FEASIBILITY OF BIOMASS FOR REGIONAL ENERGY INDEPENDENCE IN NORTHERN CALIFORNIA

Spring 2020

Master of Public Administration in Environmental Science and Policy

COLUMBIA | SIPA
School of International and Public Affairs

Feasibility of Biomass for Regional Energy Independence in Northern California

About the Authors

Pacific Forest Trust (PFT) retained a team (the Team) of eleven graduate students of Public Administration in Environmental Science and Policy at Columbia University to determine if a nine-county heavily forested region (the Region) in northern California can separate from the grid through utilization of excess small-diameter woody biomass for electricity. This report does not advocate for biomass. The analytical objective is to understand if the supply of sustainably harvested woody material can meet the energy demand of the Region. The team identified positive and negative consequences of increasing biomass energy, focusing in particular on costs, and reducing risk and scale of uncontrolled wildfires by reducing available ladder fuels. The authors recognize the complexity of tradeoffs involved in any actionable option for reducing wildfire frequency and severity. While we are interested in protecting the forests, as is our client, our analysis is intended to be objectively informative for any audience interested in learning more about biomass-generated electricity in northern California.

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Acknowledgements

We would like to thank our faculty advisor, Adrian Hill, for her support and guidance throughout this project. We would also like to thank Aiyana Bodi and Laurie Wayburn of Pacific Forest Trust for the opportunity to assist with this project and for their support. This report was finalized during the COVID-19 outbreak, which reached a peak in New York City (and the United States) in spring of 2020, fragmenting our research team across the country. Nonetheless, we can confidently say that this did not affect the quality of our report and findings.

Additionally, we want to extend special thanks to the numerous experts who shared valuable knowledge and insight, particularly during this challenging time:

- Craig Thomas | Director, The Fire Restoration Group
- Susan Britting | Executive Director, Sierra Forest Legacy
- Matt Palmer, Ph.D. | Senior Lecturer, Columbia University
- Stephen R. Kaffka | Extension Agronomist, UC Davis
- Simone Cordery-Cotter | Climate Analyst, Sierra Business Council
- Nick Goulette | Executive Director, The Watershed Center
- Jack Singer | Stewardship Associate, Pacific Forest Trust
- Dan Tomascheski | Vice President, Sierra Pacific Industries
- Tom Cuccia | Account Manager, California Independent System Operator
- Jessica Morse | Deputy Secretary, California Natural Resources Agency
- Jonathan Kuesel | Executive Director, Sierra Institute for Community and Environment
- Rizaldo E. Aldas, Ph.D. | Program Lead, California Energy Commission
- Hugh Merriam | Retired Analyst, Pacific Gas & Electric
- Dr. Gregg Morris | Director, Green Power Institute
- Marino Monardi | Procurement Director, Pacific Gas & Electric

Our depth of research and understanding would not have been possible without them.




About Pacific Forest Trust

Founded in 1993, Pacific Forest Trust is a non-profit land trust and policy shop organization that works “to sustain America’s forests for their public benefits of wood, water, wildlife, and people’s wellbeing, in cooperation with landowners and communities” by conserving forests, advancing climate solutions, protecting water sources, and saving wildlife habitat. Pacific Forest Trust works with private forest landowners across California and the northwest to conserve land through working forest conservation easements, as well as develop incentives for forest conservation and stewardship more broadly.

PACIFIC FOREST TRUST

Contents

Executive Summary

This report seeks to determine if nine counties in northern California, consisting of Butte, Lassen, Modoc, Plumas, Shasta, Sierra, Siskiyou, Tehama, and Trinity County (the Region), can utilize the surplus of woody biomass in its forests for localized energy generation. When referring to woody biomass, this report identifies the material as small-diameter wood in the forests that is too small to be sold as timber but large enough to be chipped. Other types of biomass (agricultural waste, solid waste, etc.) are not considered in the analysis. It is important to understand if woody biomass removal will adequately enhance forest health and support local communities. The analysis also seeks to understand the extent to which burning woody debris for energy could reduce the ladder fuels and associated wildfire emissions, as compared to the potential emissions from that same debris being burned in a biomass energy facility. Given the high costs of using biomass for energy, financial factors are investigated. Lastly, the report considers policy implications.

Summary of Key Findings

- Removing the surplus of small-diameter woody biomass from the forests in the Region can enhance forest health and reduce fire risk.
- There is likely a sufficient amount of small-diameter woody biomass supply in the Region to meet total energy demand.
- It is costly for the Region to completely separate from the grid through biomass utilization due to the high capital and operational cost of the biomass facilities themselves, combined with the new power line infrastructure required.
- Converting biomass to energy usually necessitates significant subsidization.
- Either one or a combination of the three scenarios for grid utilization outlined in this report, such as Community Choice Aggregation, can be used to connect more biomass facilities to the existing grid.
- After assessing publicly available data and published reports, the information suggests that biomass energy generation might increase greenhouse gas and local air emissions. However, the emissions from biomass energy would be lower than the emissions produced from wildfires due to emission controls.
- Despite clear drawbacks to increasing biomass energy generation, there are no other scalable uses of the excess wood in the forests, and with policy intervention, biomass energy could be one way to reliably remove excess woody material from forests.
- California will need to reach 100% clean energy by 2045, according to State policy mandates. Biomass energy is not classified as carbon neutral, so biomass facilities will only be a short-term solution and will need to be phased out in 25 years, unless carbon reduction technologies significantly improve within this time period.

These findings can be used by organizations looking to enhance forest health and reduce fire risk, such as Pacific Forest Trust, as well as by policymakers looking to maximize the social benefits of forests. Notably, further research is required on the true availability and feasibility of obtaining the woody biomass and whether prescribed burns or other uses for the woody biomass should be considered in combination with, or as an alternative solution to the problem.

Introduction

The Klamath-Cascade area of northern California encompasses nearly ten million acres and provides essential ecosystem services, including drinking water for almost 25 million Californians and water for $37 billion worth of agriculture.[1] Forest health is directly correlated with watershed prosperity. For example, forests filter sediment, store snow and rainwater, and regulate stream flow.[2] Forest restoration can increase water flows by 5% to 20%.[3] The Region of focus for this report, consisting of the Butte, Lassen, Modoc, Plumas, Shasta, Sierra, Siskiyou, Tehama, and Trinity Counties, surrounds the Klamath-Cascade area and spans over 19.1 million acres.

The proliferation of catastrophic wildfires in the Region, including the Camp and Carr Fires in 2018, threaten local communities' electricity supply as entire sections of the grid must be taken offline during high fire risk days. Proper forest and fire management are key to protecting this vital watershed and reducing wildfire risk but could also be part of a solution to the Region's energy problems. An essential component of healthy forest management is clearing small-diameter woody debris. This report defines "small-diameter woody biomass" to be woody residues of forest management practices that are too small to be sold as timber but large and fresh enough to be chipped. This material is of lower marketable quality and value than larger diameter sawtimber,[4] and is often disposed of through on-site burning (during low fire hazard periods) or off-site landfills.[5]

This report examines whether a solution for the Region's prolific wildfires and unreliable electricity transmission can potentially be found in the sustainable extraction of small-diameter woody biomass from the local forests for electricity generation. Such a solution would support the dire need to reduce wildfires and provide reliable electricity while capitalizing on the growing interest in decentralized, locally generated power. As mentioned, this report does not advocate for the use of biomass for electricity generation but simply examines its feasibility.

The report will review the energy potential of biomass for the Region, as well as the feasibility of transitioning the Region off the existing grid and onto localized renewable energy generation in the form of small-scale grids powered by biomass facilities. It will analyze the possible ramifications of widespread regional biomass use and determine the potential financial, economic, environmental, social, and political benefits or costs of the transition. A comprehensive review of existing policies and regulations, current energy demand, availability of biomass supply, cost indicators (e.g. capital investment, distribution, etc.), and the net environmental and socioeconomic implications will provide key considerations for policymakers and landowners setting the biomass agenda for the Region.

California's wildfires have already created a staggering amount of damage—to forests, watersheds, biodiversity, the atmosphere, property, and life.

There are several core causes of the severity and widespread nature of today's wildfires in California:

1. Decades of intentional fire suppression;
2. Inadequate forest management;
3. Ineffective land use planning in the wildland-urban interface;
4. Climate change induced warming and drought; and
5. Faulty electrical transmission and distribution lines.

The Region of focus is particularly vulnerable to wildfires, is home to approximately 600,000 California residents, and is an area outside of the economic, political, and social centers of central and southern California.[6] Notably, the California Department of Forestry and Protection (Cal Fire) named the Camp Fire, which occurred in November 2018 in Paradise, Butte County, and burned over 153,300 acres while destroying 18,800 structures and causing 85 deaths, the most destructive fire in the history of California.[7]

This paper seeks to address whether using small-diameter woody biomass as an alternative energy source is a viable economic and environmental energy option for the Region, while also addressing a few of the causes of wildfires: the abundance of woody fuel due to fire suppression techniques, the profuse young and dense tree growth produced because of poor forest management, and the faulty power lines. Further, the Region loses electricity when fire risks are high, putting people at greater risk. Ultimately, this report seeks to assess the feasibility of using biomass as an alternative energy source, examining the issue through the lenses of energy generation and distribution, rural economic sustainability, and forest health.

Background

The Region & its Forests

This nine-county Region, including Butte, Lassen, Modoc, Plumas, Shasta, Sierra, Siskiyou, Tehama, and Trinity counties, is heavily forested and largely rural. It borders Oregon and Nevada, as well as a sliver of coastal California to the west. The Region is geographically diverse with complex topography and slopes. Lightning ignited wildfires are not uncommon, although the steep terrain prevents long distance fires like those seen in southern California.[8] Much of the federal land in the northwest region is rural and not easily accessible.[9] Figure 1 below illustrates the area of the Region and the portions of land that are private, federal, or State-owned. A majority of the land area is federally managed forest.

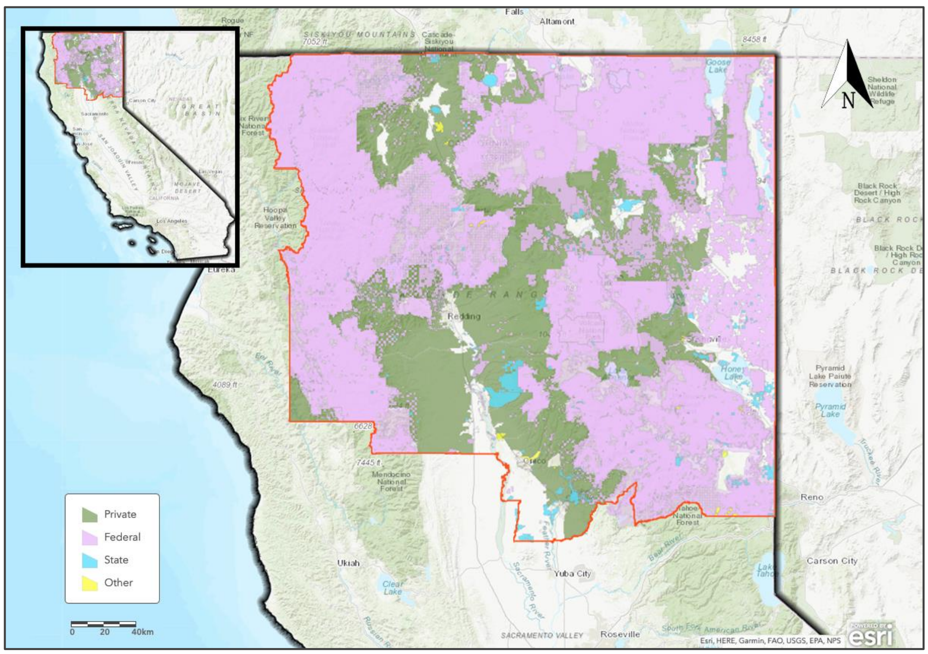

Figure 1. Breakdown of land ownership in the Region's forested regions.

While this report did not conduct a field survey of northern California's forests, there is a known century-long history of fire suppression that has contributed to making wildfires in California more widespread and more frequent.[10] In addition, fundamental forest ecology principles apply. In California's forests, fires are natural at a certain frequency and size. When they are suppressed, shrubs, small trees, and other low-lying vegetation grows, creating what is known as ladder fuel. When a fire ignites at the surface, it easily travels skyward via the ladder fuel up to the canopy, where it can travel further than if it had only been at the surface fuel level. Older trees are much more fire resistant due to their thicker bark, but the ladder fuel is not, and canopies are more combustible than trunks. Furthermore, as California's climate becomes hotter and drier, the vapor-pressure deficit increases, drawing more moisture out of biomass. This leads to more frequent and hotter wildfires, as biomass with a low moisture content ignites more easily and burns at higher temperatures. Cal Fire outlines the Fire Hazard Severity Zones (FHSZs) across the State.

While densely populated urban counties tend to have less land located in FHSZs, a majority of the Region's land is located in "Very High," "High," and "Moderate" FHSZs (Figure 2).

This illustrates the vulnerability of the Region as well as the need to address the wildfire problem. The zones were first established in 2007, so the maps have not been updated to reflect the most recent data on wildfire activity.[11]

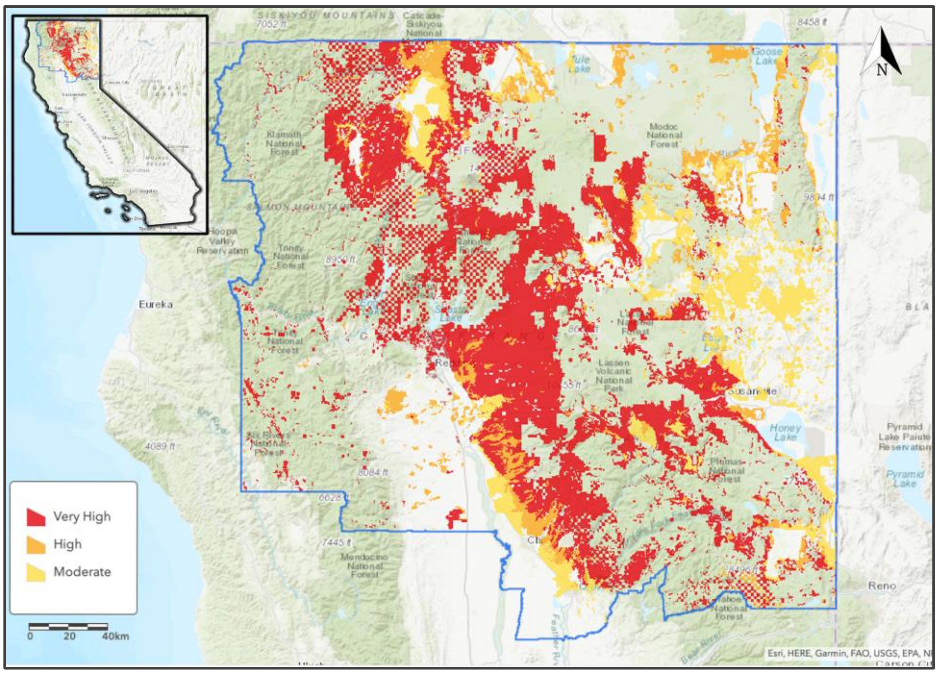

Figure 2. Fire Hazard Severity Zones in the Region.

Legislative Framework

There are a variety of existing policies that must considered when discussing the advantages and disadvantages of using biomass as fuel. California has implemented policies that explicitly promote the use of biomass and others that prioritize inherently cleaner renewables such as solar and wind (see Appendix A).

Most importantly, the Biofuel Renewable Auction Mechanism (BioRAM) incentivizes electricity generation with biomass fuel derived from High Hazard Zones (HHZs), and the Bioenergy Market Adjusting Tariff (BioMAT), provides significant funding to biomass facilities through feed-in tariffs. As of 2017, there were 7 and 8 BioRAM and BioMAT plants, respectively. BioRAM mandates California's large investor-owned utilities to procure 146 MW of electricity from biomass facilities that derive a certain percentage of their fuel from HHZs and sustainable forest management. The market for woody residues from sustainable forest management was further stimulated by Governor Brown's 2017 wildfire risk directives and SB 1112 which created BioMAT. BioMAT sets a fixed-price standard contract for biomass generators up to 5 MW in capacity (selling up to 3 MW to the grid) and directs investor-owned utilities to procure up to 50 MW from such generators. The BioRAM and BioMAT contract prices for HHZ fuel are roughly 11.5¢/kWh and 20¢/kWh, respectively.[12]

California also has a significant amount of active legislation related to the preservation of forest and water resources. For example, AB 2480 emphasizes the importance of maintaining watersheds as a method of preserving California's water infrastructure.[13] SB 859 was enacted in 2016 to subsidize the removal of small-diameter material from forests in order to help develop markets for beneficial uses of the material.[14] This bill charges customer utility bills for the social benefit of removing the hazardous wood from the forests. SB 859 also established the Wood Products Working Group, in which various governmental agencies develop strategies to introduce wood materials to market.[15]

The State provides significant amounts of subsidies for carbon neutral renewables. According to the US Energy Information Administration, "California Solar Initiative uses rebates and grants to encourage Californians to install solar power systems on the rooftops of their homes and businesses. Additionally, the state's 2019 building energy efficiency standards require solar PV systems on all new homes built in 2020 and later."[16] Whereas solar produces no emissions during electricity generation, burning biomass increases the amount of CO_2 in the atmosphere. However, over the lifetime of a tree's regrowth the CO_2 is eventually captured once again through photosynthesis processes.[17] Thus, carbon neutrality depends on the timeline being analyzed.

Since 2002, the California Renewables Portfolio Standard Program (RPS) (created by SB 1078) has required that retailers procure electricity from eligible renewable sources, including biomass. The RPS has driven bioenergy generation in the State. More recently, SB 100 updates the RPS, specifically the proportion of renewable energy sources to 50% and 60% by 2025 and 2030, respectively. However, it sets an ambitious target to achieve 100% carbon neutrality utilizing zero carbon resources by 2045. Biomass can be seen as a pathway to a zero-carbon future or it can be interpreted as an impediment toward achieving the ultimate goal of producing zero-carbon energy.

The Electricity Grid

California's deregulated electricity market is conventionally thought of in three parts: generation, transmission, and distribution. Electricity generators produce power and sell it wholesale to distributors, transmission lines carry the power across the State, and distributors sell the electricity to consumers. Transmission lines carry high voltage power and tend to be owned by an entity (or subsidiary) that does not charge consumers. Distribution lines carry low voltage power and tend to be owned by an entity that does charge consumers, such as a utility company. The three largest investor-owned utilities (IOUs) in California are PG&E, Southern California Edison, and San Diego Gas & Electric. Both types of lines pose significant fire risks when they fall into disrepair in forested areas.

Electricity supply and demand must always be balanced: at any given moment, the amount of electricity produced by all the generators on the grid must equal the amount of electricity being consumed. In California, this complex balancing act is managed by the California Independent System Operator (CAISO). Owners of generation and transmission infrastructure pay a fee for membership with CAISO, allowing them to participate in the market by bidding to supply electricity. CAISO manages the demand coming from businesses and consumers, and issues orders to switch on different generators as needed.

In the Region, PG&E is the primary distributor of electricity and owns and maintains thousands of miles of distribution and transmission power lines. However, PG&E is unable to sufficiently mitigate all of the fire risks associated with its power lines. The aging transmission and distribution lines can snap during high-wind periods, and then ignite improperly managed vegetation or dry fuel near the sparking power lines.[18] To reduce risk, PG&E shuts off power to thousands of residents across northern California with increasing frequency. According to the *Los Angeles Times*, in 2019 PG&E was only able to complete 31% of the tree-trimming work it had planned around power lines crowded by vegetation, or 760 miles out of 2,455 miles. To clear-cut vegetation around all of its power lines would require hiring 650,000 workers and cost between $75 billion and $150 billion.[19]

Nick Ut/AP

At this time, the power sector is still searching for cost-effective approaches to fire risk mitigation. Overhead lines pose a clear and present danger but burying them can be prohibitively expensive. Moving distribution lines underground can cost about $3 million per mile, while building overhead lines can cost less than one third of that at $800,000 per mile.[20] Two thirds of California's 220,000 miles of distribution lines and nearly all of California's 34,000 miles of transmission lines are overhead.[21] Less than 100 miles per year are transitioned underground.[22] The Team therefore assumes that it is cost prohibitive for the counties to consider building and utilizing their own power line infrastructure. Each of the different biomass utilization scenarios outlined later in the report will involve taking advantage of the power line infrastructure already in place.

Electricity Demand vs. Electricity Consumption

Electricity demand refers to the quantity of energy that consumers and businesses require at any given moment. This value fluctuates over the course of the day and potentially from season to season, from "base load" (the minimum quantity typically seen in the early hours of the morning), to "peak demand" (typically seen just after working hours or during the hottest times of day). It is often measured in megawatts (MW) and can be thought of in relation to the nameplate capacities of power plants. If electricity demand at a given moment is 100 MW, then the sum of the capacities of all the power plants feeding into the grid also needs to be 100 MW, assuming your power plants are operating at full nameplate capacities. If demand decreases, some power plants need to shut down, and if demand increases, others need to turn on. Electricity consumption refers to demand over time. If the average demand over the course of 10 hours was 100 MW, then 1,000 megawatt-hours (MWh) were consumed. Table 1 displays the populations and electricity consumption in 2018 for the nine counties in the Region.

County	2018 US Census Population Estimate	2018 Electricity Consumption (MWh)
Butte	231,256	1,479,000
Lassen	30,802	410,000
Modoc	8,777	148,000
Plumas	18,804	206,000
Shasta	180,040	1,573,000
Sierra	2,987	21,000
Siskiyou	43,724	485,000
Tehama	63,916	508,000
Trinity	12,535	131,000
Total	**592,841**	**4,961,000**

Table 1. Population and annual electricity consumption of the Region's nine counties.[23,24]

Distributed Generation

Distributed generation represents a unique approach to wildfire mitigation from multiple perspectives. Distributed generation allows high voltage transmission lines to be de-energized. High voltage lines move electricity over long distances and are often located in remote locations where utilities are more likely to neglect maintenance. Switching these power lines off during high winds and/or dry days reduces the risk that fires will spark. Distributed generation allows the electricity system to shift towards more reliance on local, lower voltage distribution lines. Low voltage power lines require insulation, unlike high voltage lines.[25] This insulation can prevent sparks from igniting branches, thereby reducing fire risk.

Distributed generation happens at many different scales. It can be "behind-the-meter," such as a rooftop solar panel, or it can serve a whole community when PG&E shuts off power, such as the case of Honey Lake Power discussed later in this report. Behind-the-meter solutions usually supplement a connection to the grid, essentially changing the net demand of an individual customer. Therefore, the balancing act of supply and demand on the grid is less impacted. On the other hand, when serving a whole community, supply and demand must be balanced locally. This is referred to as a microgrid, because it is acting just like the grid managed by CAISO but on a much smaller scale.

PG&E plans to invest $1 billion in microgrids in the short-term, aiming to install 20 microgrids and 500 MW of power before the 2020 fire season.[26] PG&E has identified the 20 highest priority substations based on the number of customers that could have retained electricity access had a microgrid been installed during the previous two major shutdown events, the preemptive shutdown on October 9, 2019, and the shutdown associated with the Kincade Fire on October 26, 2019.[27] The microgrids will likely be powered by temporary diesel generators parked at the substations, and which PG&E hopes will reduce wildfire related shutoffs by one third as compared to the Kincade Fire event.[28] It is unknown whether or not PG&E will be able to recover costs from microgrid investments if microgrid developers do not grant the utility asset ownership, but reducing fire risk has become a top priority for the utility.

Environmentalists argue that there should be more investment in other forms of distributed generation, such as solar panels on residential properties, because such technologies can avoid more of the uncertainty involved in some of the distribution lines remaining on at high fire-risk times. Another issue is that some of the substation locations do not have enough room for a solar microgrid with battery storage, leading some to argue that PG&E should choose gas-fired turbines instead. Lastly, lithium ion battery storage co-located with solar microgrids can also pose a fire threat.[29]

Current Energy Mix in the State and Region

In 2018, Governor Jerry Brown mandated that California must power its energy grid with 50% renewable resources by 2025, 60% by 2030, 100% zero-carbon (including nuclear) electricity by 2045.[30] The Region, too, will be required to hit the final target and remove all of the fossil fuel sources from its energy mix, as shown in Table 2. California contains 31% renewable energy, with biomass accounting for 2% of the total energy mix. Notably, Trinity Public Utilities District and Surprise Valley Electrification Corporation receive most of their power from hydro.

Utility Name	Renewable Energy					Non-Renewable Energy				
	Biomass	Geothermal	Solar	Wind	Hydro	Coal	Large Hydro	Nuclear	Natural Gas	Unspecified
Trinity Public Utilities District	-	-	-	-	100%	-	-	-	-	-
Redding Electric Utility	-	-	-	25%	4%	-	27%	-	36%	9%
City of Shasta Lake	-	7%	20%	-	-	-	-	-	-	64%
Pacificorps	2%	4%	10%	10%	3%	4%	15%	34%	9%	9%

Utility Name	Renewable Energy					Non-Renewable Energy				
	Biomass	Geothermal	Solar	Wind	Hydro	Coal	Large Hydro	Nuclear	Natural Gas	Unspecified
Surprise Valley Electrification Corporation	-	-	-	-	85%	-	-	11%	-	3%
Lassen Municipal Utility District	7%	1%	-	13%	5%	-	13%	-	-	61%
Plumas-Sierra Rural Electric Cooperative	-	4%	-	-	1%	1%	40%	-	32%	23%
Pacific Gas & Electric	4%	4%	18%	10%	3%	-	13%	34%	15%	-
All of California	**2%**	**5%**	**11%**	**11%**	**2%**	**3%**	**11%**	**9%**	**35%**	**11%**

Table 2. State of California and regional utility energy sources, and statewide energy sources (2018). [31]

Biomass is one of the most expensive types of power on the grid. Biomass has a much higher levelized cost of energy than coal, nuclear, wind, solar, or hydroelectric power, even when Investment Tax Credits and Production Tax Credits are not internalized in the price (Table 3). PTC can also apply to biomass. Closed-loop biomass (planted and harvested for specific energy purposes) receives $24 per MWh and open-loop biomass receives half the amount of the closed-loop credit. The table below was adapted from the U.S. Energy Information Administration (EIA) and only shows federal levelized tax credits. According to the EIA report, the table "reflects tax credits available only for plants entering service in 2025 and the substantial phaseout of both the PTC and ITC as scheduled under current law." The only remaining relevant credit is a 10% ITC for combined heat and power (CHP) plants that begin construction before the end of 2021.

	Levelized Tax Credit	Total System Levelized Cost of Energy	Levelized Cost of Energy including Tax Credits
Energy Type	**2019 $/MWh**		
Dispatchable Technologies			
Coal	-	76.44	76.44
Nuclear	-6.75	81.65	74.88
Biomass	-	94.83	94.83
Non-dispatchable Technologies			
Wind (onshore)	-	39.95	39.95
Solar Photovoltaic	-2.61	35.74	33.12
Hydroelectric	-	52.79	52.79

Table 3. Levelized Cost of Energy for Various Technologies[32]

Research Design and Methodology

In order to help PFT understand the feasibility and sustainability of transitioning the Region to utilizing small-diameter woody biomass for electricity production, the Team deployed the following research design and methodology techniques:

1. Conducted a literature review of legislation, recently published technical analyses, and scientific reports on biomass, forest management, and grid connectivity in California.
2. Collected and analyzed published quantitative data to assess the feasibility and environmental implications of using biomass for energy.
3. Interviewed 15 experts in the fields of biomass, energy, and sustainable forestry, among others.
4. Elaborated on three scenarios for grid utilization in the Region.
5. Analyzed five case studies of biomass facilities in northern California.
6. Considered policy mechanisms for biomass energy integration and forest health.

More information on the research methodology utilized in this report can be found in Appendix B.

Feasibility of Biomass for Electricity Generation in the Region[33]

At present, woody biomass generation capacity in the Region is approximately 250 MW.[34]

The Team sought to analyze the feasibility and environmental implications of the Region scaling up its biomass generation capacity to supply 100% of its average electricity demand. This essentially assumes that the Region will want to be as reliant upon biomass as possible, so that all other energy sources, even renewables like wind and solar, will only be depended on during moments of above average demand. To serve the total average residential and non-residential demand, biomass generation capacity would need to increase by about 700 MW, based on the following estimation:

- The total annual electricity consumption in the Region, averaged over five years from 2014 to 2018, was approximately **5 million MWh**.[35]
    - This is about 23 kWh per day per person, substantially below the US average of about 33.4 kWh per day per person.[36]
- The average annual capacity factor of a wood-burning utility-scale generator in the United States from 2009 to 2019 was **60.2%**.[37]
- This yields a required nameplate capacity of **948 MW** of biomass generation capacity to serve average annual consumption.

Actual capacity factors vary significantly and depend heavily on fuel availability and maintenance requirements.[38] If the existing 250 MW of capacity operated at the average 60.2%, and new capacity operated at 83%, then only 500 MW of additional capacity will be required instead of 700 MW.[39]

Supply of Biomass

Lawrence Livermore National Laboratory (LLNL) performed an in-depth analysis of the biomass fuel available from residues of forest management practices, such as mechanical thinning, on public and private land in California.[40] The LLNL analysis selects forest stands for management under different uneven-aged thinning scenarios based on potential to reduce fire mortality, generate net revenue, and maximize in-stand carbon. They claim that, “The data from these plots is statistically representative of all economically available biomass from fire- and carbon-beneficial forest management on California timberland.”[41]

Their analysis concludes that **California’s forests contain 15.1 million BDT** of biomass chips, derived from non-merchantable timber, available per year through 2045.

Of this, 5.1 million BDT per year would be available from the forests in the Region.

Based on the Team's estimate that annual electricity consumption in the Region was 5 million MWh, the switch to relying on biomass generation conveniently requires an annual fuel supply of approximately 5 million BDT. Therefore, there is theoretically a sufficient amount of woody biomass in the Region that can be sustainably harvested through 2045 to fuel all of the electricity generation necessary to meet the Region's annual electricity consumption.

Economic and Financial Feasibility

Given that there are new biomass facilities in the local pipeline, this means that some projects are financially feasible (whether that is through subsidization or not).[42] According to a chart published by the North Coast Resource Partnership in 2018, construction costs for biomass facilities decrease exponentially with the capacity of the facility.[43] For example, a 2 MW biomass plant costs $16 million, while a 30 MW plant costs $90 million, as shown in Figure 3 below.

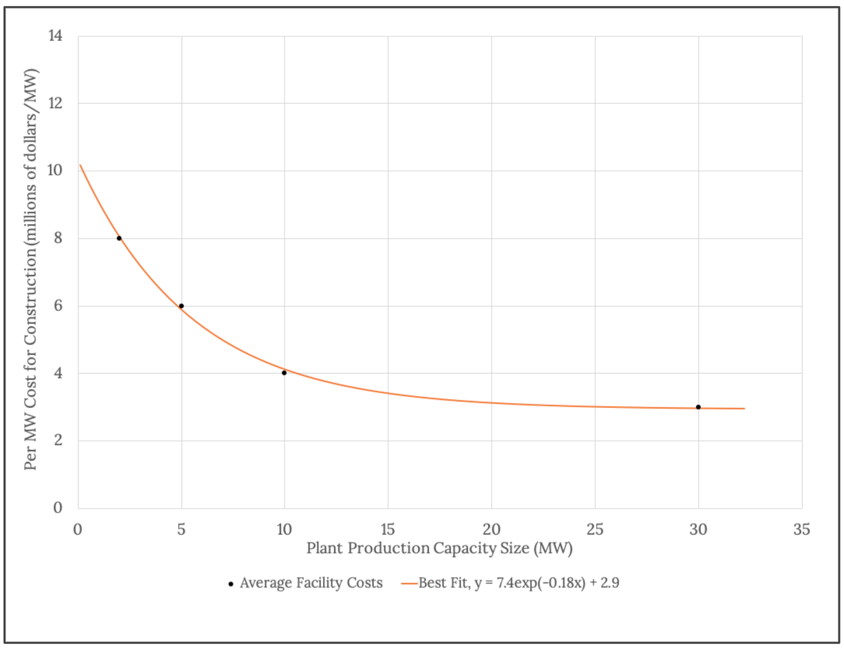

Figure 3. Cost per MW of Biomass Plants of Varying Capacity.

Using the estimates above, in order to serve the entire Region through the increase of biomass power by 700 MW, capital costs alone can range from $2.1 billion (with 30 MW facilities) to $5.6 billion (with 2 MW facilities). This estimate does not include the operational costs of the facilities, and other grid connectivity issues that might arise.

Building biomass facilities close to the fuel source (e.g., the forests) and near to roads will keep costs as low as possible, given that transportation of fuel represents the largest barrier to cost-effective biomass electricity generation; access to grid infrastructure will also play a key role. Cal Fire acknowledges the challenges to using woody biomass for energy, stating that current pricing mechanisms do not fully cover the high costs of collection and transport of biomass, technological challenges, concerns about local community support, and electric grid/gas pipeline interconnectedness.[44] Costs can vary widely based on distance traveled, fuel price, moisture content, and more.[45] In general, costs of transport vary from $10 to $30 per BDT (2009 estimate), or can even be as high as $52 per BDT (2011 estimate) if the wood is retrieved from national forests.[46]

Current woody biomass facilities in the Region rely on extracting revenue streams from excess heat (using it to dry wood products and fuels), legal requirements for procurement of electricity derived from biomass sources (BioRAM), and tariffs (BioMAT) to achieve sufficient profitability. New facilities will face similar challenges. Investor owned utilities (IOUs) require a higher rate of return than publicly owned utilities, so public investment can lower overall costs. Due to the economies of scale associated with engineering, procurement, construction, and labor, large facilities with higher generation capacities (at least 15 MW) are more cost effective than small facilities with lower generation capacities (0 to 5 MW).

Utilizing the Current Grid Structure

Introduction to the Scenarios

To completely separate from the grid, meaning to abandon the use of PG&E's and other utilities' infrastructure, it would cost an exorbitant amount to build local distribution lines. Therefore, this report identifies how the Region can become more energy secure and minimize fire risk through the expansion of biomass power, while utilizing the current grid infrastructure.

> It is important to note that diversifying the energy mix is a crucial part of achieving energy security, and a large-scale electricity grid facilitates this by combining power generated from a wide variety of sources and locales into a single energy stream. Under any truly realistic and ideal scenario, biomass power would be one source among many. In considering heavy reliance on biomass power, these scenarios are intended to illustrate the maximum costs and practicalities of expanding its use.

This report outlines three different scenarios for dramatically transforming the energy mix in the Region towards biomass generation. These three scenarios are not mutually exclusive and might contain similarities and overlaps in how they function within the current energy system. The scenarios each estimate capital costs but do not include estimates of fuel procurement costs because these depend heavily on the details of a biomass power plant site, such as distance to the fuel source and access to roads. Investors in new biomass power plants will try to minimize the distance of the plant to its fuel source, while ensuring reliable connection to transmission infrastructure and reliable fuel delivery. The scenarios also do not include implications of different technology options, such as combined heat and power, or the manufacture of co-products like synthetic fuels. Any additional revenue stream that could be derived alongside that from electricity would dramatically change the economics and are beyond the scope of this report.

Scenario 1 focuses on creating microgrids at PG&E's substations. Substations are the part of grid infrastructure that step power up or down to different voltages for different purposes, such as stepping down high voltage power from long-distance transmission lines to lower voltage power for local distribution. To operate a substation as a microgrid, the onsite generators must be variable, so that electricity supply always equals electricity demand (measured in MW). For this reason, in Scenario 1, the Team estimates capital costs based on electricity demand. On the other hand, in Scenarios 2 and 3, the Team estimates capital costs based on electricity consumption, because new biomass generators would not be required to dynamically serve customers, but rather contribute to a broad energy mix.

Scenario 1: Biomass-Fueled Microgrids at PG&E Substations[47]

As discussed in the section providing background on the electricity grid, on January 21, 2020, PG&E gave testimony to CPUC outlining a fire risk mitigation plan for the 2020 fire season. It involves deploying temporary diesel generators to 20 high-priority substations to allow for on-site generation during power shutoff events, creating microgrids intended to maintain power supply for customers whose distribution lines are connected to those substations. The Tyler substation in Red Bluff, Tehama is the only one out of the twenty substations that is within the Region. However, twelve other substations that lie within the Region just missed PG&E's selection criteria, representing over 20,000 customers that could have retained power with microgrids at these substations during at least one major shutoff in 2019. Here the Team considers the possibility of constructing biomass power plants at these thirteen substations, including Tyler, in anticipation that in the 2021 fire season and beyond, PG&E may move to install temporary diesel generators at these locations.

Biomass-fueled generation is generally considered "base load" because it produces electricity at a consistent rate at any time of day. While biomass generation could be paired with energy storage technologies or other types of generation technologies to meet peak demand, here the Team considers the cost if peak demand was met entirely with biomass generation to illustrate maximum reliance on biomass power. Since peak demand data was only immediately available for the twenty substations that PG&E is targeting for the 2020 fire season, the Team needed to calculate peak demand for the other substations. To do this, the Team performed a linear regression to estimate peak demand as a function of the number of customers that could have retained power with microgrids at their substations during at least one major shutoff in 2019, essentially as a proxy for the number of customers served by the substation.

The estimated peak demand at the thirteen substations averages just over 11.25 MW.

The Team estimates the average cost of each facility to be $43.7 million, for a total of $568 million for all thirteen locations.

Due to the declining costs per MW as the capacity of a facility increases (Figure 3), if instead biomass generation was only intended to meet half of peak demand, the total cost would only decrease to $397 million. However, four of the substations are in the city of Red Bluff and two are in the city of Redding. If the peak demand of those substations is supplied by the same facilities, meaning one facility per city instead of one per substation, then total costs would fall to $517 million to meet peak demand and $330 million to meet half of peak demand. The breakdown by substation and city is shown below in Table 4. This does not include costs to transport the biomass to the facility, though each of the thirteen substations are within 20 miles of dense forest, so transportation costs should not be a confounding variable. This also does not include capital expenditures related to substation upgrades to achieve microgrid readiness. For example, there would be additional capital costs to allow the four substations in Red Bluff to all be supplied by the same power plant.

Substation Name	Postal City	County	Estimated Peak Demand (MW)	Cost to meet Peak Demand ($M)	Cost to meet Half Peak Demand ($M)
Redding (all)			15.76	53	37
Keswick	Redding	Shasta	8.09	37	26
Girvan	Redding	Shasta	7.67	36	25
Red Bluff (all)			59.81	175	89
Tyler	Red Bluff	Tehama	16.09	53	37
Rawson	Red Bluff	Tehama	13.84	49	35
Dairyville	Red Bluff	Tehama	8.69	39	27
Red Bluff	Red Bluff	Tehama	21.18	65	42
Wildwood	Platina	Trinity	7.18	35	24
Los Molinos	Los Molinos	Tehama	12.60	46	33
Gerber	Gerber	Tehama	11.69	44	32
French Gulch	French Gulch	Shasta	7.55	36	25
Vina	Coming	Tehama	7.16	35	24
Jessup	Anderson	Shasta	12.83	47	33
Anderson	Anderson	Shasta	11.99	45	32
Total (one facility per substation)			**146.57**	**568**	**397**
Total (one facility per city)			**146.57**	**517**	**330**

Table 4. Estimated peak demand and cost of facilities to serve that demand at the thirteen substations referenced in Scenario 1 above.

Due to the ongoing negotiations between PG&E and the State of California in light of the bankruptcy proceedings, the State may be able to require PG&E to procure additional biomass power for its microgrid expansions. If the State feels that placing this requirement on PG&E is part of reducing fire risk and therefore the general public good of all Californians, it could consider charging all electricity customers Statewide. This would be unprecedented, as up to the present all consumer charges for State-mandated biomass power procurement have gone through particular utilities, and therefore were passed on only to customers of the utilities. Such an arrangement would allow the State to value the environmental and social benefits of biomass power, and factor that into the public charge. This further begs the question of how funds should be spent, especially if the goal is to reduce fire risk.[48]

Scenario 2: Biomass Procurement through Community Choice Aggregation (CCA)

This scenario considers how a group of rural municipalities, a county, or a group of counties could form a Community Choice Aggregation (CCA) to be the load-serving entity. CCAs gives residents that are serviced by an investor-owned utility, such as PG&E, control of electricity generation while maintaining the ability to choose the provider.[49] Residents can choose to continue buying power from the IOU or buy power from the CCA. CCA delivers electricity through the utility's infrastructure but sells electricity at a different price based on its choice of procurement. The utility continues to handle billing customers, managing transmission and distribution infrastructure, and generally retains all the same obligations to deliver power to the CCA's members.

A CCA takes over the role of procuring electricity through mechanisms such as long-term power purchasing agreements (PPAs) with biomass power plants or other generators, and then sells electricity at rates corresponding to the different energy mixes. By providing various combinations of energy sources and prices, a CCA gives residents direct control over the energy mix. Oftentimes, this leads to reduced renewable energy costs for consumers, since a CCA can manage the price of plans providing the State-mandated minimum quantity of renewable energy alongside plans offering up to 100% renewable energy.[50] Many existing CCAs have experienced a trend of residents opting-in to source more energy from renewables than required by the State because California's Renewable Energy Credits are presently inexpensive relative to previous years, and the future price is expected to increase.[51]

Specific energy cost savings directly depend on the current price for energy. Table 5 shows the current residential energy prices for the Region's utilities. Residents with the lowest rates have the lowest economic incentive to form a CCA.

City of Shasta Lake	Lassen Municipal Utility District	Pacificorps	Plumas-Sierra Rural Electric Co-Op	PG&E	Redding Electric Utility	Surprise Valley Electrification Corporation	Trinity Public Utilities District
$0.162	$0.135	$0.153	$0.148	$0.117	$0.143	$0.074	$0.078

Table 5. Current Energy Prices by Utility ($/kWh).

Butte County stands out as a potential candidate for where CCA could feasibly procure biomass power because the county contains large swaths of forested area and lies entirely under PG&E's jurisdiction. Total energy consumption in the county in 2018 was 1,497,000 MWh.[52] The county is already in the exploratory phases of forming a CCA and has conducted feasibility studies and technical assessments in order to determine if CCA could be cost effective. Current studies suggest that a CCA would save the county's residents $5 million annually, equivalent to around $0.02 per kWh in residential energy costs.[53] However, this report's calculations indicate that a CCA eventually procuring 100% biomass power is highly improbable due to cost.

Widely distributing a large number of small capacity plants would be more expensive than a small number of high capacity plants.

The Team approximates that 206 MW of new biomass power could supply the county's annual electricity consumption, based on the assumption that new facilities would operate with an 83% capacity factor.[54]

As shown in Figure 3 above, the Team estimates that a series of eight 25 MW plants across the county, delivering 200 MW of energy, will cost about $75 million per plant, for a total of $600 million in capital costs. A smaller network of plants larger than 25 MW will be less expensive, but not significantly less: five 40 MW plants will cost $587 million in total. To further illustrate the point, increasing the network of smaller plants even more will be significantly more expensive, given the exponential shape of the cost curve: forty 5 MW plants will cost nearly $1.2 billion in total. Regardless of the dispersal and number of biomass plants overall, this is a high capital cost that the county's residents will likely not be able to afford if they were to form a CCA. An alternative approach to bring facilities into rural areas could be a regulation targeting PG&E that forces the construction of a small number of facilities with relatively high capacities, say greater than 25 MW, in the area of the Region surrounding the Northern Sierra Nevada mountains, to be run at cost.[55]

Scenario 3: Urban-Based Biomass Facilities

This scenario considers how the Region's most densely populated cities could provide locally generated biomass power to the residents. This scenario differs from Scenario 1 in addressing municipal needs rather than demand on substations and differs from Scenario 2 in that it measures municipal consumption rather than county-wide consumption. The cost estimates in this scenario do not include the potential required upgrades to distribution infrastructure, since these depend on implementation details such as the exact location of the biomass power plants and the dynamics of the local network of power lines and transformers.

The approach to implementation could target reliability on the level of a microgrid, such as in Scenario 1, or, more conservatively, provide back-up power that would only be relied upon to serve a limited load under emergency circumstances.

While the on-site generation and distributed consumption of this energy would be urban based, it would still rely on the woody biomass extracted from forests. Similarly to the other two scenarios, Scenario 3 would still facilitate healthy forest management and reduce fire risk by converting the overgrown ladder fuel to electricity. This approach would provide efficient electricity by siting biomass facilities close to the sources of greatest demand, thereby reducing energy input requirements. However, it would also bring added transportation costs to move the extracted woody biomass from the forest to urban areas, in comparison to some more rural substations in Scenario 1 and potential plant locations in Scenario 2. While the power generated could be delivered to rural residents along existing distribution lines, the required capacities are calculated here to serve the municipalities' demand, under the assumption that the municipalities may not have the jurisdiction to charge rural residents.

The three cities in the Region with a population of over 25,000 are Chico and Paradise in Butte County and Redding in Shasta County. While this report is not arguing that a municipality with a population of less than 25,000 is not urban (the US Census, for example, defines "urban" as an area with at least 2,500 residents[56]), it is assumed that 25,000 is a reasonable cut-off for the purpose of siting biomass facilities in the more densely populated areas of the Region.

For the following calculations, the Team once again assumes an 83% capacity factor for biomass power plants.[57] The analysis also assumes that the ratio of each city's population to its county's population is equal to the ratio of the city's electricity consumption to the county's consumption. To provide all of each city's electricity, the three biomass facilities would have to have the nameplate capacities indicated below in Table 6.

	Chico	Paradise	Redding
US Census Population 2018 Population Estimate	94,776	26,800	91,772
Percent of County Population	40.98%	11.59%	50.97%
Approximate Annual Electricity Consumption (MWh)	606,000	171,000	802,000
Required Nameplate Capacity (MW)	83	24	110
Estimated Construction Cost (millions)	$243	$73	$323

Table 6. Populations of municipalities in the Region with at least 25,000 residents and their annual electricity consumption,[58,59] alongside nameplate capacities and capital costs for biomass facilities under Scenario 3. Capital cost estimates assume the required nameplate capacity is met by a single facility in each city.

Like in Scenario 2, a CCA would be the best way to make this scenario actionable. Chico and Butte County have already filed a plan to establish CCAs, though not necessarily intended to procure biomass power. Paradise and Redding could do the same to purchase biomass-generated electricity for its residents. Realistically, biomass would not serve as the single source of electricity, and if the potential CCAs chose to increase reliance on other renewables, then the required nameplate capacity, and therefore the cost, of these facilities would be lower.

Environmental Assessment

Wildfires

California has faced a staggering increase in destructive wildfires since the 1970s. The increase in fire burn acreage can be attributed to the effects of climate change as early as 1972.[60] Figure 4 shows that from 1984 to 2015 the area burned by wildfires in the western US was more than twice what it would have been without the effects of climate change.[61]

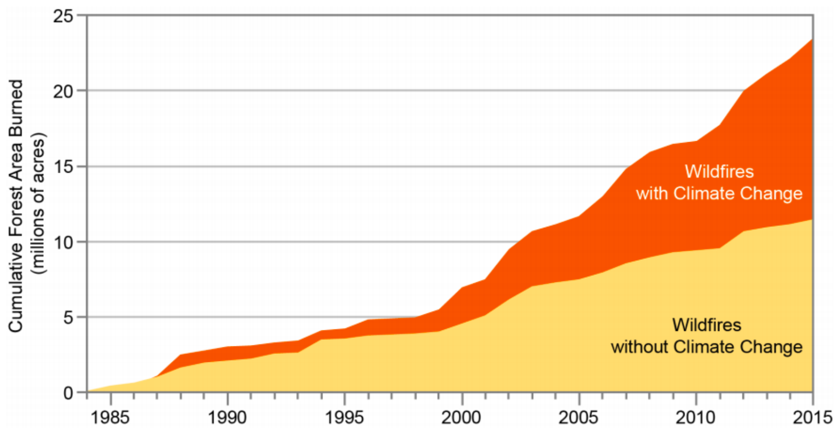

Figure 4. Cumulative forest area burned in the western United States from 1984 to 2015.[62]

On average, the amount of CO_2 emitted between 2017 to 2018 was much higher than historical averages in California. However, it is important to note that it is difficult to compare the net emissions given the lack of data availability and difficulty in comparing the current data to a specific historic baseline.

As of 2017, the State of California's total CO_2 emissions were 424 million metric tons.[63] Of this, the electricity sector produced 15% of emissions,[64] with biomass energy generation currently responsible for 1.8% of California's total electricity-related CO_2 emissions.[65] In 2018, wildfires in California burned 1.59 million acres and released an estimated 45 to 61 million metric tons of CO_2.[66,67] These carbon emissions from the wildfires contribute to global emissions, worsening climate change and its impacts.

The 2018 wildfires alone produced nearly as much CO_2 emissions as the entire electricity sector produces in a given year.[68]

In continuing to look at the State as a whole, California wildfires also released local air pollutants, including 542 thousand metric tons of coarse particulate matter (PM_{10}) and 460 thousand metric tons of fine particulate matter ($PM_{2.5}$) in 2018.[69] These wildfires are becoming worse each year, with end-of-century estimates projecting that average burn area will increase by 77 percent within the State.[70]

Within the Region, a majority of the land is at high or very high risk of wildfires, according to The Fire Hazard Severity Zones in State Responsibility Areas map, adopted by Cal Fire (Figure 2).[71] In 2018, the Region had 71 wildfires that totaled 614,290 acres burned,[72] and the wildfires produced about 84,522 metric tons of particulate emissions (see Table 7). The particulate, CH_4, CO, and NO_x emissions were calculated using the emissions factors and wildfire fuel consumption factors from the Environmental Protection Agency's AP-42: *Compilation of Air Emissions Factors* (see Appendix D.1 for complete list of emissions factors). Note that the CO_2 emissions were approximated by assuming every burn acre of land in California produced, on average, the same amount of emissions.

County	Number of Fires	Acres Burned	Estimated Emissions (metric tons)					
			Particulate	Min CO_2	Max CO_2	CH_4	CO	NO_x
Butte	13	155,553	21,403	4,402,443	5,967,757	30,531	178,149	5,099
Lassen	10	20,289	2,792	574,217	778,383	3,982	23,236	665
Modoc	4	41,554	5,718	1,176,057	1,594,210	8,156	47,590	1,362
Plumas	2	137	19	3,877	5,256	27	157	4
Sierra	-	-	-	-	-	-	-	-
Shasta	16	343,503	47,264	9,721,783	13,178,417	67,420	393,400	11,260
Siskiyou	10	38,738	5,330	1,096,358	1,486,175	7,603	44,365	1,270
Tehama	14	12,465	1,715	352,783	478,217	2,447	14,276	409
Trinity	2	2,051	282	58,047	78,686	403	2,349	67
Total	**71**	**614,290**	**84,522**	**17,385,566**	**23,567,101**	**120,568**	**703,522**	**20,136**

Table 7. Acres burned and emissions from forest fires in the Region in 2018.

These emissions serve as rough estimates, given that the calculations used an average fuel consumption value for the entire State. Since the Region only encompasses nine counties, similar calculations should utilize a fuel consumption value representative of the type and amount of fuel found within the Region. Thus, further research would benefit from a more detailed calculation.

Though beyond the scope of this report, it is important to note that in addition to contributing to local air pollution and the State's greenhouse gas emissions, wildfires threaten the vital ecosystem services provided by forests.

Woody Biomass, Forest Management, and Emissions

According to Cal Fire, using woody biomass for energy would have a wide range of benefits for forest health. Good forest management practices such as forest restoration, thinning, and fuel hazard reduction work to increase the health and resilience of forests, while simultaneously generating excess woody biomass that can be used for energy generation.

In comparison to open burning or disposing of this woody biomass in landfills, biomass energy reduces GHG. California requires the “best available technology” to be used for emission controls. Newer biomass facilities are likely to operate more efficiently and thus pollute less, so future emission comparisons should also take this into account.

The emissions estimates from using biomass for energy are compared to wildfire emissions, and the results are discussed in more detail below.

- Total emissions of CO_2 from use of 5 million BDT of woody biomass for energy production would result in **8.16 million metric tons**, compared to **20 million metric tons** from wildfires in the Region.
- Total PM10 from use of 5 million BDT of woody biomass for energy production would be 1187.7 metric tons, compared to 84,522 metric tons from wildfires in the Region.

Adequate forest management also reduces the frequency and severity of wildfires, emissions from wildfire smoke, and the cost of fire suppression.[73] The reduction of wildfires produces additional environmental co-benefits for the entire State, and biomass energy can play an important role by incentivizing the removal of hazardous, small-diameter wood.

Similarly, a review of 56 studies on the efficacy of various fuel treatments (removal of wood) across eight states on the West coast found that fuel treatments had positive effects on fire reduction and tree mortality, when compared to untreated sites. Although the study concluded that the fuel treatments do not help the forest store more carbon, it resulted in less emissions post-wildfires. Further research is needed to understand the impact of wildfires on issues other than carbon emissions and burn area, such as the effects of fuel treatments on plants, soil, insects, and water.[74]

A study conducted by the United States Department of Agricultural (USDA) for the California Energy Commission, titled *Biomass to Energy: Forest Management for Wildfire Reduction, Energy Production, and Other Benefits*, models the potential costs and benefits of using woody biomass as an energy alternative in California over a 40-year period. The results of the scenario built to test the model offer promising results for woody biomass energy generation. The outcomes projected by this model include: $1.58 billion in power revenue, a 65% net reduction in GHG emissions, a 22% reduction in the number of acres burned, and minimal cumulative effects on watershed health over the 40 years. However, impacts on forest habitat suitability cannot be fully determined.[75] Nonetheless, this model offers key insights on the future of woody biomass energy generation in California.

In *Assessment of the Emissions and Energy Impacts of Biomass and Biogas Use in California*, the California Air Resources Board (CARB), in collaboration with the California Biomass Collaborative, analyzes several biomass scenarios to understand possible air quality consequences. This report includes estimated emissions factors of direct and indirect emissions for a wide variety of pollutants caused by harvesting, transporting, and combusting several types of biomass.[76] Forest biomass is one of the biomass types included and the others are: green and food waste, landfill, and manure. The estimated emission factors for each biomass type can be seen in Table 8 below.

	Woody Biomass	Green and Food Waste	Landfill Gas	Manure Gas
Units	metric tons/MWh			
VOC	1.16E-04	1.58E-05	3.45E-04	3.58E-04
CO	1.50E-03	5.29E-05	1.08E-03	1.12E-03
NO_x	2.14E-03	9.14E-05	2.62E-04	2.80E-04
PM_{10}	2.38E-04	6.68E-05	2.40E-05	3.58E-05
$PM_{2.5}$	1.21E-04	2.05E-05	2.20E-05	3.08E-05
SO_x	8.13E-05	6.44E-06	1.11E-05	1.86E-05
CH_4	1.17E-04	7.17E-05	1.73E-03	1.74E-03
N_2O	1.98E-04	6.80E-07	3.40E-06	3.56E-06
CO_2	1.63	0.034	0.226	0.232

Table 8. Emission factors from different types of biomass for electricity in metric tons/MWh.

The conclusions from the CARB report suggest that current biomass combustion technologies will increase air pollutants; however, next generation biomass facilities may decrease emissions from energy generation.[77]

Using the estimated 5,000,000 BDT necessary for the Region and the emissions factors from the CARB report, the Team calculated emissions estimates for the Region for harvesting, transportation, and conversion of biomass (Table 9). It is estimated that approximately 6 million BDT of fuel were lost to wildfires in the Region in 2018 using the Region's total burn acreage, AP-42 emissions factors, and assuming the fuel had a 40% moisture content on average (a typical value for 1000-hour fuels[78]). Using this value and average CO_2 emissions for the Region allowed us to calculate the approximate CO_2 emissions from 5 million BDT of burnt fuel in the Region. In addition, AP-42 pollutant yields and emissions factors allowed us to calculate approximate particulate, CO, CH_4, and NO_x emissions from 5 million BDT of burnt fuel in the Region (Table 10).

Burning woody biomass for energy rather than allowing it to burn in a wildfire could potentially decrease the nine pollutants below significantly, according to these preliminary calculations (Table 10).

However, these emissions are still high in comparison to other clean energy alternatives, and the extremely high CO_2 emissions would exacerbate climate change. These numbers are all approximations; further research and more in-depth, Region-specific calculations are necessary.

	Total Direct Emissions	Total Indirect Emissions	GRAND TOTAL EMISSIONS
Units	metric tons	metric tons	metric tons
VOC	558.8	22.5	581.3
CO	7,456	61.7	7,518
NO_x	10,519	176.4	10,696
PM_{10}	1,166	21.5	1,188
$PM_{2.5}$	594.2	10.0	604.2
SO_x	370.4	36.1	406.4
CH_4	351.5	231.1	582.6
N_2O	989.5	0.5	990.0
CO_2	8,116,204	42,999	8,159,203

Table 9. Emissions from use of 5 million BDT of woody biomass for energy production.[79]

	Total Wildfires in the Region	Wildfires (5 million BDT)	Biomass Facility (5 million BDT)	Ratio (1 BDT wildfires/1 BDT facility)
Units	**metric tons**	**metric tons**	**metric tons**	**metric tons/metric tons**
VOC	-	-	581	-
CO	703,522	589,583	7,518	78
NO_x	20,136	16,875	10,696	1.6
Particulate	84,522	71,458	1,188	60
SO_x	-	-	406	-
CH_4	120,568 (4,099,321 CO_2eq)	101,042 (3,435,417 CO_2eq)	583 (19,810 CO_2eq)	173
N_2O	-	-	990 (295,010 CO_2eq)	-
CO_2	20,476,333	17,160,096	8,159,203	2.1

Table 10. Comparison of net emissions from all wildfires in the Region, 5 million BDT of fuel burned in wildfires, and 5 million BDT of woody biomass burned at a plant.

In terms of forest management and fire reduction, utilizing woody biomass could be beneficial. The Sierra Business Council, a strong advocate of biomass energy in western states, supports the use of biomass energy in the short-term (10 to 20 years) because the organization recognizes the urgency of preventing the wildfires and related emissions.[80] However, overall, it is difficult to determine precisely whether biomass energy generation would increase or decrease emissions in the Region.

Likely, biomass energy generation would not fully prevent wildfires either, so local air pollutants from facilities would be in conjunction with additional wildfire emissions. With strict air quality policy and emerging biomass emission conversion technologies, emissions could be better mitigated.

Other Environmental Trade-Offs

The majority of experts consulted for this project agreed that removing small-diameter woody biomass from forests is essential to the fire resiliency of the Region.

Many experts asserted that finding functional uses for this material, such as biomass energy, is preferable to letting the wood burn in a pile or wildfire.

JCook Fisher

However, experts differ in their perspectives on how the forests should be cleared and by whom, how much biomass should be utilized as energy, and what the broader biomass energy plan for the Region should look like. Opinions on biomass energy vary widely due to its complicated environmental tradeoffs and externalities, and the respective priorities of stakeholders.

For the purposes of this report, the Team focused on the tradeoffs surrounding wildfires, biomass combustion, and net emissions reductions, but a comprehensive analysis that incorporates all potential positive and negative impacts is needed.

In addition to potentially reducing net greenhouse gas and local air pollutant emissions, biomass energy has the capacity to:

- Incentivize forest thinning through removal of fuel from HHZs
- Reduce fire risk
- Reduce pile burning
- Improve forest health
- Enhance water capture

Additionally, possible negative impacts should be noted, including the potential for biomass energy to:

- Increase short-term local or Regional air pollution as a result of biomass combustion
- Incentivize the over thinning of forests and lead to a decrease in biodiversity
- Displace clean energy sources that would generate significantly more net emissions reductions
- Divert Regional resources for the construction of biomass facilities that will need to be phased out by 2045 per the California Climate Plan

Case Studies

Several biomass facilities in or near the Region (see Figure 5 below for facility locations) provide useful insights on some of the economic costs and benefits, the amount of power that can be generated, and potential challenges to operating biomass facilities.

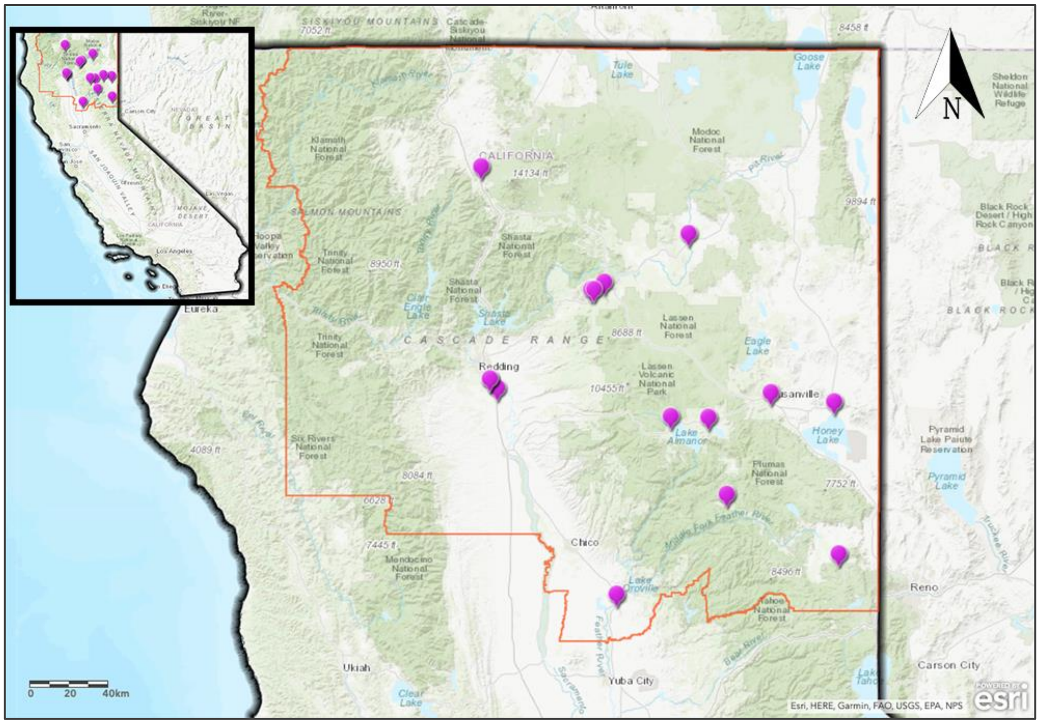

Figure 5. Active biomass facilities in the Region

Burney Forest Biomass Plant

Burney Forest in Shasta County, California is a cogeneration woody biomass plant adjacent to a sawmill. The biomass plant primarily uses sawmill residues for fuel, supplemented with natural gas and offsite woody residues, and also recycles residual heat from steam generation to dry wood residues. Burney Forest employs about 25 people directly and an additional 100 people indirectly. The facility has a generation capacity of 31 MW, and it sells its power to PG&E. In 2016, Burney Forest had planned to shut down operations due to PG&E not seeking to renew their expiring contract, stating that woody biomass is not as competitive as renewables like solar and wind. Shutting down Burney Forest would have led to its 25 employees being laid off as well as the likely shutdown of the adjacent sawmill, which could not afford the infrastructure to power its own operation. Later in 2016, former Governor Jerry Brown of California signed SB 859, which aimed to increase the competitiveness of biomass through the mandate that utilities enter into five-year contracts with biomass facilities that use woody biomass harvested from high fire risk areas. In 2016 Burney Forest signed a new five-year contract with PG&E and continues to supply biomass power to the grid.

North Fork Community Power

The North Fork Biomass Project is set to begin construction in April 2020 at a 5,000 square foot retired sawmill site with a 2 MW generation capacity. The total construction cost is estimated at about $15 million, with the state issuing $9.3 million in tax-exempt bonds and $5.5 million in non-tax-exempt bonds. The project is a partnership between the North Fork Community Development Council and private power companies Phoenix Energy and EQTEC. EQTEC will provide plant infrastructure equipment at a discounted rate. North Fork Community Power plans to take advantage of BioMAT to sell its energy to PG&E for $0.199 per kilowatt-hour. The power plant will directly employ about a dozen people when it is operational.

Camptonville Forest Biomass Business Center

The Camptonville Community Partnership, Inc., (CCP) is a non-profit organization that is in collaboration with the Yuba Watershed Protection and Fire Safe Council, a private landowner, and the local community, together developing the Forest Biomass Business Center (FBBC) at the site of a former sawmill near Camptonville, California. FBBC is creating markets for biomass and small diameter wood, which are currently underutilized, the FBBC will facilitate much-needed forest fuels reduction projects in the Region.

The small-scale power generation facility that FBBC will feature will generate up to five MW of energy from wood, consuming over 54,000 bone-dry tons (BDT) of biomass. This plant will utilize a direct combustion boiler and steam turbine. A majority of the energy will be purchased by PG&E under California's BioMAT program. This plant aims to create local jobs, reduce the risk of catastrophic wildfire, attempt to build viable business models for using forest biomass, and produce renewable energy.

Wheelabrator Shasta

Wheelabrator Shasta is located in Anderson in Shasta County, California, and is one of the largest biomass power plants in California, with an electric capacity of 55 MW. The power plant employs 50 people directly and supports about 75 indirect jobs, largely suppliers who gather, process, and transport woody biomass. The power plant's annual revenue is $25.5 million. Wheelabrator Shasta uses forest residues and logging debris as fuel and processes up to 1,250 tons of woody biomass per day. Additionally, Wheelabrator Shasta operates a recycling program in which the community can contribute various types of woody biomass, such as plywood and lumber debris, to the power plant. Wheelabrator Shasta has a power purchase agreement (PPA) with PG&E in which the biomass facility sells energy back to the utility to help PG&E meet renewable portfolio standards.

Honey Lake Power

Honey Lake Power (HLP) is a 30 MW woody biomass power plant located in Lassen County, which operates year-round, providing baseload electricity. For many years, HLP had a long-term contract to sell power to PG&E. HLP is located within the service area of the Lassen Municipal Utility District (LMUD). PG&E is the entity responsible for transmitting the power to LMUD, and LMUD purchases its electricity wholesale from PG&E. Despite these facts, HLP was not able to supply LMUD with power. When PG&E shut down the transmission lines into Lassen due to fire risk or other reasons, LMUD would often lose power for extended periods of time and HLP would sit idle.

Recently, however, HLP entered into a new long-term contract to sell its electricity to San Diego Gas and Electric (SDG&E), while also benefiting from the Biofuel Renewable Auction Mechanism (BioRAM) Phase 1. In light of the increasing unreliability of PG&E's transmission to LMUD, SDG&E allowed HLP to work with LMUD to ensure that when PG&E cuts power, LMUD's customers can receive electricity from HLP. HLP only supplies LMUD during outages because of an agreement the utility made with SDG&E when negotiating its PPA price. The price of electricity supplied through PG&E's transmission line is significantly lower than what HLP requires to be profitable. SDG&E passes on above-market costs incurred by purchasing HLP's relatively expensive power to its customers through an aggregated Public Purpose Programs charged on customers' bills. LMUD is not under any mandate to purchase biomass-fueled electricity. In 2018 LMUD charged $0.135 per kWh to residents and purchased 26% of its power from renewable sources. While biomass facilities can be slow to ramp up and down, with the reorganization from the new agreement, the facility can easily switch over to transmit power to Lassen County during times that PG&E cuts off power.

Lessons Learned

All of these biomass plants sell, or previously sold, energy to PG&E to help PG&E meet renewable portfolio standards. For the most part, these biomass plants do not help the Region reach energy independence because when PG&E shut down transmission lines due to fire risk or other reasons, the Region often loses power for extended periods of time. However, HLP helps to correct this issue by flexibly providing energy locally when PG&E turns the power off.

The largest biomass facility among the five case study plants, Wheelabrator Shasta, has a capacity of 55 MW and creates 50 direct jobs and 75 indirect jobs. The smallest biomass facility, North Fork Community Power, generates 2 MW and creates 12 direct jobs. This hints at the potential range in size and job generation potential of future biomass facilities for the Region. These biomass plants are benefiting from policies that aim to increase the competitiveness of biomass. Without these policies, such as SB 859, BioMAT, and BioRAM, these biomass facilities are likely to be shut down due to excessive costs, as shown in the case of Burney Forest Biomass Plant.

Policy Considerations

Policy Analysis: Incentives and Disincentives

BioRAM and BioMAT, as discussed earlier, subsidize the biopower at a higher rate than the market rate, a price that utilities ultimately pass on to ratepayers.[81] Only a small number of biomass facilities meet the HHZ qualifying fuel requirements. The HHZ requirements have been increasing from initially 40% to 80% for BioRAM resulting in increased competition for fuel sources between BioRAM plants.[82] Some interviewees suggested that further expanding the HHZs could help biomass facilities lower costs. SB 859 established a working group on expanding wood product markets that can utilize woody biomass from HHZs. It also provides grants and cooperative agreements to implement programs that improve forest health and minimize greenhouse gas emissions, including mandating electricity retailers to enter into 5-year contracts to procure 125 MW of power from bioenergy facilities. SB 901 calls for electrical corporations, investor owned utilities, or CCAs to extend or enter into new contracts to procure electricity generated from these woody residues. In summary, legislation must be adapted based upon market constraints, and long-term contracts with fixed prices are necessary to guarantee revenue streams to those making a capital investment in biomass facilities.

Other renewables have received different types of incentives (not procurement-oriented) at the federal level. Since 2010, solar and wind prices have decreased by 50% and 85%, respectively;[83] as other types of renewable energy become cost competitive with conventional fossil fuels, less funding will be required for those sources. Federal funding for solar and wind, such as the Investment Tax Credit and Production Tax Credit funds, will be coming to an end soon. These factors indicate that there might be more room for funding biomass energy if policymakers choose to take that path.

Some State legislation is focused on rural development, such as AB 417 (Agriculture and Rural Prosperity Act), and watershed and forest management, like AB 2551 (Wood, Forestry, and Fire Prevention: Joint Prescribed Burning Operations: Watersheds) and AB 2480 (Source Watersheds: Financing). These laws are driving not only forest restoration and fire prevention activities in the Region, but also biomass utilization through grants administered by California's Environment Protection, Natural Resources, and Forest and Fire departments. Such complementary legislation incentivizes biomass usage through subsidies and encourages the development of markets for the small-diameter woody material. For example, AB 1947 provides over $340 million in fiscal 2020-21 from the Greenhouse Gas Fund, administered by Cal Fire through grants for healthy forest, fire prevention and fuel reduction activities. Legislation such as these significantly increase funding for and continue to improve forest health.

Stakeholder Analysis

When designing policy options, biomass advocates should address the following stakeholders: 1) local communities, 2) private landowners, 3) IOUs operating within the Region, and 4) State legislators.

Local Communities

The nine-county Region covers a large part of northern California but is an extremely rural part of an otherwise densely populated state: only 592,841 residents live in the Region. The average per capita income within the Region is $26,950, which is below both the California ($35,021) and national ($32,621) averages.[84] Most residents depend on forest resources for their livelihood in some way: the primary industries are outdoor recreation, tourism and related services, and forestry. As the Region develops, more and more homes are being constructed in the wildland-urban interface, exacerbating the fire risk to these communities. A small portion of the Region's residents have moved from major cities in the southern part of the state, slowly changing the traditional culture of a historically agricultural-intensive place.[85]

Considering the rural nature of the Region and the lack of diverse economic opportunity, many experts consulted for this project cited the need for economic development programs. Ideally, communities within the Region could sustainably utilize the resource rich forests to create jobs and generate new revenue streams. Biomass energy could be an effective strategy, but it would require comprehensive policies that protect the forests while serving communities. For some forest communities, the promise of enhanced energy security and climate resiliency will outweigh the potential economic benefits of a new biomass plant. These types of communities are motivated less by revenue and more by collective sustainable principles. Researchers and policymakers must engage with each community to understand local goals and needs.

Ultimately, forest communities are highly vulnerable to a multitude of factors. Wildfires threaten public health and private property and improving fire resilience is essential to ensuring the viability of these communities in the long term. Biomass energy, however, has great potential to negatively impact local air quality. Integrating biomass into the grid through a mechanism such as Community Choice Aggregation indicates that the community has considered the pros and cons of biomass and ensures that most of the community is on board with the project.

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Private Landowners & the Timber Industry

Private landowners are a key stakeholder within the Region. Timber and forest product companies not only profit from forest resources, but also play an important role in forest management. Sierra Pacific Industries (SPI), consulted for this project, is the largest private landowner within California, the 2nd largest landowner in the country, and the 2nd largest lumber producer within the United States. Land holdings of this scale within high hazard zones present a huge liability for SPI, and the removal of woody biomass is an integral part of their long-term forest management. The company lost roughly 74,000 acres of forest to wildfires in 2018 and is more vested than ever in improving fire resiliency.[86] Timber companies like SPI are required by the state to properly dispose of waste products, but not all companies have access to biomass facilities. Subsequently, woody debris and other small-diameter waste from timber operations is often collected in a pile and burned or brought to a landfill.

Large landowners have clear incentives to properly maintain forests and guarantee their long-term health and profitability. What they lack are incentives to do anything with the woody waste other than burning it in a pile. Transportation is the single highest cost when dealing with biomass energy on an operational level, and not all timber operations are in proximity to one of the few active biomass facilities within the Region. Larger companies such as SPI have been able to overcome this problem by building their own biomass energy facilities collocated with sawmills, but this option will not be viable for all landowners in the Region. According to SPI, the company welcomes the opportunity to expand biomass facilities through the help of subsidies to make it more economically feasible.[87]

Investor Owned Utilities (IOUs)

Utilities in the Region (i.e. PG&E) have a "last mile obligation" to their customers that involves delivering power to hundreds of thousands of homes and businesses. State biomass policies have recently targeted IOUs through the mandated procurement of energy from power plants that utilize woody biomass from high hazard zones (i.e. plants with BioRAM contracts). These policies may generate some positive impacts but are not suitable long-term solutions on their own; IOUs are investor driven companies, not social impact organizations, and their business models are not made to deliver vital social benefits at the expense of profits. Thus, mandating the increase of biomass capital and associated costs will increase utility bills rather than reduce company profits. More State intervention and an expansion of the BioRAM program would force more action at the IOU level, but additional interventions are also needed. In speaking with the Director of Procurement at PG&E,[88] the employee indicated that PG&E had no plans to integrate biomass facilities with its new substations, as outlined in Scenario 1 of this report. Several experts consulted for this project suggested that utilities should carry more financial liability for their faulty infrastructure, and that some of these liabilities could directed towards renewable energy and distributed generation.

California State Government

California State leaders are responsible for ensuring the health and safety of residents as well as their access to essential basic services such as heat and power. Removing the excess small-diameter wood from the forest can be considered a societal benefit, so it is in the government's interest to incentivize the removal through subsidization (whether this is for biomass energy generation or not). Depending on the policy implementation, this could increase taxpayer and/or utility bills. If the social benefit of healthier forests outweighs the cost of the subsidy, the policy should be carried out.

Ambitious state policies aiming for carbon neutrality illustrate California policymakers' understanding of the dire need to combat climate change. Jessica Morse, Deputy Secretary for Forest Resource Management for the California Natural Resources Agency, also emphasizes that biomass to energy is more impactful and less carbon intensive than the current solution of pile-burning of wood wastes, but it must be considered in harmony with innovative long-term technologies.[89] While biomass might not be a preferable solution in some aspects, policymakers must consider the net benefits of utilizing biomass in this specific Region.

Forest management treatments, including thinning, are costly and might prove inhibitive for state and federal land agencies, as well as private landowners to sustain. Landowners will need to scale up further to meet California's 2018 Forest Carbon Plan Goals to aggressively increase forest restoration and improvements by one million acres annually, which will cost up to $4 billion per year through 2030. Much of Cal Fire and the Forest Service budget goes towards fire suppression, but public funding is insufficient to meet this target. Though there is lack of funding in forest management, biomass utilization through private and public investment could represent an indirect opportunity to improve forest health.[90,91]

Barriers to Biomass Expansion

The challenges faced by the biomass industry represent opportunity areas for policymakers. Effective policies will be those that comprehensively address all externalities associated with pile burning, wildfires, and fire risk reduction, foster positive co-benefits, and address public concern.

Cost

For biomass energy producers, high transport costs, capital expenditures, and lengthy permitting processes drive up the cost, making it economically infeasible for many who consider entering the market. As a general fuel source, biomass cannot compete with cheaper options in California, such as natural gas.[92] Advocates argue that if the positive externalities of biomass energy were properly quantified and reflected in biomass policy, the price would be much more competitive.

Discussed below, CCAs generates unique opportunities for forest communities looking to develop local biomass facilities. CCAs can help developers of smaller facilities overcome the diseconomies of scale present in the biomass industry, such as the fact that labor costs are approximately constant regardless of the size of the facility.[93]

The vertical integration of biomass into large timber companies is arguably the most economically viable strategy. Sierra Pacific Industries has integrated biomass energy into its operations as both a cost savings and sustainability measure. In order for it to be cost effective, the fire risk reduction benefits are minimal; while 85% to 90% of its biomass fuel is large-diameter woody waste from forestry operations in the Region, only 10% to 15% is from forest management activities such as thinning and brush clearing in fire hazard zones. Woody biomass is collected and burned at one of several cogeneration facilities located alongside SPI sawmills. Incorporating biomass utilization into the SPI business model can decrease waste and power costs.[94]

Physical and Financial Infrastructure

The capital costs of building a biomass facility, like any large electricity generator, requires a significant initial investment for construction. Together with uncertainty around long-term prices only guaranteed by legislation, this limits the market of lenders and investors looking to get involved in building a biomass generator. There is also a lengthy administrative process with the State of California.[95]

There is no existing market for shipping wood pellets abroad, and there is more economic potential in large timber for biomass than small-diameter fuel.[96] Without an established long-term trading partner abroad, there is no international demand.[97] The lack of an existing revenue stream indicates that incentives are needed for more private interest to be established outside of the few existing venture capitalist startups.[98]

In addition to the lack of an existing revenue stream abroad, there is an uncertain supply chain for biomass within California. The US Forest Service is the mainland-leaser for wood fiber contracts, but only controls a portion of the State's forested land. [99] In order to meet the demand in a long-term power purchasing agreement, a consistent supply for a set period of time (20+ years) needs to be procured at a more or less guaranteed price.[100]

Technological Limitations

There are several technological concerns associated with biomass plants. Although it is a renewable energy source, it still produces pollution. A report by the Global Carbon Capture and Storage Institute indicates that bioenergy with carbon capture and storage (BECCS) requires carbon capture technology to be more widely deployed, and that among the negative carbon technologies, BECCS is the best option. BECCS technology can cost anywhere from $15 to $400 per ton of CO_2 avoided, with bioethanol (used for vehicle fuel rather than electricity) being on the lower end of the spectrum.[101]

Another possibility is the creation of biochar, a process which uses the burning of biomass to capture carbon and creates a product that can be used as a soil amendment.[102] In interviewing the California Energy Commission, torrefaction is an emerging technology similar to biochar that also has potential to be deployed in the future.[103] Creating these bio-pellets and thus storing the associated carbon can help to reduce air pollution and subsequent health impacts. Using carbon capture technology would decrease the environmental effects of biomass energy, however, due to the price point of biomass this would create a situation that increases the price without much economic return.

The biomass plants currently in use are characterized by old technology. While biomass facilities can be powered on and off when needed, they cannot do so quickly, and cannot scale up easily, so they are not sufficiently flexible to supply all types of energy demand. Additional uses for biomass are an option in the future, but currently the technology is not available for conversion to alternatives like syn-fuels.

Public Sentiment

Public sentiment about biomass varies. Although many want it in their communities, determining who is responsible for the costs is a barrier. Potential environmental effects have also generated some opposition to biomass in the Environmental Justice community in some areas, such as around wood pellet factories in the Southeastern United States, where a study found biomass facilities 50% more likely to be located in poor communities with an over 25% non-white population.[104] Public sentiment in California is also mixed, with concerns about worsening existing air quality in the Central Valley area, as well as general concerns about the burning of any kind—including prescribed burns—after the spate of recent fires in California.[105] As noted by climate analyst Simone Cordery-Cotter of the Sierra Business Council, there is a need for greater public engagement, especially on the topic of public health, as it is one of the most controversial parts of building biomass facilities.[106]

Considerations for the Future

During the development of new biomass facilities, there are several factors that should be considered.

Location

- Three of the most important factors for site selection, according to Green Mountain Institute, are access to roads, proximity to fuel, and proximity to the grid.[107]
- Distance from the forest was cited as the most common reason for facility closure; thus, proximity to forest resources is arguably the most important consideration when selecting a location for new biomass facilities.
- Biomass facilities needs to be close enough to the grid to connect, but do not need to be located at a substation.
- Other considerations include availability of space, topography, land use planning, and permitting requirements. Modeling software such as BioSum (utilized by the Forest Service) can aid in the identification of ideal locations.[108]
- Without a community organization pushing for the development of a new facility, or a timber company with the resources to build a biomass facility on site, the likelihood of new construction is low.

Size & Scale

- On a cost per MW basis, the higher the capacity the biomass facility the better. Labor costs are relatively consistent regardless of the size of the facility.
- High capacity facilities present more risk regarding air pollution and are subsequently more difficult to permit and finance.
- Developing a few centrally located high capacity biomass facilities could be preferable to several distributed low capacity facilities.

Technology Options

- Combined heat and power (cogeneration)
    - Most efficient designs are those that recover waste heat as seen in Europe[109]
- Collocation: hybrid microgrids
- Gasification
- Co-products: cross laminated timber, synthetic fuels, others

Economic Development

- The barriers listed above highlight the many inherent risks in using biomass energy as a strategy for rural economic development.
- Small biomass facilities experience diseconomies of scale over larger facilities due to high capital and operating costs. This could complicate the ability of biomass energy to deliver socioeconomic benefits at the community level.

- The industry is nascent and highly dependent on subsidies; without a fully functioning market for small-diameter woody biomass, there will be little economic benefits to forest communities.
- Streamlining the permitting process for community-scale biomass plants could improve the economic return of these projects. Smaller facilities will generate less impacts, and could benefit from a standard design, permit application, and environmental impact assessment. The Sierra Institute for Community and Environment is deploying this strategy to facilitate its own projects.[110]
- With greater supply chain confidence, there would be opportunity for cottage industries to emerge (i.e. furniture made from beetle kill wood). These cottage industries could also aid in forest clearing.[111]

Funding: Subsidies, Taxes, and Credits

- Biomass energy is not feasible without the availability of public funding in the form of subsidies or tax incentives. Expanding biomass energy generation in California will require increasing the amount of public funds available.
- Existing biomass programs (i.e. BioMAT and BioRAM) are intended to generate revenue streams from small-diameter woody biomass. These programs may work as designed but would need to be scaled up significantly to meet forest and fire management needs. Complementary initiatives may be added in the future.
- Current biomass policy targets IOUs, and the increased economic burden is then placed on utility ratepayers. This creates several issues: not all ratepayers support biomass or directly benefit from its use and making electricity more expensive will exacerbate existing socioeconomic inequities. Meanwhile, other renewable energy sources are cheaper and cleaner.
  - California mandates action at the IOU level because it is more politically feasible than other types of intervention.
- A Statewide tax based on income would be a more equitable yet less politically feasible option to generate public funding for biomass. In this case, however, a tax to directly fund forest management may be more sensible.
- State leaders and investors should continue to invest resources in the development of markets for small-diameter woody biomass including alternatives to biomass energy.
- Both California and the federal government have programs that provide funding for alternative fuel projects, green projects, and biomass-specific projects.
  - In the California Department of Forestry and Fire Protection's (Cal Fire) 2017-18 budget, $220 million were available for California Climate Investment (CCI) grants. CCI does not apply to biomass plants.
  - The USDA Wood Innovations Grants program offers funding to wood construction in commercial buildings, traditional wood use projects, and expanding wood energy markets to support the Agriculture Improvement Act of 2018.
  - AB-1492 established the Timber Regulation and Forest Restoration Fund, which provides additional funding for the production of forest products.

- California's Greenhouse Gas Reduction Fund, part of the State's cap-and-trade system, represents another opportunity for funding.

The Role of CCAs[112]

- CCAs are public-sector, not-for-profit entities that allow customers of IOUs to take control over their procurement of electricity, while IOUs retain responsibility for billing and managing transmission and distribution.
- CCAs compensate the IOUs for their lost customers through a Power Charge Adjustment (PCIA) on customers' bills.
- CCAs must be approved by a public vote of a local government, after which the CCA has the responsibility for procuring the service for that community.
- CCAs tend to be formed by communities that want to purchase higher quantities of renewable energy than what their IOU makes available.
- There are 19 operating CCAs in California, with more in the application phase.
- The regulatory agencies, including CAISO and CPUC, are still developing policies to govern how CCAs will integrate with the larger electric grid.
- CCAs would want to integrate with the larger electric grid so that they may sell power at market rates in the event that they have oversupplied their community.
- Although it is rare now, it is becoming more common for CCAs to own generation facilities, rather than simply contracting them through PPAs.
- There is a lengthy and costly process for CCAs to form microgrids, and only 25% of planned microgrid projects are completed.

For Further Research

- More research is needed regarding the net emissions impact of expanded biomass combustion for electricity generation, given existing emissions from wildfires and current sources of electricity generation.
- More research, development and innovation are needed on technology options for development of useful products from small diameter wood other than for biomass energy, which could facilitate fire risk management.
- More funding and research are needed on the current state of the forests in order to conduct a more accurate fuel stock availability assessment.
- Wood must be taken out of the forests sustainably, but more research is needed to determine what that looks like within the Region. Dr. Matthew Palmer, a Senior Lecturer in the Discipline of Ecology, Evolution and Environmental Biology at Columbia University, stresses that the unintended consequences of forest thinning must be considered and addressed in any wood removal strategy. Transporting the material can spread diseases and invasive species, and there may be other negative impacts such as soil compaction or decreased biodiversity.[113] In speaking with The Watershed Center, the organization noted that manual thinning is labor intensive and not as effective as mechanical thinning, but it might be easier on the forest and this activity is already happening as a way to keep fire crews employed during off seasons.[114] Different techniques should be assessed, in addition to quantifying the optimal amount of wood to take out of the forests.

- Further research should be done on utilizing woody biomass for on-site heating, including the degree to which this already occurs (in fireplaces and wood-burning stoves) and whether it is an environmentally or economically preferable alternative to other sources of home heating, such as fuel oil, propane, natural gas, or electricity.
- Utilities like PG&E will need to continue to insulate lines, upgrade connections to towers, and implement remote sensors. More research is needed on how to speed up the process and/or identify funding to upgrade the power lines and minimize wildfire risk.
- Other solutions for utilizing the wood in the forests could be considered in conjunction with biomass facilities, such as prescribed burns or cross laminated timber (see Appendix E).
- Urban planning in the WUI plays a role in mitigating wildfire risks with relation to property destruction and health dangers. Planners can consider protecting populations from wildfires through zoning changes. However, the Cal Fire maps of FHSZs have not been updated since 2007, so zoning changes should be made in accordance with map upgrades.
- California requires "best available technology" to be used for emission controls. More research should be done on what technologies qualifies as this for biomass facilities. Technology used in Europe should be considered.
- SB-100 mandates 100% carbon-neutral energy generation within California by 2045, but it does not specify how lifecycle emissions are calculated and quantified. Discussions with legislators could work to clarify 1) if the potential positive impact of biomass energy on future forest carbon sequestration is considered, and 2) if the full lifecycle emissions of other renewable energy technologies (manufacturing, construction, transport, generation, etc.) are considered.

Key Findings

This report explores the feasibility of utilizing woody biomass as an alternative power source for the nine-county region in northern California. The Region has been underserved by PG&E, which cuts power to the Region due to wildfire risk. Utilizing responsibly collected woody biomass from the forests could reduce wildfire risk while providing a more reliable energy source to the Region's residents.

Through interviews with experts and industry professionals, as well as a review of recent literature and quantitative data, the Team has made the following key findings:

There is enough woody biomass in the Region's forests to sustainably meet average energy demand, but additional biomass facilities would need to be developed for the Region to achieve such a heavy reliance on biomass power. Approximately 5.1 million BDT can be sustainably harvested from the Region annually. If all of the Region's current biomass capacity (250 MW) was redirected to serve the Region's consumption, then they would need between 500 and 700 additional MW of capacity to meet average residential and commercial demand. Additional electricity sources would still be necessary to meet peak demand.

Current woody biomass facilities in the Region rely on extracting revenue streams from excess heat (using it to dry wood products and fuels), legal requirements for procurement of electricity derived from biomass sources (BioRAM), and tariffs (BioMAT) to achieve sufficient profitability. All rely on the ability to sell energy back to the grid. GHG emissions legislation also plays an important role in this discussion, because California will need to reach 100% clean energy by 2045. Biomass is not classified as clean energy, so biomass facilities will only be a short-term solution and need to be phased out in 25 years. Although burning biomass increases the amount of CO_2 in the atmosphere, the CO_2 is eventually captured during a tree's regrowth. Carbon neutrality depends on the timeline being analyzed. Biomass can be seen as a pathway to a zero-carbon future or it can be interpreted as an impediment toward achieving the ultimate goal of producing zero-carbon energy.

Small-diameter woody biomass in particular has little market value and no other scalable uses at this time. Other options, such as international shipping and cross laminated timber production, are not currently economically feasible.

Large biomass facilities that generate more than 15 MW are significantly more cost effective than small ones generating 0 to 5 MW due to economies of scale associated with engineering, procurement, construction, and labor. Public investments can lower costs because publicly owned utilities require lower rates of return than investor owned utilities.

The Team outlined three scenarios for drastically expanding the use of biomass: one or a combination of these scenarios can be used as guidelines for considering the addition of biomass capacity to the existing grid.

Scenario 1: Biomass-fueled microgrids at PG&E substations ● This scenario considers constructing 13 biomass power plants at PG&E substations in the Region, representing 20,000 customers who lost power during at least one major shutoff in 2019. ● The average cost of each facility is $43.7 million, totaling $568 million. Several substations are located in the same cities, so if one facility were to be built in each city, rather than having multiple facilities per city, the total cost is lowered to $517 million.
Scenario 2: Biomass procurement through CCA ● Scenario 2 considers how a group of rural municipalities could form a CCA, giving residents representative control of their electricity generation and the ability to choose their provider. CCAs procure electricity and sell electricity at rates corresponding to different energy mixes and choice of procurement. Most CCAs in California choose to source most of their energy from renewables because California's Renewable Energy Credits are inexpensive. ● Energy cost savings are highly variable and depend entirely on the price of electricity a CCA is able to negotiate with generators, and what costs it incurs in ceasing procurement through the IOU. ● The Team estimates that eight 25 MW plants across Butte County, delivering a total of 200 MW of energy, would cost $75 million per plant, totaling $600 million. Alternatively, five 40 MW plants would cost $587 million, while forty 5 MW plants would cost $1.2 billion.
Scenario 3: Urban-based biomass facilities ● Scenario 3 considers how the Region's most densely populated cities (Chico, Paradise, Redding) could provide locally generated biomass power to residents. ● To meet average electricity demand with one facility in each city, the Team estimates that an 83 MW plant in Chico, a 24 MW plant in Paradise, and a 110 MW plant in Redding are sufficient. ● These plants would cost $243 million, $24 million, and $110 million, respectively, for a total of $639 million. ● A CCA is the best way to make this scenario actionable.

Diversifying the energy mix is a crucial part of achieving energy security, and a large-scale electricity grid, such as the statewide grid managed by CAISO, facilitates this by combining power generated from a wide variety of sources into a single energy stream. Under any realistic and ideal scenario, biomass power would be one source among many.

Biomass facilities can serve as a backup energy source for municipal areas during power shutoffs. An example of this is the Honey Lake Power facility in Lassen County, which sends power to a large utility year-round but is able to switch to providing power to the Lassen Municipal Utility District during PG&E shutoffs.

Biomass facilities produce significant levels of air pollutants and greenhouse gas emissions, but fewer than wildfires. Next generation facilities might be able to mitigate some of these emissions. Because biomass energy generation would not stop wildfires, local air pollutant emissions from facilities would be in conjunction with wildfire emissions. With strict air quality policy and advanced biomass conversion technologies, emissions could potentially be mitigated.

Removing the excess small-diameter woody biomass will enhance forest health and reduce wildfire risk. Multiple barriers have barred biomass from taking off in California, such as high costs, physical and financial infrastructure, technology, and public sentiment:

Cost: ● High transport costs, capital expenditures, and permitting processes make woody biomass utilization economically infeasible ● Biomass cannot compete economically with cheaper fuel options like natural gas
Physical and financial infrastructure: ● Capital costs of building biomass facilities require large investments and long-term fixed price contracts, which today are guaranteed only by legislation, limiting the supply of investors and lenders willing to participate ● There is no existing international revenue stream or demand for small diameter fuel ● The biomass supply chain in California is uncertain, but to meet demand in a PPA, a consistent supply chain is required
Technological limitations: ● Biomass plants produce significant levels of pollution ● Carbon capture technology is too expensive for small scale facilities ● Technology is not yet available for alternative uses like synthetic fuel
Public sentiment: ● Even when communities want biomass, it is difficult to determine who is responsible for costs ● There is some opposition to biomass within environmental justice communities ● Sentiment in California is mixed due to air quality concerns

If it is determined there is a social benefit of healthier forests from expanded biomass which outweighs the cost of the subsidy, the policy should be carried out. However, policymakers might want to consider subsidizing forest management over biomass power if the primary goal is to remove excess woody biomass.

Conclusions

Using woody biomass for power can be an effective tool to remove excess forest material, such as ladder fuels and other small-diameter wood, in hazardous areas. Biomass advocates promote woody biomass as a revenue stream for forest management that can create a market for woody residues, while providing reliable power to local communities. In practice, however, woody biomass facilities are generally only feasible with the support of State legislation that requires or subsidizes biomass procurement or promotes the use of woody residues in high hazard zones. The capital and operational costs are too high for a market to emerge without subsidization. Thus, bioenergy subsidies might not be a long-term solution for forest management given other price competitive energy sources like wind and solar. Nonetheless, biomass facilities can be useful in the Region because they can supply energy during power shut offs. Biomass facilities might be more feasible in certain scenarios where there is local support and the plant is located near the forests, among other factors.

Prioritizing forest management over new biomass facility subsidization might be a more effective strategy in the long-term. Rather than constructing new biomass plants, which are costly and pollutive, forest management addresses the problem of excess debris directly. Forest management prioritization can look like increased public forest management budgets to create new forest management jobs or enhanced research and development for alternative forest debris uses. However, these options may be less politically palatable because they lack a revenue stream. Woody biomass does not currently have any other marketable uses, but more funding could be effective in developing other solutions.

It is unlikely that the Region will be able to completely separate from the grid using biomass due to the significant cost of new power lines, but the three scenarios outline other grid integration options. To reduce wildfire risk in high hazard areas, a more effective strategy could focus on forest management directly rather than attempting to create a market for a product with little value. Alternative uses for woody biomass like shipping internationally and producing cross-laminated timber are not currently feasible in California, but other uses should be explored in the future in place of pile burning and landfilling.

Glossary

BDT	Bone dry ton | One metric ton of woody material at 0% moisture content
CCA	Community Choice Aggregation | A local entity that purchases power on its customers' behalf
CHP	Combined heat and power | Using an engine to produce electricity and heat at the same time
CO_2eq	Carbon dioxide equivalency | For a given greenhouse gas, it describes the amount of CO_2 that would have the same global warming potential
Cogeneration	Synonym for CHP
Fuel moisture	Tool to gauge fire potential, expressed as dry weight. Time lag categories (10-hour, 100-hour, 1,000-hour) express how long it will take fuel to respond to atmospheric changes
Gasification	Technology that converts biomass without combustion, resulting in lower net greenhouse gas emissions
IOU	Investor-owned utility
MW	Megawatt | A unit of power
MWh	Megawatt-hour | A unit of energy
Microgrid	A localized group of interconnected loads and distributed energy resources that is connected to the traditional grid, but can disconnect from the grid and operate autonomously
Positive feedback loop	An unstable system in which the product of a reaction leads to an increase of the reaction
PPA	Power purchase agreement | A contract that defines the terms between an electricity buyer and seller
RPS	Renewable portfolio standards | A state regulation that requires increased production from renewable energy sources
Second generation facilities	Next generation facilities that will convert fuel into higher value components with lower emissions
Substation	The interface between electrical transmission and distribution systems, transforms voltage from high to low and vice versa

Appendices

Appendix A. Relevant Legislation

Legislation	Brief Description
Rural Economic Development	
AB-417 Agriculture and Rural Prosperity Act	Creates a Rural Economic Development Account providing financial support for rural agricultural economic development.
Watersheds and Forest Management	
SB-1386 Resource conservation: working and natural lands	Establishes that the protection and management of natural and working lands (including forest, watersheds or production of forest products) are integral to meeting California State's greenhouse gas (GHG) reduction targets. Require all state's departments to consider the protection of working lands when establishing policies, regulations, expenditures and grant criteria.
AB-2551 Forestry and fire prevention: joint prescribed burning operations: watersheds.	Authorizes the Natural Resources Agency and the California Environmental Protection Agency to jointly develop a spatially explicit plan for forest and watershed restoration investments in the drainages that supply the Oroville, Shasta, and Trinity Reservoirs (HWC region). Establishes a Headwaters Restoration Account to fund watershed restoration activities.
AB-2480 Source watersheds: financing	Defines source watersheds as a critical part of California's water system infrastructure and for maintaining a reliable water supply. Makes maintenance and repair of source watersheds (limited to forest ecosystem restoration and conservation activities) eligible for the same forms of financing as other water collection and treatment infrastructure.
SB-5 California Drought, Water, Parks, Climate, Coastal Protection, and Outdoor Access For All Act of 2018	Authorizes issuance of $400 billion in State General Obligation Bonds to fund the implementation of this program which includes various provisions for wildfire risk reduction, forest restoration and source watershed projects, and deferred maintenance at Department of Fish and Wildlife facilities.
AB-1471 Water Quality, Supply, and Infrastructure Improvement Act of 2014	Allocates $7.12 billion in State General Obligation Bonds to fund watershed protection and restoration, water supply infrastructure, surface and groundwater storage, and drinking water protection projects. It also reallocates $425,000,000 of the unissued bonds to finance a water quality, supply, and infrastructure improvement.
Climate Resilience and Biomass Utilization	
SB-859 Public resources: greenhouse gas emissions and biomass.	Requires California Natural Resources Agency (CNRA) to provide financial support to disadvantaged communities for the implementation of specified green infrastructure projects and to establish a working group on expanding wood product markets that can utilize woody biomass from high hazard zones. Cal Fire must provide grants to or enter into contracts/cooperative agreements to implement projects and programs which improve forest health

	and reduce GHG emissions. Electrical corporations must enter into five-year contracts procuring 125 MW of power from bioenergy facilities where 80% of its feedstock comes from the byproduct of sustainable forest management including biomass removed from specific high fire hazard zones
AB-1942 Forestry and fire protection: reduction of emissions of greenhouse gases.	Appropriates $330 million for the 2020–21 fiscal year from the Greenhouse Gas Reduction Fund to Cal Fire for healthy forest and fire prevention programs and projects that will reduce greenhouse gas emissions caused by wildfires. $10 million will fund the California Conservation Corps' fire prevention activities.
SB-901 Wildfires (2017-18)	Authorizes $1 billion in funding over five years from the Greenhouse Gas Reduction Fund for forest health, fires prevention and fuel reduction projects to be undertaken by Cal Fire and streamlines of landscape and forestry management practices Requires electrical corporations owned electric utility, or community choice aggregators to extend or enter into a new contract to procure electricity generated from biomass (including biomass removed from specific high fire hazard zones) for a period of 5 years.
SB-100 California Renewables Portfolio Standard Program: emissions of greenhouse gases	Updates the state's current RPS program requiring electricity retailers to procure 50% and 60% of electricity from eligible renewable energy resources (including biomass) by 2025 and 2030, respectively. Sets goal to achieve 100% carbon neutrality from zero carbon resources state's electricity by 2045.
Biofuel Renewable Auction Mechanism (BioRAM) program (Resolution E-4770)	A procurement, feed-in tariff program for large investor-owned utilities (IOU) to procure electricity from biomass facilities which utilize biomass from high hazard zones.
SB-1122 Energy: renewable bioenergy projects (The Bioenergy Market Adjusting Tariff (BioMAT)	Directs electrical corporations to procure at least 250 MW from bioenergy projects. A feed-in tariff program for small bioenergy renewable generators less than 5 MW. It offers up to 250 MW to eligible projects through a fixed-price standard contract to export electricity to California's three IOUs.
Other Renewable Energy Financing Sources	
Federal Investment Tax Credit (ITC)	Funds solar energy (and battery) projects, with a 26% tax credit for residential and commercial solar properties. Funding will decrease to 22% in 2021 and have further restrictions in 2022 (the year the funding ends). ITC also supports wind, providing a 12% to 30% credit on investment costs.
Production Tax Credit (PTC)	Provides a 1¢ to 2¢ per kilowatt-hour tax credit for wind energy. This only applies for the first 10 years of electricity generation, and it must be a utility-scale project.

Appendix B. Research Design and Methodology

1. The literature review allowed the Team to gain background information and a better understanding of northern California's energy needs, current forest and fire management practices, and woody biomass utilization. California policies were also identified to understand opportunities and barriers to woody biomass energy production in the Region.

2. The data used includes:
    - Forestry data determines the Region's current energy needs and the amount of energy the woody material required for electricity generation. Spatial data obtained from California's geoportal consists of maps of active utility lines, utility zones, fire danger, forest cover, population density, and land use. California's Biomass Collaborative contains maps and information regarding location, number of employees, energy capacity, technology, and fuel types for existing and previous biomass plants in the State. This data indicates ideal locations and requirements for biomass facilities in the Region.
    - Financial and economic data illustrate potential costs and economic feasibility of woody biomass facilities and transmission lines for the Region.
    - Environmental data helps to assess the environmental impacts related to woody biomass facilities.
    - Publicly available datasets from the California Energy Commission provide energy demand, consumption, and source portfolio information.
    - 2018 US Census Bureau population and income data for each of the nine counties presents critical information about the characteristics of the local communities.

3. Interviews were conducted over the phone and in-person. They provide insight on gaps in the literature and first-hand knowledge of the practicality of woody biomass energy production for the Region. The interviews also reveal considerations such as political will, regulatory restrictions, technical and financial feasibility, and other barriers and opportunities that determine uptake of woody biomass energy production. Interviewees included energy experts from the California Energy Commission and CAISO, researchers from Columbia University and UC Davis, the California Natural Resources Agency, local non-profits such as PFT staff and the Sierra Forest Institute for the Community and the Environment, and constituent representatives from the Sierra Pacific Industries.

Name	Title	Organization	Date
Craig Thomas	Director	The Fire Restoration Group	2/18/2020
Susan Britting	Executive Director	Sierra Forest Legacy	2/18/2020
Matt Palmer, PhD	Senior Lecturer	Columbia University	2/18/2020
Stephen R. Kaffka	Extension Agronomist	UC Davis	2/19/2020
Simone Cordery-Cotter	Climate Analyst	Sierra Business Council	2/24/2020
Nick Goulette	Executive Director	The Watershed Center	2/26/2020
Jack Singer	Stewardship Associate	Pacific Forest Trust	3/2/2020
Dan Tomascheski	Vice President	Sierra Pacific Industries	3/4/2020
Tom Cuccia	Account Manager	CA Independent System Operator	3/5/2020
Jessica Morse	Deputy Secretary	CA Natural Resources Agency	3/12/2020
Jonathan Kuesel	Executive Director	Sierra Institute for Community and Environment	3/12/2020
Rizaldo E. Aldas, PhD	Program Lead	CA Energy Commission	3/12/2020
Hugh Merriam	Retired Analyst	Pacific Gas & Electric	3/26/2020
Dr. Gregg Morris	Director	Green Power Institute	4/10/2020
Marino Monardi	Procurement Director	Pacific Gas & Electric	4/10/2020

4. The case studies conducted include: The economic costs and benefits, capacity generation, and operational challenges for using biomass as energy for Burney Forest, North Fork, Camptonville Community, Wheelabrator, and Honey Lake Power biomass facilities were analyzed.

Data collection presented several challenges. A limitation of the literature review is that several technical reports are skewed towards the opinions of the authors, who are both pro-biomass and anti-biomass. There are also critical gaps in environmental data. For example, comprehensive data on the catastrophic 2018/2019 wildfires has not been collected yet. Finding fuel consumption data to estimate past or future emissions from wildfires in specific areas is difficult to come across. Acquiring information on case studies, such as the Lassen Municipal Utility District, is also difficult because representatives from the utility have declined to elaborate on how the plant operates, how they manage to go off-grid during outages, and how they struck a deal with SDG&E. Cost estimates for biomass facilities are difficult to project, given the varying costs of transport, size, and location of facilities. Lack of time to follow-up on leads or sift through the gamut of information given during the interviews was also a considerable challenge.

Nonetheless, based on analysis of the data available and new information collected, the Team provides options to PFT on the way forward for pursuing an energy transition, incentivizing forest management, and supporting local economies. Further research needs are identified for alternative energy options that could be used in conjunction with woody biomass energy production.

Appendix C. Assumptions for Feasibility Analysis

Assumptions for Capacity Addition Calculations

1. Biomass generators are not appropriate to exclusively rely upon to meet peak demand, so when considering maximum reliance on biomass in the Region, some other energy source, such as wind or solar power, is assumed to be operational.
2. The Region would want to shift to maximum reliance upon biomass, meaning that all other existing energy sources, including renewables, would only switch online during peak demand, at best.
3. The capacity factor of new and existing generation facilities will be 60.2% on average. Actual capacity factors vary significantly, and depend heavily on fuel availability and maintenance requirements.[115] Newly constructed facilities can be expected to operate at 83% utilization.[116] If the existing 250 MW of capacity operated at the average 60.2%, and new capacity operated at 83%, then only 500 MW of additional capacity will be required instead of 700 MW.
4. Existing biomass generators in the Region could be redirected to supply the Region. Noting that some biomass facilities have contracts with utilities serving customers outside the Region, in practice this would be a case-by-case process.

Assumptions for Biomass Supply Calculations

1. One BDT of woody biomass produces approximately one MWh when converted to electricity.
2. LLNL performed an analysis of the woody biomass available as a byproduct of public and private forest management in California.[117] It is assumed that this "byproduct" wood represents the small-diameter woody biomass (that is detrimental to the forests) because timber industries would likely use the larger, more commercially viable wood.
3. The LLNL analysis used BioSum,[118,119] a forest management decision-making tool that incorporates both economic and geospatial inputs, to develop five management scenarios under which forest stands could supply woody debris in a manner consistent with forest health. Their decision criteria for identifying stands prioritized reducing fire risk reduction, followed by reducing cost, followed by maximizing in-stand carbon. They identified 2,134 Forest Inventory Assessment plots, totaling 12.3 million acres, that met the decision criteria under at least one of the five scenarios. They claim that, "The data from these plots is statistically representative of all economically available biomass from fire- and carbon-beneficial forest management on California timberland."[120]
4. Merchantable timber will be sold at market price and non-merchantable timber will be chipped, hauled to a processing facility, and sold at $100 per BDT. 2,134 Forest Inventory Assessment plots are identified, totaling 12.3 million acres, which could be economically managed under at least one of five uneven-aged thinning scenarios.
5. Separately, the Team analyzed the total supply of coarse woody debris (i.e. downed woody material) in the Region since it is the largest diameter category of woody

debris and also identified as 1,000+-hour fuel, while debris of any smaller diameter is identified as 100-hour fuel or shorter. The USFS Forest Inventory Analysis tools identifies 95 million BDT of coarse woody debris in the Region. The area of analysis was approximated by a circular region with a radius of 110 miles and center at a point about twenty miles northeast of Redding. This area therefore includes a small proportion of forested areas outside of the Region.

Appendix D. Additional Environmental Data

Appendix D.1. Summary of emissions factors from wildfires by geographic area[121]

Geographic Area	Area Consumed By Wildfires (acres)	Wildfire Fuel Consumption (metric tons/acre)	Emission Factors (metric tons/acre)				Emissions (metric tons)			
			Particulate	CO	VOCs	NO_x	Particulate	CO	VOCs	NO_x
Rocky Mountain	774,421	34	0.29	2.35	0.40	0.07	220,907	1,819,237	311,869	51,978
Pacific	1,161,163	17	0.15	1.21	0.21	0.03	170,090	1,400,738	240,126	40,021
California	46,943	16	0.14	1.15	0.20	0.03	6,514	53,645	9,196	1,533
Alaska	1,046,565	15	0.12	1.02	0.17	0.03	129,098	1,063,154	182,255	30,376
Pacific Northwest	67,657	55	0.46	3.81	0.66	0.11	31,296	257,738	44,183	7,363
Southern	1,992,384	8	0.07	0.57	0.10	0.02	138,244	1,138,484	195,168	35,528
North Central and Eastern	232,751	10	0.08	0.70	0.12	0.02	19,739	162,555	27,867	4,644
Eastern Group	116,253	10	0.08	0.70	0.12	0.02	9,859	81,191	13,918	2,320
Total	**4,276,974**	**15**	**0.13**	**1.08**	**0.19**	**0.03**	**560,552**	**4,616,317**	**791,369**	**131,895**

Appendix D.2. Detailed emissions from woody biomass for energy production[122]

Process	Harvest	Transport	Conversion
Description	Biomass collection and pre-processing	On-road transport	Biomass Combustion
Equipment	Off- road equipment	Diesel Truck	CA average biomass boiler
Energy Type	Diesel fuel	Diesel fuel	
Energy Use	3.32	0.22	
Energy Units	gallons/BDT	gallons/BDT	
Direct Emissions			
Units	metric tons/BDT	metric tons/BDT	metric tons/BDT
VOC	1.52E-05	4.99E-07	9.61E-05
CO	1.10E-04	4.54E-07	1.38E-03
NO_x	1.24E-04	2.00E-06	1.98E-03
PM_{10}	4.63E-06	9.07E-07	2.28E-04
$PM_{2.5}$	4.17E-06	8.16E-07	1.14E-04
SO_x	3.18E-07	0	7.38E-05
CH_4	1.36E-06	0	6.89E-05
N_2O	9.07E-08	0	1.98E-04
CO_2	3.09E-02	2.28E-04	1.59
Indirect Emissions			
Units	metric tons	metric tons	
Description	Diesel Production	Diesel production	
VOC	4.22E-06	2.72E-07	
CO	1.16E-05	7.71E-07	
NO_x	3.31E-05	2.18E-06	
PM_{10}	4.04E-06	2.72E-07	
$PM_{2.5}$	1.86E-06	1.36E-07	
SO_x	6.76E-06	4.54E-07	
CH_4	4.34E-05	2.86E-06	
N_2O	9.07E-08	0	
CO_2	8.07E-03	5.35E-04	

Appendix D.3. Detailed Emissions from green and food waste for energy production[123]

Process	Handling/Processing	Plant Operation	Conversion
Description	Biomass handling and compost processing	Electricity Use	Anaerobic Digestion
Energy Type	Diesel fuel	Electricity	Biogas
Energy Use	0.09	0.22	0.05
Energy Units	MMBtu/BDT	MMBtu/BDT	MMBtu/BDT
Direct Emissions			
Units	metric tons/BDT	metric tons/BDT	metric tons/BDT
VOC	9.84E-06		9.07E-08
CO	3.69E-05		1.32E-06
NO_x	6.73E-05		1.36E-06
PM_{10}	3.99E-06		1.36E-07
$PM_{2.5}$	3.99E-06		1.36E-07
SO_x	7.26E-07		4.54E-08
CH_4	9.07E-07		4.54E-08
N_2O	9.07E-08		0
CO_2	7.07E-03		2.66E-03
Indirect Emissions			
Units	metric tons/BDT	metric tons/BDT	
Description	Diesel Production	Electricity production	
VOC	9.07E-07	4.94E-06	
CO	2.45E-06	1.22E-05	
NO_x	7.08E-06	1.56E-05	
PM_{10}	8.16E-07	6.19E-05	
$PM_{2.5}$	4.08E-07	1.60E-05	
SO_x	1.45E-06	4.22E-06	
CH_4	9.30E-06	6.15E-05	
N_2O	0	5.90E-07	
CO_2	1.73E-03	2.28E-02	

Appendix D.4. Detailed emissions from landfill gas for energy production[124]

Process	Harvest	Conversion
Description	Landfill gas recovery	Landfill gas combustion
Energy Type	Electricity	
Energy Use	9,262	
Energy Units	Btu/MMBtu	
Direct Emissions		
Units		metric tons per MMBtu of gas recovered
VOC		1.01E-04
CO		3.15E-04
NO_x		7.53E-05
PM_{10}		6.17E-06
$PM_{2.5}$		6.17E-06
SO_x		3.08E-06
CH_4		5.05E-04
N_2O		9.98E-07
CO_2		6.52E-02
Indirect Emissions		
Units	metric tons per MMBtu of gas recovered	
Description	Electricity for blower	
VOC	1.36E-07	
CO	9.07E-07	
NO_x	1.50E-06	
PM_{10}	8.62E-07	
$PM_{2.5}$	2.72E-07	
SO_x	1.81E-07	
CH_4	2.04E-06	
N_2O	0	
CO_2	1.16E-03	

Appendix D.5. Detailed emissions from manure for energy production[125]

Process	Harvest	Conversion
Description	Digester gas collection	Biogas combustion
Energy Type	Electricity	
Energy Use	22,209	
Energy Units	Btu/MMBtu	
Direct Emissions		
Units		metric tons per MMBtu of gas recovered
VOC		1.05E-04
CO		3.27E-04
NO_x		7.85E-05
PM_{10}		8.44E-06
$PM_{2.5}$		8.44E-06
SO_x		5.08E-06
CH_4		5.05E-04
N_2O		9.98E-07
CO_2		6.52E-02
Indirect Emissions		
Units	metric tons per MMBtu of gas recovered	
Description	Electricity for blower	
VOC	3.18E-07	
CO	2.13E-06	
NO_x	3.63E-06	
PM_{10}	2.04E-06	
$PM_{2.5}$	5.90E-07	
SO_x	3.63E-07	
CH_4	4.90E-06	
N_2O	4.54E-08	
CO_2	2.77E-03	

Appendix E. Alternative Uses for Small-Diameter Woody Biomass

While this report primarily considers the feasibility of using biomass for electricity in the Region, alternative uses should be mentioned. More research and development are needed on innovative ways to use small-diameter woody biomass.

Shipping Internationally

Europe and China have increased imports of woody material from the United States for energy production. Most US exports currently come from the Southeast, not California. Economists and industry actors are exploring California's potential role in the international woody biomass trade.

A briefing by the US International Trade Commission, *International Trade in Wood Pellets: Current Trends and Future Prospects*, summarizes many factors in the US wood pellet market. The European Union's (EU) Renewable Energy Directive (RED) has mobilized Europe to use woody biomass, in the form of wood pellets, as a low-carbon energy alternative. In 2017, the U.S exported 5.1 billion kg of wood pellets, totaling $666 million. As of 2018, the biomass rules in the EU have not changed, but due to the large emissions of CO_2 and particulate matter from burning woody biomass, the demand for wood pellets in the EU may not persist. On the other hand, it is argued that much of the additional CO_2 released will be absorbed by increased reforestation. The demand for wood pellets, especially in the EU, is highly variable and subject to much variation over time due to future scientific and policy advancements.[126]

Within Asia, China is likely to become a larger importer of US wood pellets, but a massive market development must take place first.[127] Shipping from California may be preferential for wood pellet exporting since California is closer to Asia than the East Coast of the US, but there is a potential for increased emissions from shipping overseas in comparison to utilizing the woody biomass locally for energy generation. An article entitled, *An Environmental Impact Assessment of Exported Wood Pellets from Canada to Europe*, analyzed the energy consumed and subsequent emissions from shipping wood pellets from Canada to Europe.[128] For each ton of wood pellets shipped from Canada to Europe, 40% of the total energy content in those wood pellets was consumed. The researchers suggest a local market may decrease these adverse environmental, health, and energy results.

There may be some potential for California to enter the international wood pellet market, but this industry will be difficult to reconcile with existing state climate goals for the reasons outlined above. Furthermore, timber companies in the Region lack economic incentives to pursue this trade. According to the Sierra Pacific Institute, (the 2nd largest lumber company in the United States), the manufacturing and exporting wood pellets is not an economically feasible option given the size of California, logistical issues, cost to transport the material to the port, and lack of infrastructure.[129]

Cross Laminated Timber

Several forest management and timber experts consulted for this project cited cross laminated timber a potential use for small diameter woody biomass. Cross laminated timber (CLT) is a building material made of multiple layers of laminated lumber that can be used to build walls, floors, and roofs, and is strong enough to replace steel or concrete. Studies have shown that transforming woody biomass into CLT can sequester significant levels of carbon.[130] Additionally, CLT is easier to disassemble and recycle compared to traditional wood, keeping it out of the landfill for longer. CLT manufacturing could create a revenue stream for a typically low-value wood product while aiding in responsible forest management. Typical CLT manufacturing plants have been estimated to employ 55 people directly while supporting hundreds of indirect jobs.[131]

Logging companies do not typically remove small-diameter trees because of the lack of market value for the product. Smaller-diameter wood takes the same amount of time and labor to mill as other products, but with little to no return,[132] thus a logging company could consider creating an additional mill to process smaller woody biomass. One report found that this scenario is unlikely because the costs of adding another mill would not create a large enough profit margin even with a strong demand for CLT products. To create a market for CLT, California could provide opportunity through emissions targets and public funding.[133]

Gasification & Synthetic Fuels

Several experts consulted for this project discussed synthetic fuels as a future market for small-diameter woody biomass. Through a process known as gasification, woody biomass can be heated under specific conditions to the point where it becomes a liquid fuel. This fuel can be used in place of traditional fossil fuels for vehicles, shipping, and aviation.[134] However, it will require significant technological advancements to make synthetic fuels scalable and commercially viable. If achieved, this product would likely displace biomass energy due to its increased profitability and improved net climate benefits.

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