Offsets

The general concept behind offsets is that new and expanding stationary sources can "over-control" emissions by reducing emissions more than is required by law or regulation and thus mitigate or "offset" emissions at the same location or at other existing sources. The California Health and Safety Code provides an offset credit for the use of biomass. Specifically, for a facility that uses organic wastes from agricultural, forestry, or other sources as fuel to generate electricity or in a cogeneration facility, a district is to provide credit for the incremental emissions benefits relative to disposing of those wastes by open burning or other practice. However, rules prohibiting open burning of organic wastes reduce the opportunity for emission credit generation. In addition, as more sources are required by law to reduce emissions, offsets are becoming scarcer and more costly, thereby restricting new capacity additions. To accommodate the high cost of offsets, more innovative and improved control technologies are generally required.

Other areas influenced by the ARB are emissions from distributed generation sources and motor vehicle fuels.

Distributed Generation (DG)

Some very small DG units are exempt from district permit requirements and instead are governed by ARB's general DG regulation. The DG regulation, adopted in 2001, establishes uniform emission standards for DG that are exempt from district permits and establishes a certification program for technologies subject to these standards. The certification regulation applies to DG equipment manufacturers, not individual applications and establishes two levels of emission standards. The first level reflects the best performance achieved in practice by existing DG technologies and became effective on January 1, 2003. In accordance with the enabling legislation's intent to minimize the impact of DG on air quality, the standards were to be made equivalent to BACT for permitted central station power plants by the earliest practicable date. A 2007 compliance date was chosen to give manufacturers a five-year lead-time for development. To date, ARB has not yet certified any waste gas applications, and is currently planning revisions to the regulation.

Motor Vehicle Fuels

The ARB has responsibility under the Health and Safety Code to establish specifications for motor vehicle fuels to address air pollution impacts and has set specifications for the conventional motor vehicle fuels of gasoline and diesel. The ARB has established specifications for the alternative fuels of neat methanol (M100), 85 percent methanol blend (M85), neat ethanol (E100), 85 percent ethanol blend (E85), compressed natural gas (CNG), liquefied natural gas (LNG), and hydrogen. The ARB also administers the regulations for reformulated gasoline and sets fuel performance standards to which refiners must comply. Once a minimum number of vehicles are available that use the alternative fuel and provide more emission reductions than comparable gasoline fueled vehicles, ARB regulations require that retail outlets be made available.[189]

California Integrated Waste Management Board (IWMB)

The Integrated Waste Management Act of 1989 (IWMA) set forth a policy to reduce California's reliance on landfills. The IWMB requires local jurisdictions to implement diversion programs to help achieve a goal of 50 percent reduction of solid waste disposal.

To achieve the 50 percent diversion, local jurisdictions have been required to institute waste reduction, diversion, and recycling programs. These programs are described in individual waste management plans that are submitted to the IWMB for review and approval. A jurisdiction's diversion program may involve many different techniques for reducing the amount of waste disposed in landfills but is limited in the use of "transformation" technologies. Transformation typically is used to mean incineration; however, there are certain terms also contained in the current statutory definition of transformation such as distillation, biological conversion, and pyrolysis not specifically intended to involve incineration. Exempted from the definition of transformation is biomass conversion, defined as a combustion process for producing electricity from specified materials, including agricultural crop residues, garden clippings, wood waste, and other materials. Biomass conversion facilities are not within the CIWMB's jurisdiction. This means that biomass conversion facilities can burn the specified materials without CIWMB oversight, but conversion technologies using similar materials from the waste stream might be subject to CIWMB requirements.

[189] Enabling legislation is in the Health and Safety Code, CCR Title 17 "Public Health," Division 3 "Air Resources."

Local jurisdictions are currently eligible for up to 10 percent diversion credit for biomass materials sent to biomass conversion facilities. Existing statutes, however, do not allow diversion credit for materials sent to transformation facilities that came into operation after January 1995 or for biomass sent to mixed-waste conversion facilities.[190]

State and Regional Water Quality Control Boards

The State Water Board and nine Regional Water Boards are collectively referred to as the "Water Boards."[191] The water boards do not develop or procure energy resources nor control projects to increase the utilization of biomass for energy production; however, state policy for water quality and regional water quality control plans, also known as "basin plans," may establish requirements that affect the development and use of biomass in California.

The water boards protect water quality by regulating the disposal of wastes from industrial, municipal, and agricultural sources. Such wastes may be generated in the production, harvesting, or processing of biomass and by the operation of facilities that utilize biomass. Examples of waste management issues that the water boards may need to address relative to new or expanding plants that utilize biomass are:

- Current waste discharges stop
- Current waste discharge practices are altered
- New wastes are produced and discharged to land or waters of the state.

Any of the situations listed above require that a Report of Waste Discharge (ROWD) be submitted to the appropriate regional water board along with an appropriate fee. The regional water board will review the ROWD and revise, issue, or waive Waste Discharge Requirements (WDR) for the discharge. If the WDR is the first discretionary permit for a new discharge, the regional board may become lead for responses under the California Environmental Quality Act (CEQA).

For instance, a regional water board will review a proposed animal manure digester to ensure that feedstock storage practices, digester design and operation, and wastewater disposal practices will protect water quality. Of particular concern is leakage from impoundments used for digesters, especially if imported feedstocks such as food wastes for co-digestion are used. The State Water Board is not involved in permitting and regulating specific digester facilities, but supports using digesters for improving air

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[190] Enabling legislation is in the Health and Safety Code, CCR Title 14 "Natural Resources," Division 7 "California Integrated Waste Management Board" and CCR Title 27 "Environmental Protection."

[191] Enabling legislation for the water boards is in the California Water Code, Division 7, which is commonly cited as the "Porter-Cologne Water Quality Control Act."

quality and electrical supply in a manner that does not adversely impact water quality. The State Board also supports using digesters in a system that treats wastewater prior to discharge.

California Department of Food and Agriculture (CDFA)

The Department of Food and Agriculture works to encourages farming, ranching and agribusiness, while protecting consumers and natural resources. Its goals are:

- Ensure that only safe and quality food reaches the consumer.
- Protect against invasion of exotic pests and diseases.
- Promote California agriculture and food products both at home and abroad.
- Ensure an equitable and orderly marketplace for California's agricultural products.
- Build coalitions supporting the state's agricultural infrastructure to meet evolving industry needs.

California Energy Commission (CEC)

Created by the Legislature in 1974 under the Warren-Alquist State Energy Resources Conservation and Development Act, the Energy Resources Conservation and Development Commission is the state's principal energy policy and planning organization and has five major responsibilities:

- Forecasting future energy needs and keeping historical energy data
- Licensing thermal power plants 50 megawatts or larger
- Promoting energy efficiency through appliance and building standards
- Developing energy technologies and supporting renewable energy
- Planning for and directing state response to energy emergency

The Commission's role includes overseeing funding programs that support public interest energy research; advance energy science and technology through research, development and demonstration; and provide market support to existing, new and emerging renewable technologies.

The Energy Commission certifies the siting, construction, and operation of electrical generating facilities that use any source of thermal energy and have a generating capacity of 50 megawatts or more. The Commission's site-certification for thermal power plants covers all related facilities, including transmission lines that carry electric power from the power plant to a junction with any interconnected transmission system. With respect to such thermal power plants and those that already exist, the Commission certifies any modification that results in a 50-megawatt or more increase in generating capacity or an increase of 25 percent in a line's peak operating voltage or peak kilowatt capacity. All state and local, and most federal level reviews are consolidated in the Energy Commission's certification process, which is completed in approximately 12 months.

California Public Utilities Commission (CPUC)

The California Public Utilities Commission regulates privately owned electric, telecommunications, natural gas, water and transportation companies, in addition to household goods movers and rail safety. The CPUC is charged with ensuring that California's energy is reliable, affordable, environmentally sound and technologically advanced. The Commission is also charged with ensuring that energy is supplied, delivered and used in an environmentally sound way that addresses local, regional and global environmental threats, especially climate change. The Commission has responsibilities in implementing California's renewable portfolio standard (RPS), setting the market price referent for renewable power, and in managing programs such as the self-generation incentive program.

Department of Water Resources (DWR)

DWR is charged with managing the water resources of California in cooperation with other agencies and to protect, restore, and enhance the environment. DWR operates and maintains the State Water Project, including the California Aqueduct. DWR provides dam safety and flood control services, assists local water districts in water management and conservation activities, promotes recreational opportunities, and plans for future statewide water needs.

DWR is responsible for preparing the California Water Plan Update (Water Code Section 10000 et seq.). The plan is updated every 5 years to address challenges currently facing California, such as satisfying the needs of the state's growing population, quantifying water demands and supplies based on sound information, and identifying management strategies to diversify the regional portfolio assets. It identifies water management strategies, such as conservation, energy efficiency, water recycling, water transfers, conjunctive management, and structural measures.

One important mission of DWR is to perform efficiently all statutory, legal, and fiduciary responsibilities regarding management of the state's long-term power contracts and servicing of power-revenue bonds.

During the 2000-1 electricity crisis, the Governor and legislature gave DWR the statutory authority to purchase and schedule all electricity used by the nearly three bankrupt major power utilities in the state. DWR used its authority to enter into long-term contracts with power producers to stabilize the volatile wholesale energy market and to provide the revenue needed by suppliers to secure financing for construction of necessary new power plants. DWR has been charged with the responsibility of managing the long term contracts, including renegotiating their terms and conditions when possible.

5.5.3 Policy issues for biomass

California needs to establish an efficient process to address policy and regulatory issues in collaboration with the biomass industry. Only with a broad, overall approach will it be possible to address existing constraints and develop new policies, laws and regulations that promote the expanded use of biomass while protecting the state's environment.

Addressing the following issues related to biomass may require state agencies to change existing policies or develop new ones. In addition, changes in existing laws or regulations may be required before some of the new policies can be fully implemented. New state policies will need to be coordinated with federal policies.

Accounting for externalities

As described earlier, the use of biomass provides a number of environmental benefits but there is not yet a specific mechanism to credit biomass industries for these benefits. While the state's bioenergy action plan establishes targets for in-state biofuel production and for increased electricity generation, it does not prescribe changes to the RPS or to other statutory requirements guaranteeing these targets be met. While the state benefits from continuing to increase total renewable energy supply, competition from lower cost options under existing approaches may preclude the necessary capacity expansion in bioenergy to meet the action plan targets. New legislation intended to reduce greenhouse gas emissions and establish a carbon market constitutes an important incentive for the development of biomass, as well as other renewables, if the value of carbon under the cap becomes sufficiently high.

The rate of expansion in biomass capacity envisioned in the scenario described earlier to help satisfy objectives under the state RPS, bioenergy action plan, and petroleum reduction and clean fuel policies, will largely be predicated on the rate at which the carbon market develops unless more specific incentives are established or economic conditions change substantially. Although the RPS does not at present provide a targeted incentive for biomass or any other individual renewable energy sector, a renewable fuel standard would tend to favor biomass, at least over the nearer term.

Meeting the multiple objectives of the bioenergy action plan will require careful design of incentives in order to shape the markets in the ways intended.

In the absence of a substantial national policy, a market-based carbon management system may result in industry moving out of the state to avoid carbon caps and costs of carbon mitigation, while still delivering product into the state (the leakage problem). Carbon taxes or fees have direct consequences for consumers, and in combination with a carbon market system may better achieve the reductions desired. Whether a carbon tax could be supported at a state level as opposed to a national level remains debatable, but the ability to send direct price signals to consumers should be given serious consideration.

Waste Management

The present waste management practices of the state derive from policies established nearly twenty years ago. The current diversion-based solid waste management strategy has increased recycling of materials but has not reduced total disposal or met the objectives for reduced landfilling. The method used to determine diversion rate in California has large uncertainties as only disposal is comprehensively and directly measured. Per capita disposal in California has not changed for ten years despite perceived high diversion rates.

A number of alternative waste management approaches can be considered to reduce landfilling if this remains a state objective, recognizing that landfilling also provides energy benefits through the recovery and use of landfill gas. Alternatives include establishing overall disposal limits or limiting the amount of biodegradable material that can be landfilled. Similar approaches have been adopted within the European Union through their landfill directive. For California to adopt such policies, alternative waste management measures must be developed simultaneously to handle the volumes of material involved and avoid increases in illegal dumping and other unintended consequences.

Unabated landfilling, improvements in alternative technologies, and increases in the cost of energy and other economic changes since the enactment of the integrated waste management act in 1989 encourage a reassessment of waste management policies and laws. Several legislative attempts have been made over the last several years to change definitions regarding transformation that influence crediting of diversion allowances for a number of conversion technologies. Whether the state should retain a transformation category in the waste management hierarchy also is debatable. Comprehensive revisions to state policy and statute in this area may be needed to take full advantage of the large resource potential represented by the waste stream. Specific recommendations are difficult to make because the full life cycle impacts and health risks of different alternatives are not fully known. The recent LCA study of selected waste conversion alternatives is a start for conducting more comprehensive assessments.[192]

A comprehensive life cycle assessment should compare the full range of alternative waste management techniques and strategies including landfilling, composting, conversion of all types with energy and product recovery, and recycling. The LCA should include disposal and recycling processes in states and foreign countries that receive waste or recycling stock from California.

The comprehensive LCA can be used to identify best management practices for waste. Decisions that led to the present waste hierarchy embodied in statute need to be addressed and reaffirmed or vacated. For example, portions of the waste stream sent overseas for recycling may not be handled in a sustainable manner or given proper consideration in terms of environmental justice. Solid waste disposal continues to increase and landfill capacity in some regions is reaching capacity requiring that replacement options be decided in the near term. A large body of data on life-cycle inventory and impacts from integrated waste management has been developed in Europe and can be reviewed for potential application or adoption in California.

Financing biomass development

Policies encouraging sustained investment in biomass development will be needed to achieve the targets set forth in the bioenergy action plan and the potential level of growth projected under the scenario described earlier. Loans and loan assistance of the sort discussed under the market access section above can help reduce risk to lenders and stimulate investment capital for new technologies with uncertain risk. Other options include bundling of projects into resource portfolios or packages. By pooling capital-intensive emerging technologies into a resource package with more mature, less expensive technologies, the overall blended risk may be more acceptable to lenders.

Identifying additional ways to provide long term contracting will also be important. Securing contracts under RPS solicitations are currently the principal mechanism for long term contracting, and biomass has not so far competed to the level necessary to satisfy action plan targets. Establishing a renewable fuel standard and opening up direct access would create improved opportunities for long term contracting.

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[192] RTI International, Boisson & Associates, Hilton, Farnkopf & Hobson, LLC, National Renewable Energy Laboratory, "Market and Life Cycle Impact Assessment of Waste Conversion Technologies," CIWMB contract no. IWM-C2030, March, 2004

Net metering should also be uniformly allowed for all biomass technologies including thermal conversion technologies within capacity size limits. Net metering provides direct economic incentives through valuation of electricity at retail rates. It also can provide stimulus for developing peaking or hybrid power systems to take advantage of the energy storage attributes of biomass. Increasing valuation of the baseload capabilities of biomass in complement to intermittent power from wind and solar resources would also provide a direct economic incentive.

5.5.4 Regulatory issues for biomass

Perhaps more than any other single resource, biomass usage affects economic and environmental conditions throughout California, and is therefore subject to regulation by many state and local agencies. This confronts biomass project developers with a complicated and confusing regulatory process. Compared to states with less onerous permitting requirements, California's permitting process for bioenergy appears to have made it harder to take advantage of new federal programs and incentives created in the Energy Policy Act of 2005. California needs to simplify siting and permitting requirements without lowering its environmental standards, and improve communication and education regarding regulatory standards and permitting processes.

Renewable Fuels Standard

A Renewable Fuel Standard (RFS) would define eligible fuel products and set production and consumption goals. It could also set new performance and quality standards and establish a credit-trading system. Due to limited options for other renewable resources to provide transportation energy other than through hydrogen and electricity generation, biomass resources are likely to realize greater incentive for development under an RFS than under the RPS. Emission-offset requirements for biofuel production facilities also may not prove as restrictive as those for power plants due to the shifting of some emissions into the mobile source category. Because the bioenergy action plan does not require specific levels of biofuels production but only targets for in-state production shares, an RFS should be established to ensure meeting non-petroleum use targets and compliance with the intent of the bioenergy action plan.

Permitting process

Because multiple state and local agencies have roles in regulating biomass projects, obtaining permits can be a difficult and time-consuming process. Improving communication among agencies and educating project proponents as to regulatory and permitting requirements may make the process less arduous. Clear permitting pathways formalizing agency coordination and, where appropriate, acknowledging the shift from waste to industrial feedstock need to be established. Consolidating permitting activity within interagency coordinating bodies or through Master Agency Agreements or memoranda of understanding where agencies work under one regulatory framework would likely expedite review, improve communication regarding cross-media impacts, and reduce permitting costs, both for developers and the agencies.

Performance-based standards
Most new biomass projects will require a land-use permit, conditional-use permit, a zoning or master-plan amendment, or some combination of these. These permits are discretionary and usually require approval by elected bodies such as county supervisors or city councils. Obtaining a permit cannot be assured at the onset of a development process. The process can take months or years, and is generally very expensive. Regulations attempting to define technologies and resources often create narrow or technically inaccurate definitions that inhibit application. In general, using performance-based standards may prove more effective in achieving environmental objectives without inhibiting technical innovation; however, their use requires extensive monitoring and measurement on the part of the oversight agencies.

Emission Offsets
The limited availability or high costs of emission offsets is a significant barrier to technology development and deployment. New policies or legislation will be needed to overcome this barrier to meet the original legislative intent of encouraging such technologies. Without recognition that biomass plants reduce overall emissions, permitting of new facilities is not likely. Emission reduction credits (ERCs) are available for purchase in only a few areas of the state; availability in amounts necessary to offset the potential growth of the industry is particularly limited in the central valley and Southern California. Mechanisms to provide offsets, such as trading between mobile and stationary sources where reductions can be certified and recognition of reductions associated with avoided emissions from wildland fires will be important to future industry development. Identifying methods to properly relate stationary power plant and mobile source emissions are also needed for establishing additional emission offset credits if electricity becomes more important as a transportation energy source.

Interconnection standards and net metering
The current interconnection process, CPUC Rule 21 Standardized Interconnection Guidelines, includes standards for certification of the generator-set interface. Proponents of distributed generation technologies claim that Rule 21 unfairly burdens smaller biomass-to-energy projects such as those located at wastewater treatment plants, dairies, and more remote locations in forested regions. Avoiding the cost of

transporting biomass to more centralized facilities can be achieved in some instances through the use of distributed generation technologies in local communities. Additional concerns arise from utility interconnection and power flow studies assuming power is consumed at a central load center which is not always the case. Instead of charging losses to a central load center, utility policies can be designed to reward appropriate-sized, distributed biomass plants that provide local load and voltage support, save on line losses, and improve reliability in remote areas. A number of legislative actions are currently pending to address possible improvements in the transmission system, some of which directly address the needs of biomass.[193] Additional actions may be needed to ensure proper consideration of renewable energy facilities that can provide local power system benefits. Continuing review of interconnection standards should occur to determine where processes can be simplified while maintaining system technical integrity.

In addition to the non-uniform application of net metering among biomass technologies, surplus export power is not currently compensated under NEMBIO[194] utility tariffs. Compensating generators for this energy would improve economic feasibility of small power systems, although potentially increasing administrative costs for utilities.

Forest biomass harvesting
Currently, only limited harvesting of small-woods, mid- and under-story growth is occurring on forest lands. The main limitation is the lack of harvesting capacity within the forest products industry, which has substantially diminished in the last few decades. Current capacity is mostly occupied with processing timber for lumber needs. To make fire prevention and fuels-reduction programs viable, affordable processing capacity needs to be developed to provide markets for those materials and to lower the cost of removal from fire-prone areas. Expanding the exemption from California Environmental Quality Act review for fuels thinning in timberlands governed under the Forest Practices Act, while continuing to require compliance with protective operations and stewardship standards, would accelerate removal and make the material more competitive with timber processing operations. Non-timberland oak woodlands and montane forests would still be subject to the standards within the regulations for forestry assistance programs.

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193 e.g., AB974 (Nunez) Energy Resources: Public Utilities Commission Transmission Siting, would require the CPUC to prepare and implement a comprehensive plan to streamline the transmission permitting and siting process; and SB 1059 (Escutia) Electric Transmission Corridors would provide designated corridors for future transmission lines.

194 net energy metering for biogas

Working landscapes and agricultural buffers
Currently, thirty to forty thousand acres per year of forest land are converted to a land use that does not involve the growing or harvesting of trees.[195] This trend will significantly impact the ability of California forest and range lands to provide biomass for a developing market. Under current land-use law, the local government has the authority for land-use decisions. The local government is to develop and adopt a general plan to guide decision makers as to the best use of land within their jurisdiction. The guidelines for these general plans are developed by the State Office of Planning and Research.

An effort should be made to include forest biomass as an agricultural use for the purposes of land use zoning. This should help influence decisions to require higher density development in residential zones and work to relieve the pressure for further development of working landscapes. Also, development-impact fees for converting working landscapes could provide for purchasing easements to preserve other working landscape outside the development.

Alternative fuel credits
The state is currently reviewing alternative fuel options through a process required under AB 1007 (2005). ARB has adopted regulations requiring the reduction of greenhouse gases from 2009-and-future model-year motor vehicles. These regulations allow manufacturers to obtain a credit for the amount of alternative fuel used by these vehicles.[196] Credits also should be awarded for non-vehicular uses of biofuels where they displace fossil fuels.

State procurement
The state can expand the market for electricity, fuels, technologies, and products by requiring government purchases, including acquisition of flexible fuel vehicles (FFVs) for publicly owned fleets. Other product markets can be expanded by mandating additional purchases of "green" products by state and local agencies. Increasing state use of FFVs could stimulate development of fueling infrastructure, thereby further stimulating additional purchases of FFVs and alternative fuels by the public and helping to satisfy legislation requiring increasing sales of FFVs and alternative fuel use.

Capital outlay projects such as facility construction should be required to include renewable energy technology where appropriate. Federal agencies now receive

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[195] B. Steward, 2005, personal communication.
[196] CCR Title 13, Sections 2180 through 2189.

assistance, funding, and guidance in these efforts from the Federal Energy Management Program (FEMP). California should institute an equivalent state level program.

Enterprise zones
California's 42 enterprise zones can be used to help reduce the cost of business and industry development and speed the development of biomass markets, especially through co-locating bio-based energy and manufacturing facilities, including biorefineries. Several such locations might be established with the goals of using agricultural or food-processing residues in areas such as the Central Valley and Salinas Valley; forestry residues in the north coast and Sierra foothills, urban residues in the San Francisco Bay Area and LA basin, and others. There should be strong linkages between the various enterprise zones to optimize collaboration on new technologies across commodities, regions, and products.

Best management practices
Policies or regulations requiring the use of best management practices need to be adopted where they do not currently exist. Establishing these practices may require additional research. Practices and the implementing policies should not be overly prescriptive and should include mechanisms to ensure sustainable operations.

Environmental Justice
The state has made environmental justice part of its environmental programs. All agencies involved with permitting biomass facilities need to establish policies that implement environmental justice programs. As part of this effort, the California Environmental Protection Agency has directed its regulatory agencies, including the Air Resources Board and the State Water Board, to evaluate and mitigate the environmental and health effects on local communities affected by industrial facilities, including those that will produce or use bioenergy.

There are three basic environmental justice issues: procedural inequality, geographical inequality, and incompatible uses. Procedural inequality occurs when the planning and approval process is not applied equally. Geographic inequality occurs when the burdens of an undesirable land use are concentrated in certain communities or neighborhoods. Issues surrounding incompatible uses occur when the decision to site or expand a facility or otherwise enhance the use of biomass limits or negatively impacts a community's current land uses or future development plans or opportunities. If any of these three conditions exist, or potentially exist, early engagement with the community on how to eliminate, mitigate or compensate for this impact is appropriate.

Among states the best environmental justice programs have been found to include[197] 1) a process for establishing long-term partnerships with the communities they serve, including local governments, the business and academic communities, advocates, and residents, 2) a willingness to honestly assess who will benefit and who will be negatively impacted by pursuing certain actions and policies, and 3) a comprehensive view of the needs of the impacted communities and means of directing resources to mitigate underlying economic and social conditions which negatively impact their current quality of life.

While biomass offers many significant opportunities for the people of California, environmental justice issues have been raised by communities near agricultural lands, dairies, landfills, and other biomass-related facilities. Under current best practices, a careful cost and benefit analysis and health risk assessment must be undertaken to ensure government and private actions do not have negative environmental justice implications.

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[197] *Environmental Justice in California State Law*, Office of Planning and Research, October 2003, page 14.

Table A1. Resource Access action timeline.

Resource Access - Feedstock Supply and Market		Near-Term		Mid-Term		Long-Term					
	Action Area	2006	2010	2015	2020	2025	2030	2035	2040	2045	2050
Sustainability	Implement standards and apply best practices for sustainable biomass supply (agronomic harvest rates, erosion control, crop rotation, sustainable yields, balanced age structure, biodiversity, water use efficiency, etc)	■	■	■	■	■	■	■	■	■	■
Sustainability	Update and improve best management practices and technologies		■	■							
Sustainability	Conduct fuels treatment in forests to enhance fire prevention efforts and forest health		■	■	■	■	■	■	■	■	■
Sustainability	Establish resource baselines and monitor. Apply detailed, interactive information systems using satellite imaging, aerial surveys, and other data gathering techniques for biomass inventory, location, and availability. Publish as GIS model and database. Repeat on five-year or more frequent cycle		■	■	■	■	■	■	■	■	■
Sustainability	Establish support payments for sustainable biomass supply		■								
Sustainability	Enforce standards and best practices	■	■	■	■	■	■	■	■	■	■
Socio-economic	Implement system to balance competing land uses and prioritize working landscapes		■	■							
Socio-economic	Identify and prioritize immediate forest management actions	■	■								
Dedicated crops	Increase use of dedicated crops on marginal and degraded land particularly in association with phytoremediation			■	■	■	■	■	■	■	■
Dedicated crops	Establish dedicated energy crops (e.g., short-rotation trees, dedicated oil and/or herbaceous crops) on retired lands under sustainable conditions			■	■						
Collection and Handling Technology	Expand biomass collection, processing, handling and storage infrastructure. Implement intermediate processing techniques to densify or modify feedsrock for ease of storage and transport.		■	■							
Collection and Handling Technology	Deploy innovative preparation and processing technologies that allow for multiple feedstocks to be handled more uniformly			■	■						
Collection and Handling Technology	Reduce toxicity and improve urban waste resource through increasing source separation of household hazardous wastes and implementing producer responsibility, take-back programs, and pay-as-you-throw programs			■	■	■	■	■	■	■	■
Collection and Handling Technology	Improve separation technologies at materials recovery facilities		■	■	■						
Marketing	Establish and maintain a commodity market for biomass			■	■	■	■	■	■	■	■
Marketing	Create brokerage infrastructure			■							
Enterprize zones	Define feedstock sheds and link to conversion facilities for identifying and selecting enterprize zones		■								
Enterprize zones	Establish production centers and handling facilities in enterprize zones			■	■						
Enterprize zones	Implement mechanisms to support biomass development within enterprize zones				■	■					

Table A2. Market Access action timeline.

Market Access, Expansion, and Technology Deployment		Near-Term		Mid-Term		Long-Term					
	Action Area	**2006**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Financial Incentives	Increase value of carbon reductions through emissions cap and trade system and enact carbon taxes on fossil fuels	■	■	■							
Financial Incentives	Assess value-added taxes on sales of primary products for residue management		■	■	■						
Financial Incentives	Designate tax credits/waive taxes for entities producing/purchasing sustainable biomass feedstocks/products		■	■							
Financial Incentives	Create low-interest loan and loan guarantee programs		■								
Financial Incentives	Provide long-term contracting mechanisms and increase RPS goals.		■	■	■	■	■	■	■	■	■
Financial Incentives	Extend price supports/payments			■	■	■	■	■	■		
Financial Incentives	Require government purchase of biomass energy and products		■	■	■	■	■				
Financial Incentives	Expand net metering and apply uniformly across biomass technologies		■	■	■	■	■	■	■	■	■
Financial Incentives	Revise interconnection standards and UL certification		■								
Financial Incentives	Reinstate direct access		■								
Infrastructure	Ensure adequate transmission line and pipeline capacity			■	■	■	■				
Infrastructure	Install infrastructure for E85,	■	■	■	■	■					
Infrastructure	Add biodiesel blend stock capacity	■	■	■							
Infrastructure	Add B100 fueling infrastructure		■	■	■						
Infrastructure	Develop compressed and liquefied biomethane capacity		■	■	■						
Infrastructure	Ensure adequate infrastructure for syndiesel and other synthetic fuels			■	■	■					
Infrastructure	Develop hydrogen storage, distribution and fueling infrastructure					■	■	■	■	■	■
Biofuel standards	Implement standards and regulations for use of biomethane (landfill gas, digester gas) in natural gas pipelines.		■								
Biofuel standards	Specifications for biosynfuels		■	■							
Deployment	Repower and upgrade power facilities		■	■	■	■	■				
Deployment	Deploy fuelcell power systems			■	■	■	■	■	■	■	■
Deployment	Deploy advanced IGCC power systems			■	■	■					
Deployment	Expand landfill gas-to-energy systems at existing waste facilities		■	■							
Deployment	Shift to bioreactor landfills			■	■	■	■				
Deployment	Add waste-to-energy and conversion technologies for biomass in MSW		■	■	■	■	■	■	■	■	■
Deployment	Site biochemical biorefineries		■								
Deployment	Site thermochemical biorefineries		■								
Deployment	Deploy advanced integrated biorefineries			■	■	■	■	■	■	■	■
Deployment	Expand use of digester technologies at animal operations and WWTP	■	■	■	■	■					
Deployment	Expand biofuel capable conventional vehicle fleet (FFV, hybrids, plug-in hybrids, diesel, other)	■	■	■	■	■	■	■	■	■	■
Deployment	Expand biofuel capable fuel cell vehicles				■	■	■	■	■	■	■
Deployment	Add collection, harvesting, handling, storage and transportation capacity	■	■	■	■	■					
Deployment	Integrate biomass feedstocks and intermediates into petroleum refinery operations				■	■	■				
Deployment	Deploy distributed generation, small modular and combined heat and power systems that meet improved emission and performance standards. Deploy district heating and cooling systems where feasible.		■	■	■						
Deployment	Integrate hybrid biomass-solar renewable power systems				■	■	■	■	■	■	■
Deployment	Construct biopower/fuel systems at government and other facilities			■	■						
Deployment	Deploy biomass to hydrogen production facilities				■	■	■	■	■	■	■

Table A3-a. Research, Development and Demonstration action timeline.

Research, Development, and Demonstration			Near-Term		Mid-Term		Long-Term					
		Action Area	2006	2010	2015	2020	2025	2030	2035	2040	2045	2050
Resource Base, Sustainability and Access	Best Practices	Identify best practice knowledge gaps for all resource types										
		From knowledge gaps, determine best practices for all resource types										
		Investigate and update best sustainable practices (all biomass resource types)										
	Dedicated Energy Crops	Evaluate the long-term sustainability of dedicated energy cropping systems in California										
		Improve agronomic techniques to reduce water and other inputs										
		Evaluate energy crop potential in California (assess yields, production practices, economics for: marginal, idle, and currently producing lands)										
		Assess potential for biomass crops in remediation of saline, marginal or idle ag. lands										
	Inventory Assessment and Monitoring	Improve factors used for gross and technical agricultural residue estimates										
		Develop or expand resource economic models										
		Develop GIS-based biomass resource models to facilitate industry siting										
		Develop or adapt remote sensing technologies, and systems for assessing biomass inventory and monitoring of sustainable practice										
		Review and update assessment and monitoring techniques										
	Infra-structure	Find innovative solutions to ethanol/gasoline distribution incompatibility										
		Develop biofuels that are fungible with petroleum industry infrastructure										
		Develop, and deploy biomass/fossil cofiring solutions for increasing production of biopower (e.g., co-firing w/natural gas or coal, solid fuel&natural gas 'hybrid' boilers, etc.)										
Bioscience/ Biotechnology	Coordinate with Federal (and others') activities	Coordinate with and build on Federal Biomass Roadmap, GTL roadmap, and others										
		Leverage state funding to facilitate California industry and academic participation in federally sponsored research programs and activities										
		Adapt and build upon results from Federal, European, and other reasearch activities creating solutions to California biomass feedstock and product needs										
	Develop Cellulase for California Feedstocks	Establish program to develop cellulase and other enzymes suitable for conversion of California feedstocks to fuels and other products										
		Develop and demonstrate enzymes for California feedstocks. Coordinate with multi-trait energy crop development										
	Develop Energy Crops	Develop crops that have: enhanced yield of energy feedstock higher cellulose:lignin ratio reduced resistance to hydrolysis and fermentation treatments in-plant enzymes or new hydrocarbon expression/production reduced agronomic inputs and enhanced disease and pest resistance multi-traits suitable for both bioproducts and bioenergy										

Table A3-b. Research, Development and Demonstration action timeline (continued).

Research, Development, and Demonstration			Near-Term		Mid-Term		Long-Term					
		Action Area	**2006**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Biomass Conversion	**Thermochemical**	Demonstrate in California advanced heat, power, and syngas systems for improved efficiency and environmental performance with potential application to thermochemical and advanced biorefineries (i.e., biomass integrated gasifier combined cycle [BIGCC])		■	■							
		Replicate BIGCC demonstrations and improve economics and performance			■	■						
		Demonstrate and commercialize advanced thermochemical systems for power, fuels and hydrogen				■	■	■	■			
		Improve and demonstrate advanced DG, CHP, and cooling technologies that can meet environmental performance requirements (especially air permitting and NOx issues)		■	■	■						
	Biochemical	Assess technical, economic, and environmental performance of state-supported biomass programs for possible replication (e.g., California Dairy Power Program)	■	■								
		Determine food and food processor residue amounts and location for siting of anaerobic digestion/co-digestion systems	■	■								
		Demonstrate advanced digestion systems that utilze combinations of food, industrial, animal residues		■	■							
		Demonstrate and commercialize biomethane systems for pipeline and vehicle fuel application	■	■	■	■						
		Develop inexpensive and robust sensor and control systems to improve anaerobic digestion process stability for systems with varying loading rates and feedstock types.		■	■	■	■					
		Improve manure and feedstock collection/handling systems for anaerobic digestion	■	■								
		Develop technologies to treat anaerobic digestion effluent for nutrient, water, and salt management	■	■	■							
		Conduct basic research on microbiology for biogas and bio-hydrogen production	■	■	■	■	■					
	Landfill Bioreactors	Research design requirements for bioreactor landfills: Lining techniques, pressure monitoring and control, slope stability, timing and placement of temporary covers, selectively permeable membranes allowing water transfer	■	■	■	■	■					
		Develop reactor control methods and strategies	■	■	■							
		Assess lifetime safety, environmental and economic performance (LCA) for comparison with other waste management techniques	■	■	■	■	■	■	■			
	Hydrogen	Develop and demonstrate thermochemical biomass to hydrogen pathways			■	■	■	■	■			
		Demonstrate biogas/landfill gas reformation to hydrogen systems for hydrogen enrichment for combustion engines and for future renewable hydrogen fuel sources	■	■	■							
		Demonstrate high yield bio- and biophotolytic hydrogen systems			■	■	■	■	■			
	Biorefinery technologies and systems	Demonstrate biorefineries for conversion of California lignocellulosic feedstocks	■	■	■							
		Research and develop systems and components to adapt BIGCC systems to liquid fuels production (feedstock handling, gas cleaning, syn-gas conversion (catalysts, etc.)).	■	■	■	■	■	■	■			
		Demonstrate thermochemical biomass to liquids (BTL) technologies		■	■	■	■					
		Research / design Integrated biorefineries (thermochemical and biochemical platforms) using best demonstrated systems and crops developed for California conditions		■	■	■	■					
		Demonstrate and deploy integrated biorefineries (combined thermochemical & biochemical platforms)				■	■	■	■			

Table A3-c. Research, Development and Demonstration action timeline (continued).

Research, Development, and Demonstration			Near-Term		Mid-Term		Long-Term					
		Action Area	**2006**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Feedstock Processing	**Harvest Systems**	Develop innovative or improved harvest systems for small diameter wood and shrubs for forest fuels reduction activities		■	■							
		Develop improved harvest systems for dedicated biomass crops and agricultural residues		■	■							
	Process-ing	Develop processing techniques that increase density and extend storage life		■	■	■	■					
		Develop innovative separation and processing techniques for access to MSW biomass		■	■	■	■					
	Logistics	Optimize logistics for feedstock harvest, transport, preparation/processing and storage		■	■	■						
Systems Analysis	**Life-cycle Assessment**	Conduct Life-cycle assessments (LCA) of biomass and bioenergy systems to account for impacts and benefits from utilizing in-state resources as well as imported biomass	■	■	■							
		Document and value external benefits of sustainable biomass utilization for cost internalization (update as knowledge and techniques evolve)	■	■	■	■	■	■	■	■	■	■
		Conduct comprehensive LCA of integrated waste management strategies in order to inform policy and technology innovation	■	■	■							
	Socio-economic/ Resource Competition	Determine economic impacts of biomass management & conversion	■	■	■	■	■	■	■	■	■	■
		Investigate future land and resource-use scenarios: crop land and water adequacy for expanded biomass production (food/energy crop/urban lands competition)	■	■	■	■						
		Assess environmental justice issues for future resource development	■	■	■							
	Climate Change Effects	Assess effects climate change on biomass productivity, water availability, use and other system impacts including soil carbon	■	■	■	■	■	■	■	■	■	■
		Develop predictive tools for climate and land-use change with respect to biomass supply and utilization	■	■	■	■	■	■	■	■	■	■
Knowledge / Information Resources		Establish biomass research centers		■								
		Coordinate research centers with education, training, and outreach activities for disseminating information			■	■	■	■	■	■	■	■

Table A4. Education, Training and Outreach action timeline.

Education, Training, and Outreach		Near-Term		Mid-Term		Long-Term					
	Action Area	**2006**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Public Education and Outreach to Decision Makers	Develop public education programs										
	Provide outreach to decision makers										
Consumer Information and Education	Establish information clearinghouses										
	Conduct public workshops										
	Establish speakers' bureaus										
	Establish adult education and lifelong learning courses										
	Employ mass media communication										
	Design product labeling standards										
Environmental Justice	Establish clear guidelines for considering environmental justice										
	Provide industry and public education on environmental justice										
Industry training and professional education	Develop bioenergy short courses										
	Establish joint academic and industry training programs										
	Provide specialized instruction on permitting, best practices, regulations, codes and standards										
	Conduct investor workshops on corporate social responsibility and sustainable practices										
K-12 education	Create grade-level appropriate curricula in biomass and bioenergy										
	Implement and periodically revise K-12 biomass related curricula										
	Establish teacher training and exchange programs										
	Fund extramural or after-school science and field programs										
	Create video and web-based education materials										
Higher Education	Expand university curricula in biomass, bioenergy, and bioproducts										
	Fund and implement scholar exchange programs										
	Implement higher education degree and training programs (update as needed)										
	Develop and support teaching laboratories										
Research extension and technical interaction	Support formal cooperative extension programs										
	Develop extension programs with research centers										
	Conduct specialized extension short courses										
	Hold technical conferences and workshops										
	Fund international exchange programs										
	Provide paid internships										

Table A5. Policy, Regulations and Statute action timeline.

Policy, Regulations, and Statute		Near-Term		Mid-Term		Long-Term					
	Action Area	2006	2010	2015	2020	2025	2030	2035	2040	2045	2050
Accounting for externalities	Coordinate on implementation of carbon market and carbon tracking system		■	■	■	■					
	Implement carbon tax in event of excess leakage			■							
Waste Management	Enact Extended Producer Responsibility (EPR) requirements to improve feedstock quality and availability.		■	■							
	Open proceedings to reasses waste management policies and laws	■									
	Eliminate technology and transformation definitions from statute		■								
	Implement revised management policies			■							
	Revise definitions for conversion technologies as waste disposal facilities		■								
	Change IWM statutory definitions concerning biomass and transformation		■								
Financial incentives	Enabling actions for extended price supports,			■							
	Enact state and local government procurement requirements for biopower, biofuels, and bioproducts		■								
	Enact loan guarantee programs, establish low-interest loans		■								
	Establish alternative mechanisms for long-term contracts		■	■							
	Establish incentives for biomass enterprise zones, authorize zone-wide EIRs, zoning and General Plan inclusion			■							
Incentives	Provide mechanisms for emission offsets			■							
Permit Assitance	Improve communication among permitting agencies and educate project proponents on permitting process		■	■							
	Establish and fund regulatory clearinghouse and permit assistance center			■	■	■	■	■			
RFS	Establish Renewable Fuels Standard	■									
RPS	Unbundle RECs		■								
Intercon-nection	Review and revise interconnection standards as needed to simplify process	■									
Environmental protection	Regulatory review of standards and Best Management Practices and revise standards as needed	■	■								
	Implementing actions for best practices		■	■	■	■	■	■	■	■	■
	Design and implement performance based standards for environmental quality, health and safety, fuels and products			■	■	■	■	■	■	■	■
	Establish policies that implement environmental justice review		■								