How Does Electricity Generated from Woody Biomass Fit into California's Energy Future?

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Technological advances in biomass to energy conversion, along with recently enacted legislative requirements, have generated renewed interest in biomass power plants in California. In particular, the enactment of the revised Renewable Portfolio Standard (RPS) in 2011 creates a compelling case for wider integration of biomass power plants into California's energy landscape. This review will examine and describe how electricity from woody biomass will fit into California's future and what barriers could prevent that expansion from happening. In particular, electricity generated from woody biomass will play an expanded role in California's energy future provided that policy mechanisms designed to create a market for renewable energy are enforced.

INTRODUCTION

Technological advances in biomass to energy conversion, along with recently enacted legislative requirements, have generated renewed interest in biomass power plants in California. In particular, the enactment of the revised Renewable Portfolio Standard (RPS) in 2011 creates a compelling case for wider integration of biomass power plants into California's energy landscape. Generation of electricity from biomass is interesting and important for three primary reasons. First, the technology and associated business models are decades old and require no additional research funding to generate a guaranteed product. Second, the technology can be implemented at small and large scales and can be adjusted to accommodate biomass feedstocks local to a particular area. Third, the returns on the woody biomass power plants are predictable and provide an attractive option for investors looking for consistent, low risk returns.

Biomass to electricity conversion currently comprises 2% of California's electrical generation capacity and includes a range of sophistication in terms of technologies. It includes both traditional direct-fire combustion and cogeneration, a process that improves the efficiency of plants by utilizing waste heat. In addition, small-scale, pilot gasification plants are demonstrating new opportunities for even more efficient generation technologies. All of these technologies can accommodate a range of woody biomass feedstocks, most of which are waste products from forestry and agricultural activities.

This review will examine and describe how electricity from woody biomass will fit into California's future and what barriers could prevent that expansion from happening. Electricity generated from woody biomass will play an expanded role in California's energy future provided that policy mechanisms designed to create a market for renewable energy are enforced. There are three reasons that electricity generated from woody biomass will expand within a strong renewable energy market. First, the technology is mature and flexible. Woody biomass power plants have worked well for decades on predictable generation schedules and can accommodate a range of feedstocks. Second, power plants provide local environmental benefits by diverting and safely disposing of waste woody biomass. Third, a large supply of feedstock and predictable costs and revenue streams make the technology a sound investment.

TECHNOLOGY REVIEW

Woody biomass power plants in California can vary based on available feedstock consumed, conversion technology, and production capacity, and this flexibility makes them appealing. Power plants can be designed for capacities appropriate for the user and the availability of woody biomass resources. Even once the plant is built, operating parameters can be adjusted based on the type of feedstock and operating conditions. This technology review describes the three broad classes of technologies used to convert woody biomass to electricity and highlights the technological barriers and strengths of these methods.

Three Categories of Biomass Power Plants

Biomass power plants can be categorized into three primary categories: combustion, co-firing/conversion and gasification. Each of these technologies consists of three main components. First, they include an energy conversion system, or structure that makes steam, heat, or gas from biomass. Second, a prime mover, such as a turbine, uses this steam, heat, or gas to make electricity. Third, an air emissions cleanup system improves the air quality out of the exhaust.[1] The overall process of the biomass to electricity is outlined in the process flow diagram below:

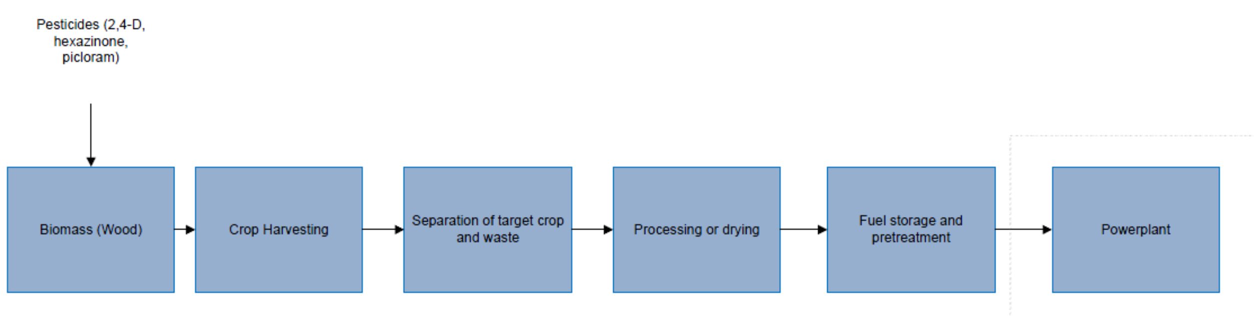

Figure 1: Overall Biomass to Electricity Process Diagram

Direct-Fire Combustion

Combustion is the oldest and most commonly used method of converting generating electricity from biomass. Biomass is combusted in a boiler, and steam is produced. This steam goes through a turbine generator to create electricity. After the steam goes through the generator,

[1] Mayhead, Gareth and John Shelly. "Woody Biomass Fact Sheet" Available at http://ucanr.edu/sites/WoodyBiomass/newsletters/InfoGuides43283.pdf. Last accessed 3/17/13.

its temperature must be reduced before returning to the boiler. This temperature reduction requirement means a great deal of the heat is lost, and process efficiencies are low, around 17-25%.[2] If this waste heat is applied, or recovered, in the process before the steam reenters the boiler, the overall efficiency of the process can be improved to up to 70%.[3] These systems that recover waste heat are called cogeneration facilities, "co-gen".[4]

Co-firing/Conversion

Co-firing involves the combustion of biomass along with coal by substituting a portion of coal with biomass, and conversion is the transitioning of coal-fired power plants to biomass combustion plants. Co-firing and conversion are often grouped together because plants may transition from coal-fired to biomass combustion gradually. The advantages of converting from coal to biomass are reductions in both emissions and production cost, which can have favorable economics to both power plant owners and customers.[5]

Gasification

Gasification involves the high temperature conversion of biomass *along with added coal* into a gaseous fuel. Biomass gasification is still primarily in pilot phases and includes mostly pilot biomass power plants in California (there is one market scale gasification plant operating in Merced). In biomass gasification, two products result: syngas and a biochar. To produce electricity, the product of the gasification, referred to as syngas, can be burned in an internal combustion engine or turbine-generator. Gasification has several advantages over combustion in emissions control. Emission control is simpler in gasification than in combustion because the produced syngas in gasification is at higher temperature and pressure than the exhaust gases produced in combustion. High pressures and temperatures allow for easier removal of sulfur(SOx) and nitrous oxides (NOx), and trace contaminants such as mercury, arsenic, selenium, and cadmium.[6] According to information from Department of Energy, gasification can "achieve almost an order of magnitude lower criteria emissions levels than typical current U.S. permit levels".[7] In addition, gasification also leads to efficient removal of carbon dioxide (CO_2) due to the high temperature and pressure of the produced syngas. Typically, CO_2 can be removed through processes such as carbon dioxide enchanted oil recovery (CO_2EOR) or carbon

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[2] *Ibid*

[3] "Electricity," University of California Woody Biomass Utilization, accessed May 9, 2013, http://ucanr.edu/sites/WoodyBiomass/Woody_Biomass_Utilization_2/Energy/

[4] US Environmental Protection Agency- Combined Heat and Power Partnership. 2007. "Biomass Combined Heat and Power Catalog of Technologies", accessed March 15, 2013, http://www.epa.gov/chp/documents/biomass_chp_catalog.pdf.

[5] Silverstein, Ken, "Converting to Bioenergy: Benefits and Challenges," *Forbes*, February 7, 2013, accessed May 9, 2013, http://www.forbes.com/sites/kensilverstein/2013/02/07/biomass-breathing-new-life-into-coal-plants/

[6] "Gasifipedia: Advantages of Gasification," National Energy Technology Lab, , accessed May 10 2013, http://www.netl.doe.gov/technologies/coalpower/gasification/gasifipedia/7-advantages/

[7] National Energy Technology Lab

sequestration.[8] In CO_2EOR, CO_2 is injected underground into oilfields to sweep residual oil and gets stored underground in the process. [9] In carbon sequestration, CO_2 is injected into a deep geologic formation for permanent storage.

For all of these processes, biomass feedstocks must meet certain size and moisture requirements. While biomass may come from diverse sources such as sawmills, agriculture, and even urban waste, most biomass power plants require chip sizes no larger than 3 inches in diameter. The cost of feedstock varies depending on its source, though the cost to produce and use waste products, such as mill and agricultural refuse, is less than that to use farmed crops.[10] For reference, for one particular 20MW Woody Biomass Plant in Woodland, California approximately 500 tons of wood are burned per day. 60% of the wood is urban waste, while the remaining 40% comes from agriculture waste.[11]

A schematic detailing both the biomass gasification and direct combustion is shown in the process diagram below:

[8] National Energy Technology Lab

[9] *The Future of Coal - An MIT Interdisciplinary Study*, Massachusetts Institute of Technology. March 2007, http://web.mit.edu/coal/The_Future_of_Coal.pdf

[10] California Energy Commission. 2008. “An Assessment of Biomass Resources in California” 2007. Available at http://biomass.ucdavis.edu/files/reports/2008-cbc-resource-assessment.pdf.

[11] Personal communication, Ronald Sichau, Plant Manager, NAES Corporation. May 1, 2013.

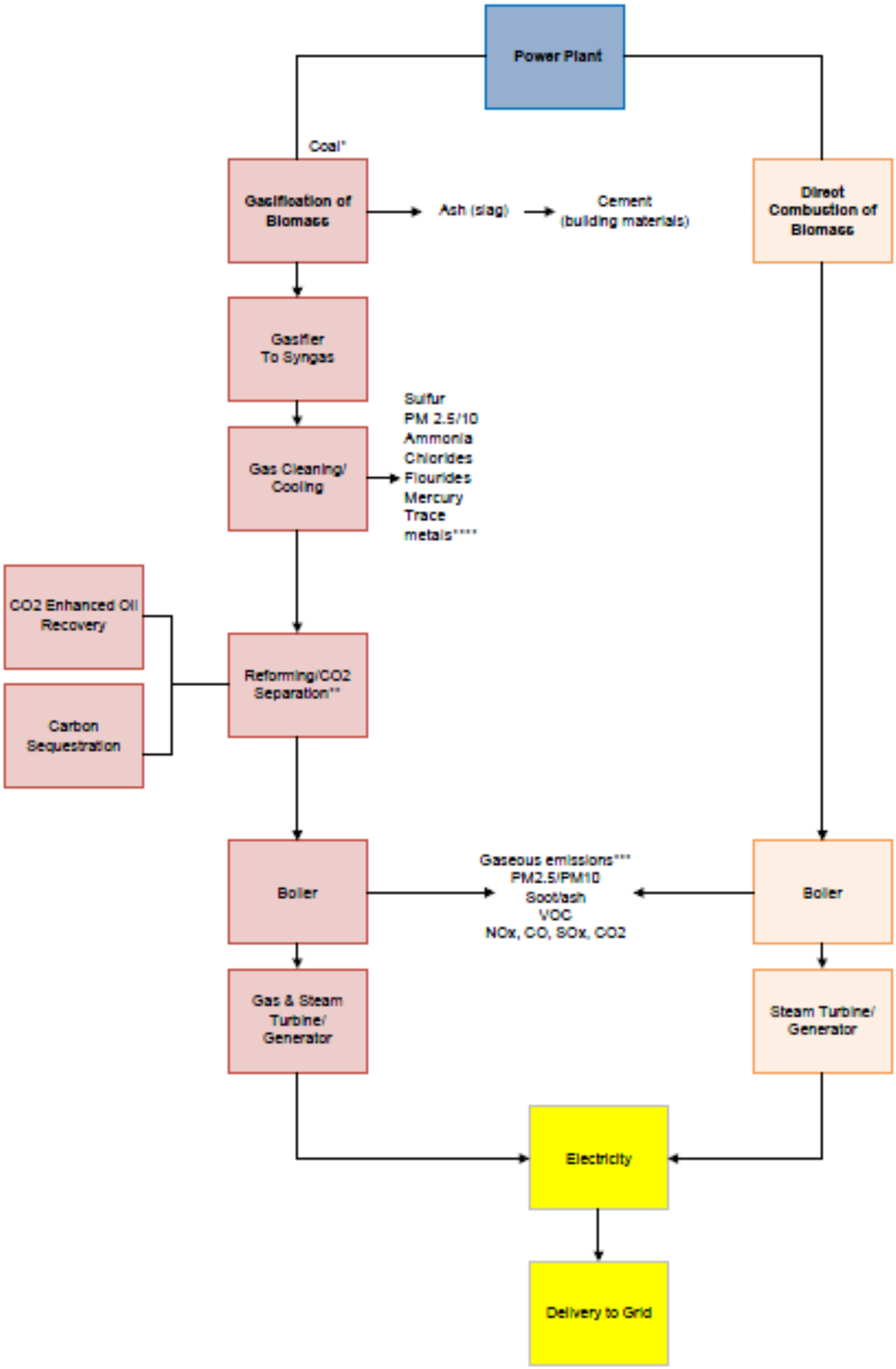

Figure 2: Gasification and Direct Combustion Process Flow[12,13,14,15,16,17,18]

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[12] Zhang Xiaotao; Wang Aijun; Arellano-Garcia, H.; Wozny, G., "Performances Evaluation of Biomass Gasification and Synthetic Gas Co-Firing in Coal-Fired Boiler," Power and Energy Engineering Conference (APPEEC), 2011 Asia-Pacific , vol., no., pp.1,4, 25-28 March 2011

Table 1 below shows comparisons between the two processes:

	Direct Combustion	Gasification
Conversion Process	Fuel burning in boiler to generate heat to run steam turbines	High temperature chemical conversion of biomass to syngas, followed by combustion to run steam/gas turbine
Fuel	+ Urban & agricultural waste + Forestry products	+ Urban & agricultural waste + Forestry products (more precise moisture content required)
Efficiency (without cogeneration)	17-25%	38-41%
Emissions & byproducts	SOx, NOx, PM, CO, CO2	SOx, NOx, PM, CO, CO2 Char

Table 1: Table of Comparison for Combustion & Gasification Processes

Operational Challenges

Maintenance Costs and Low Efficiency (direct combustion)

While combustion is the most commonly used technology, it is not without its drawbacks. Significant maintenance is required to keep these systems running, and these maintenance requirements can vary based on the type of feedstock used. This frequent maintenance means reduced capacity of the power plant or even temporary shutdowns. Even when operating at full capacity, the systems have fairly low efficiencies (17-25%) when not used with combined heat and power[19].

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[13] Knoef, H.A.M., Handbook Biomass Gasification. Biomass Technology Group. Netherlands. 2012

[14] Faaij, A., "Modern Biomass Conversion Technologies", *Mitigation and Adaptation Strategies for Global Change*. Springer Netherlands, Volume 11, Issue 2, March 2006, pp. 335-367.

[15] Annette Evans, Vladimir Strezov, Tim J. Evans. "Sustainability Considerations for Electricity Generation From Biomass". *Renewable and Sustainable Energy Reviews*, Volume 14, Issue 5, June 2010, pp.1419–1427

[16] McKendry, P. Energy production from biomass (part 2): conversion technologies. Bioresource Technology, Volume 83, Issue 1, May 2002, pp. 47–54

[17] National Energy Technology Lab.

[18] Heebink, Loreal V. "Utilization of Fly Ash from Biomass and Biomass-Coal." *Biomass Magazine*. N.p., 20 Sept. 2011. Web. 18 Mar. 2013.

[19] Personal communication, Ronald Sichau, Plant Manager, NAES Corporation. May 1, 2013.

Emissions (direct combustion)

High particulate matter (PM) emissions from the direct combustion process require expensive cleanup. Typically, an electrostatic precipitator (ESP) is used for removing PM in biomass power plants.[20] Electrostatic precipitators removes particles from a flowing gas (such as air) using the force of an induced charge. ESPs are highly efficient, which can remove as much as 99.99% of PM.[21] One of the disadvantages of ESPs are their high capital costs and large space requirements.[22] Compared with conventional scrubbers technologies which cannot remove particles below a few microns, ESPs are more highly efficient collectors, even for small particles and large volume of gas, making ESP a technology with a much higher capital cost than conventional scrubbers.[23]

High capital cost (gasification)

In contrast to direct combustion systems, gasification systems require more expensive infrastructure since they cannot be created from "recycled" or retrofitted coal-fired plants. In addition, gasification is a more complicated fuel conversion process than direct combustion that require higher temperatures operation, which means additional equipment cost.

Competition with Natural Gas (gasification)

In California, natural gas dominates the power generation market due to its low cost and high availability. Gasification is still considered an unproven technology in California since the current gasification plants are all operating in pilot scale.[24] Until there are greater investments in gasification plants, natural gas will remain dominant in CA's energy market.

Regulatory Barrier (gasification)

The research and development in biomass gasification has been static for the past four decades, despite the incentives for renewable energy in California. The reason is that developers of electricity from biomass projects face a significant regulatory hurdle: under state environmental laws (Integrated Waste Management Fee Law - Sec. 40117)[25], biomass gasification plants must produce no discharges of air contaminants or emissions, including

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[20] Personal communication, Ronald Sichau, Plant Manager, NAES Corporation. May 1, 2013.

[21] "Comparing Alternatives for Submicron Particulate Control: Venturi, Wet ESP, CCS," Tri-Mer Coporation, accessed May 9, 2013, http://www.tri-mer.com/q&a/comparing-electrostatic-precipitator.htm

[22] Rod Hansen And Robbie Van Rensburg, *Cost Comparisons Between Electrostatic Precipitators And Pulse Jet Fabric Filters And Inherent Challenges Of Both Technologies At Eskom's 6 X 600 Mw Units At Duvha Power Station*,

[23] "Electrostatic Precipitator," Environmental Protection Agency, accessed May 10, 2013, http://www.epa.gov/ttn/oarpg/t1/reports/sect5-2.pdf

[24] Personal communication, John Shelly, CE Advisor, University of California Woody Biomass Utilization. April 3, 2013.

[25] State of California Board of Equalization "Integrated Waste Management Fee Law - Sec. 40117." http://www.boe.ca.gov/lawguides/business/current/btlg/vol4/iwmfl/iwmfl-40117.html (accessed 4/4/13).

greenhouse gases (as defined in subdivision (g) of Section 38505 of the Health and Safety Code). As a result, many companies have located their bioenergy projects in other states to avoid this law, as the no-emission gasification process is not technologically feasible at present.

In short term, changing this policy would help gasification plants compete on a level legal playing field with other electricity generation technologies. However, even if the laws are lifted, capital investment costs are prohibitively high and have long payback periods that make it less attractive than conventional energy sources. Policy intervention is therefore necessary to push biomass-to-electricity projects forward by creating economic incentives. Some policies provide economic incentives for companies to develop bioelectricity projects, while other policies set standards for pollution emissions and siting of the projects.

Combustion temperature control for complete combustion (direct combustion)

Due to the variations of biomass fuel from agriculture and urban waste, controlling burning temperature to achieve complete combustion is an issue for biomass power plants. According to experts at the Woodland Biomass Powerplant facility[26], there needs to be rigorous control and monitoring of the combustion process to ensure safe combustion reactions. Compared with coal burning, where combustion temperature and properties are well-studied and known, variations in biomass mixtures (i.e. different types of farm crops in biomass fuel) can complicate control of combustion temperatures and emissions. This can cause an increase labor cost (since someone has to be monitoring the combustion process 24/7, as in the case of the Woodland Powerplant).

Grid stability (all)

Gird integration is another challenge for biomass to electricity generation. Development of renewable energy resources such as biomass power gives rise to technological challenges not previously faced by the grid, such as the location of renewable resources far from population centers and also the variability found in renewable generation.[27] While small penetrations of renewable generation on the grid can be smoothly integrated, accommodating a greater amount of power generation from biomass will require new approaches to extending and operating the grid.[28]

[26] Personal communication, Ronald Sichau, Plant Manager, NAES Corporation. May 1, 2013.

[27] Tittman, Peter. "Wood Bioenergy in CA: Current Trends and Potential Drivers". Presentation, Green Chemistry Poster Session, UC Berkeley, CA, May 6, 2013

[28] "Integrating renewable electricity on the grid". *American Physical Society*, accessed May 10,2013. http://www.aps.org/policy/reports/popa-reports/upload/integratingelec.pdf

Public acceptance and opposition (all)

Public support is recognized as an important factor in shaping the widespread implementation of renewable energy technologies. Some typical public attitudes towards biomass power generation may include fear or distaste towards siting a power plant near their home, or the “not-in-my-backyard effect." Others involve fear of the impact upon forests, which is often driven by the misunderstanding the woody biomass plants get their feedstocks from virgin forests. Both public acceptance and opposition are major drivers to policy change and the achievement of energy policy targets. Outreach and education are essential in increasing public understanding of, and attitude towards biomass to electricity.

Environmental Benefits of Woody Biomass to Electricity

Using woody biomass power plants reduces the local environmental and health burdens for a number of reasons. Most importantly, these power plants often use wood products that would otherwise be disposed of in controlled burns or even unplanned forest fires. Burning waste wood in controlled environments prevents the release of these harmful emissions.

As stated above, feedstock from woody biomass can come from a variety of sources based on the availability of local resources. Woody biomass can be used to produce electricity either through direct combustion (of biomass or co-firing with coal) and gasification. Regardless of which process is used, the woody biomass is generally obtained as chips and shipped to the facilities in trucks. Wood can come from lumber operations, which generate a lot of waste wood products, although sometimes trees are farmed specifically for use as biomass. For example, fast-growing tree species such as hybrid willow (Salix) and poplar have been developed for production in agricultural settings (i.e., grown like row crops on farms).[29] In addition, woody biomass can be sourced from agricultural waste (e.g., orchard trimmings, nut shells) and from urban waste (e.g., construction debris). Finally, woody biomass can come from public forests in partnership with the federal and state governments. According to the U.S. Forest Service, “The woody biomass removed during ecological restoration, wildfire risk reduction, and conventional silvicultural activities can become a source of energy and wood products that are renewable, are climate- neutral over the life cycle of production and use, and contribute to U.S. energy independence.”[30]

Trees and wood products that would otherwise be burned or sent to landfills to degrade can instead be transformed into electricity. Wood and wood byproducts that go into a landfill will generate either carbon dioxide, through aerobic decomposition, or methane, through

[29] Wisconsin Grasslands Bioenergy Network, “Sources of biomass,” http://www.wgbn.wisc.edu/key-concepts/grassland-biomass-sources/sources-biomass. Accessed May 8, 2013.

[30] USDA, Woody Biomass Utilization Strategy (2008). http://www.fs.fed.us/woodybiomass/strategy/documents/FS_WoodyBiomassStrategy.pdf. Accessed May 9, 2013.

anaerobic decomposition. Forests that do not undergo regular management by tree removal face the high risk of forest fires which emit harmful particular matter (PM) emissions. When waste biomass is combusted in biomass power plants, toxic emissions are captured. If this waste biomass were disposed of in open burns, thousands of pounds of pollutants would be released.[31, 32] The following table gives the amount of pollutants released (per ton of wood) when trees and wood products are burned in the open, such as in forest fires or controlled burns.[33]

Pollutant	Quantity Captured [lbs/ton biomass]
PM_{10}	19-30
$PM_{2.5}$	17-27
NO_x	3.5
SO_2	0.1
VOC	8-21
CO	154-312

Table 2: Pollutants captured in direct-fire combustion woody biomass power plants

Similar pollutant levels are generated from open burning of other sources of woody biomass. In electricity generation from woody biomass, from both direct combustion and gasification, there are gaseous emissions, including $PM_{2.5}$, PM_{10}, NOx, and SOx. Since the syngas produced during gasification is composed of carbon monoxide and hydrogen (and because much of the carbon is retained in the char residue), there is much less of each of these pollutants in gasification than in direct combustion. As can be seen from the above table, SOx is not a large component of direct combustion of wood, however.[34] In addition, the furnaces tend to have excellent particle filters on them, so PM is not going to be a big factor with direct combustion either.[35] Data reported in literature indicates that emissions from controlled units equipped with efficient dust cleaning devices burning biomass, are well within particulate emission limits.[36] As reported

[31] Jenkins, B., "Atmospheric Pollutant Emission Factors From Open Burning of Agricultural and Forest Biomass by Wind Tunnel Simulation," UC Davis (April 1996). http://www.arb.ca.gov/research/apr/past/a932-126a_1.pdf. Accessed May 9, 2013.

[32] Gaffney, P., "Emission Factors for Open Burning of Agricultural Residues. August 2000. California Air Resources Board Planning and Technical Support Division. http://www.arb.ca.gov/ei/see/memo_ag_emission_factors.pdf. Accessed May 9, 2013.

[33] San Joaquin Valley Air Pollution Control District, Open Burn Emission Factors. March 2001. http://www.valleyair.org/policies_per/Policies/SSP%202005.pdf. Accessed May 8, 2013.

[34] Mayhead and Shelley

[35] U.S. Dept. of Energy, Federal Energy Management Program (2011), "Biomass for Electricity Generation." Available at http://www.wbdg.org/resources/biomasselectric.php (accessed 3/17/2013).

[36] Khan, A. et al, "Biomass combustion in fluidized bed boilers: Potential problems and remedies," *Fuel Processing Technol. 90(1)*: 21-50 (2009).

to our group in a trip to the Tracy (CA) Biomass electricity generation plant, 99.99% of particulate matter is removed during "scrubbing" and collected as fly ash.[37] In addition, any nitrogen and sulfur is removed using the following processes:

$NO_x + NH_3$ (ammonia) → $N_2 + H_2O$
SO_2 + CaO (calcium oxide) → $CaSO_4$ (gypsum)

Using these cleaning processes, the Tracy plant limits its emissions of NO_x to 27.2 lbs/hr and of SO_2 to 6.25 lbs/hr, according to the terms of its operating permit.[38]

Both gasification and direct combustion produce ash as a byproduct; direct combustion produces more ash, but this is generally recycled as concrete, and ash can be reduced by burning at higher temperatures.[39] Both processes also generate CO_2; gasification produces less CO_2 because it also produces char. Because the CO_2 (as well as the char) can be used for carbon sequestration and enhanced oil recovery processes, both processes can be operated with a net negative production of green house gases.

Since gasification is often co-fired with coal, there is an issue of the contribution from NOx and SOx from the coal in addition to that from the wood.[40] Heavy metals are also produced whenever coal is used.[41]

Environmental Comparison To Natural Gas

Although coal is a major source of fuel for electricity generation throughout the United States, it is generally not used in California, where the primary fossil fuel used in electric plants is natural gas, primarily consisting of methane. Although natural gas is relatively clean burning, it is a non-renewable fossil fuel. In addition, approximately 3-8% methane leaks during well operation, which is problematic because methane is twenty times worse than CO_2 as a greenhouse gas.

The biggest positive impact of using woody biomass versus methane is the fact that wood is regenerated, leading to a net zero emission of CO_2. "The carbon neutrality of forest biomass used to produce electricity and heat is a long-established convention in greenhouse gas (GHG)

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[37] Personal communication, Ronald Sichau, Plant Manager, NAES Corporation. May 1, 2013.
[38] Personal communication, Joginder S. Khalsa, Plant Engineer, NAES Corporation. May 6, 2013.
[39] Etiégni, L. and Campbell A.G., "Physical and chemical characteristics of wood ash," *Bioresource Technol. 37(2)*:173-178 (1991).
[40] Kern, S., et al., "Synergetic Utilization of Biomass and Fossil Fuels: Influence of Temperature in Dual Fluidized Bed Steam Co-gasification of Coal and Wood," *Int. J. Env. Sci. and Devel. 3(3)*: 294-299 (2012).
[41] Rubin, E., "Toxic Releases from Power Plants." *Env. Sci. Techn., 33(18)*: 3062-3067 (1999).

accounting."[42] This is a somewhat controversial position because biomass generates carbon dioxide when it burns just as methane does and trees take years and even decades to regrow, so the concept that wood is regenerated is disputed. The reality, though, is that most of the sources of woody biomass used in California electricity plants is either waste products or material that needs to be removed for the health of the forests. There is currently no plan to cut down forests for the sole purpose of burning it for fuel. Under the latter scenario, woody biomass utilization truly is carbon neutral and can be considered a regenerative resource.

Impact of Policy on the Future of Electricity from Woody Biomass

Despite its proven technology and clear environmental benefits, generating electricity from woody biomass requires policy incentives to make it economically competitive. The costs involved in processing biomass material from urban sites and forests are more expensive than the conventional electricity generated from natural gas. There are several policy incentives that could help expand the reach of electricity generated from woody biomass in California.

Federal Policies

Several pieces of legislation, from federal to local scales, aid the renewable energy sector. A number of these address the use of biomass to electricity directly.

The Biomass Research and Development Act of 2000

The act describes the need for biomass research, encourages coordination between the United States Department of Energy (U.S.DOE) and United States Department of Agriculture (USDA), created the Biomass Research and Development Board, and set the scope of the joint U.S.DOE-USDA Biomass Initiative.[43] Specifically to biomass to electricity, the board coordinates research and development activities to improve the conversion efficiency. This act would be most helpful to biomass

The Healthy Forest Restoration Act of 2003

The act recommended thinning programs to reduce accumulation of woody fuel to lower the risk of catastrophic wildfire. The collection and removal of small-diameter trees and understory

[42] National Alliance of Forest Owners, "Carbon Neutrality of Energy from Forest Biomass." http://nafoalliance.org/carbon-neutrality-of-energy-from-forest-biomass/, Accessed May 9, 2013.
[43] Biomass Research & Development, "Advancing Biomass Technology", http://www.biomassboard.gov/ (accessed 4/4/13)

shrubs has spawned local biomass utilization efforts.[44] Being able to use more woody waste would provide high quality, low cost fuel for electricity generation and benefit this sector.

Tax credits and incentives

All types of biomass energy are currently considered renewable and carbon neutral and thus qualify for many tax credits, subsidies, and incentives. These credits help woody biomass power plant owners by providing them with additional sources of revenue beyond just sales of electricity. With one type of credit, the Renewable Energy Credits, each megawatt-hour of electricity generated by biomass earns a credit. That owner of the plant that generated that electricity can sell that credit, independent of the electricity itself, to other utilities that are required to purchase renewable energy.[45] Also, biomass feedstock production is exempt from carbon allowances and eligible for subsidies from the U.S. Department of Agriculture.[46] In addition, the Energy Production Tax Credit pays biomass energy producers 1.1 cent per kilowatt-hour for 5 years.[47] Finally, an Investment Tax Credit created under the federal stimulus package reimburses 30% of biomass plant development if it is started by 2011.[48] Each of these tax credits, incentives and subsidies of course supports and stimulates use of woody biomass for electricity generation by providing other sources of revenue beyond just electricity sales.

Toxic Substance Control Act

The generation of electricity from woody biomass through direct combustion or gasification does not produce any chemical products either directly or as a byproduct and is therefore not implicated under either TSCA or REACH. This represents a significantly lower regulatory burden than many liquid biofuels face. If TSCA and REACH are strongly enforced and impose strong burdens on producers of chemicals covered under these laws, the economics might point to using biofuels to generate electricity, which is not covered under these regulations.

State and Local Policies

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[44] Rahmani, M.; A. W. Hodges, and M. C. Monroe. 2007. *Federal Policies and Incentives*, Wood to Energy Outreach Program. Florida Cooperative Extension Service, Circ 1526. University of Florida, Gainesville, FL,

[45] State of the planet, "Is Biomass Really Renewable?" http://blogs.ei.columbia.edu/2011/08/18/is-biomass-really-renewable/. Accessed May 9, 2013.

[46] Id.

[47] Union of Concerned Scientists, "Production Tax Credit for Renewable Energy." http://www.ucsusa.org/clean_energy/smart-energy-solutions/increase-renewables/production-tax-credit-for.html. Accesses May 8, 2013.

[48] Id.

In California, the manner in which state and local policies are enforced will have a significant impact on the success and growth of the woody biomass to electricity sector. This section outlines some of the initiatives that have the greatest impact on the woody biomass-electricity sector.

The Renewable Portfolio Standard

If enforced and implemented well, the Renewable Portfolio Standard (RPS) could be a powerful tool to expand the reach of electricity from woody biomass in California. The RPS requires that 33% of California's electricity to be sourced from renewable feedstocks, and 20% of those renewables be from biomass, by 2020.[49] Today, electricity from biomass comprises only 2% of all California's electricity, so meeting this goal and expanding that penetration to 6% would be a three fold increase in capacity and generation.[50] This RPS essentially expands the market for renewable energy and places the onus on investor owned utilities, electric service providers, and community choice aggregators to meet incorporate renewables into their electricity portfolio.[51] But the impact of the RPS requirements is entirely dependent upon how well it is enforced. Recently, California failed to meet its first RPS goal of achieving its goal of sourcing 20% of electricity from renewables by 2010. One California legal scholar, Deborah Behles attributes this failure to several factors including decentralized administration, lack of independent data collection and analysis, and minimal enforcement of its standards.[52] If these negative trends continue and California fails to provide the necessary resources to achieve this goal, electricity from biomass would miss opportunities for tremendous expansion. Fortunately, there are still opportunities to for woody biomass power plant utilization to increase through other impetuses.

Green Power Purchasing

State and local governments, businesses, and other nonresidential customers can serve as role models to the rest of the community by purchasing electricity from renewable resources, a practice commonly called green power purchasing. The US EPA has formalized these initiatives, and recognizes them accordingly, through the Green Power Partnership.[53]

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[49] UC Woody Biomass Utilization, "Renewable Portfolio Standard" http://ucanr.edu/sites/WoodyBiomass/Woody_Biomass_Utilization_2/Energy/ (accessed 4/4/13).
[50] California Energy Commission, "Electricity Generation Capacity and Energy: 2001-2012," http://energyalmanac.ca.gov/electricity/electric_generation_capacity.html (accessed 5/1/13).
[51] California Public Utilities Commission, "California Renewables Portfolio Standard (RPS)", http://www.cpuc.ca.gov/PUC/energy/Renewables/ (accessed 5/14/13).
[52] Behles, D. "Why California Failed to Meet Its RPS Target" 17 Hastings West-Northwest J. of Env'l. L. & Policy 163 (Summer 2011).
[53] US EPA, Green Power Partnership, http://www.epa.gov/greenpower/basic/index.htm (accessed 5/13/13).

Community Choice Aggregation

Initiatives specific to California include Community Choice Aggregation that allows cities and counties to pool their citizens' purchasing power to buy green electricity, with the price of electricity determined by the contract. [54] By coming together and essentially buying renewable energy "in bulk", the community can access locally produced clean energy at a lower cost. Disclosure and community education are necessary precursors for Community Choice aggregation, as communities and citizens will rarely chose a more expensive or complex option without understanding the downsides to their current energy mix.

Generation Disclosure Rules

By educating consumers about the sources of their electricity, Generation Disclosure Rules can generate increased interest in renewable energy. Generation disclosure rules require utility companies to provide information regarding the energy they supply to their customers. This type of information, which may include fuel mix percentages and emission statistics, is often included on a customer's monthly bill.[55] Related to disclosure, certification is an industry practice that guarantees customers that the utility company uses the types and amounts of renewable energy it claims to. By providing consumers with detailed information about local energy systems, practices like disclosure and certification can help raise consumers' awareness about their energy supplies.

Paradox of Woody Biomass- Controversy on Carbon Accounting

Biomass is considered a renewable energy source because the carbon in biomass is part of the natural carbon cycle: trees use carbon dioxide from the atmosphere and convert the carbon into biomass, while releasing oxygen. When plants die and decompose, they release the carbon back into the atmosphere.[56] Whether trees are burned or whether they decompose naturally, they release the same amount of carbon dioxide into the atmosphere. If trees harvested as biomass are replanted as fast as the wood is burned, new trees take up the carbon produced by the combustion, the carbon cycle theoretically remains in balance, and no extra carbon is added to the atmospheric balance sheet—so biomass is considered "carbon neutral." Since nothing offsets the CO_2 that fossil fuel burning pro duces, replacing fossil fuels with biomass supposedly results in reduced net carbon emissions.

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[54] PG&E, "Community Choice Aggregation", http://www.pge.com/cca/ (accessed 4/7/13).
[55] U.S. Environmental Protection Agency Clean Energy, "Fuel Source Data", http://www.epa.gov/cleanenergy/energy-and-you/how-clean.html
[56] National Alliance of Forest Owners, "Carbon Neutrality of Energy from Forest Biomass." http://nafoalliance.org/carbon-neutrality-of-energy-from-forest-biomass/, Accessed May 9, 2013.

When some agricultural biomass, such as annual crops, is burned, the carbon dioxide generated can be taken up quickly by the growing of new plants. However, when wood and trees are used as the burned biomass, the growth of new trees and the recapture of carbon would take years or decades. Another issue is to quantify the carbon that the trees would have sequestered (i.e., naturally stored) if left untouched. It is very difficult to measure the amount of carbon sequestration in forests because tree growth rates can fluctuate. “There has been uncertainty in the scientific community whether old growth or fast growth forest sequester carbon more efficiently.”[57]

A group of prominent scientists wrote to Congress in May 2010, arguing incorrectly that all biomass energy production results in a 100% reduction of carbon emissions.[58] In principle, biomass can reduce carbon dioxide if fast-growing crops are grown on otherwise unproductive land; in this case, the regrowth of the plants offsets the carbon produced by the combustion of the crops. Conversely, cutting or clearing forests for energy, either to burn trees or to plant energy crops, releases carbon into the atmosphere that would have been sequestered if the trees had remained untouched, in addition to producing carbon in the combustion process, resulting in a net increase of CO2.

The Natural Resources Defense Council warns against using forests for fuel: “You can plant new trees, but forests aren’t ‘renewable’. Natural forests, with their complex ecosystems, cannot be regrown like a crop of beans or lettuce… tree plantations will never provide the clean water, storm buffers, wildlife habitat, and other ecosystem services that natural forests do.”[59] So there is controversy over the advisability of using forests for fuel. So long as the sources of woody biomass remain primarily waste wood products along with a moderate amount of trees from careful forest thinning, this controversy can be avoided.

CO_2 emissions of biomass versus fossil fuels

The combustion of both fossil fuels and biomass produce carbon dioxide. According to the Partnership for Policy Integrity (PFPI), a 50-MW plant burns 2,550 lb. of green wood (i.e., freshly cut wood that has not been dried) each minute.[60] PFPI calculates that, at this rate, the 115 new biomass plants being built over the next 3 years will burn around 55 million tons of wood—which is equivalent to 650,000 clear-cut acres of forest per year by 2014. This is not to say that

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[57] “Forest Sequestration Controversy: Old-Growth vs. Young-Growth Forests as Viable Carbon Offsets.” http://oldvsyounggrowthforestasoffset.weebly.com/why-is-it-controversial.html. Accessed May 9, 2013.

[58] “Scientists Call for Proper Bio-energy Accounting.” May 17, 2010. http://www.env.state.ma.us/eea/doer/biomass/comments-oct21-2010/Matera,%20Chris%20-%20Mass%20Forest%20Watch%20(appendix%202).pdf. Accessed May 9, 2013.

[59] Natural Resources Defense Council, “Our Forests Aren’t Fuel.” http://www.nrdc.org/energy/forestsnotfuel/. Accessed May 8, 2013.

[60] Partnership for Policy Integrity, “Biomass Energy Overview.” http://www.pfpi.net/biomass-basics-2. Accessed April 12, 2013.

clear cutting of forests is being or will be done to supply woody biomass. To the contrary, to the extent wood is being taken from forests for biomass, it is being removed in small amounts to promote forest health. In short, regardless of their size, biomass-burning power plants actually produce more CO_2 than fossil fuel plants: 150% the CO_2 of coal, and 300 to 400% the CO_2 of natural gas, per unit of energy produced.[61] As stated above, however, the fact that biomass is a renewable resource means that burning woody biomass is still considered a net carbon neutral activity.

Carbon Emissions of Woody Biomass exempted from Clean Air Act permitting requirements

In 2011, the EPA deferred, for three years, Clean Air Act permitting requirements for carbon dioxide emissions from bioenergy sources to allow the agency time to conduct a detailed examination of the science on this issue.[62] New EPA guidance is also being provided to help permitting authorities determine whether using biomass as a fuel can be considered the best available control technology (BACT) for CO_2 emissions from large sources needing permits.[63] Sources covered by this proposal would include facilities that emit CO_2 from burning forest or agricultural products for energy, wastewater treatment, waste management (landfills), and fermentation processes for ethanol production.

In summary, there are many policies and incentives at the federal, state, and local level that support the utilization of biomass and bioenergy. On the federal and state level, incentives expressed in the form of tax credits, rebates, grants or loan programs for the use of woody biomass for energy production are provided through policies such as the Federal Renewable Energy Production Credit and Grants for Forest Biomass Utilization[1]. In addition, the Renewable Portfolio Standards require that utility companies must generate a certain amount of energy from renewable resources by 2020. While policies are abundant at both the federal and state level, there are few policies that support power production from biomass on the local level. As previously mentioned, biomass power plants required large upfront capital cost, therefore, implementing local policies to encourage energy generation from biomass would be beneficial to sustain biomass electricity production in the long run.

There are many ways to increase biomass electricity production on a local scale through policy and law changes. Policies can be implemented to increase collaboration with local communities

[61] "Carbon emissions from burning biomass for energy," http://www.pfpi.net/wp-content/uploads/2011/04/PFPI-biomass-carbon-accounting-overview_April.pdf (accessed 4/8/13).
[62] "EPA Proposes to Defer GHG Permitting Requirements for Industries that Use Biomass/Agency aims for science-based, reasonable approach to biomass," 3/4/11, http://yosemite.epa.gov/opa/admpress.nsf/1e5ab1124055f3b28525781f0042ed40/8a075999ffaf58e285257853005acb83!OpenDocument (accessed 4/7/13).
[63] Federal Register, Vol. 76, No. 54, p. 15249, March 21, 2011.

to devise strategies to utilize woody biomass and educate the public on the amount and value of woody biomass. Laws to better manage forests for biomass production would help sustain supply of woody biomass for power generation. Furthermore, establishing agreements through use of contracts with local suppliers and growers will provide long-term reliable supplies of biomass. These policies and law changes will help develop biomass systems and thus create more job and economic opportunities in the long term for the local community. As the United States moves towards goals of energy independence, policy and law support for biofuels and bioenergy will become increasingly important. Therefore, policies and incentives at the federal, state, and local level to support biofuel and bioenergy production are crucial for the long-term sustainability of electricity production from biomass.

Market Trends

Current Trend in Biomass Power Plant

An abundance of natural resources and unused power plant capacity make expansion of woody biomass power plants an attractive electricity generation option. Thanks to California's abundant biomass resources, California has the most biomass power plants of any state as of year 2012.[64] Biomass power plants produced 2% of California's total electricity.[65] Interestingly, California is not even tapping all of their existing biomass power plant resources. While California's 48 commercial direct-fire combustion scale power plants include 988 MW of generation capacity, only 24 of these plants are operational currently and produce 594.5 MW of electricity. The operational plants range in size, with the smallest generating 4MW and the largest 50MW. The remaining plants are either active, meaning they are being constructed or converted and not ready for use, idled, and could be restarted with a simple procedure, or non-operational, meaning that the facility has not been in operation for years, and using this facility would require major capital investment[66]. An additional three plants, with a combined capacity of 113 MW, have been proposed, with one being a new construction and the other two involving the conversion of two coal-fired power plants to biomass fired.

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[64] Mayhead, G. & Tittman, P. Uncertain future for California's biomass power plants, 2012 *California Agriculture*, 66(2).

[65] California Energy Commission. "Waste to Energy & Biomass in California", http://www.energy.ca.gov/biomass/. (accessed 4/7/13).

[66] Mayhead, G. & Tittman, P. Uncertain future for California's biomass power plants, 2012 *California Agriculture*, 66(2).

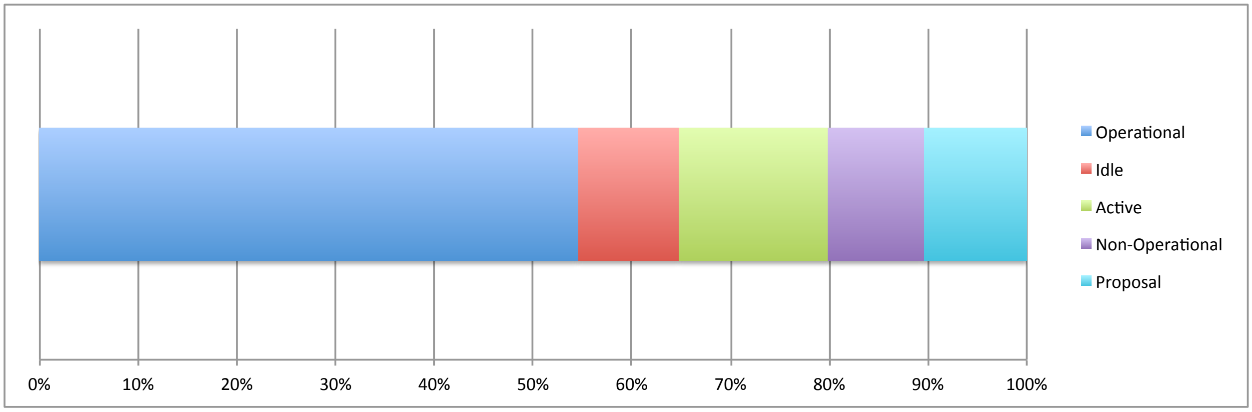

Figure 3a: Status of Direct-Fire Combustion Woody Biomass Power Plants in California, May 2011
Data Source: University of California Woody Biomass Utilization, Available at http://ucanr.org/sites/WoodyBiomass/Woody_Biomass_Utilization_2/California_Biomass_Power_Plants/

In addition to the direct-fire combustion plants described above, California also has 5 pilot-scale gasification plants. These pilot plants operate at scales orders of magnitude smaller than currently existing direct-fire combustion. For now, the high upfront capital costs involved in building gasification plants makes building them at full-scale unlikely. But for now, they provide important sites for research and opportunities to explore new ways to use the ubiquitous woody biomass.

Figure 3 shows a map of biomass to electricity plants in California.[67] The green pins on the map represent operational power plants; yellow pins indicate facilities that are currently idle but that could restart with minimal capital investment; red pins represent potential projects that may restart, re-power, and co-firing plants; white pins are the non-operational facilities; orange pins represent pilot projects; and purple pins represent projects that are in the planning stage. Table 1 shows a list of biomass power plants in California, along with their operating status.[68]

[67] "California Biomass Power Plants". University of California Woody Biomass Utilization. http://ucanr.edu/sites/WoodyBiomass/Woody_Biomass_Utilization_2/California_Biomass_Power_Plants/

[68] "CA Biomass Power Plants May 2011". University of California Woody Biomass Utilization http://ucanr.edu/sites/WoodyBiomass/newsletters/Industry_Information33479.pdf

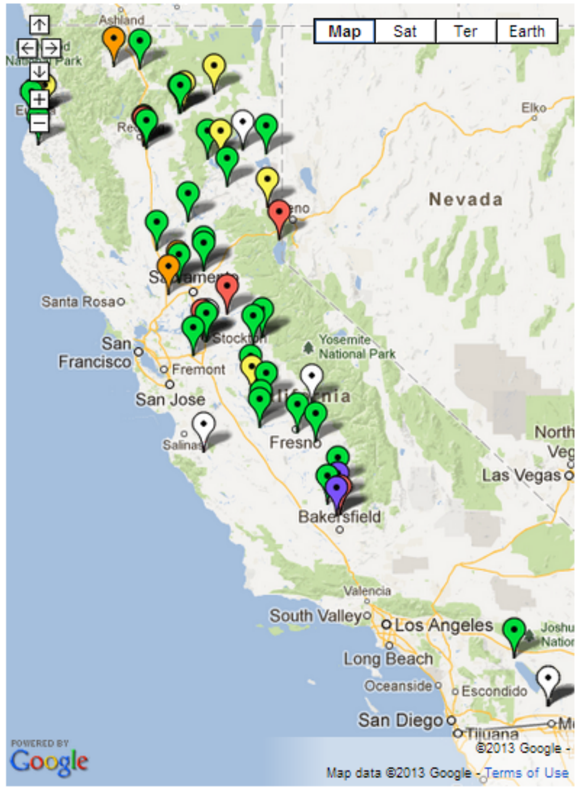

Figure 3: Map of biomass to electricity plants in California

Name	Location	Details	Status
AIR PRODUCTS STOCKTON	STOCKTON, CA	45MW, Co-fire or conversion (from coal, petcoke or TDF), cogen	Operational, 20% biomass
BIG VALLEY BIOMASS POWER	BIEBER, CA	7.5MW, Biomass solid fuel, not cogen	Idle,
BLUE LAKE POWER	BLUE LAKE, CA	11MW, Biomass solid fuel, not cogen	Operational,
BUENA VISTA BIOMASS POWER	IONE, CA	18.5MW, Co-fire or conversion (from coal, petcoke or TDF), not cogen	Active project, 100% biomass
BURNEY FOREST POWER	BURNEY, CA	31MW, Biomass solid fuel, cogen	Operational,
BURNEY MOUNTAIN POWER	BURNEY, CA	11MW, Biomass solid fuel, not cogen	Idle,
CAL FOREST NURSERY	ETNA, CA	41kW, Gasification, cogen	Operational,
CHOWCHILLA	CHOWCHILLA, CA	12.5MW, Biomass solid fuel, not cogen	Idle,
COLLINS PINE CO. PROJECT	CHESTER, CA	12MW, Biomass solid fuel, cogen	Operational,
COLMAC	MECCA, CA	47MW, Biomass solid fuel, not cogen	Operational,
DELANO ENERGY CO. INC.	DELANO, CA	50MW, Biomass solid fuel, not cogen	Operational,
DG FAIRHAVEN	FAIRHAVEN, CA	18MW, Biomass solid fuel, not cogen	Idle,
DIAMOND WALNUT	STOCKTON, CA	4.5MW, Biomass solid fuel, not cogen	Non-operational,
DINUBA ENERGY INC.	DINUBA, CA	12MW, Biomass solid fuel, not cogen	Operational,
DIXON RIDGE FARMS	WINTERS, CA	50kW, Gasification, cogen	Operational,
DTE STOCKTON (POSDEF)	STOCKTON, CA	45MW, Co-fire or conversion (from coal, petcoke or TDF), cogen	Active project,
FRESHWATER PULP	SAMOA, CA	50MW, Biomass solid fuel, cogen	Non-operational,
HONEY LAKE POWER	WENDEL, CA	32MW, Biomass solid fuel, not cogen	Operational, Operating at 19MW
IMPERIAL VALLEY RESOURCE RECOVERY PROJECT	BRAWLEY, CA	18MW, Biomass solid fuel, not cogen	Idle,
KIARA SOLAR (WHEELABRATOR HUDSON)	ANDERSON, CA	6MW, Biomass solid fuel, cogen	Active project, Restart
MADERA POWER LLC	FIREBAUGH, CA	28MW, Biomass solid fuel, not cogen	Operational,
MENDOTA BIOMASS POWER LTD	MENDOTA, CA	25MW, Biomass solid fuel, not cogen	Operational,
MERCED POWER (EL NIDO)	EL NIDO, CA	12.5MW, Biomass solid fuel, not cogen	Idle,
MESQUITE LAKE RESOURCE RECOVERY	BRAWLEY, CA	18.5MW, Biomass solid fuel, not cogen	Non-operational, Restart?
MT POSO COGENERATION	BAKERSFIELD, CA	44MW, Co-fire or conversion (from coal, petcoke or TDF), cogen	Active project, co-fire, then 100% biomass
MT. LASSEN POWER	WESTWOOD, CA	11.5MW, Biomass solid fuel, not cogen	Idle,
PACIFIC OROVILLE POWER INC.	OROVILLE, CA	18MW, Biomass solid fuel, not cogen	Operational,
PACIFIC ULTRAPOWER CHINESE STATION	JAMESTOWN, CA	22MW, Biomass solid fuel, not cogen	Operational,
PHOENIX ENERGY	MERCED, CA	500kW, Gasification, not cogen	Operational,
PLACER COUNTY	KINGS BEACH, CA	3MW, Gasification, cogen	Active project, New build
RIO BRAVO FRESNO	FRESNO, CA	25MW, Biomass solid fuel, not cogen	Operational,
RIO BRAVO JASMIN	BAKERSFIELD, CA	40MW, Co-fire or conversion (from coal, petcoke or TDF), cogen	Proposal,
RIO BRAVO POSO	BAKERSFIELD, CA	40MW, Co-fire or conversion (from coal, petcoke or TDF), cogen	Proposal,
RIO BRAVO ROCKLIN	ROCKLIN, CA	25MW, Biomass solid fuel, not cogen	Operational,
ROSEBURG FOREST PRODUCTS	WEED, CA	12MW, Biomass solid fuel, cogen	Active project, Addition of turbine/genset
SCOTIA BIOMASS	SCOTIA, CA	28MW, Biomass solid fuel, cogen	Operational,
SIERRA BIOMASS (AUBERRY)	AUBERRY, CA	7.5MW, Biomass solid fuel, not cogen	Non-operational,
SIERRA POWER CORP.	TERRA BELLA, CA	9.5MW, Biomass solid fuel, cogen	Operational,
SOLEDAD ENERGY	SOLEDAD, CA	13.4MW, Biomass solid fuel, not cogen	Non-operational,
SPI BURNEY	BURNEY, CA	20MW, Biomass solid fuel, cogen	Operational,
SPI ANDERSON	ANDERSON, CA	4MW, Biomass solid fuel, cogen	Operational,
SPI ANDERSON PROJECT	ANDERSON, CA	31MW, Biomass solid fuel, cogen	Active project, New build
SPI LINCOLN	LINCOLN, CA	18MW, Biomass solid fuel, cogen	Operational,
SPI LOYALTON	LOYALTON, CA	20MW, Biomass solid fuel, not cogen	Idle,
SPI QUINCY	QUINCY, CA	25MW, Biomass solid fuel, cogen	Operational,
SPI STANDARD	SONORA, CA	8MW, Biomass solid fuel, cogen	Active project, Restart
SUSANVILLE	SUSANVILLE, CA	12.5MW, Biomass solid fuel, not cogen	Non-operational, Restart
TRACY BIOMASS PLANT	TRACY, CA	19.4MW, Biomass solid fuel, not cogen	Operational,
VALLEY BIO-ENERGY	MODESTO, CA	33MW, Biomass solid fuel, not cogen	Proposal,
WADHAM	WILLIAMS, CA	26.5MW, Biomass solid fuel, not cogen	Operational,
WEST BIOFUELS	WOODLAND, CA	200kW, Gasification, not cogen	Operational,
WHEELABRATOR SHASTA	ANDERSON, CA	50MW, Biomass solid fuel, not cogen	Operational,
WOODLAND BIOMASS POWER LTD	WOODLAND, CA	25MW, Biomass solid fuel, not cogen	Operational,

Table 3: Biomass Power Plants in California

State of Woody Biomass Direct Combustion Market

Currently, there are 50 biomass power plants using direct combustion in the state of California. All of these plants are operating in full scale, ranging from 12-50MW in capacity. The ownership and business models for biomass power plants can vary. One particular plant, Woodland Biomass Power LTD, operates a 25MW direct combustion biomass plant in Woodland, CA and sells electricity to Pacific Gas & Electric under a long term power purchase agreement.[69] In another example, Sierra Pacific Industry, a forest products company based in Anderson, California, operates seven cogeneration plants, where electricity is produced and any waste heat is also utilized. Together, these facilities produce over 150 megawatts of electrical power.[70] The company uses power produced in the co-generation plant to operate the lumber

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[69] Wooland Biomass Power. http://dteenergyservices.com/businessLines/powerAndRenewables/lobPowerAndRenewables.html#

[70] Sierra Pacific Cogeneration Plants. http://www.spi-ind.com/html/operations_cogen.cfm

mills where the power is generated. Any excess electricity is sold back to the local public utilities, such as PG&E or to other energy service providers. The company is currently building their eighth cogeneration plant in Placer County, California.

State of Gasification Power Plants in California

While there are no commercially operating gasification plants in California, there are limited initiatives underway to prove out the feasibility of gasification plants. West Biofuels has partnered with University of California and Department of Energy to build a 250kW demonstration plant in Woodland, CA that uses gasification for power generation instead of the traditional direct combustion process.[71] The gasification plant converts biomass to syngas, a cleaner gas that can be processed into liquid biofuels. The gasification plant is in its pilot stage. West Biofuels hopes to further develop this technology further if proven successful at the pilot stage.

The high capital costs and unproven state of the technology have resulted in little investment in gasification plants in California. While gasification is a much cleaner process than direct combustion, there is a very high overhead capital cost associated with gasification plants because it involves a more complicated fuel conversion process that requires additional equipment than traditional combustion plants. Gasification is also an unproved technology for generating electricity in California. While gasification provides the additional benefits of cleaner emissions, higher efficiency, and higher value end products, there are numerous barriers to large-scale implementation in California due to the economics and technical challenges associated with this process. Fortunately, there are funding sources, though limited, to invest in biomass to electricity development.

Economic Viability of Woody Biomass Power Plants

The economic viability of traditional, direct-fire combustion woody biomass power plants is highly dependent up on the costs of operation and the revenue these plants can generate from sales of electricity and other credits and incentives. The ability to move the more early stage technology of gasification forward, is dependent up primarily grant funding from public sources.

Costs of Operation

Costs of feedstocks are the biggest drivers of whether electricity generated from woody biomass can compete with other electricity options. All commercial biomass-based electricity plants are currently based on direct combustion, and many of these plants are decades old and do not use the most efficient available technologies, so those less efficient plants are even more sensitive to fluctuations in feedstock prices.

[71] West Biofuels Company. April 2013. http://www.westbiofuels.com/about.htm

Feedstocks

There are two primary sources of woody biomass feedstocks. These are (1) the residual wood products left over from lumber mill operations and (2) in-fill from forest land that needs to be cleared as part of forest management.[72] In addition, biomass from agricultural operations (including fruit tree trimmings) and wooden construction waste are also used in electricity production. The problem with the residual lumber products is that there are competing uses (like pressed wood products and wood shavings for animal pens) that drive up the cost for the "waste." The problem with the forest "waste" is much more complicated. Starting in 1988, policy changed at the U.S. Forest Service after environmental groups complained about the economic use of National Forests. Around the same time, the Northern Spotted Owl became a protected species and the Federal Courts ordered the Forest Service to limit logging on federal land to preserve the owls' habitat. As a result of these two changes, logging in National Forests was reduced by 90%.[73] Ironically, years of reduced harvesting of wood and made the forests unhealthy and unmanaged, and prone to forest fires. Wildfires contribute to poor air quality – especially particulate matter.[74]

Scaling

Appropriate scaling is critical to maintaining economically viable woody biomass power plants. First, the amount of woody biomass, as well as the cost of retrieving this material, must be considered, as even costs of "waste" feedstock can vary dramatically based on geography. Dempster et al. identified the slope of the area where waste woody biomass is harvested as a major driver of costs. In particular, retrieving biomass from an area with 60% slope versus 10% slope can more than double the overall costs of retrieval.[75]

The amount of biomass available for use in woody biomass is highly subject to competition for other, higher value biomass fuel uses. Jenkins et al. note that at prices below $1.50 per gge, low value biomass would be used for electricity generation, but as prices increase, waste biomass might go towards other, higher value transportation fuels.[76] Thus, in summary, the capacity for biomass exists to supply biomass to meet the RPS demands of 6% of total electricity in California provided that there exist enough market incentives to use this biomass for electricity generation.

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[72] Shelly, John, and Tittman, Peter. Personal Communication. 4/3/13.

[73] Barnard, Jeff. "Feds Aim to Double Habitat for Spotted Owl" Associated Press. http://bigstory.ap.org/article/feds-aim-double-habitat-spotted-owl (accessed 5/14/15).

[74] Dale, Lisa. "The True Cost of Wildfire in the Western U.S." April 2010. Western Forestry Leadership Coalition. http://www.wflccenter.org/news_pdf/324_pdf.pdf (accessed 5/14/13).

[75] Dempster, P., Gallo, N., Hartsough, B., Jenkins, B., Tittman, P. "Final Report to the State of California Department of Forestry and Fire Protection" University of California, Davis. December 2008.

[76] Jenkins, B. et al., "Sustainable Use of California Biomass Resources Can Help Meet State and National Bioenergy Targets." California Agriculture (63) 4, 2009.

Market Summary

Since cost is such a critical issue for the utilization of woody biomass, the top policy issue is requiring utilities to use renewable fuels. There is already a requirement under the Renewable Portfolio Standard to have 33% of California's electricity from renewable sources – including 20% from biomass – by 2020. Under current markets, woody biomass-generated electricity cannot compete with natural gas, which is just too inexpensive and readily available. Perhaps moving the RPS date to 2015 would be the best policy decision to promote the use of woody biomass. By mandating the early use of renewable electricity, it would make economic sense to use the lumber waste.

There also needs to be a change in U.S. Forestry policy to once again allow forest management through controlled logging. There needs to be a balance between environmental concerns about commercializing our federal forestlands and having a policy that takes advantage of commercial logging to keep the forests healthy.

Market Summary: Future of Gasification Plants

The most important impediment to commercial gasification at this point is the capital costs of building the plants. If the market supported the true cost of biomass electricity, that would help justify the investment in gasification. In addition, it may take significant grants from government agencies investing in commercial plants to jump start large scale gasification of woody biomass.

Industry/governmental partnerships are necessary to support the expansion of gasification from the pilot stage to commercial operations. Ultimately it will be worth the investment because of the higher efficiency and lower pollution. NGOs also need to support the biomass electric industry because it is not the enemy; they can work together to manage forests and produce cleaner fuel.

Potential Funding Sources

There are a number of funding programs geared toward biomass to electricity development. As the bio-related industry has been known to rely on subsidies from public sectors in order to remain active, private companies have been refraining from funding outside projects. As a result, the funding sources are primarily in the public sector.

Woody Biomass Utilization Grant Program: One source of public funding is available from the Forest Service (managed by the State). The program, called Woody Biomass Utilization Grant Program, has been running on an annual basis since 2005[77]. The program offers up to $250,000

[77] "Request for Proposals: 2013 Hazardous Fuels Woody Biomass Utilization Grant Program." *Federal Register* https://www.federalregister.gov/articles/2013/02/19/2013-03768/request-for-proposals-2013-hazardous-fuels-woody-biomass-utilization-grant-program

for individual projects, totaling up to 3 to 4 million dollars every year. In 2012, 20 plants were awarded (out of 34 proposals), 3 of which are in California.[78]

Eligible projects will use woody biomass, such as material removed from forest restoration activities, wildfire hazardous fuel treatments, insect and disease mitigation, forest management due to weather events, or thinning overstocked stands. Projects eligible for funding will also utilize the biomass in commercially-proven technologies to produce thermal energy, electrical power or liquid or gaseous bioenergy. However, the funding has to be used primarily for improving the engineering design of the project. Some permitted uses for the grant money include funding engineering services necessary for final design and cost analysis. Based on these criteria, the funding cannot be used on restarting an idle project unless considerable engineering revisions are made on the plant.

In addition, to be considered, projects must have already completed a comprehensive feasibility assessment of the project by qualified and credible parties and a woody biomass resource supply assessment. Eligible parties must also submit three years of financial statements. Given the amount of the effort to prepare the information relative to the amount of grant received, one may argue that the funding is somewhat limited. Despite that, several other programs have been offering grants on a similar funding scale.

USDA Farm Service Agency Biomass Crop Assistance Program (BCAP): BCAP provides financial assistance to producers or entities that deliver eligible biomass material to designated biomass conversion facilities for use as heat, power, bio-based products or biofuels. It was first funded in 2009 and took the form of a transportation subsidy (of up to $45/bone dry ton) for the Collection, Harvest, Storage and Transportation (CHST) costs associated with the delivery of eligible biomass materials. During this initial period there were 4,275 contracts nationally and almost $244m was spent by the program[79]. However, the program was placed on hold in February 2010 pending review of comments on a new notice of funding availability (NOFA).

California Association of Resource Conservation and Development Councils (CARC&DC) Biomass Technical Assistance Grant: The grant was aimed at biomass conversion technologies which utilize large amounts of wood fuel from national forests and other areas to reduce wild fire hazards, especially in the wild land urban interface. There was a limit of $40,000 per project. A match of 25% minimum was required, which could be in-kind. This program, which was funded by the US Forest Service Region 5 State & Private Forestry, ended in December 2010.

It funded many feasibility studies in California and led to a number of biomass utilization projects moving forward. For example, in 2008, the funding has allowed Placer County,

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[78] "USDA Forest Service Awards Nearly $4 Million for Renewable Wood Energy Projects." *Forest Products Laboratory* http://www.fpl.fs.fed.us/news/newsreleases/releases/20120726a.shtml
[79] "BCAP Project Area Information" Farm Service Agency http://www.fsa.usda.gov/FSA/webapp?area=home&subject=ener&topic=bcap-pjt

California to conduct a feasibility assessment of small-scaled biomass combined heat and power at Lake Tahoe Basin, evaluating direct combustion and gasification systems of electricity production with air emission low enough to be permissible in the area. Then, financial analyses and recommendations are given for a site identified as having potential for CHP installation.

Biomass Research and Development Board

Through the Food Conservation and Energy Act of 2008, the federal government established the Biomass Research and Development Board[80], an interagency office that specializes in biomass research projects. Collaborative efforts between the U.S. Department of Agriculture and the U.S. Department of Energy administer grant programs designed to stimulate the development of biomass technology. The Board also works with a technical advisory committee that determines the direction and focus for research and development efforts.

Grant funding supports three areas of study involving feedstock development, biofuels and bio-based products and biofuels analysis. Feedstock development projects research methods for producing the organic materials or feedstock used to power biomass gasification technologies. Projects involving biofuels and bio-based products develop cost-effective methods for using biomass materials and increasing the overall growth yield of feedstock materials. Biofuels analysis projects involve tools designed to analyze the effects of biomass gasification usage and creates rural-based markets to specialize in biomass production.

As of April 2011, the federal government created the Biomass Research & Development Initiative as part of an effort to reduce America's reliance on oil imports, according to the U.S. Department of Energy[81]. In the process, the federal government has set aside $30 million in grant funding for research projects involving biomass gasification products and technologies. The overall goal for the Biomass Research & Development Initiative intends to reduce oil imports by one-third by the year 2025. Environmental goals for biomass research see a 50 percent overall reduction in fossil fuel and greenhouse gas emissions. Eligible applicants for grant funding include universities, laboratories and rural-based industries.

Conclusion

Generation of biomass from electricity will play a critical role in California's energy future, but the extent of that role is highly dependent upon the state of California's enforcement of the Renewable Portfolio Standard. California's abundant natural resources support the expansion of electricity from biomass to at least 3 times it current penetration of 2% of electricity generated to the 6% required by the Renewable Portfolio Standard. Importantly, that increase can happen just with available waste woody biomass, as the economic and environmental evidence does not support the use of virgin forests for electricity generation.

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[80] Biomass R&D Board http://www.usbiomassboard.gov/

[81] "Funding Opportunities" Department of Energy http://www1.eere.energy.gov/biomass/financial_opportunities.html

Increasing the penetration of woody biomass will have added environmental and health benefits. This technology is considered net carbon neutral, so using it will displace other net carbon positive forms of electricity generation. Furthermore, disposing of waste woody biomass in controlled environments, as opposed to open burning, will result in improved air quality in communities in close proximity to waste biomass.

Finally, electricity from woody biomass will continue to be dominated by direct fire combustion and co-firing plants, while gasification will remain at the pilot scale. Limited research funding, particularly in California, means that this newer, potentially more efficient technology will likely not be developed to the extent that it could were more prolific funds available. The high cost of capital required to build a full-scale plant makes the implementation of this technology at a commercial scale unlikely.