Paying For Forest Health: Improving the Economics of Forest Restoration and Biomass Power in California

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ABSTRACT

Forest restoration treatments throughout California's forestlands are needed to restore landscapes to a more resilient state in the face of climate change, tree mortality, and higher risk of catastrophic wildfire. This report investigates the numerous economic activities associated with biomass utilization that are essential to the development of restoration needed to sustain California's forests and watersheds. Best forestry practices involve treatments that include thinning small diameter trees and removing biomass material. Investment in landscape restoration alone is incomplete; there must also be investment in biomass utilization technologies because forest restoration and fuels reduction treatments are expensive and the removed residual material has low monetary value.

This report discusses ways of improving forest restoration economics, and highlights community scale bioenergy development and related businesses as a critical pathway to best restoration practices. Biomass power plays an important role in advancing landscape-scale forest restoration as it provides an outlet for the lowest-value residual biomass material and can offset costs of forest restoration and biomass hauling; by itself, however, it typically does not offset enough of the costs and requires subsidy. Biomass power plants co-located with waste heat-utilizing businesses (that secure revenue via heat sales) or integrated with other co-product development operations can pay higher premiums for feedstock. Related co-product businesses discussed in the report include woodchips, firewood, posts and poles, mass timber, wood pellets and shavings, and biochar. In addition to producing electricity, biomass conversion technologies such as gasification and pyrolysis can produce liquid fuels, natural gas and hydrogen that, coupled with carbon capture and storage, represent a primary pathway for California to achieve carbon neutrality.

Payments for ecosystem services (PES) are necessary to stabilize the long-term economics of market pathways for low-value biomass material as well as to address the extent of restoration treatments needed. PES and payment for technologies to achieve carbon neutrality can support restoration work that leads to healthy forests and watersheds. In this way restoration generates income that can be reinvested into the land, support rural communities, and additional restoration needed to sustainably maintain healthy forests and watersheds on which all Californians rely.

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Introduction

An example of a typical stand of overstocked mixed conifer forest in California with high fuel load.

This report focuses on identifying pathways to improve handling efficiencies of woody biomass, markets for biomass, and mechanisms to support forest restoration to tackle California's forest health crisis. As the number of California wildfires increase along with their destructiveness,[1] the need to increase the pace and scale of restoration across the state's forested landscapes grows.

Restoration of California's forests makes them less susceptible to high severity, destructive burning and more resilient to climate change. Critical restoration practices include thinning small diameter trees and removing flammable biomass[2] material, and includes the reintroduction of fire on the landscape. Reintroduction of fire on the landscape has an important role in forest restoration, but it is beyond the scope of this report, as many forested acres must first be thinned to allow fire to be reintroduced.

Forest restoration activities are expensive due to the costs of harvesting, transport, and limited markets for the material. Because markets for biomass material are limited, those involved in restoration are challenged not only to pay for the work without subsidy, but also to find places to take the byproducts of restoration.

The result is that forest restoration is left undone or biomass is left piled in the woods and burned later when air quality, moisture, and weather windows allow.[3]

The State of California has recently embarked upon a five-year program of investment in forest restoration totaling one billion dollars. Investment in the additional infrastructure to utilize restoration byproducts like biomass, however, is lacking. This investment is essential to increase pace and scale of restoration, as well as for a long-term landscape restoration program to succeed.

Cost effective biomass harvesting and development of businesses to create value-added wood products from biomass are needed to improve the economics of forest thinning and restoration activities in California.

Energy generation from woody biomass has long been the primary outlet for low-value material in California and remains a critical pathway to increased biomass utilization.

To incentivize market opportunities for biomass power facilities, state legislators passed Senate Bill 1122 in 2012, requiring the state's Investor Owned

1 See, for example, Miller and Safford, 2012 and Miller et al., 2009.
2 "Biomass" in the context of this report refers to forest biomass, primarily byproducts of forest restoration and fuels reduction activities
3 This does not include material left on the forest floor after mastication, involving mulching or reduction of forest vegetation into small pieces.

The Moonlight Fire burned 65,000 acres in the northern Sierra, with more than 60% burned at high severity.

Utilities (IOUs) to procure biomass energy from community-scale bioenergy facilities—initially 3 MW or less in size and launching the Bioenergy Market Adjusting Tariff (BioMAT) program. Stimulating utilization of residual biomass material by BioMAT facilities is an important step to advance forest restoration, yet development of this infrastructure requires subsidy and development of markets to support co-product development and co-located heat-using businesses. Subsidies include a combination of grants and loans to pay for community-scale BioMAT plant construction and operational costs.

The report begins with a review of forest restoration and how bioenergy and co-product development contribute to forest restoration in the state. Senate Bill 1122 and the BioMAT Program, including a discussion of the challenges and benefits of community-scale bioenergy facilities are also briefly reviewed.

The report then highlights bioenergy development and related businesses as a critical pathway to restoration. Related businesses involve co-product development, which includes a variety of wood products that when produced on a single site create an integrated wood product yard, or what is described in this report as a wood utilization campus.

Bioenergy development and co-located businesses are critical pathways to landscape restoration because the two create a critical self-reinforcing and financing feedback loop: bioenergy development increases the value of biomass and restoration work, and increased value of biomass, in turn, leads to increased restoration work. In a recent report, Lawrence Livermore National Laboratory (2020:44) recognized this relationship stating: “It is possible that, as a consequence of increased demand for residues, more forest management would occur additionally to the Forest Carbon Plan goal” [of California]. Community-scale bioenergy development also reduces negative environmental and climate impacts by utilizing biomass in new, clean bioenergy facilities that can offset fossil fuel use.

The report concludes with a discussion of payment for environment services (PES). Securing payments for a diverse array of environmental services is a step California must take to pay for restoration. PES represents the additional and continuing revenue needed for long-term restoration to reduce the risks of catastrophic fire and increase climate resilience of California forests and watersheds that are vital to the health of all of California.

Forest Restoration through Biomass Removal

Making the Case: Catastrophic Wildfire and Need for Forest Restoration

The Feather River Watershed offers a powerful example of the impacts of catastrophic wildfire. As home to the California State Water Project serving 25 million Californians, the impacts to habitat, water flow, hydropower, recreational, economic, community interests and more in this watershed are as important as anywhere in the state. Over the last 13 years, fires in the Feather River Watershed have ranged from small fires that have threatened critical infrastructure and communities, to the massive 2018 Camp Fire, the most destructive fire in California's history. (See the North Fork Feather River Major Wildfires Map and Table 1 located on pages 4-5, for a list of major wildfires since 2007, acres burned, suppression costs, and other impacts.)

The scale and severity of these fires have left considerable impacts on the surrounding area as well as impacts to "downstream" (and downwind) urban residents, ranging from short term impacts such as harmful emissions, destruction of property, and loss of life, to more long term impacts including compromised watersheds, loss of timber supply, and depleted carbon stores. Current restoration costs for the infamous Camp Fire (2018) that destroyed the town of Paradise has, as of writing, amounted to over ten billion dollars and requires continued efforts. On a smaller scale, the Chips Fire (2012) blanketed the town of Chester and the greater Lake Almanor community with heavy smoke for the month of August, extinguishing one-third of the economically vital summer tourist season. Economic damage from this fire and harm to human health was locally restricted, quite unlike the dangerous emissions of the Camp Fire that spread over northern California, including the Bay Area and Sacramento.

Addressing the Challenge

California's forests require investment to restore resilience following a century of fire suppression, poor harvest practices, reduced active management, and the impacts of drought and climate change. Wide social agreement around the value of reducing wildfire threat and improving forest resilience to drought, insects, and disease is leading to an increased number of restoration projects that reduce the likelihood of stand-destructive wildfires and create forests that can better withstand climate change. Best practices involve removal of small-diameter trees, limbs, and other low-value woody biomass sourced from commercial and restoration treatments and reintroduction of fire on the landscape. This report focuses on the former item because many areas require fuels reduction to enable reintroduction of fire, and because discussion of it is described extensively by others.[4] Removal of small-diameter trees, limbs, and other low value material face two major challenges: 1) the high cost of forest treatments, and 2) the lack of markets and infrastructure that utilize small-diameter wood.

Removing small-diameter trees and forest residue to create resilient forests is expensive; markets and costly infrastructure needed to utilize and support restoration projects for the most part do not exist. This is the root of the forest restoration treatment problem.

Historically, restoration and biomass utilization have been supported, or "carried," by integrating the harvest and sale of large diameter sawlogs into the management activity (Lord et al 2006), and by transportation subsidies for delivery of biomass to conversion facilities and power plants.[5] (See a discussion of the results of transportation subsidies below in Box 1 on page 6.) Today, timber sales are designed in ways that encourage, but do not require, small tree and waste material harvest and removal. For many federal contracts removal of this material is optional. The result is that small material is often left on site due to high removal costs and limited market value. Though some timber harvest projects involving biomass removal are financially viable, the vast majority are not (Evans et al., 2009).

4 See, for example, Fiedler et al., 1998; Lake et al., 2017; and Moritz and Stephens, 2008.
5 See, for example, https://www.fsa.usda.gov/programs-and-services/energy-programs/BCAP/index or https://ucanr.edu/sites/WoodyBiomass/Grants/FSA_Biomass_Crop_Assistance_Program_888/

North Fork Feather River Major Wildfires 2007-2019

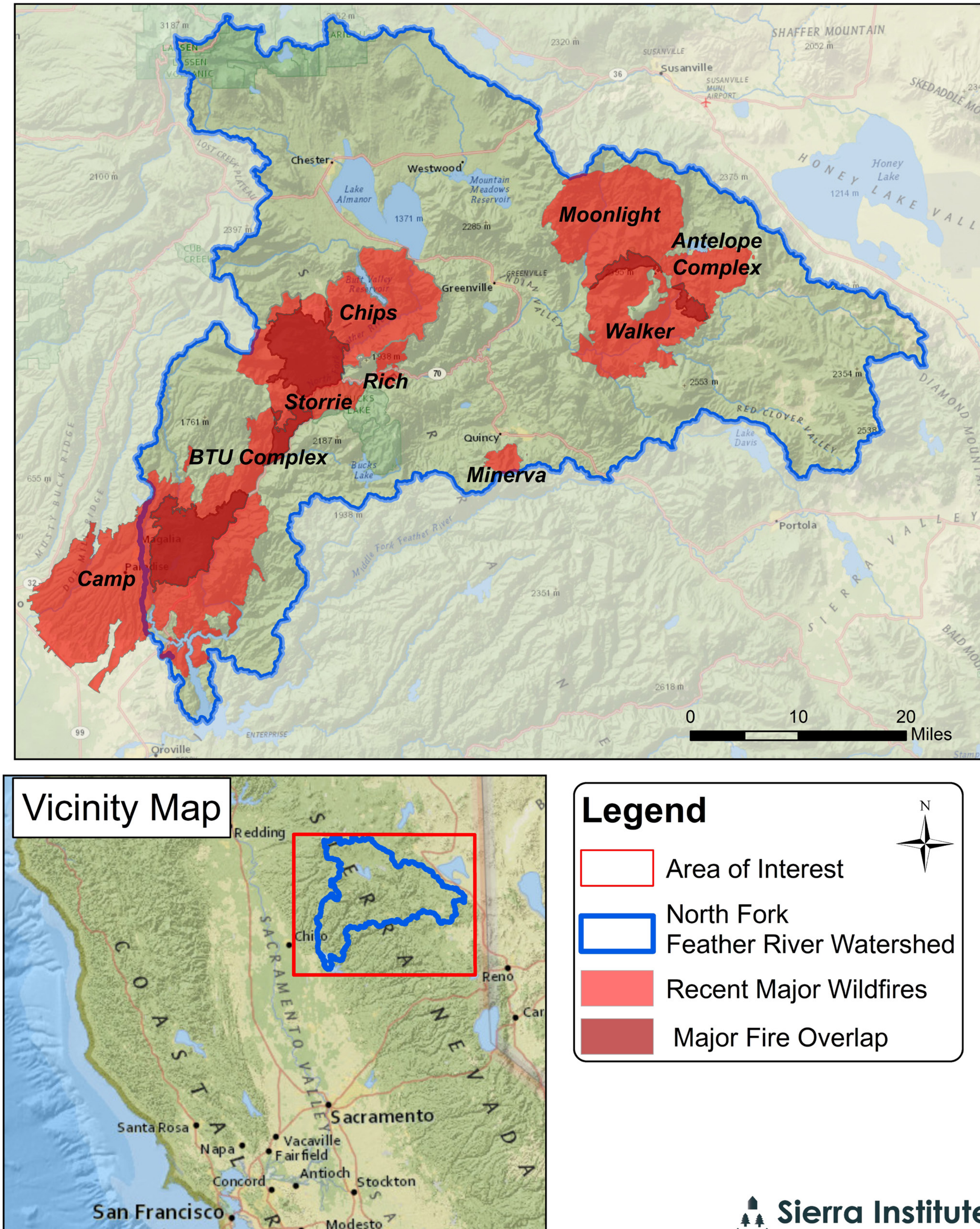


Table 1: Fires in the Feather River Watershed: The Cost of the No-Action Alternative

Fire	Acres	Suppression Costs[1]	Other Impacts of Note
Moonlight Fire (2007)	65,000	$31.5m 2,300 personnel	• >60% high severity • Closed local schools for a week • 7 structures destroyed • Burned protected areas for California spotted owl and goshawk • Over 40% of the burned landscaped was old forest and is now a shrub complex
Antelope Complex (2007)	23,420	8.4m	• Around Antelope Lake, owned/managed by CA Department of Water Resources for State Water Project • Burned spotted owl and goshawk habitat
BTU Complex (2008)	59,440	$25.8m	• 41 fires in lightning complex • 1 fatality • 69 injuries • 106 homes burned • Threatened hydropower plants and transmission lines in Feather River Canyon
Rich Fire (2008)	6,100	$4.7m 1,066 personnel	• Destroyed two structures
Chips Fire (2012)	75,431	$55m	• Choked Almanor Basin with smoke for month of August, shortening the tourism season by one-third and closing businesses • Threatened critical PG&E power infrastructure • Cost well over $1 million to de-power and re-power lines during the fire
Minerva Fire (2017)	4,310	1,800 personnel	• While this fire was small, the fire burned in very close proximity to Quincy, resulted in an evacuation of a youth camp and prompted numerous volunteer evacuations, hence, was heavily staffed
Camp Fire (2018)[2]	153,336	Tens of millions of dollars (over 600 engines and 5,600 firefighting personnel at peak), but does not include damage estimates of over $10 billion	• 86 fatalities • 13,972 residences destroyed • 528 commercial buildings • 4,293 other structures • Toxic residues from burning • Extensive smoke and dangerous emissions • Contaminated water supplies
Walker Fire (2019)	54,612	>$37m	• 9 structures destroyed

Table 1 Footnotes

1 From USFS data.
2 The Camp Fire is included here because the majority of burned areas were in the Feather River Watershed.

Box 1.

Biomass Crop Assistance Program: Is it effective?

Some hauling subsidies have been introduced in the last decade to support the high costs of treating and hauling biomass to a distant power plant. USDA's Farm Service Agency offers the Biomass Crop Assistance Program (BCAP) to assist forest landowners and operators with the collection, harvest, storage, and transportation of eligible material for use in biomass power facilities, provided that material is from hazardous fuels reduction or other activities resulting in low value material below the product value market. Criticisms of the program include that it distorted prices and supply of biomass without necessarily creating any new biomass supplies, and resulted in higher prices for customers ineligible to participate in BCAP, such as particleboard makers (Kemp et al, 2011).

Perhaps more importantly, BCAP subsidies may result in larger, older biomass facilities with "grandfathered" or old emissions control equipment—many in the Central Valley—operating with what amounts to subsidized chips with haul distances approaching 100 miles. Also, BCAP subsidies went to businesses that moved the fastest, typically some of the higher capacity, well off operations. Demand for BCAP subsidy vastly exceeds available dollars.

To date, no programs have been established to directly subsidize haul costs to BioMAT or other community-scale biomass facilities.

With no financially viable avenue for removal, it is common for contractors performing restoration treatments to leave piles to be burned, or large decks of biomass on landings to decay.

Treatment costs vary as a result of many site-specific and operational variables (Evans et al., 2009), as well as whether administrative costs are included in a per-acre cost for restoration, or an unseen overhead cost. For example, site conditions including forest type, density, age, slope, and elevation all affect cost, as do operational factors including the silvicultural prescription and harvesting machinery used. In California's southern Sierra, Yosemite Stanislaus Solutions, a collaborative group focused on forest restoration, estimate treatment costs ranging from \$500/acre for commercial thinning and biomass removal to \$1,500/acre for hand-thinning, piling, and burning (Yosemite Stanislaus Solutions, personal communication, 2018). In the northern Sierra, treatment costs for private lands ranged from \$575 per acre for mastication or thinning with lop and scatter to \$1,200 per acre for thinning and biomass removal based on estimates of the South Lassen Watersheds Group, another collaborative focusing on landscape scale restoration and involving the U.S. Forest Service (USFS) along with a number of industrial timber companies. The Lassen National Forest estimated the cost of a restoration project in a sensitive area with special circumstances at over \$2,000 per acre (South Lassen Watersheds Group, personal communication, 2018). Table 2 lists restoration costs and factors contributing to their differences and likelihood of change in costs.

While operational costs and comparative value of sawlogs to biomass are currently central to the economic viability of forest restoration and biomass removal, agencies (such as the United States Forest Service (USFS)) and private landowners incur costs for environmental analysis and project monitoring that further challenge cost efficiencies. Larson and Mirth (2004) estimated these costs at \$126/acre for surveys, document and timber preparation, and monitoring. Sierra Institute, working with the South Lassen Watershed Group and the Lassen National Forest, estimated planning costs for projects on public and private lands in northeastern California range from \$45/acre for thinning and mastication to \$223/acre for more complex integrated meadow restoration and fuels reduction projects. Sierra Institute developed these data in 2019 through direct consultation with USFS officials and contractors for the purposes of implementing restoration projects.

Table 2: Forest Restoration Costs

Forest Restoration Project Elements	Value	Potential Change in Costs	Drivers of Change
Administrative Costs: planning, preparation, administration, and monitoring. [1]	Low: $45/acre High: $223/acre	Decrease possible	Economies of scale from landscape-level project planning may reduce administrative costs by up to 50%. [2]
Operational Costs[3]	Low: $575/acre High: $1,198/acre	Change Unlikeley	Contractors gaining experience or investing in specialized equipment may reduce costs.
In-Woods Costs	Low: $620/acre High: 1,421/acre		
Biomass Value[4] (10 BDT/acre* biomass value)	$30-$70 per BDT $300/acre - $700/acre	Variable dependent on whether material is sourced from high hazard zone and proximity to BioRam supported operations (see Section 2.1)	New purchasers of biomass are likely to be connected to BioMAT facilities with revenues driven by 20-year power purchase agreements, their ability to pay is unlikely to change.
Net Cost of Forest Restoration (in woods cost-biomass value)	Low: $80 (profit) to $320/acre (cost) High: $721(cost) to $1,121/acre (cost)	Decrease Possible	Drivers discussed above may decrease costs, but restoration remains likely to be a cost for agencies, necessitating further investment.

Table 2 Footnotes

1 High and low bounds are derived from estimates provided by project partners in the South Lassen Watersheds Group in 2018. Costs include all pre-implementation activities, high bounds represent more complex projects, such as those including both forest and meadow restoration. The recent French Meadows Project estimated out-of-pocket planning costs at approximately $46/acre (Edelson and Hertslet, 2019).

2 Based on estimates from Four Forest Restoration Initiative Stakeholder Group 2010 as described in Larson 2012.

3 Estimates developed in partnership with leading private and public land managers in the South Lassen Watershed Group area. Low estimates represent masticating, thinning/lopping, while high-end estimates cover thinning and biomass removal. North et al., (2012) reported an average cost of $565 for mechanical treatment across eight National Forest units in CA from 2004-2011, and a range from $252 - $1,077. Personal communication with other Collaboratives in CA suggest a range of $500 to $1,500 in different areas of CA in 2018.

4 Purchase prices per bone dry ton (BDT)* are estimates based on personal communication between Sierra Institute and operators in the Northern Sierra between 2018 -2019.

Piling and subsequently burning is a common method for disposal of biomass without a material outlet.

New financial commitments by the State of California and CalFire through Greenhouse Gas Reduction Funds and California Climate Investment (CCI) grants are subsidizing USFS costs for preparing and administering projects through the use of contractors. CCI grants that pay for some or all of an environmental analysis can help ensure projects take place not only by reducing costs but by paying for the work of outside contractors that are needed by agencies lacking staff capacity. Increased efficiencies gained through landscape-level planning can reduce the cost per acre for environmental analyses thereby further increasing the likelihood of restoration work.

To balance the high costs of restoration treatments, inclusion of merchantable timber is an ideal method to make treatments more economically feasible (Lord et al., 2006). Momentum is gaining among timber management officers in California to use Stewardship Authority for offering restoration work through a service contract.

USFS Stewardship Authorities provide federal agencies the ability to design contracts or agreements focused on the "end result" of activities – the desired condition of the land following restoration treatment rather than product removed. Stewardship contracts and agreements may include both service work (e.g., restoration activities) and timber harvest; excess funds, termed "retained receipts," generated from the sale of timber remain with a national forest for re-investment in future restoration activities.

Through such a contract or agreement, a national forest could trade goods for services. For example, if a contractor removes timber from a forest, they could then be responsible for completing stewardship work (e.g., removal of small-diameter trees) equal to the value of timber removed. Combining service work, such as removal of small-diameter trees, with merchantable sawlog harvest is typically more desirable to contractors when combined with long-term stewardship contracts.[6]

Some national forests are disinclined to pursue development of stewardship contracts due to a lack of familiarity with them and a perception that they are more time-intensive to prepare, and because of the high cost of restoration treatments relative to the value of available sawlogs.

6 In-depth guidance on stewardship authority for the USFS can be found in the Forest Service's Renewable Resources Handbook, Stewardship Contracting (FSH 2409.19, Ch. 60) and an example offered by the South Gifford Pinchot Collaborative can be found here: http://southgpc.org/stewardship-authority-and-retained-receipts/.

A biomass log deck on Mount Hough of the Plumas National Forest

For example, a recent project to improve forest health and increase stand resilience on roughly 5,000 acres of plantation in the Shasta-Trinity National Forest after accounting for the value of sawlogs estimated the net cost to the USFS to implement would be approximately $3.4 million (Westside Plantation Project EA, 2014).

The relative ability of individual national forests to include biomass removal with timber sales demonstrates the importance of markets for this material. For example, due to well-established biomass outlets at both Honey Lake Power and Burney Forest Power north of the forest, the Lassen National Forest was generally able to sell projects with a biomass component of up to 25% of the total volume removed as of 2016. This underscores the value of nearby bioenergy facilities and connection to forest restoration. The Shasta-Trinity National Forest, to the east, was unable to find buyers for sales that included biomass work (Fall River RCD and TSS Consulting, 2016).

In a somewhat similar vein, the Plumas National Forest experienced sales in which purchasers elected not to remove biomass included in a sale, effectively "returning" this material to the Forest Service, which then had to dispose of the material through pile burning or re-packaging it for sale via a new contract.[7]

Loggers and forestry contractors in the northern Sierra and southern Cascade regions interviewed by Sierra Institute report a range of perspectives on the opportunities and value of material removal as part of their work. Though some expressed frustration with limited sale offerings, others suggested they had steady work and would be capable of providing biomass from purchased sales to prospective small-diameter wood utilization enterprises. One contractor reported to Sierra Institute that if the small-log market pays $30 per ton, one could "purchase all the small logs they could want." It is likely that this contractor had a timber sale contract within close proximity, and the small logs referenced here are surplus. However, other contractors reported barriers to removal of biomass including inexperience in handling small logs and a lack of trucks and trailers to haul small or short logs, and that some practices are not conducive to biomass removal, e.g., not delimbing tops or small trees and piling without processing this type of material. These factors play into the cost-effectiveness of biomass removal, and provide little evidence to contradict

7 We highlight the example of the Plumas National Forest only to note the challenges faced by even a relatively high capacity national forest with multiple existing users of biomass. Based on this, it is not hard to envision managers in other regions of the state with leaner staffs, less valuable sawtimber, and more limited outlets for biomass being restricted in their ability to make any biomass removal cost-effective.

findings in the literature that operational costs regularly exceed market values of biomass (e.g., Nicholls et al., 2018; Larson, 2012).

Planning and implementing restoration treatments that result in the removal of small-diameter trees is economically challenging, even in areas where markets do exist for this material.

Research in Oregon has shown that eight inches is the "magic" tree diameter for timber harvesting operations, as profitability rapidly declines when average log diameter drops below this number (Oregon Wood Innovation Center, 2007). Similar to California, where markets are absent or demand insufficient, contracts result in an undesirable "end result"– biomass cut, skidded, and left on the deck, or to be pile-burned by USFS staff.

Furthermore, a timber-oriented approach to forest restoration that uses value from sawlogs or markets for small-diameter trees to pay for treatments presents both political and economic hurdles that can derail broad agreements about forest restoration treatments (Hjerpe et al., 2009; Nie, 2011). As Nie (2011) states, "If timber value is overestimated, or markets for small-diameter timber do not materialize or cannot be sustained, restoration projects will not be financed."

It is also worth recognizing that with the passage of California Public Utility Commission (CPUC) Resolution E-4805, requiring Bioenergy Renewable Auction Mechanism (BioRAM) facilities to procure biomass that is a byproduct of sustainable forest management with 80 percent drawn from CalFire "high hazard zones,"[8] a price premium has in turn been created for high hazard zone material in the northern Sierra and southern Cascades as well as a potentially lucrative revenue stream for private land managers with such material. Prices have reportedly risen to as high as $70 dollars per bone dry ton, almost a windfall for forest managers that supports forest management including thinning (personal communication, 2019).

However, the temporary price increase for biomass due to BioRAM fuel procurement requirements should not be relied upon when analyzing costs of forest restoration given the uncertainty of the long-term fate of BioRAM facilities with reliance on these contracts.

Investment in forest restoration and in utilization technologies for small material is needed to increase the pace and scale of restoration.

Utilizing sawlogs to capture value for small-diameter tree utilization is a pathway to restoration but, ignoring for the moment the social and political challenges, is woefully inadequate to address the scale of restoration needs and to do so at the pace needed given the threats facing California's forests.

8 http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M167/K479/167479395.PDF

Section Summary

- *Forest treatment costs depend on a variety of factors, including site conditions (e.g., forest type, density, slope, etc.) and operational specifics (e.g., silvicultural prescription, harvest machinery used, etc.)*

- *Integrated harvesting, or inclusion of merchantable timber with biomass removal, can help improve economics of forest restoration treatments but is itself inadequate if considerable small unmerchantable material is included, as is often the case with landscape restoration.*

- *Biomass removal and transportation is expensive, even if bundled with selling sawlogs.*

- *Biomass energy should be viewed as a method to partially offset high costs of forest restoration and biomass hauling but by itself is insufficient given the costs of facilities and transporting material.*

- *Opportunities to gain efficiencies by planning at the landscape-scale and issuing long-term contracts can reduce costs and, importantly, can provide certainty needed for investment.*

- *The full non-market benefits of forest restoration treatments and biomass energy production need to be considered for a full cost accounting of the economics of forest restoration.*

Improving Forest Restoration Economics through Biomass Utilization

As discussed previously, there is widespread recognition of the need to increase the pace and scale of forest restoration throughout California, including increased thinning and fuels reduction projects, as made evident by California Governor's Executive Orders B-52-18 of May 2018[9] and N-05-19 of September 2019.[10] With limited markets for small diameter material and forest biomass, biomass power facilities continue to be one of the primary utilization pathways for low value material.

Identifying and funding co-product development and heat using businesses can make construction and operation of bioenergy facilities cost effective. Subsidy can be secured through direct investments, low-interest loans, or longer-term and more sustainable mechanisms that secure payments for ecosystem services (discussed below). Co-product and heat-using businesses are described in detail in this report.

Ultimately, improving the economics of biomass residue removal and utilization are key pathways to sustainably reducing the risk of catastrophic wildfires, and avoiding societal cost of environmental degradation associated with poor air quality, threatened carbon storage, and compromised watersheds (OFIC, 2006).

Additional opportunity for support for bioenergy facilities may be secured through efforts to achieve carbon neutrality in California. In a recent report, Lawrence Livermore National Lab (2020:5) identified that processing woody biomass through conversion technologies that produce CO_2 that is captured or stored "has the largest promise for CO_2 removal at the lowest cost" for achieving negative emissions needed for California to become carbon neutral by its 2045 goal.

Biomass Power in California

In the context of this report, biomass energy is the generation of electricity or heat from biomass. Various technologies exist for converting woody biomass into heat and electricity. A key advantage of biomass power is the ability to make use of low-quality wood, including that of dead and deteriorating trees, particularly relevant given widespread tree mortality in California over the last eight years (Beck Group, 2017). Biomass power facilities range in size from less than 1 MW to over 50 MW that sell power via power purchase agreements (PPA) with utilities.

There are two primary wood-to-electricity conversion technologies deployed or currently in development in California utilizing forest biomass material: 1) conventional direct combustion boiler with steam turbine generator and 2) gasification units that are coupled with an internal combustion engine-generator powered by gas produced by the gasifier.

Biomass electricity has long had an important role in California's renewable energy portfolio, with close to 1,000 MW of biomass power generating capacity in the state by the mid-1990s. A number of these facilities have had their power purchase contracts expire and not renewed, because utilities opted out to switch to other renewable energy sources, such as solar and wind, due to their price advantages, and due to some facilities exceeding their useful life. Thus, many biomass power plants are currently idle (Tittmann, 2015).

Most recently, the unprecedented tree mortality and the emergency proclamation issued by former Governor Brown in 2015 required the California Public Utility Commission (CPUC) to extend contracts on existing forest biomass electricity facilities provided they procure feedstock from CalFire High Hazard Zones. The CPUC later passed Resolution E-4770

9 https://www.adaptationclearinghouse.org/resources/california-eo-b-52-18-executive-order-to-improve-forest-and-community-resilience-to-wildfire-and-other-climate-impacts.html

10 https://www.adaptationclearinghouse.org/resources/state-of-california-executive-order-n-19-19.html

requiring Investor Owned Utilities to procure 50 MW of forest biomass energy from Renewable Auction Mechanism (RAM) facilities. In 2016, Senate Bill (SB) 859 added to this requirement by mandating an additional procurement of 125 MW of biomass power using primarily forest biomass as feedstock.

However, larger BioRAM facilities are old with outdated emissions control technology, and the future of the BioRAM program is uncertain.

To effectively move forest biomass energy forward in California, development of new, state of the art biomass facilities is needed to comply with current air quality regulations and gain more widespread social acceptance.

Concerns by environmentalists about large facilities that require either localized intensive management or long distance transport of biomass, coupled with localized air emission impacts, has resulted in smaller community-scale facilities proposed as a solution. This has led to a new program that scales down biomass power plant size but inadvertently scales up the economic challenge of biomass energy utilization.

California Senate Bill 1122 and the Bioenergy Market Adjusting Tariff Program

The introduction of California SB1122 in 2012 and its Bioenergy Market Adjusting Tariff (BioMAT) program offers a chance for the rebirth of biomass energy through community-scale facilities in order for power production to be in closer proximity to feedstock sources, and in the case of forest biomass, to rural forested communities. SB1122 mandates that California's Investor Owned Utilities (Pacific Gas & Electric, Southern California Edison, and San Diego Gas & Electric) procure 250 MW of renewable energy from facilities no larger than 3 MW in size (effective capacity) at higher than market prices. California Assembly Bill 1923 allows BioMAT facilities of up to 5 MW to be built, provided that no more than 3 MW are sold through the grid.[11]

The increase to 5 MW improves the market economics of these otherwise cost-prohibitive facilities (Beck Group, 2017), but does not lead to a development scale that by itself is cost effective. Underscoring the challenge facing smaller facilities, Black & Veatch (2013) found that the cost of a 20 MW biomass project tends to be better understood, has less variation, and is considerably lower per MW compared to 3 MW biomass facilities. Labor needs to operate a 3-5 MW facility are no different than those of a 20 MW facility.

A total of 50 MW must be procured from bioenergy using byproducts of sustainable forest management (BioMAT Category 3), including material sourced from High Hazard Zones.[12] The pricing mechanism of the BioMAT program varies: it increases every 30 days until a project strikes at a price, with a price cap at $199.72 per MWh, or 19.9 cents per kWh. In November 2017, the CPUC initiated a BioMAT program review and capped the Category 3 offer price at $199.72 and requires the use of at least 60% high hazard zone fuel (California Public Utilities Commission, 2017).

As of February 2020, four projects have received Power Purchase Agreements from PG&E for Category 3 BioMAT facilities, all based in rural forested areas with an abundance of High Hazard Zone biomass in surrounding forestland. Only one of these facilities reported that it secured adequate financing to advance construction in the near future. Many more facilities are being planned within PG&E's service territory, but there remain a number of barriers to development of these projects, including: high capital costs relative to the facility size, securing investment in poorer rural areas, securing long-term fuel supply agreements with the U.S. Forest Service and other landowners, and brownfield liability issues affecting site utilization, among others.

11 California Public Utilities code 399.20

12 https://www.fire.ca.gov/fire_prevention/fire_prevention_wildland_zones

The market for biomass created by BioMAT facilities could begin to address the cost-challenges of forest restoration. However, the BioMAT program has yet to successfully incentivize the construction of a new 5 MW or less facility, and IOU resistance to the program and the recent bankruptcy of Pacific Gas & Electric has slowed program implementation. Projects are further challenged by operating expenses of a small-scale system—an issue discussed immediately below.

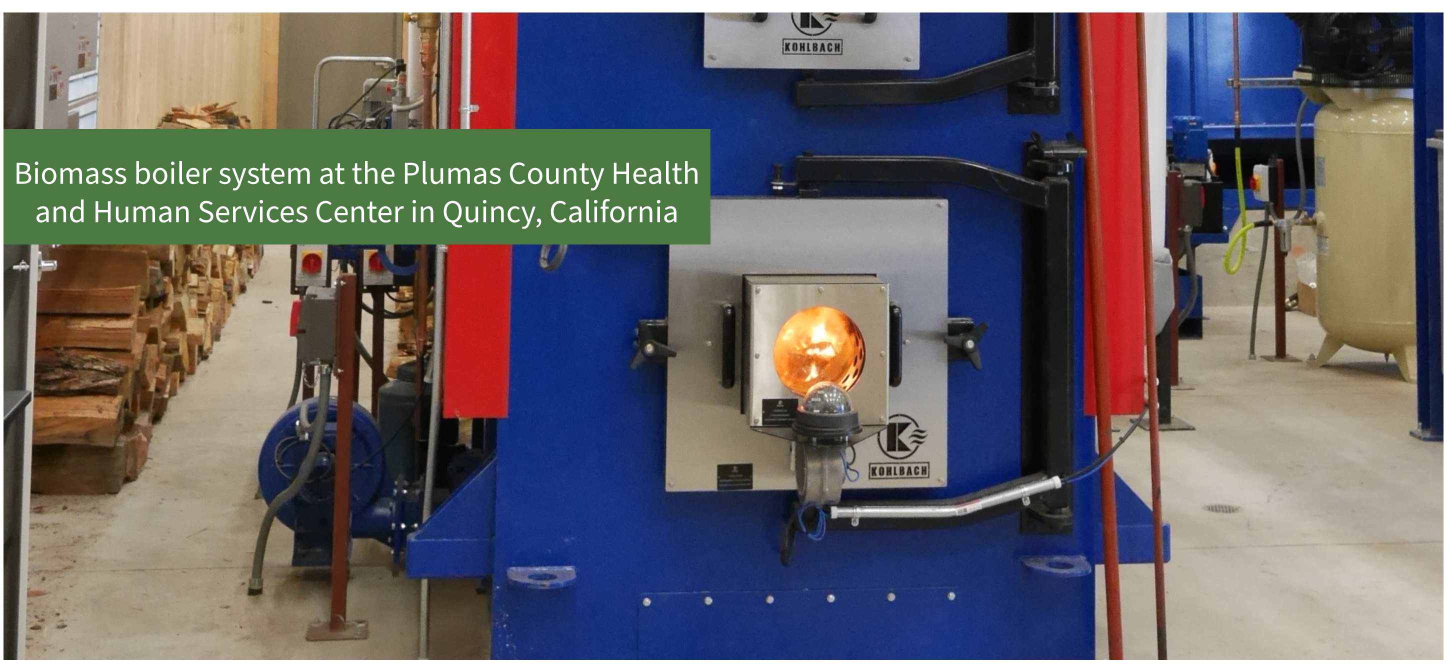
Challenge of Small-Scale Biomass Power

Compared to BioRAM facilities, the 5 MW size restriction of BioMAT reduces the material required for operation thereby effectively reducing the area from which biomass is sourced and reducing transport costs and associated emissions. But 5 MW is not a standard-sized technology; historically the smaller wood-fired, direct combustion biomass plants have been 12-15 MW size. Financial projections associated with projects of 5 MW suggest they will struggle to break even with electricity-only sales, even based on higher PPA prices currently offered. This accentuates the challenge of securing investment for facilities based only on revenue from electricity sales.

Additionally, there are limited examples of successful biomass gasification plants in operation in the United States. Black and Veatch (2013) in a consultant report prepared for the CPUC regarding SB1122 implementation stated, "There are relatively few gasification technology suppliers for small-scale gasification systems that have demonstrated the capability to provide and fulfill performance guarantees and secure project financing." For example, performance guarantees for well-proven biomass direct combustion systems typically range from 7,500-8,000 hours of annual power production, which can be difficult to achieve with gasification technologies.

The cost of generation can vary considerably based on feedstock cost. Projects co-located at facilities with an ample supply of inexpensive feedstock, such as those at sawmills, have much lower levelized cost of electricity (LCOE) compared to stand-alone facilities that procures material off site. LCOE involves calculating a facilities total capital and operating costs divided by its energy production over the projected lifetime of a facility.

In an LCOE estimate developed by Black & Veatch, they identified that if feedstock were free, LCOEs would drop by 15 to 20 percent; the LCOE difference if feedstock were purchased at $20 compared to $40 per bone dry ton is $10/MWh (Black & Veatch, 2013). The smaller supply areas, or working circles, from which a 3-5 MW facility will collect biomass are unlikely to appreciably reduce LCOEs given that harvest



Biomass boiler system at the Plumas County Health and Human Services Center in Quincy, California and movement of material to a road typically dwarf transport costs from the road to an energy facility. These numbers indicate that feedstock cost represent yet another challenge to cost competitiveness of BioMAT facilities, and these costs can vary considerably based on different operating parameters.

The BioMAT process also relies on well-capitalized owners and developers. Development of community-scale technology is challenging from an investor feasibility standpoint. Sierra Institute has been working to establish a 3 MW BioMAT facility in Plumas County and has received cost estimates for gasification systems ranging from an early estimate of $5 million per MW at the launch of the BioMAT program to $10 million in 2020. This is likely due to developers being overly-optimistic at the outset of the BioMAT program and now modifying costs based on experience and recognition of the challenges of biomass facilities at the 3 – 5 MW scale. Direct combustion construction costs may be lower, but generally have a less clean emissions profile compared to gasification systems (National Energy Technology Laboratory).

The California Senate Bill 859 Wood Products Working Group and the California Forest Management Task Force have been working to address challenges to small-scale biomass power development, but investment in these facilities will continue to be a challenge until the technology and market feasibility are proven.

PG&E's declaration of bankruptcy has generated considerable investor unease and led to some investors to retract offers or hold back the same until more clarity emerges about the bankruptcy along with the state commitment to the BioMAT program.

It is increasingly recognized that development of other biomass-derived co-products alongside BioMAT facility is a key pathway to making biomass electricity generation economically feasible (SB 859 Wood Products Working Group, 2017; Beck Group, 2015).

This includes the sale of low-grade waste heat to co-located businesses, sale of biochar (a co-product of some gasification processes), or incorporating an integrated product development model to lower feedstock costs.

Development of an independent combined heat and power (CHP) facility should therefore involve co-location with new or existing heat load demand to both improve economics of the biomass facility operation, and to be able to pay higher prices for feedstock that will support costs of biomass harvest and transport.

Market and Non-Market Drivers of Biomass Power: Co-Product Development and Integrated Product Yards

Generating energy from biomass is relatively expensive compared to other established renewables such as solar and wind, a fact that has ultimately resulted in many large-scale biomass power facilities sitting idle due to expired contracts and lack of incentives for utilities to renew them.

Arguing against community scale biomass energy facilities based on their high cost, however, ignores the subsidies that decades ago helped launch the now well-proven and low cost wind and solar energy technologies.

It also ignores ecosystem and societal benefits of forest biomass removal and utilization, and the recognition that biomass energy generation coupled with CO_2 capture is one of the best ways for the state to achieve carbon neutrality (Lawrence Livermore National Lab, 2020).

By facilitating better forest management and improved forest health, biomass energy development leverages considerable climate and other environmental benefits (Tittmann, 2015), and plays a critical role in sustainable forest restoration. But investment in forest restoration through climate and environment benefits of the CCI program for example, though currently substantive, are temporary. Investments in marketing, wood utilization technologies, including biomass power facilities with co-located businesses to handle the lowest value material, are needed. Exploration of these technologies follow. Electricity production provides value for wood residue processed through a chipper, known as "hog fuel"—the least valuable by-product of forest restoration. But by itself, as pointed out above, electricity sales are inadequate to ensure successful economics of a 3 MW biomass power facility. Extracting value from other products and developing co-located businesses are critical paths to improving the economics of both forest restoration and community-scale (5 MW or less) biomass energy generation.

Development of "integrated product yards" is a mechanism being pursued by a small but increasing number of communities in California to improve economics of utilizing low-value biomass material.

Integrated product yards are locations where contractors can haul logs, limbs, or other woody biomass material where it can be sorted based on the value-added stream to which material will be dedicated. When a contractor delivers logs to a product yard with a biomass power facility, optimizing value from logs involves sorting them and dedicating not only high quality logs to higher quality and more expensive products but cutting an individual log and sorting pieces of the log by value. For example, the thickest, stoutest part of a small tree may be milled or dedicated to posts and poles, smaller material can be cut into rounds or lengths for firewood, and the smallest material can be chipped and used for landscaping or in a biomass power facility. All of these products not only incur sorting and handling costs but require marketing to secure value. Successful business owners of small-log operations say the key to success is ensuring market outlets for the lowest value material—hog fuel.

Sorting whole logs and portions of the logs based on value at a product yard enables capture of more value from the material. There are handling costs on site but doing so eliminates the need to process and sort material in the woods.

The Integrated Biomass Resources Campus in Wallowa County, Oregon estimates that simplified and reduced sorting and processing in-woods reduces total harvesting costs 15-18% per acre (Davis, 2014).

Potential value streams for low-value small diameter trees and biomass have been assessed by a variety of groups (Beck Group, 2015, Beck Group, 2017, SB 859 Wood Products Working Group 2017, Kusel et al., 2017). Products explored below include: 1) wood chips—beyond those serving as feedstock for biomass electricity facilities; 2) firewood (dried: bulk or packaged); 3) posts and poles; 4) mass timber; 5) pellets; 6) wood shavings; and 7) biochar. We conclude this section with a brief discussion of chip-based chemical, fuel, and energy products that can displace fossil fuels and generate what are called negative carbon emissions, which are needed if California is to reach carbon neutrality by 2045.

Wood Chips, Beyond Biomass Electricity

Hog fuel and wood chips are derived from the lowest-value forest biomass material—slash and other debris left over from forest thinning operations. Chips are clean wood without the bark, leaves, and other impurities that allow them to be used for shavings or pellets. When chipped material is screened for removal of fines, dirt, needles, bark, and other large chunks, the material can be used in markets hog fuel cannot, and the value increases. Outlets and markets for this material is thus an appealing solution for addressing the abundant biomass supply in California. Processed, clean wood chips can be used as fuel for boilers, playground chips, compost amendments, and, if pilot tests continue to prove effectiveness, for de-icing roads in place of salt or gravel (CBC News, 2018).

Wood chips for thermal energy

<u>Institutional Heat</u>

Beyond electricity generation, wood chips can be used to fuel biomass heating systems located at public buildings in rural forested areas with cold winters, a high heat load, lack of access to affordable natural gas, and resultant reliance on sometimes expensive propane.

Tub grinder generating material to be used in playgrounds, at the Wilseyville Biomass Utilization Yard.

While community-scale applications of biomass heat do not require much wood supply, they generate a multitude of other benefits to a community, and with replication can turn hazardous fuels around homes into a source of useable and inexpensive renewable energy and a way of displacing fossil fuel use.

Sierra Institute in 2018 completed development of a small biomass combined heat and power (CHP) facility. Primarily funded by a California Energy Commission Electric Program Investment Charge grant, this facility heats the Plumas County Health and Human Services Center in Quincy, California. Successful completion of this system has drawn attention from other entities in Plumas County and elsewhere, as it demonstrates biomass heat as a reliable, renewable, low-cost alternative to propane and other fossil fuels. CalFire and the California Department of Corrections recently announced a plan to move forward with installation of biomass boilers at various Conservation Camps in California, including already designed projects in Trinity and Modoc Counties.[13] There are a multitude of biomass heat applications at public buildings in Oregon, Montana, and Vermont, all of which have operated successfully since being installed (Biomass Energy Resource Center, Biomass Case Studies Series) (McElroy, Biomass Magazine).

Return on investment for converting a building's heat source to biomass depends on a number of variables, such as whether existing systems are failing and need replacement, and the ease of tying in a biomass boiler to a building's existing heat distribution system. Installing biomass heating systems with new building construction can be an economical way to justify biomass especially if long term operational costs are included with capital costs. Biomass heating feasibility studies commissioned by Sierra Institute for entities in Plumas County have shown the potential for up to tens of thousands of dollars in annual savings in heating costs to be achieved for a single building when compared to fossil-fuel based alternatives.

Capital costs for biomass boilers are higher than conventional systems but fuel costs are considerably lower and more stable, enabling adequate return on investment with larger heating systems.

Biomass boilers that use clean, even sized wood chips are less expensive than boilers that can handle unprocessed hog fuel with its variable feedstock characteristics. These boilers can help reduce capital costs and also create a market opportunity for a wood chip processing business providing clean, even sized wood chips.

13 https://thewatershedcenter.com/regional/ca-state-conservation-camps/

Biomass systems installed at larger buildings with a higher heat demand are more likely to generate a faster return on investment to justify installation. Similarly, using a single boiler to serve multiple sites creates a community distributed energy system that uses more wood while substituting renewable wood for fossil fuels.

Greenhouses

Given their demand for low-grade heat and the need for protection from extreme weather to grow many crops in higher elevation or more northern latitudes, greenhouses are an excellent heat user that can be co-located with biomass cogeneration facilities. Sierra Institute performed initial heat modeling for a 22,000 square foot greenhouse, identifying that it would use 0.6 MMBtu per hour of heat.

A school district in Prince of Wales, Alaska, is using biomass boilers to heat a greenhouse so students can grow produce as part of the school's curriculum (Kauffman, 2018).

Wood Chips for Playgrounds, Decorative Bark, Compost, and De-icing Roads

There are limited markets for utilizing wood chips as landscaping products, and those that do exist are saturated. Markets for decorative bark generally prefer large pieces of bark derived from large diameter trees processed in sawmills—not thin, fine textured bark of small diameter trees coming from forest thinning projects.

The Beck Group (2015) advises this market should be approached with caution due to existing markets already meeting supply needs, and high competition with existing sawmills that already generate bark and sawdust as a byproduct of their sawmilling operations—hence the cost of processing bark is borne by the sawmill with no manufacturing cost. As a result, stand-alone decorative bark businesses will have difficulty competing with existing sawmills. This underscores the value of multi-product or co-product development at a single site to achieve economies of scale. It also serves as a warning for facility managers to assess markets carefully before investing or banking on what appear to be vibrant markets.

Some initial market research for compost and landscaping retailer outlets was performed by a consultant to the Sierra Institute, and results were as expected—all composting or soil amendment businesses in larger metropolitan areas find ample supplies produced from existing green waste operations nearby, and have reached capacity in accepting woody material.

Firewood

Firewood has one of the lowest market entry costs among potential small-scale wood products businesses, according to several consultants to the Sierra Institute. Firewood can be sold locally as well as transported and sold to buyers in nearby towns and more distant urban locales if heat treated.

Split and dried firewood is a viable business opportunity for small-diameter trees, with low market entry costs.

There is also opportunity for contracts with retail companies for packaged firewood, such as with grocery stores or home improvement hardware stores, provided the product is dried and certified pest free. Equipment costs are among the lowest of all potential value-added products. The challenge for sellers is securing markets and minimizing handling costs. Work performed by the Watershed Research and Training Center and by the Sierra Institute indicates that sufficient demand is available to support new businesses, especially with cooperative sales and marketing.

Scaling up and including kiln drying for firewood offers opportunities for significantly increasing production totals, and while most local firewood contractors rarely engage in marketing beyond their home counties, the demand appears high nonetheless. Generally, packaged firewood is required to have moisture content of no more than 20%.[14] While whole logs can be left to dry naturally over time (though more challenging in moister climates such as the coast ranges of California), kiln dried firewood is a better and higher-value product, especially because kiln drying can eliminate pest dispersion concerns associated with transporting untreated firewood. Firewood kilns are an ideal heating load for co-location with biomass power facilities.

In their 2017 report for the California Tree Mortality Task Force, the Beck Group identified bundled and bulk firewood to be the top-rated low capital but low volume (total demand is low compared to volume of dead trees) opportunity for utilizing dead trees and biomass. It is difficult, however, for a stand-alone firewood operation to successfully operate at a large scale.

Replication of multiple small firewood operations can approach the scale needed to absorb the residue generated by landscape scale forest management and restoration and improve the economics of community scale operations.

Sierra Institute has initiated discussions with other wood product yards to explore cooperative business development for firewood as well as other businesses.

14 https://woodheat.org/firewood-too-dry.html

Posts and Poles

Posts and poles are manufactured and treated from straight, low-taper softwood for fences, agricultural poles, and other uses.

Markets for post and pole products primarily call for lodgepole pine, some Douglas-fir, and minimally for white fir and ponderosa pine. Lodgepole pine is preferred for its straight grain, ability to take preservative treatment, and ability to withstand aging. Douglas-fir is a structurally stable wood type but more difficult to treat. Ponderosa pine takes treatment well but is unstable and tends to warp. White fir takes treatment well but is better for posts (generally for fencing) than poles (generally for utility poles, gates, structural support), limiting order quantities for a post and pole business, according to a forest products consultant to Sierra Institute. Species mix of predominantly lodgepole pine are hard to find in California, so a clear market for lodgepole pine would need to be identified for success of a post and pole business in California.

Because a post and pole operation generally requires specific species and log sizes, such a business is best suited at an integrated products yard where log sorting and merchandising occur, and there are alternative outlets for logs that do not meet size, shape, or species specifications (Anderson).

Residuals from post and pole operations could make excellent feedstock for animal bedding and processed wood chips.

Construction of California's first full cross-laminated timber building in Quincy, CA, December 2017

Mass Timber

Mass timber refers to engineered wood products that are structurally sound alternatives to concrete and steel building products, that also offer an opportunity to sequester carbon in a building product.

Mass timber products include cross laminated timber (CLT), glulam, dowel laminated timber (DLT), nail laminated timber (NLT), and mass plywood panels, as well as other products.

CLT is made of cross-layered and laminated lumber and has superior structural strength. Blast testing performed by the U.S. Department of Defense, WoodWorks, Softwood Lumber Board, and the USFS in 2016 showed mass wood to have "acceptable levels of damage under significant explosive loading," demonstrating opportunities to expand use of CLT for Department of Defense applications and other blast-resistant construction. CLT structures also have inherent ductility, which allows them to dissipate energy when faced with the sudden loads of an earthquake. A strong market for CLT in California has been anticipated for some time, and CLT building projects are beginning to take off throughout the state.

Sierra Institute oversaw development of the first full CLT building in California to house a biomass heating system in Quincy in 2017.

The new Brentwood Public Library has CLT wall and floor panels, and a school in Truckee has CLT wall panels. Microsoft has also revealed plans for their new campus in Mountain View to include a significant CLT component.

California is an attractive market for use of CLT as: 1) the state's forests offer an abundant supply of material, 2) there is a need to create rural jobs, 3) there is a need to improve forest and watershed health through sustainable forest management and therefore a need for more high value wood products to financially support the costs of sustainable forest management, and 4) it has an existing built-in market demand for CLT given seismic retrofit requirements and new building seismic code compliance.

Unfortunately, there is limited ability to use ponderosa pine in mass timber panels, the primary species affected by the pine beetle epidemic in California, and one of the most common byproducts of forest thinning activities. Sierra Institute does not anticipate the growth of mass timber markets in California to single-handedly address the lack of outlets for small diameter trees and biomass. Rather, production of mass timber panels utilizes dimensional lumber and therefore is an additional revenue source for sawlogs; biomass removal could be bundled with these activities for improved forest restoration economics.

The passage of Assembly Bill 2518 passed in 2018, titled “Innovative Forest Products and Mass Timber”, the work of the Wood Products Working Group, enacted by Senate Bill 859, and the Wood Utilization subcommittees of the Forest Management Task Force to promote wood products innovation in California, give hope for the future of the mass timber market in California. Sierra Institute hopes manufacturing facilities that operate at a community-scale are advanced. These can focus on specialized timber-framing jobs throughout rural forested California in the years to come but, like small scale energy facilities, are challenged to secure investors, especially for a market that is in an early development phase. Despite the growing demand for CLT, its current reliance on dimensional lumber raises questions about its value as a destination for forest management residues.

Wood Pellets

There is an increasing demand for pellets locally, regionally, and internationally, with projections suggesting a dramatic increase in the coming years due to concerns associated with continued fossil fuel use and climate change. Pellet production offers an opportunity to dramatically increase utilization of low value forest material. Production of pellets also offers significant potential for waste heat utilization if coupled with a biomass electricity facility—the Beck Group (2015) modeled a 50,000 tons per year capacity pellet mill to use 22.8 million Btu per hour.

Entry costs for pellet production are generally high, and higher production capacity requires increased capital investment. While one operation can relatively easily produce 50,000 tons of pellets per year, this is likely an insufficient volume to be competitive in the international market (personal communication, 2017).

To be considered a serious supplier in international markets there is a need for considerable investment to develop an appropriately-scaled facility, or coordination of multiple facilities, coupled with significant time requirement to develop partnerships with buyers.

There are nascent efforts in California to advance construction of pellet facilities to serve Asian buyers. Key challenges will be to secure long-term purchase contracts; supply contracts from the USFS and other land owners; investors; and determining whether multiple community-scale operations or large facilities are constructed.

The former distributes demand for supply across the landscape, the latter concentrates demand or requires long haul distances of raw material.

In addition to capital costs, a key barrier to entering the international market involves trans-shipment; one consultant to the Sierra Institute suggested the West Sacramento Port will require a $25 million upgrade to efficiently handle pellets. California could become a leading player in the pellet market, but considerable investment is needed, both for development of pellet production facilities and potentially in port upgrades. As of this writing, additional ports are being examined for their costs and efficiencies for handling pellet shipments.

Wood Shavings

With California’s substantial agriculture industry comes a market for wood shavings to be used as animal bedding. Shavings can be produced from whole log shaving machines to convert roundwood into shavings, or derived from residues if co-located with other wood products businesses. The Beck Group (2015) modeled a 700,000 bags per year (roughly 10,000 BDT per year) facility utilizing 9.4 million Btu per hour of heat. Wood shavings are often generated as a by-product of sawmill operations, specifically from planer mills (Beck Group, 2017). One drawback to shavings in the context of supporting forest restoration activities is that production technology generally requires whole logs to be shaved and peeled, so there is limited opportunity to utilize biomass and slash material.

Biochar

Some gasification technologies for biomass power production produce char as a co-product, commonly referred to as biochar. The Wood Education and Resource Center (2018) studying the biochar industry surveyed 135 biochar producers in the US; half of these producers responded and indicated that the market has been strenghtening (US Biochar Initiative, 2018).

Biochar may generate considerable value for carbon sequestration along with water storage potential when added as a soil amendment.

Payment for biochar in California has approached as much as $1.00 a pound, though this has involved extremely limited amounts of biochar used for cannabis cultivation. Widespread agricultural application in California remains a dream of biochar producers. Much of the work on biochar in California is in a research and development phase including, for example, a $4.3 million dollar California Climate Investment grant through the Strategic Growth Council to the University of California examining carbon sequestration in agricultural soils. Another Strategic Growth Council grant for $3 million was made in December 2018 to UC Merced to advance mobile biochar production.

When considering water retention and carbon sequestration potential on agricultural soils, private entities and universities have started employing educational and marketing activities associated with biochar. This suggests future market opportunities. To date, however, enthusiasm has outrun reality as markets have been slow to develop. Some claim that wood-based biochar can be used as an activated carbon filter, but this market is also not mature.[15]

Biofuels and Related Products

Biomass conversion technologies such as gasification and pyrolysis in addition to electricity can produce liquid fuels, natural gas and hydrogen to mention just a few products. (For a detailed description of these conversion technologies see Lawrence Livermore National Laboratory (LLNL) (2020), which provides a detailed description of the technologies and includes a discussion of products they are capable of producing.)

Both gasification and pyrolysis technologies can be used to convert biomass to fuels that can offset fossil fuel use. Similar to the challenge of paying for biomass utilization using more conventional direct combustion or simple gasification, however, capital costs for such facilities are high and require pipelines, trucking or rail transport that add costs. Few rural areas have gas pipelines, which is why biomass utilization that includes heat utilization ("cogeneration") can be useful and provide a better return on investment if there is substantial local heat demand.

Using biomass to make electricity and fuels and provided technology to capture and sequester CO_2 is included, biomass utilization will generate negative emissions and offers perhaps one of the most productive pathways for California to meet its 2045 goal of carbon neutrality (LLNL, 2020).

15 https://apps.fs.usda.gov/nicportal/WOODINNOVATIONS/dspProjectDetailReport.cfm?id=366

Networked Approach to Integrated Campus Development at a Community Scale

Many communities and groups throughout rural forested California are working to advance BioMAT facilities and integrated wood product yards with the objective of rebuilding local economies based on forest restoration and sustainable forest management. Successful build-out of this regional network of biomass campuses will expand the demand for low-value biomass material coming from forest restoration projects, and improving economics of sustainable forest management across California.

While a variety of potential outlets for low-value biomass exist (as identified above), those markets will not be realized without entrepreneurial buy-in within these communities. Furthermore, reduction of investment risk is key to successfully advancing small-scale wood products yards in more impoverished rural communities (Lowell et al., 2017). Thus, many of these communities are exploring the viability of cooperative business ventures to reduce start up risk for individual sites, improve local business bargaining power, and possibly improve product or service quality.

There is a role here for the State of California and regional and local agencies to offer debt and equity sources to leverage investment and spur development, but community-scale wood utilization initiatives have yet to see opportunities that provide sufficient support. Feasibility of cooperative product development for community-scale wood utilization efforts should be pursued further as a means to advance development of integrated wood products campuses that can help address the wood utilization challenge faced by the state.

Collaboration and peer-learning among communities advancing wood utilization efforts is key to success.

Section Summary

- *Biomass energy is an ideal outlet for biomass as it makes use of the lowest value material (hog fuel and wood chips); establishment of a power purchase agreement with a utility offers a guaranteed market that is key to attracting investors in such facilities.*

- *Electricity generation is often the only off-take option for lowest value biomass material, which is often critical to the economics of integrated multi-product "cascading usage" operations, but is by itself economically uncompetitive.*

- *Small-scale biomass/BioMAT sized projects at 3-5 MW are not economical unless co-located with existing mills for low-cost feedstock or with waste heat-utilizing and other co-located businesses.*

- *Co-product development can improve the economics of small-scale biomass power operations by deriving higher value from biomass and securing value from residual heat that otherwise may have no value. Improved economics allow facilities to pay more for feedstock, and by covering more costs of forest restoration treatments, additional acres can be treated.*

- *A networked, cooperative approach to product development can reduce start-up risk for communities seeking to advance small-scale integrated wood product campuses.*

- *The lack of markets, supply challenges, and limited direct investment by the State of California, the federal government, and others have forestalled development of community-scale bioenergy facilities and other operations that will utilize biomass and other restoration byproducts.*

- *Biomass Utilization coupled with fuels production and CO_2 capture is one of the primary ways California can become carbon neutral.*

Payments for Ecosystem Services

As discussed above in the section Forest Restoration through Biomass Removal, costs of forest restoration treatments and biomass removal are high. Creation of local outlets and markets for biomass material is an important strategy for improving the economics of forest restoration and biomass removal, but money supporting additional value streams beyond wood products are needed to improve the long-term economics and long-term ecological benefits of this work.

California's forests and watersheds generate many non-market services such as water and air quality maintenance, erosion control, and carbon sequestration.

These ecosystem services (ES) are passively enjoyed if not consumed by millions of downstream residents in California but are not monetized and are thus unpaid for by beneficiaries. Continued provision of these services is threatened by wildfire, drought, and a changing climate, therefore posing significant post-catastrophe remediation costs.

Risks to watersheds and to their ability to provide ecosystem services to "downstream users" can be mitigated through payment programs that link payments for hydrological, air quality and forest-based services to consumers and use the resulting funds for forest restoration (Greenwalt, 2009).

Payment for ecosystem services (PES) refers to the practice of offering financial compensation to individuals or communities in exchange for undertaking actions that increase the provision of ES. Simply defined, ES are a range of benefits people obtain from the environment. ES include provisioning (food, water, timber); regulating (flood control, regulation of local climate factors, water quality); cultural (recreation, tourism, education, spiritual); and supporting services needed to maintain other services (soil formation, nutrient cycling) (Smith et al., 2013; Deal et al., 2012).

PES programs utilize incentives to induce behavioral change and are classified within the suite of incentive and market-based mechanisms for environmental policy. A variety of actors are typically involved in programs, including buyers (beneficiaries of ES), sellers (providers of ES) as well as intermediaries and knowledge providers familiar with natural resource management.

Typically, three types of PES programs exist: 1) a public payment where the government pays for ES on behalf of the public; 2) a private payment where beneficiaries directly contract with providers; and 3) a public-private payment where governmental and private funds jointly pay ES providers. Programs may package ES together as a single credit to create a "bundle" or account for and sell each ES separately thereby "stacking" services (Deal et al., 2012).

As identified in previous sections, the cost of conducting forest restoration treatments generally exceeds the value of biomass and, as a result, there is rarely an incentive to extract biomass for the sole purpose of supplying power (Tittmann, 2015). Subsidizing forest restoration treatments through PES reduces the cost to market for biomass while diminishing the risk of catastrophic wildfire, protecting water quality related ecosystem services and providing public goods to society.

With monetization of these ecosystem services, California can dramatically improve economic challenges of landscape-scale forest restoration activities.

For example, the Sierra Nevada Conservancy found the economic benefits of fuel treatments can be three or more times their costs based on a 2014 avoided cost analysis to determine the costs and benefits associated with fuel treatments in the Mokelumne Watershed (Buckley et al., 2014).

A PES scheme to encourage the removal of small diameter trees and biomass from forestland could assume different forms. We explore some examples below.

Examples of and Potential Types of PES Programs in California

BioMAT Feed-in-Tariff

While not a direct PES mechanism, California's Bioenergy Market Adjusting Tariff program (BioMAT), launched through the passing of CA Senate Bill 1122 in 2012, has gained attention for being one of the state's first efforts to create a mechanism for supporting restoration of forests and watersheds and addressing the forest waste problem. Payment for environmental services is oblique; the state is encouraging renewable energy production from small-scale forest biomass facilities. BioMAT carves out 50 MW from of a total 250 MW for bioenergy produced using byproducts of sustainable forest management, including fuels from designated CalFire High Hazard Zones. As such, BioMAT is functioning as a proxy mechanism by which society is valuing ecosystem services and, to an extent, directing payments to ensure their continued provision.

To meet this goal, California's three largest investor owned utilities (IOU) are obligated to purchase power from generators exporting 3 MW or less of electricity to the grid produced from forest biomass. Without the feed-in-tariff, utilities would have little incentive to contract with small-scale biomass plants given the lower cost of procuring power from other renewable sources. Unfortunately, only a handful of projects have obtained Power Purchase Agreements since the inception of BioMAT, and no projects have completed construction of a facility. The program and its auction mechanism is slated to end in 2020.

Integrating ecosystem service valuation into the tariff price offerings could increase attractiveness of participation in the BioMAT program. The California Air Pollution Control Officers Association (CAPCOA) released a policy statement in 2016 stating the California Public Utilities Commission (CPUC) has indicated they "…take a narrow view of societal benefits and recognize only benefits that accrue directly to ratepayers. They do not monetize benefits such as air quality improvements, wildfire mitigation, landfill diversion, and public health cost savings in their rate-making activities" (CAPCOA, 2016). CAPCOA recommends that the CPUC require the purchase of biomass power at a rate that recognizes other societal benefits of biomass energy.

Investment by Water Utilities

The application of PES by water utilities has been on a steady increase in the past few years, as seen by the North Yuba River watershed effort mentioned above. This is due to the increasing recognition that the natural filtration services provided by forested watersheds directly benefit downstream facilities and provide a way for water utilities to invest proactively in the quality of water delivered to customers (Ernst, 2004). PES programs have often emerged after a catastrophic event significantly impairs water supply, damages water supply infrastructure, and/or endangers the supply of ecosystem services. For example, the Denver Water Agency launched the Forests to Faucets program in partnership with the U.S. Forest Service in response to the costly impacts of the 1996 Buffalo Creek and 2002 Hayman wildfires.[16] Similarly, the City of Santa Fe Water Division launched the Watershed Investment Program in 2013, directly supported by the water utility's rate payers, building from progress accomplished with the 2002 Santa Fe Municipal Watershed Project following the devastating Cerro Grande Fire.[17] See Box 2 on the next page, for more details on these two PES programs.

California has historically used general obligation and revenue bonds to fund water-related public projects. However, bonds fall short of an effective mechanism for forest restoration because they require lengthy statewide voter approval and they provide only temporary funding. From 1998-2011, California funded electricity public purpose programs by charging ratepayers a small, usage related fee called a Public Goods Charge (PGC) that was collected by the major investor owned utilities (IOUs) and publicly owned utilities (POUs) (Quesnel, 2015). Stanford University's Water in the West partnership as well as the Public Policy Institute of California have pro-

16 https://www.denverwater.org/your-water/water-supply-and-planning/watershed-protection-and-management
17 https://www.santafenm.gov/municipal_watershed_plan

Box 2: Examples of Upstream Investment By Downstream Users

Example 1: Santa Fe Watershed Management Plan

- Five-year utility service rates increase
- Used as insurance policy against threats to water supply
- Cost to treat and maintain forest within the municipal watershed: $5.1 million over 20 years versus $11.9 to $48 million for fire suppression and rehabilitation costs plus $80 to $240 million to dredge 2,000 acre-feet of ash and sediment from reservoirs following fire damage. Costs also include:
- Shut down of water treatment plant for at least 4 months after fire
- Replacing or repairing destroyed homes and other indirect socioeconomic costs

Example 2: Denver Forests to Faucets Partnership

- A public federal-local partnership between Denver Water and USFS began in 2010 after Hayman Fire in 2002 caused $40 million in firefighting costs, $37 million in restoration and stabilization costs and $10 million in costs to Denver Water for “water quality treatment, sediment and debris removal, reclamation techniques and infrastructure projects” (Botoroff, 2014)
- In 2010-2015 5-year partnership, Denver Water used ratepayer funds to match the USFS contribution of $16.5 million to treat 48,000 acres of forests upstream of Denver Water’s reservoirs and infrastructure (Colorado State Forest Service, 2017).
- Renewed and expanded 5-year partnership signed for 2017-2022 and allocated an additional $33 million in cost sharing funds to treat an additional 40,000 acres while maintaining previously treated forest (Denver Water, 2018).

posed a public goods charge on water in California that would parallel the electrical PGC (Hanek et al., 2011, Quesnel, 2015). In this partnership, water utilities would be required to fund public purpose projects that benefit ratepayers and the general public in areas including ecosystem improvement, management of water-related risks, and water system changes that improve recreational opportunities.

Forest restoration reasonably falls within the types of projects that water utilities would be required to fund to benefit the general public. Implementing a PES scheme in this way would capitalize on the existing disparity between a utility’s collected revenue based on low water prices and the greater total costs associated with constructing, operating and sourcing water for a system (Ajami and Smith, 2013).

A PES scheme in California could mirror the Colorado and New Mexico-based programs with USFS as sellers of ES and utility customers as buyers. It has been noted that non-profits play a particularly important role as intermediaries linking beneficiary utilities and ES providers to ensure improved watershed health (Bennett et al., 2013). Studies of water utilities across the U.S calculated that every dollar invested in watershed protection has the potential to save tens to hundreds of dollars in costs for new water treatment facilities (Johnson et al., 2000).

In their April 2018 report, the California Legislative Analyst’s Office identified that downstream beneficiaries in the state are not contributing much to forest health activities, and recommended that the state take steps to generate additional investments from these beneficiaries (Taylor, 2018).

They also recommend that the California Department of Water Resources spend a specific amount on projects to maintain and improve the health of the Feather River Watershed above Oroville Dam, and directed the department to recover costs through its State Water Project contracts. In Fall 2018, the California Legislature passed Assembly Bill 2551, directing the California Natural Resources Agency and the California Environmental Protection Agency to develop a plan for forest and watershed restoration investments in the drainages that supply the Oroville, Shasta, and Trinity Reservoirs; the bill also established the Headwaters Restoration Account in California's General Fund. These represent initial steps toward recognizing the value of ecosystem services and monetizing them so that ES can directly contribute to forest restoration thereby helping ensure continued provision of these services.

Private Investment

Restoration projects are often drawn out for years longer than necessary due to agency budgetary restrictions. Blue Forest Conservation in partnership with the World Resources Institute and Encourage Capital developed the Forest Resilience Bond in 2018 to spearhead a new type of public-private partnership. Their approach shifts financial responsibility from cash-limited agencies to a range of private investors. Entities such as foundations, banks, businesses, and insurance companies would make the initial capital investment needed for forest restoration projects in at-risk watersheds, thereby accelerating the pace of forest fuel reduction activities. In this case, beneficiaries, including the U.S. Forest Service, electric and water utilities, and state and local governments would enter into a cost share agreement to re-pay investors over time with interest (Blue Forest Conservation, 2017). The bond monetizes the benefits of restoration activities by converting the conservation of ecosystem services into cash flows for investors.

Blue Forest Conservation's first project launched in North Yuba River watershed in 2018 and will receive $4.6 million from the Yuba Water Agency, the Rockefeller Foundation, the Gordon & Betty Moore Foundation, Calvert Impact Capital and the CSAA Insurance Group to restore 15,000 acres of forestland (Blue Forest Conservation, 2018). Beneficiaries from the Yuba Water Agency utility partnered with the State of California's Climate Change Investment program to commit money for repayment of the bond.

Air Quality Improvement and Carbon Sequestration as Ecosystem Services

Just as water quality declines due to sediment flows following a major wildfire, so too does air quality from the release of unhealthy emissions during wildfire events, including black carbon, volatile organic compounds, fine particular matter, oxides of nitrogen and sulfur (California Air Resources Board, 2017). As the Camp Fire demonstrated, high severity fires can affect many people including distant residents of urban areas (Fairley, 2019). Reducing fuel loads reduces the risk of catastrophic wildfire and hazardous emissions. Additionally, burning biomass in controlled combustion systems such as biomass energy facilities with emissions control equipment drastically improves the emission profile when compared to open pile burning (Springsteen et al, 2011). Prescribed burns can increase emission levels, unduly burdening local airsheds, but should be recognized as a preventative measure to reduce the risk of catastrophic wildfires. Further, when biomass facilities are utilized for baseload energy generation they offset fossil fuel energy generation (Abbs, 2017).

There is increasing recognition in California of the importance of biomass energy in reducing criteria pollutant emissions as it provides an alternative to open pile burning and catastrophic wildfire (CAPCOA, 2016).

Carbon offsets represent one further example of creating a value for forest biomass materials. Projects that reduce greenhouse gas emissions can generate offsets, or credits, for sale to entities bound by regulation to reduce their carbon footprint or to those who voluntarily wish to do so. In a project funded by public and private partners, the Avoided Wildfire Emissions Methodology (AWE) quantifies greenhouse gas (GHG) emissions from implementing fuel reduction treatments in forests in California and Colorado that are at risk for catastrophic wildfire from fire-suppression, drought, insect attack, and past harvest history. It considers fuel reduction thinning and prescribed fire. GHG benefits are achieved through: (1) modifying fire behavior such that severity and size (fire "shadow") are reduced; (2) increased stored carbon in large fire-resilient trees; (3) enhanced tree growth rate from increased availability of water, nutrients, and light; (4) use of treatment residuals for long lived wood products that sequester carbon and displace energy intensive alternative such as concrete and steel, and renewable energy; and (5) reduced occurrence of "delayed reforestation" resulting from high severity fire that converts forest to long-term grass- or shrub-land. AWE combines field data with probability-based wildfire models to calculate GHG emissions in the absence (baseline scenario) and presence (project scenario) of fuel treatments that are additional to current practice.

Burning biomass in a boiler for electrical power generation (instead of in an open pile with harmful emissions) or quantifying the benefits of fuel reduction treatments, are different but similar approaches that can be valued and, in turn, create purchasable carbon credits. This is another example of alternative ways of improving the economics of forest restoration and biomass utilization (Springsteen et al., 2015).

Moving Forward: Using PES Programs to Support Forest Restoration

Monetizing benefits provided by ecosystem services can support the continued provision of these services to society. Successful examples from outside California - such as those from Santa Fe, New Mexico and Denver, Colorado, described in Box 2 above, demonstrate how forested regions are taking investment in restoration seriously when faced with the expensive alternative of a wildfire's aftermath. California's current landscape of resource management necessitates involving partners invested in the security of the state's water, air quality, and other ecosystem services, and including those who are interested in integrating PES into their portfolios, as shown by innovative tools like the Forest Resilience Bond.

California's BioMAT program is an important first step in incentivizing community-scale biomass power and by extension to increased forest restoration activities, serving as an indirect PES mechanism. However, despite the relatively high contract prices, small-scale BioMAT facilities are not economically viable if their only revenue source is the sale of electricity, and cannot by themselves be relied upon to address forest health needs. Simply put, development of stand-alone biomass energy facilities is insufficient to improve the economics of current forest management challenges, though it will likely play an important role, particularly for deriving value from the lowest value material.

Developing payment mechanisms to secure value from ecosystem services need to be advanced not only to ensure future funding streams are available for forest restoration but also to ensure that the lowest value material is not left in the woods to increase fire risks or degrade on the forest floor—producing methane as one of the byproducts.

Compared to in-woods burning, confined burning in bioenergy facilities can reduce GHGs and dramatically reduces emissions that compromise human health.

Section Summary

- *Local outlets and markets for biomass material are an important strategy for improving the economics of forest restoration and biomass removal, but payments for ecosystem services, in parallel with market product pathways for wood products, are necessary to support the high costs of forest restoration.*

- *Monetizing benefits provided by ecosystem services will support continued provision of these services, such as water quality, erosion control, carbon sequestration, and improved air quality.*

- *Successful examples of this elsewhere include the Santa Fe Municipal Watershed Project and the Denver Forests to Faucet Program.*

- *California needs to monetize ecosystem services to draw direct support from those who benefit from these services in order to improve the economics of increased pace and scale of forest restoration and help assure continued provision of these services and support truly sustainable resource management.*

Conclusion

Forest restoration treatments throughout California's forestlands are needed to restore landscapes to a more resilient state in the face of climate change and high risk of catastrophic wildfire. Unfortunately, forest restoration and fuels reduction treatments are expensive because residual material has little value. There are, however, opportunities to improve restoration project efficiencies by planning at a landscape-scale and issuing long-term contracts that can reduce treatment costs and provide long-term assurance needed for investment, or by bundling biomass harvesting with removal of merchantable sawlogs.

Biomass energy plays an important role in advancing landscape-scale forest restoration and wood utilization solutions in California as it provides an outlet for the lowest-value residual biomass material and can offset high costs of forest restoration and biomass transport. But by itself it is not enough. Forest restoration treatment costs combined with the cost to haul biomass material exceed what biomass energy facilities can reasonably pay for feedstock, particularly stand-alone power generation facilities. Electric sales without subsidy (whether for biomass removal, biomass hauling, or utility contract prices for power sales) will not result in feedstock costs that support forest restoration and hauling biomass from the woods to energy facilities.

Additional mechanisms are needed to ensure increased pace and scale of forest restoration treatments in California. Biomass power plants co-located with a sawmill (reduced feedstock costs), with waste heat-utilizing businesses (revenue via heat sales), or with other co-product development operations can pay higher premiums for feedstock and therefore more effectively respond to high restoration costs.

Numerous co-product opportunities are discussed in this report but investments in infrastructure and marketing are needed for them to be successful.

Sustainable resource management and restoration in California will not succeed without investment in the wood utilization infrastructure and development of markets that will increase the value of low-value wood products.

Success in the near term will require the State of California to contribute or stimulate direct investment or to help build markets. It is in the state's interest to advance this work, as community-scale investment offers opportunities to tie landscape restoration to badly needed restoration of rural economies.

Incentivizing better forest management and improved forest health, biomass energy and co-product development will leverage climate and other environmental benefits. Thus a comparison of renewable energy sources solely based on the production cost of electricity misses important benefits of utilizing low-value forest biomass that is a byproduct of forest restoration activities. Use of biomass conversion technologies like gasification and pyrolysis when integrated with CO_2 capture and sequestration, offer the opportunity—indeed are one of the primary ways—for California to become a carbon neutral state. What is needed is commitment coupled with investment.

To stabilize the long term economics of restoration and utilization of low-value biomass, it is necessary to secure payments for ecosystem services dedicated to restoration in parallel with investment in co-product businesses and conversion technologies. A payment scheme for ecosystem services includes non-market benefits of forest restoration that provide public goods to the state, such as wildfire reduction risk, emissions reduction, carbon sequestration and enhanced water quality. California can and should be a leader in establishing a PES system that helps maintain forests and the vital services they provide. A PES program can bridge the current commitment of the state to forest restoration through what is now a temporary CCI program (and other related programs) to one that is itself sustainable by its tie to continued provision of services on which California residents rely and support.

The current investment of one billion dollars of Cap and Trade funding is really a down payment on the investment needed for long term stewardship of California's forests and watersheds.

We recommend that mechanisms be developed to value the benefits of improved forest health, including the removal of small-diameter trees and biomass material. Biomass energy can play a key role in helping California achieve its carbon and climate goals by supporting forest health treatments that promote resilient landscapes and sustainable natural resource management with a changing climate. Work in this arena can also make significant contributions to rural development.

Whether bioenergy production by itself is cost efficient and whether it is better than less expensive wind and solar may be an interesting conversation but it is incomplete and misses the mark when discussing long term forest and watershed restoration. Discussion must include the many benefits of biomass utilization and ask whether we can afford not to support this utilization given the restoration needs and threatened environmental services of California's forests and watersheds.

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Sierra Institute promotes healthy and sustainable forests and watersheds by investing in the well-being of rural communities and strengthening their participation in natural resource decision-making and programs.

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Sierra Institute recognizes the direct relationship that rural communities have with forested landscapes. With this in mind, we work to advance integrative programs that support rural environmental, economic, and community health at the local, regional, and national levels.

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