

SHOULD CALIFORNIA SUPPORT FOREST-SOURCED BIOENERGY? CONSIDERATIONS FOR WILDFIRE, CLIMATE, AND ENVIRONMENTAL JUSTICE

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Should California Support Forest-Sourced Bioenergy?

Considerations for Wildfire, Climate, and Environmental Justice

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Executive Summary

Biomass utilization for energy has ramifications for climate change, waste management, wildfire mitigation, air quality, and environmental justice. This paper examines bioenergy in the California context, with a specific focus on whether forest-sourced biomass should be used for energy. We examine debates about biomass use and offer criteria and recommendations relevant for advocates and policymakers.

Forest management techniques that aim to reduce the risk of high-severity wildfire, such as mechanical thinning, produce significant quantities of biomass in the process. These practices, and related ones like prescribed burning and biomass removal, are sources of debate within the environmental community. Given that the state intends to continue thinning forests, an important part of this debate is whether slash should be removed from or left in forests. Most evidence indicates that removing biomass from forests where mechanical thinning has occurred reduces the risk of high severity wildfire and associated emissions. The ensuing question, which is the focus of this report, asks: what is the most equitable, economic, and environmentally sound use or disposal option for the biomass created by forest management? Several considerations inform the answer.

We examine evidence that suggests that in most cases, bioenergy should not be viewed as a carbon neutral energy source. This contradicts the stance of various state, national, and international agencies. Arguments supporting the carbon neutrality of bioenergy tend to assume that emissions are absorbed by subsequent vegetation growth. In practice, however, this does not always occur, or it occurs on timespans longer than the critical one- to three-decade window for mitigating climate change.

At the point source, combusted bioenergy without pollution controls emits more greenhouse gases (GHGs), particulate matter, and volatile organic compounds per unit of energy than coal. Under conventional lifecycle emissions accounting, the climate impact of bioenergy depends largely on the purpose and source of biomass harvesting. When biomass is clearcut for energy from tree plantations, lifecycle emissions tend to be worse than that of coal, but this scenario is rarely the case in California. Biomass generated as a byproduct of sustainable forestry practices is a more common scenario in California, and as such, is the focus of this report.

Despite its non-carbon neutrality, in California's present status quo, bioenergy from sustainable forestry byproducts may be beneficial from an emissions standpoint, especially when displacing fossil fuel use. In comparison to the most common fate of forestry byproducts (pile burning, landfilling, mastication, and/or leaving them to decompose in place), combusting or gasifying this biomass in a bioenergy facility leads to drastically reduced GHG and criterion air pollutant emissions. When biomass is removed from forests with frequent fire intervals, it reduces carbon emissions compared to leaving it in place.

Similarly, many scientists argue that forest management combined with fuels removal or prescribed fire is essential to forest health and ecology. Given the last century's history of fire suppression, most evidence suggests that restoring forests to a more natural and healthy condition would result in less understory vegetation and fewer trees per acre. This would also match the state of California forests when they were under Indigenous land management and prior.

These variables point to the need for a just and environmentally sound offtake option for forestry byproducts. State programs in the 1980s and '90s supported the construction of several large biomass power plants in disadvantaged communities, mostly in the Central Valley. Commercial-scale facilities created in this early wave of biomass power are associated with a plethora of environmental justice issues and air quality violations. Past models are unacceptable from an environmental justice and climate standpoint.

Criteria and Recommendations for Biomass Utilization in California

Given this complicated set of interacting issues, we offer guidelines that could improve biomass utilization in California. Since the balance of evidence implies that, in many areas, the byproducts of sustainable forestry should be removed from forests for wildfire, ecological, and climate benefits; and, since state authorities intend to scale up such forest management in coming years, there is a need for an improved prescription of how to handle this biomass.

Therefore, we recommend a different model. Small-scale biomass facilities located close to the forest source will reduce air pollution in the greater Central Valley and create jobs in rural, low-income, and Indigenous communities.

Based on our research, we propose that any new forest-sourced biomass facilities meet the following criteria:

1. Feedstock comes only from ecological thinning, mill residues, or home hardening and defensible space practices as opposed to logging activities
2. Small-scale – 5 megawatts or less, in accordance with BioMAT program requirements (discussed in more detail on pg. 15 below), or slightly larger facilities approved on a case-by-case basis
3. No more facilities are built than are needed to process the wood waste associated with sustainable forest management activities within a reasonable distance of the facility. This avoids creating an industrial complex that requires constant and increasing feedstock
4. Companies engage local communities for input and collaboration in the planning, design, and deployment of new facilities
5. Facilities are located close to the sources of biomass production, which tend to be rural and mountainous locales, to reduce emissions and costs of long-distance shipping; facilities will not be sited in already over-polluted Central Valley communities
6. When feasible, new facilities should use gasification or pyrolysis technologies, along with the best available emissions controls, to minimize GHG impacts
7. When possible, feedstock is produced by work crews that create jobs for local communities and Indigenous peoples

Modeling by state agencies could determine how much biomass land managers expect to produce over a 10- to 20-year period so that the appropriate number and distribution of facilities – and not more – are built to handle that feedstock quantity. The state could then issue permits for new facilities only up to the amount needed for ecological restoration and fire mitigation. We also recommend permanently closing the most polluting large-scale biomass facilities located in disadvantaged communities or places with high air pollution burdens. The resulting power gap should be replaced by new clean energy installations such as solar or wind power.

Community-scale facilities that meet the criteria listed above improve climate, justice, and air quality outcomes compared to the state's present status quo. Simultaneously, California should no longer build, subsidize, or otherwise support bioenergy projects that follow the model of the high-capacity, highly polluting combustion facilities in disadvantaged Central Valley communities.

Introduction

The increasing threat of cataclysmic wildfires in California has intensified the level of concern and generated calls for emergency action. To address the issue, the State of California created a *Wildfire and Forest Resilience Action Plan* (FMTF, 2021). According to this plan, an estimated 500,000 acres of federal land and 500,000 acres of non-federal land in California's forests will be treated annually, producing a large quantity of woody biomass byproducts (FMTF, 2021). Some organizations support this approach, and others contest it. If implemented, should this biomass be left in place or removed? If it should be removed, what should be done with all the material that will flow out of California's forests for many years to come? Should this biomass be used to produce energy?

The response to these questions have significant implications for wildfires, the climate crisis, criteria air pollutants, and environmental justice in California. But they are not easily answered. Sharp debate among those who are typically allies is currently taking place (Thompson, 2021). The purpose of this paper is to examine the evidence relevant to this debate and offer recommendations for consideration by advocates and policymakers.

Discussions around bioenergy are necessarily geography specific. Some broad lessons apply universally, but local contexts are influential in making assessments relevant to the setting in question. This report aims to examine bioenergy in the California context, with a specific focus on bioenergy fueled by forest-derived biomass, and not other types of biomass applications, like ethanol, hydrogen, or agricultural waste and energy crops.

Rather than providing a comprehensive examination of all factors that touch the bioenergy issue, we synthesize material most relevant to California's climate, business, justice, energy, and policy context. After offering introductory and background information, the report reviews California issues like wildfire mitigation approaches, air pollution in the Central Valley, rural and mountain economies, and state policies. Synthesizing this evidence, we offer criteria and recommendations for what decisionmakers and communities should avoid and what they should support. We do so while aiming to address the climate crisis and pollution burdens in disadvantaged communities.

Issue Framing and Background

Bioenergy Feedstock and Production Processes

Bioenergy inputs come from sources as diverse as agriculture, forestry, the marine environment, and municipal solid waste (MSW). These inputs can be transformed by thermochemical means or by anaerobic digestion. The end products can include electricity, heat, biofuels, synthetic gas (syngas), hydrogen, biochar, and ash, among others. These supply and output flows are influenced by market conditions, policy, and climate and justice considerations. The multifaceted forms bioenergy can take means discrete analysis is required to determine where bioenergy can be applied beneficially and where it would be detrimental.

Biomass from forest products, the focus of this report, can be converted to energy through combustion, gasification, or pyrolysis. Biomass combustion facilities that produce electricity often use boiler technology, wherein biomass is burned to heat water, and the resulting water vapor spins a turbine to produce electricity. Bioenergy facilities that combust biomass in boilers have far lower emissions than open burning of biomass (Springsteen, Christofk, & Eubanks, 2011). Gasification, on the other hand, uses extremely high temperatures and a limited supply of oxygen to convert carbon-based material into a synthetic gas referred to as syngas (pyrolysis is similar but uses no oxygen). Syngas is made up of hydrogen, carbon monoxide, carbon dioxide, and water – unlike natural gas, which is usually about 90% methane (CH4). It has a heating value around 10% to 30% that of natural gas. Rather than burning the biomass itself, this process burns the syngas to create energy while leaving ash as a residual with little to no unreacted carbon char (although biochar is produced when biomass is burned in low oxygen environments). This offers several practical and environmental benefits. Syngas can be piped to multiple users. Additionally, the ash is left as a usable byproduct in this process. Finally, gasification tends to produce far fewer emissions of CO_2, fine particulate matter, and NO_x than conventional combustion technology (Briones-Hidrovo, et al., 2021).

Geography Matters

Biomass makes up 1.4% of total U.S. electricity generation (EIA, 2021). The South and Southeast use more biomass electricity than other regions of the U.S. Between 2005 and 2015, the South's biomass electricity generation grew from 26.7 terawatt-hours (TWh) to 31.1 TWh, well ahead of the next most region, the Northeast, at 13.5 TWh (EIA, 2016). The South also exhibited more growth in biomass electricity generation than other regions in the same timeframe.

Bioenergy in the Southeast is characterized by clearcutting forest tracts (often corporate-owned) to produce combustible wood pellets which are shipped to Europe for electricity generation. The industry was largely driven by demand growth from European Union policies that treat woody biomass as a carbon neutral, renewable feedstock, and therefore made it eligible for subsidies (SELC, 2021).

The United Kingdom national government conducted a lifecycle analysis study to examine total emissions associated with the production, shipping, and combustion of their biomass feedstocks from North America. Woody biomass can come from wood residues or from roundwood harvest. Using wood residues from sawmill operations and forestry for electricity that would otherwise be burned as waste results in significantly reduced GHG emissions – lower even than that of natural gas in many cases (Stephenson & MacKay, 2014, p. 8). Roundwood, on the other hand, is timber left as small logs, not sawn into planks or chopped for fuel, that is typically taken from near the tops of trees and used for furniture. Using roundwood for bioenergy tends to lead to higher emissions. Roundwood feedstock has higher lifecycle emissions than coal when it comes from an increased harvest of natural timberland (Stephenson & MacKay, 2014, p. 12).[1] Lifecycle emissions can be kept lower than those of natural gas combustion when the roundwood comes from abandoned or degraded land that is converted to energy crop production or pine plantations (Stephenson & MacKay, 2014). When energy needs to prepare the feedstock for combustion – e.g. trans-Atlantic shipping and drying wet biomass – are incorporated, lifecycle emissions can significantly increase.

A key insight from this study is that context matters in determining the utility and sustainability of bioenergy. From a climate perspective, it is beneficial to harness biomass for electricity when the biomass comes from woody residues that would otherwise be burned as waste. On the other hand, other variables can make bioenergy disastrous for the climate, including if it leads to land conversion for energy crops or pine plantations, requires long distance shipping, and uses dedicated roundwood as opposed to woody residues.

The impacts of bioenergy differ in different parts of the country. For example, it is more likely that wood pellets produced in the Southeast be transported to Europe and thus incorporate a sizable shipping emissions footprint in lifecycle assessments. Similarly, beetle-kill pine trees are most prevalent in the West,

[1] This scenario is more typical of the Eastern U.S. and rarely applicable in California.

and some proponents advocate for using this deadwood for bioenergy. This consideration is less of a factor in the Southeast. One of the most significant variables that impacts the bioenergy conversation is the risk of wildfire, discussed in detail below. Wildfire is a major factor in the West and almost a nonissue in the Southeast.

California's coniferous forests differ from those in the South and Southwest for several reasons. Many scientists point to California's history of wildfire suppression, past management, severe droughts, and bark beetle infestations as causes for the increased incidence of severe wildfires in the state. Anthropogenic climate change has also significantly increased the aridity of forest fuels in the western US, creating the dry conditions in these forests that cause wildfires to flourish (Abatzoglou & Williams, 2016).

The carbon emissions impact of forest fuel treatment is thus geography dependent. Removing and combusting biomass for energy from a forest that would otherwise burn may decrease overall emissions. On the other hand, sourcing biomass from forests with low fuel aridity like those in the South and Southeast is unlikely to reduce wildfire intensity or emissions and may therefore result in net positive carbon emissions.

These geographic differences lead to important ramifications for the bioenergy debate. While some facets of the discussion apply universally, other facets of the discussion must be tailored to specific regional considerations. Most headlines biomass-related in the popular news examine the issue in the Southeast U.S. context, which differs from the California context in critical ways (Grunwald, 2021; Elbein, 2019; de Puy Kamp, 2021). Due to this variation, it is important for advocates and policymakers to specify exactly which biomass scenarios they support and oppose when expressing their views on biomass utilization.

In California, efforts to mechanically thin forests to reduce wildfire risk produce significant amounts of biomass. This will continue to be the case as California grapples with the increasing threat of wildfire. The presents an immense waste disposal issue for the state. At present in California, most of this biomass is chipped or pile burned on site. Using it instead to produce electricity and heat could be less polluting and could generate income (Stephenson & MacKay, 2014) – this possibility is examined below.

Wildfire and Forest Health Issues

Wildfire Mitigation Tactics Produce Woody Biomass Residues

In California, forest management activities that aim to reduce the risk of wildfire produce large quantities of biomass in the process. Mechanical thinning of California's dry coniferous forests is a key element of the state's *Wildfire and Forest Resilience Action Plan*, published in January 2021. It calls for 1,000,000 acres of fuel treatment annually by 2025, and 100,000 acres of prescribed burn total by 2025 (FMTF, 2021). If this plan comes to fruition, such treatments are expected to produce significant amounts of forest biomass as byproducts over the next decade.

Support for California's *Wildfire and Forest Resilience Action Plan* comes from scientists, foresters, and Indigenous leaders.[2] Some scholars even argue that California's plan for active forest management does not go far enough. A report from the Stanford Woods Institute for the Environment suggests that existing plans in the state undershoot the necessary targets. This report calls for $3 billion of annual wildfire reduction spending, including 10 million acres of fuel treatment through 2030, 1 million home hardening retrofits through 2030, and additional community readiness actions (Wara, 2021).

[2] Other experts dispute the Action Plan. Their opposition is discussed below.

If current policies remain in place, the state will thin and/or burn a million acres of forest annually. Large quantities of biomass will be produced in the process. Given this likelihood, this report aims to determine the most environmental, economic, and equitable method to optimize the utility of the biomass.

Yet considerable debate regarding the ecological impact and economic viability of active forest management exists among scientists, environmental activists, and forestry professionals. Understanding the viability of bioenergy in California requires an analysis of the evidence cited by both sides of this debate.

Evidence Supporting Mechanical Thinning and Removing Slash

While Traditional Ecological Knowledge (TEK) varies from tribe to tribe, many Indigenous practices are based on the notion that humans are an integral part of the environment (Goode, et al., 2018). Prescribed ritual burning is an example of TEK, one which paused when Indigenous people were displaced from their ancestral California lands and when Spanish colonizers and the federal government banned it (Cagle, 2019). TEK made Indigenous communities more "resilient to climate variability and extreme fire behavior" (Roos, et al., 2021). Under Indigenous management and prior, California forests had fewer trees per acre and less understory vegetation.

Twentieth century fire suppression caused dramatic changes to California's forest ecosystems. Many scholars advocate for reintroducing Indigenous practices to improve forest health outcomes in the state (Kimmerer & Lake, 2001). In the state's Fourth Climate Change Assessment, Indigenous scholars urged California to continue to form partnerships with tribes and tribal communities while incorporating TEK into land management practices (Goode, et al., 2018).

Many fire ecologists and scientists in the forestry profession also advocate for active land management. One reason for this is that mechanical thinning and prescribed burning in California's dry conifer forests provide ecological benefits and can improve forest health. Numerous studies have found that mechanical thinning coupled with prescribed burning of forests both reduces wildfire risk and increases forest resilience (Collins, et al., 2014; Graham, McCaffrey, & Jain, 2004; Huggett Jr. & Shepperd, 2008). Mechanical thinning can increase forest resilience in part by reducing vulnerability to bark beetles and increasing host tree vigor (Bradford & Bell, 2017; Fettig, et al., 2007).

Proponents of active forest management also argue that it reduces the risk of high severity wildfire. A study in *Environmental Research Letters* found that the presence of live fuel is the most significant contributor to high-severity wildfire (Parks, et al., 2018). These live fuels are often treated in forests through mechanical thinning followed by hauling excess biomass out of forests and/or prescribed burning the slash. Fargione and colleagues argue in *Science* that this form of fuels treatment is necessary to avoid a net decrease in forest ecosystem production that, without treatment, would occur from frequent, tree-killing, destructive fires (2018). Other post hoc studies found that areas that were thinned and prescribed burned had lower tree mortality and reduced wildfire intensity during conflagrations that were elsewhere more severe and destructive (Prichard, Povak, Kennedy, & Peterson, 2020; Johnson, Crook, Stuart, & Romero, 2013).

Many studies find that these thinning treatments only reduce wildfire risk if coupled with removal of the biomass created in the process (Raymond & Peterson, 2005). As noted above, the removal of this biomass can occur by several methods, including prescribed burning, pile burning, and physical removal via hauling. Pile burning is, however, a highly polluting method of biomass disposal compared to hauling biomass out of forests for combustion in bioenergy facilities (Springsteen, Christofk, & Eubanks, 2011).

A study of dry forests in the western United States came to a similar conclusion: "thinning alone does not reduce wildfire severity [but] thinning followed by prescribed burning is effective at mitigating wildfire severity" (Prichard, Peterson, & Jacobson, 2010). Evans and Finkral write that while "some controversy about the ability of biomass removal to reduce wildfire severity remains, most research generally supports the idea" (2009, p. 216). Such findings not only support the mechanical thinning of California's dry forests as a wildfire mitigation technique but necessitate the removal of the biomass produced to make such projects effective.

The impact on terrestrial carbon stocks is another reason that many support the mechanical thinning of wildfire-prone forests. One study found that when wildfires occur on an interval more frequent than 31 years, forest carbon stocks are higher after fuels treatment and removal than if these forest tracts were left alone (Winford & Gaither Jr, 2012). The study found that when biomass is removed (and used for bioenergy) from forests where wildfires occur often, the initial loss of biomass from fuel treatment is smaller than the (avoided) loss due to wildfire. As climate change intensifies, more and more forest regions may arrive at fire intervals shorter than 31 years, making the thinning and removal approach more effective for more areas over time.

Recent research by the state Air Resources Board found that due to vegetation overstocking, current wildfire emissions per acre are more than 3 times higher than they prior to the last century of fire suppression (2021). As referenced above, a state of good health for California forests may involve restoring them to historical conditions in which there were fewer trees per acre, less understory vegetation, and regular fire. Doing so means removing carbon from forests. This removal can be seen as paying back a carbon debt accumulated over the past century. This could improve forest health and ecological outcomes.

Evidence Against Mechanical Thinning and Removing Slash

A contingent of scientists and environmental organizations oppose active land management. The Center for Biological Diversity, a vocal opponent to biomass power, instead advocates for leaving dead and dying trees to decompose in forests (CBD, 2021). Several studies of fire severity, speed, and extent in California forests found that pine beetle outbreaks that caused tree mortality did not exacerbate wildfires (Bond, Lee, Bradley, & Hanson, 2009; Hart, Schoennagel, Veblen, & Chapman, 2015; Meigs, Zald, Campbell, Keeton, & Kennedy, 2016; Hart & Preston, 2020). These findings suggest that mechanical thinning of pine beetle-infested forests may not be an effective wildfire mitigation technique.

Studies further indicate that both standing and fallen dead trees provide ecological benefits. A 2010 study of post-wildfire forested ecosystems found that dead trees provide habitat for surviving and colonizing species. It further found that some traditional forestry activities, including clearcutting and post-disturbance logging, reduce species richness and key ecological processes in these early successional ecosystems (Swanson, et al., 2010). This study indicates that sourcing biomass from forests that have recently burned decreases ecological diversity.

Studies of California's conifer forests similarly found that mixed-severity fires, which include patches of high-severity fire, produce complex early seral (intermediate) forests which support diverse and unique plant and wildlife species (DellaSala, Bond, Hanson, Hutto, & Odion, 2014; Hutto, et al., 2016). Such findings suggest that keeping some mixed severity wildfire on California's landscapes is ecologically beneficial (and impossible to eliminate – wind and weather will always ensure the presence of some high-severity wildfire).

Opponents of California's current wildfire plan also look to studies that concluded fuel treatments removed large amounts of carbon stocks from forests. In contradiction to findings summarized above, one study concluded that fuel treatments caused three times the loss of carbon as would be avoided by wildfire emissions (Campbell, Harmon, & Mitchell, 2012). Another study of Pacific Northwestern forests similarly found that fuel treatments removed more carbon from forests than were avoided in wildfire emissions (Mitchell, Harmon, & O'Connell, 2009). Winford and Gaither's study in California's northern Sierra Nevada came to the same conclusion when looking at forests with fire intervals greater than 31 years (Winford & Gaither Jr, 2012). The scope and geographic location of these studies support the assertion that in less arid forests or where fires happen infrequently, carbon storage is higher when no fuel treatment occurs.

Opponents of active forest management further argue that treated areas are unlikely to be exposed to fire at frequent intervals. This would either render the fuel treatment less effective over the timespan that fuels remain low (~20 years) or require even more frequent thinning treatments, which could be expensive (DellaSala & Koopman, 2015).[3]

Other experts assert that we should "work from the home outward" because home hardening and community resilience measures are more effective and economic wildfire strategies – at least from a built environment perspective – than active forest management (Bevington, 2021). This, coupled with updated zoning regulations that prevent development (or redevelopment) in most fire-prone areas, would be an economical wildfire response that also reduces the human cost of these natural disasters. Forest Unlimited argues that home hardening should be prioritized in wildfire strategies, but also supports thinning and prescribed burns where evidence shows they would make the most difference for emissions, carbon retention, and forest health (2021).

Many opponents to current California forest management espouse a perspective that all forest management is "logging in disguise" and that organizations or governments that do forest management are indistinguishable from the logging industry (Hanson, 2021). This distrust, likely based on past negative experiences of industry capture, ignores the possibility of ecologically warranted thinning.

As such, much of the discussion around how to manage California's forest conditions finds itself in a polarized state. There are scientific studies and respected organizations on both sides. The weight of evidence suggests that thinning and fuel removal with the goal of restoring mature forest conditions is likely to improve wildfire outcomes, even though in some circumstances there may be ecological, carbon, or economic reasons not to pursue this approach.

While the science around wildfire management and forest ecology is not entirely in consensus, the goal of this report is not to determine wildfire and forest management strategies for California. The two "sides" of this debate are likely not fueled by irreconcilable differences. Still, as the science develops, California is faced with an urgent problem, which is how to handle the biomass that is produced by current forest management practices according to existing state policy and how to improve pollution outcomes compared to today's status quo. Rather than settling the scientific debate, these are the questions on which we focus the rest of our analysis.

[3] This study, however, is from 2015, prior to more recent wildfire seasons that have increased the prevalence of large and severe fires.

Carbon Emissions and Air Pollution Profile

Bioenergy Should Not be Considered Carbon Neutral

Bioenergy is commonly viewed as a renewable and/or carbon neutral energy source. The California Energy Commission (CEC) lists biomass, biomethane (produced from digester or landfill gas), and biodiesel (produced from biomass or MSW) as renewable under its Renewable Portfolio Standard Eligibility guidebook (2017). The United States Environmental Protection Agency (EPA) treats emissions from point-source biomass combustion for electricity as carbon neutral (2018). The United Nations Intergovernmental Panel on Climate Change (IPCC), the world's leading authority on climate science, includes biomass combustion in its Agriculture, Forestry, and Other Land Use Sector and not in its Energy sector to avoid double counting (2021). Searchinger and colleagues argue that this essentially means the IPCC treats bioenergy as carbon neutral in most scenarios (2009).

The logic behind this assertion is that emissions from the use of bioenergy restore CO_2 to the atmosphere that was absorbed when biomass grew, thus leading to a canceling out of sequestration and emissions. In practice, however, there are several reasons why this equation rarely balances out.

One reason for this is that the timeframe relevant to efforts to stop climate change – one to three decades – is not enough time for biomass sources to regrow and capture the same amount of carbon as was emitted when used as bioenergy (Cherubini, Peters, Berntsen, Strømman, & Hertwich, 2011). As the Partnership for Policy Integrity, an anti-biomass organization, writes, "it takes seconds to burn a tree, and many decades to grow it back" (2011, p. 3). Similarly, it takes decades to centuries for a mature, old growth forest to reach its rich carbon stock levels. Even if logging companies replant trees after harvest and let them grow for a few decades, the total carbon stocks found in linear, monocultured tree stands are far lower than in mature, biodiverse forests.

A second reason bioenergy is not carbon neutral is that, in the case of clearcutting,[4] there is no guarantee or requirement that forests be allowed to regrow at all. New trees may be cut repeatedly, or land may be developed into other uses – meaning the emitted carbon will never be reabsorbed equally (CBD, 2021). As Searchinger and colleagues write,

> Bioenergy therefore reduces greenhouse gas emissions [compared to fossil fuels] only if the growth and harvesting of the biomass for energy captures carbon above and beyond what would be sequestered anyway and thereby offsets emission from energy use… Harvesting existing forests for electricity adds net carbon to the air. That remains true even if limited harvest rates leave the carbon stocks of regrowing forests unchanged, because those stocks would otherwise increase and contribute to the terrestrial carbon sink. (2009, p. 528)

Chatham House also asserts that whole-tree harvesting for energy use usually emits more than fossil fuel burning "because of the loss of future carbon sequestration from the growing trees – particularly from mature trees in old-growth forests, whose rate of carbon absorption can be very high – and of the loss of soil carbon sequestration upon the disturbance" (2017, p. 3).

Lifecycle Emissions Profile of Bioenergy

The combustion of wood without pollution controls yields more point source greenhouse gases (GHGs) than coal per unit of energy produced (Table 1). Biomass contains more moisture and less hydrogen, and

[4] Again, clearcutting forests for bioenergy is not a common scenario in California, but clearcutting remains an illustrative example for the purposes of the emissions accounting and carbon neutrality discussions.

is less energy dense, than fossil fuels, and as a result, it is less efficient to combust and produces more emissions per unit energy (Chatham House, 2017). Many coal plants operate at a thermal efficiency between 40-45%, and most biomass plants operate at 20-35% thermal efficiency (Chatham House, 2017).

Source	Wood	Anthracite	Bituminous	Lignite	Natural Gas
Carbon dioxide	112,000	98,300	94,600	101,000	56,100
Methane	30	1	1	1	1
Nitrous oxide	4	1.5	1.5	1.5	0.1

Table 1. GHG emissions from wood, coal, and natural gas. Units for all numbers are in kg CO_2/TJ (1 TJ = 278 MWh). Adapted from Chatham House, 2017.

Drax, an energy company in the United Kingdom, reports GHG emissions intensities of 856 kg CO_2/MWh (megawatt-hour) for its coal units and 965 kg CO_2/MWh for its biomass units (Chatham House, 2017). The Schiller power station in the U.S. Northeast reports emissions of 1,243 kg CO_2/MWh for its coal boilers and 1,444 kg CO_2/MWh for its biomass boilers (PFPI, 2012; Chatham House, 2017).

In addition to the methane, nitrous oxide, and carbon dioxide emissions quantified in Table 1, biomass combustion also releases particulate matter (PM), sulfur dioxide (SO_2), and volatile organic compounds (VOCs), all of which are pollutants that contribute to reduced air quality and poor health outcomes. Biomass is more polluting than coal for PM and VOCs, and less than coal for SO_2 (Booth, 2014).

Lifecycle emissions, however, depend on the purpose and source of biomass generation. Within the California context, utilizing byproducts of sustainable forestry for bioenergy may offer emissions benefits and result in the release of fewer criteria air pollutants than alternative methods of disposal. California's plan to treat a million forested acres annually will produce an enormous quantity of slash over the next several years. There are several possibilities, with differing pollution profiles, to consider for this biomass. These possibilities include:

- Chipping and/or leaving slash in forests to decay
- Burning the biomass in open piles in forests
- Combusting biomass in bioenergy facilities
- Gasifying biomass in bioenergy facilities

Some environmental advocates argue that these forest management byproducts should be left in forests to decay. This usually comes from a desire to preserve forest carbon stocks. California forests are, however, overstocked with carbon to the point of putting them into a risky state of unhealth.

The pollution profile of this option depends on whether leaving slash in forests to decompose results in a higher likelihood of wildfire or increased wildfire emissions. As discussed in detail in the previous section, numerous studies indicate that leaving slash to decompose in California's coniferous forests increases the risk of high-severity wildfire and associated emissions of CO_2, black carbon, methane, and criteria air pollutants (Evans & Finkral, 2009). Vegetation overstocking in forests has also more than tripled emissions per acre in present-day wildfires compared to wildfire over a century ago under Indigenous management and prior (CARB, 2021).

The increased risk of wildfire and associated emissions leads most forestry professionals to conclude that leaving slash in forests is not a viable option for biomass disposal. Indeed, this approach would leave behind such extreme fuel loads that it would not meet basic standards in CAL FIRE's Forest Practice Rules.

In California, most of the biomass that is currently produced from forest management is open burned in piles. Compared to this option, biomass combustion using boilers performs significantly better in terms of their pollution profile. Biomass facilities reduce NO_x by 54%, PM by 96%, CO by 97%, CO_2 by 15%, and methane by 96% compared to open pile burning of biomass (Springsteen, Christofk, & Eubanks, 2011). Biomass gasification offers an even cleaner emissions profile than combustion. One study found that gasification performs better than combustion on 5 of 8 environmental variables, including 29% lower CO_2 emissions, 73% lower fine particulate matter emissions, and 79% lower NO_x emissions (Briones-Hidrovo, et al., 2021).

These studies suggest that removing biomass from forests where ecological thinning has occurred reduces the risk of high severity wildfire and associated emissions. They further support the assertion that compared to the current practice of pile burning the byproducts of forest management, combusting or gasifying this biomass in a bioenergy facility leads to reduced GHG and criterion air pollutant emissions.

The impacts of forest management and bioenergy on carbon stocks is also a subject of controversy between scientists in the forestry profession. Several studies of forests in the Pacific Northwest led to the conclusion that forest management removes significantly more carbon from terrestrial stocks than it prevents in wildfire losses (Campbell, Harmon, & Mitchell, 2012; Mitchell, Harmon, & O'Connell, 2009). Winford and Gaither's study in *Forest Ecology and Management* brought more specificity to this claim. It found that when fire intervals are greater than 31 years, forest management decreases terrestrial carbon stocks (2012). However, Winford and Gaither also found that for forests with fire intervals less than 31 years, forest carbon stocks are higher after fuels treatment and bioenergy use than if these forest tracts were left alone. A study by Stephens and colleagues found that the median fire return interval in California forests prior to European fire suppression was 13.4 years (2007).

When slash is removed from forests with high risk of wildfire and frequent fire return intervals – which is becoming more common as wildfires grow in frequency and intensity – bioenergy use increases terrestrial carbon stocks. From a lifecycle emissions perspective, assuming that biomass comes from ecological thinning, displaces fossil fuels, and reduces wildfire emissions, it can reduce overall emissions compared to present levels.

Environmental Justice

Environmental Justice Concerns with Large Biomass Facilities

Opposition to utilizing biomass for energy in California is further linked to its historic issues with criteria air pollution and environmental injustice. In the 1980s and '90s, the state supported the construction of several large biomass power plants which, at the industry's peak, supplied over 800 megawatts (MW) of electricity to the state. With the passage of SB 771 in 2011, California created the Biomass Development Program to financially support new biomass projects in the state. About 30 of these facilities are still in operation today, averaging 21.3 MW in capacity (CEC, 2021).

Commercial scale facilities created in this early wave of biomass power are associated with a plethora of environmental justice issues. Due to their location, they require expensive long-distance transportation of the biomass, usually on polluting diesel trucks. These large biomass power plants emit several toxic air pollutants and are among the worst polluters of NOx and particulate matter in California (CBD, 2021).

In the San Joaquin Valley, 80% of both active and previously active biomass plants are in disadvantaged communities (CBD, 2021). As defined by SB 535, disadvantaged communities are those in the state with scores in the top 25% of CalEnviroScreen 3.0, a tool that calculates pollution burden and vulnerability

(OEHHA, 2018). Many low-income Central Valley communities already experience some of the worst air quality in the country, poor human health outcomes, and droughts made more severe by climate change.

While the older model of building large-scale facilities in disadvantaged communities is no longer as prevalent, new biomass power projects still cause hesitation among communities concerned with environmental justice. Dr. Jonathan Kusel, founder of the Sierra Institute, confirmed that one group he spoke to from the Central Valley had categorical concerns about biomass energy. Yet he found that they agreed with his position on building smaller facilities closer to forests. Some communities have also expressed concerns about how the consolidation of agriculture, linked to scaled up anaerobic digestion of manure and other agricultural feedstocks, may lead to worsened air quality. While agricultural biomass presents a somewhat different problem set compared to forest-sourced biomass, Kusel advocates for addressing these air quality concerns relating to biomass by having biomass facilities be built and run by local communities rather than outside industry (Kusel, 2021).

Scale is a key feature that led to negative outcomes from these plants. Because they were relatively large facilities, their pollution emissions were sizable and exacerbated poor air quality in their locales. In addition to their emissions footprint, the size of individual facilities and the number of facilities (~30) in operation led to another problem. The total power supplied by these facilities means that keeping facilities running profitably and consistently enough to meet their power generation expectations requires a constant flow of biomass feedstock. This can create a demand pull from industry that applies pressure to keep a steady stream of biomass coming from forests. (While this concern speaks to the need to ensure environmental, not industrial, outcomes from thinning practices, California may be a long way from this point. There is currently excess material that lacks offtake avenues: most mills are at capacity with burned trees and existing bioenergy capacity is too small to absorb a meaningful amount of total material.)

Any new facilities should create demand equal to, and not more than, the quantity of biomass generated from ecologically warranted forest thinning. This would avoid creating an industry that seeks to commercialize forest products beyond the point that is environmentally beneficial.

EJ Opportunities with Community-Scale Biomass Facilities

When done properly, bioenergy advocates claim that new projects in the state have the potential to create opportunities for environmental justice and equity. Facilities on a smaller scale and closer to the forest source may provide economic opportunities in rural areas, offering support to these often-ignored communities. This possibility is discussed in greater depth below.

Implementing TEK and reinstating Indigenous peoples' sovereignty over land management are also justice-related opportunities associated with creating new, smaller-scale biomass projects in the state. Indigenous leaders advocate for reincorporating tribes and tribal communities into forest management decision-making (Goode, et al., 2018). Doing so would mean utilizing TEK to reintroduce fire as a management tool to California's landscapes (Kimmerer & Lake, 2001).

A study about community impacts from wildfires in California found that the Census tracts suffering from the worst effects of wildfire are disproportionately elderly, white or Native American, and low-income (Masri, Scaduto, Jin, & Wu, 2021). Managing forests in a way that reduces the disproportionate impacts of wildfire is also important for ameliorating environmental injustice.

Impacts on Rural Employment

Biomass facilities, depending on their size and location, can impact employment and rural economic growth. The forest products industry includes about 25,000 workers in California, including scientists and professional foresters (Cal Forests, 2021). Within this, biomass facilities employ around 750 workers directly and are supported by an additional 1,500 indirect employees (CBEA, 2021).

To date, only 15.8% of the total capacity of Category 3 BioMAT facilities authorized by SB 1122 have come to fruition (CPUC, 2018; SB-1122, 2012). Back of the envelope calculations suggest that if new community-scale biomass facilities are built, the BioMAT program could employ roughly 5.3 times more rural workers than it does currently.

A report by the Sierra Business Council points out that in one community, the reopening of a mill to process biomass created 21 jobs – a meaningful amount in a community of less than 800 (2019). The report states that such jobs "are significantly higher paying and more reliable as long-term employment, especially when compared to the recreation and hospitality sector jobs that have replaced many of the viable jobs in natural resource dependent communities through the Sierra" (SBC, 2019, p. 27).

It is worth noting that community and environmental NGOs that are based in and work in the rural, often mountainous communities where biomass is produced tend to strongly support community-scale biomass. Such organizations include the Sierra Institute for Community and Environment (2021), the Central Sierra Environmental Resource Center (2021), and the Sierra Business Council (2019).

Economics and Policy Landscape

Existing Policy Support

Sept. 27, 2012	Oct. 30, 2015	Mar. 17, 2016	Oct. 2018	Aug. 27, 2020
SB-1122 passes and establishes BioMAT program	Governor Jerry Brown releases an Emergency Order on Tree Mortality	CPUC establishes BioRAM program	CPUC staff review and recommend changes to BioMAT program	CPUC implements changes to the BioMAT program

Table 2. A high-level timeline of relevant bioenergy policy developments in California.

In September of 2012, Governor Jerry Brown approved SB-1122, "an act to amend Section 399.20 of the Public Utilities Code related to energy" (Table 2; SB-1122, 2012). It established the Bioenergy Market Adjusting Tariff (BioMAT) program to offer eligible bioenergy projects a total of 250 MW of fixed-price standard contracts with the state's largest investor-owned utilities (IOUs): PG&E, SCE, and SDG&E (CPUC, 2021). Within this program, the 250 MW are broken up by category of bioenergy as follows:

- **Category 1:** 110 MW of biogas energy from organic waste and wastewater treatment
- **Category 2**: 90 MW of bioenergy from dairy and other agricultural processes
- **Category 3:** 50 MW of biomass energy from byproducts of sustainable forest management

This report focuses primarily on Category 3 bioenergy projects. These facilities must be no larger than 5 MW, and no more than 3 MW may be sold through the grid (Swezy, Rodgers, & Kusel, 2020).

Three years later, Governor Brown declared a state of emergency regarding tree mortality and wildfire risk (Brown, 2015). He ordered the CPUC to create a targeted renewable auction mechanism that would ensure contracts for bioenergy facilities that receive feedstock from high hazard zones (HHZ) in California's forests. In response, the CPUC established the BioRAM program in March of 2016. This program requires IOUs to contract 146 MWs of energy from facilities that use HHZ fuel (CPUC, 2021). Notably, the program does not cap capacity of eligible bioenergy plants, resulting in most contracts falling to 20-30 MW facilities (CPUC, 2016; CPUC, 2021). Each year, these facilities are expected to increase the percentage of their feedstock derived from HHZs to reduce wildfire risk. BioRAM requires the following from its contracted facilities:

- At least 40% of fuel from HHZ in 2016
- At least 50% of fuel from HHZ in 2017
- At least 60% of fuel from HHZ in 2018
- At least 80% of fuel from HHZ for each subsequent year

In October of 2018, CPUC Staff reviewed the BioMAT program's successes and challenges to date. One of its most notable insights was the fact that prices remained high under the current program design. This could be attributed to low program participation; only three Category 3 facilities totaling 7.9 MW of capacity were contracted as part of the program (CPUC, 2018).

The review also found that several BioMAT facilities were located in disadvantaged communities, as defined by SB 535, and could be negatively impacting local air and water quality (though no forest BioMAT facilities are in disadvantaged communities). This indicates some clear environmental justice issues with existing BioMAT projects. However, it does not necessarily indicate whether the lifecycle emissions of the facilities are net positive or negative. According to the report, this still depends on "the extent to which the project prevents the biomass feedstock from combusting alternatively, whether through open-pile burning, wildfires, or prescribed burns" (CPUC, 2018, p. 11).

The 2018 Staff Report recommended changes to the BioMAT program, and in August of 2020, the CPUC implemented several of them. To mitigate tree mortality and wildfire threat, the CPUC created a new temporary requirement for BioMAT mirroring that of BioRAM: 80% of fuel stock for Category 3 plants must come from HHZs. While the program initially capped eligible facilities at 3 MW, CPUC increased capacity for eligible facilities to 5 MW. To see how these changes would affect the success of the program, the CPUC also extended the program to February of 2026 (CPUC, 2021; CPUC, 2018).

Economic Viability of Bioenergy

The economic viability of using biomass combustion or gasification energy in California depends on several factors. First, it depends on the current estimates for the cost of creating one unit of energy from biomass, a measurement known as the levelized cost of energy (LCOE). LCOE averages all fixed and variable costs and divides this total by the quantity of energy a facility is expected to produce in its lifetime. As of 2019, the CEC estimates the LCOE for a 20 MW biomass facility at around $166/MWh (Neff, 2019). While this estimate is useful, it is important to note that this simplistic figure may not be an accurate measurement for all biomass projects in the state. Differences in facility size and hauling distance, for instance, may influence the cost of a given project. Most notably, this $166/MWh estimate is for a 20 MW facility, while the state's BioMAT program supports facilities no larger than 5 MW, for which economic challenges are more acute (CPUC, 2018).

Second, it depends on how these costs compare to the offer price for biomass. In 2018, the offer price for forest biomass was $199.72/MWh, coming in above the state's LCOE estimate for forest-sourced bioenergy (CPUC, 2018). Given that the offer price falls above the LCOE, bioenergy is currently projected to be a profitable investment. But given the potential uncertainties in the LCOE, returns on this investment are not guaranteed; and some plants with higher contract prices have recently closed due to competition from lower cost energy sources. Projects under BioRAM tend to receive a lower price and consequently face tighter economic margins.

Further complicating this analysis, subsidies on bioenergy affect the purported profitability of the industry. SB 1122 requires California public utilities to purchase 50 MW of energy from forest-sourced woody biomass (SB-1122, 2012). This requirement forces utilities to purchase bioenergy at the price ceiling set by the CPUC, effectively subsidizing bioenergy plants (CPUC, 2018; CBD, 2021). Bioenergy advocates argue that these subsidies are necessary to incentivize investment in bioenergy that would decrease costs in the future. Comparably, early subsidies for wind energy led to a drop in the LCOE from over $150/MWh in the 1980s and 1990s to $50/MWh by the early 2000s (Lantz, Hand, & Wiser, 2012). Contextualized by these historical trends, reliance on subsidies today may not determine whether bioenergy will be economical in the future. Since many forms of energy relied on subsidies early in their development, subsidies for bioenergy today do not disqualify it as a worthwhile energy source.

Finally, whether these subsidies are justified depends in part on alternative options for baseload renewable energy. Baseload power refers to the minimum amount of energy that power generators must collectively supply to the electricity grid at any given time (Hanania, Stenhouse, & Donev, 2020). Given that solar and wind are intermittent sources, a portfolio that consistently supplies baseload levels must include a source of energy capable of generating at any time of the day.

Biomass, geothermal, and hydroelectric power are some of the only sources of renewable baseload energy to date (CEC, 2021). Hydropower is relatively inexpensive but comes with significant environmental costs. Geothermal energy, on the other hand, is comparable to biomass with an estimated LCOE of $110-$140/MWh (Neff, 2019). In this context, bioenergy appears a more economically viable and sustainable option for energy portfolios than LCOE estimates alone suggest.

Conclusion: Recommendations and Solutions

Criteria for Just, Economical, Environmentally Sound Biomass Utilization

In light of the continued and increasing production of woody material from wildfire management in forests, the presence of facilities to utilize this biomass is important. In comparison to open burning and landfilling, using biomass for electricity or heat production reduces pollution and creates opportunities to sell electricity and meet community power needs.

We propose that any new biomass facilities meet the following criteria:

1. Feedstock comes only from ecological thinning, mill residues, or home hardening and defensible space practices as opposed to logging activities
2. Small-scale – 5 MW or less, in accordance with BioMAT program requirements, or slightly larger facilities approved on a case-by-case basis
3. No more facilities are built than are needed to process the wood waste associated with sustainable forest management activities within a reasonable distance of the facility. This avoids creating an industrial complex that requires constant and increasing feedstock
4. Companies engage local communities for input and collaboration in the planning, design, and deployment of new facilities
5. Facilities are located close to the sources of biomass production, which tend to be rural and mountainous locales, to reduce emissions and costs of long-distance shipping; facilities will not be sited in already over-polluted Central Valley communities

6. When feasible, new facilities should use gasification or pyrolysis technologies, along with the best available emissions controls, to minimize GHG impacts
7. When possible, feedstock is produced by work crews that create jobs for local communities and Indigenous peoples

Such facilities are often termed "community-scale," and one such example exists in Plumas County (Swezy & Kusel, 2021). Facilities like these can help address important environmental justice concerns that largely stem from inequitable and polluting bioenergy deployments in the Central Valley. The Plumas County facility is too small by itself to make a dent in the waste disposal need, but it serves as a useful template for replication. Large-scale facilities that require long-distance shipping and worsen air quality in the Central Valley are unacceptable from a justice and climate perspective. Rurally located facilities would not worsen air quality in the Central Valley and would not require expensive and polluting long-distance feedstock shipping.

Not only does community-scale biomass avoid exacerbating some inequities, it offers opportunities to redress them as well. Such facilities could create employment opportunities in rural settings far from the urban centers that drive most of the state's economic growth. Much of the strategy that would underpin community-scale biomass development would include TEK. Reincorporating TEK and forming partnerships with Indigenous peoples also offers justice for communities who were forced to abandon their lands and cultural practices. The Sierra Institute recently received a grant from the state's High Roads Training Partnership to train local and Indigenous work crews to perform forest thinning. Rural job creation and Indigenous partnerships are forms of justice that should not be overlooked.

Keeping the biomass industry at an appropriate scale is crucial. A biomass industry characterized by community-scale facilities would need to be watched carefully to ensure that the presence of these facilities does not create a demand pull for forest feedstocks beyond that which is produced by ecologically warranted thinning. This would preempt a similar scenario from developing that exists in the Southeast, where forest clearcutting increased in response to new European market opportunities. Distributed, small-scale facilities are less prone to creating a "monster that must be fed" than centralized, large-scale facilities. Material availability should drive the operation of facilities rather than industry driving the demand for material.

Modeling by state agencies should determine how much biomass land managers expect to produce over a 10- to 20-year period so that the appropriate number of facilities – and not more – are built to handle that feedstock quantity. The state could then issue permits for new facilities only up to the amount needed for ecological restoration and fire mitigation.

We also recommend permanently closing the most polluting large-scale biomass facilities in disadvantaged communities or places with high air pollution burdens. The resulting power gap should be replaced by new clean energy installations such as solar or wind power. The feedstock that powered these facilities should be used close to the point of production in community-scale facilities.

Finally, more information would ensure that community-scale biomass deployments stay within bounds for air quality and climate. First, universities or state agencies should undertake further research to establish more clearly whether forest thinning reduces the incidence and intensity of wildfire and decreases the loss of carbon in California forests. Similarly, the same actors should produce more accurate and detailed data on the emissions profiles of community-scale biomass plants – especially given that the state is offering subsidies to support their operation. The Climate Center would support the strictest air quality and GHG standards practical for these plants.

Implications and Opportunities for NGOs and Policymakers

Conversations around biomass utilization in California can spark contentious discussions. The intersection of justice, climate change, forest management, policy, and economics make achieving the right solution a challenging but achievable feat. With the right criteria, biomass utilization avoids unjust outcomes and maximizes environmental and economic benefits.

There is polarization between environmental NGOs about biomass utilization, and yet we found surprisingly little direct conflict between the talking points of advocates on either side of the debate. Biomass opponents emphasize the harms of sourcing biomass from wet Southeastern forests, of operating large powerplants in the pollution-burdened Central Valley, and of forest logging instead of ecological thinning. Proponents highlight the need for a better waste disposal option for forest-sourced biomass, emissions benefits of biomass combustion relative to open pile burning in California's dry forests, and potential economic opportunities it could provide if converted in small, local, community-run facilities. NGOs can make progress on this issue by stepping away from a black and white framework and coalescing to advocate for the many points on which they can find common ground.

The Climate Center is focused on driving a highly ambitious climate action agenda for California. The Center's Climate Safe California (CSC) campaign advocates for accelerating the state's climate goals by 15 years to a net-negative emissions scenario by 2030. CSC supports policies that will foster a just transition, climate justice and equity, and the phaseout of fossil fuels as rapidly as possible. If implemented, CSC would require a wartime-like mobilization of resources and an unprecedented level of policy and governmental coordination. This is the level of urgency the climate crisis demands – and there is ample science to justify this scale of action (Kammen, et al., 2021). We do not believe these climate goals are inconsistent with support for community-scale biomass-generated power.

If California were a state where destructive and intense wildfires did not threaten forests; where forests were not in a state of poor health due to European colonists' strategies of historic logging and fire suppression; where there were not immense quantities of biomass produced by forest management; and where there were sufficient waste disposal solutions for biomass, this discussion would reach a different conclusion. But these scenarios do not reflect California's present reality. To make matters worse, the current solution to handling biomass is no solution at all – open burning and landfilling are the worst possible outcomes for air quality and climate.

A better solution is needed, even if not the perfect solution. Forest mismanagement, combined with drought and wildfires worsened by climate change, suggest that the removal of live fuels from forests is an important mitigation approach. For centuries, Indigenous tribes maintained forest health. Forests may store an artificially large amount of carbon today because they are overstocked and out of balance, creating fuel loading conditions that make wildfires worse.

For these reasons, it is prudent to allow for community-scale biomass facilities that meet the criteria listed above. These offer rural economic opportunities and a non-fossil fuel source of baseload energy. They also improve climate, justice, and air quality outcomes compared to the present reality.

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