Joint Institute For Wood Products Innovation

Advancing Collaborative Action on Forest Biofuels in California

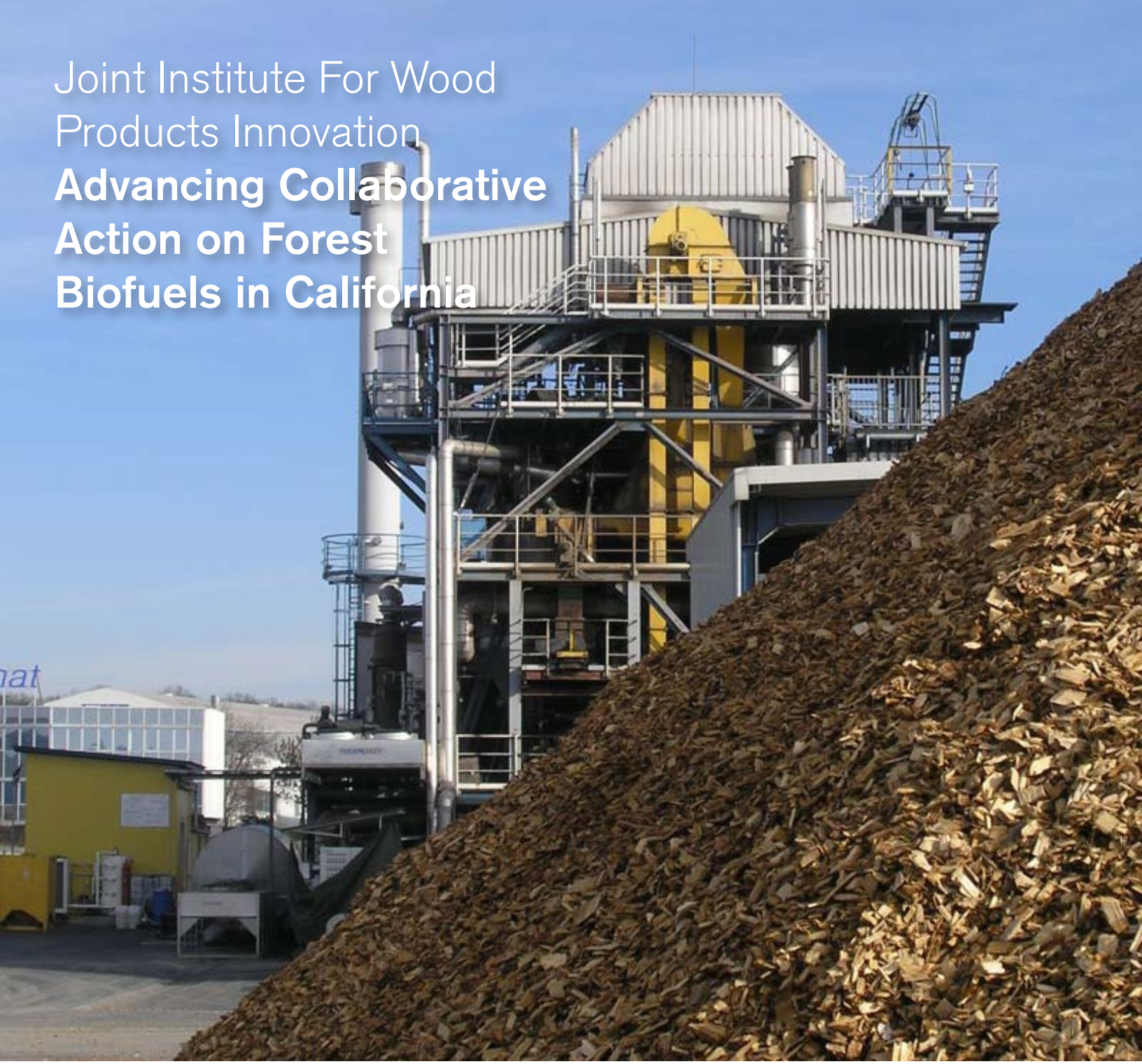

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Table of Contents

Acknowledgments

The findings and recommendations in this report could not have been developed without the contributions of numerous experts. We engaged directly with nearly 50 Californians with wide-ranging experience in project finance, supportive policy, infrastructure development, feedstock supply, social equity, and economic development.

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Summary for Policymakers

Low-carbon and carbon-negative fuels from non-merchantable forest biomass can help California attain its greenhouse gas (GHG) reduction targets and offer an opportunity to support sustainable forest restoration activities to reduce wildfire risk. Development and deployment of these innovative wood products can help the state of California increase the pace and scale of forest restoration efforts, strengthen regional capacity, support innovation, reduce vulnerability to wildfire, and promote carbon storage in long-lived products, including geologically sequestered CO2. These fuels can also play a pivotal role in California's world-leading ambition to address climate change.

Yet successful commercialization of low- and carbon-negative fuels from forest biomass is far from certain, despite existing policy support. Fundamental challenges relate to the inability to secure long-term feedstock contracts from public lands, exclusion of forest biomass from public lands under the federal Renewable Fuels Standard, supply from municipal and agricultural biomass markets, and a lack of biofuels infrastructure situated near California's forested communities. Without meaningful effort from relevant state and federal policymakers, California risks missing the opportunity to develop and deploy these fuels.

We engaged a 50-member working group on "Advancing collaborative action on forest biofuels" to promote policy and market development for forest biofuels across California. The diversity of experts in our working group allowed cross-pollination of ideas and opportunities across sectors, engagement of community members and practitioners capable of implementing recommendations directly.

We assessed four different fuel types that could be produced using non-merchantable forest biomass in California: hydrogen, ethanol, drop-in synthetic fuels that could displace gasoline, diesel or aviation fuel, and renewable natural gas (RNG).

The working group proposed several recommendations to enable low-carbon and carbon-negative forest biofuels pathways in a timely and sustainable manner, with strong environmental safeguards, and at a sufficient scale to support the state's ambitious goals.

Priority policy recommendations include:

- Catalyze first-mover projects with direct state support to demonstrate forest biomass supply chains, creating a foundation for markets to scale.
- Update the federal Renewable Fuel Standard to reflect the modern-day threat of catastrophic wildfire in the American West.

Photo Credit Getty Images

» Adopt changes in the state's Low Carbon Fuel Standard program to incentivize forest biofuels projects.

» Facilitate regulatory coordination and develop bold new policies to advance carbon dioxide removal as a climate solution.

» Establish and support new flexible, public regional entities to overcome barriers to long-term forest biomass feedstock supply.

» Support research into sustainability criteria for out-of-state projects and ensure that all forest biofuels supplied into California meet equally high environmental standards.

» Support biofuels and bioenergy project development & finance by creating a 'hub' that can convene stakeholders and share best practices across the technical, commercial, and financial aspects required for a successful project development. Such a hub could be hosted within the Governor's Office of Business and Economic Development (GO-Biz). As a state agency, it could double as a conduit for state aid to accelerate bioenergy development.

» Via the Catalyst Fund at IBank, provide strategic capital for critical infrastructure aligned with state goals for the sector, while supporting economic development in forested communities.

» California's 2021-2022 budget makes critical initial investments in realizing this vision through investments in the Catalyst Fund and a Forest Biofuels pilot project.

Working Group members also emphasized the opportunities for forest biofuels to address socio-economic resilience and to reduce climate and wildfire vulnerability for rural and forested communities in the state. Priority recommendations to enable equity and development alongside forest biofuel industry growth include:

» Ensure consistency with the Governor's All Regions Rise dictum.

» Accurately capture rural forest community conditions and vulnerability status, via improved tools and definitions built to specifically and exclusively guide non-California Climate Investments (CCI) state monies directed at forest biofuels and forest restoration in California.

› Existing definitions of 'underserved' in the state of California do not effectively target those communities which are disproportionately impacted by wildfire, by forest biofuels use, and by sustainable forest restoration. This causes associated funds and regulatory measures to ineffectively address the climate and wildfire vulnerability and socio-economic resilience of these communities. Two pathways to address this include:

(a) develop a specific definition of 'underserved' – solely for the purpose of guiding non- CCI state monies which target forest biofuels and forest restoration.

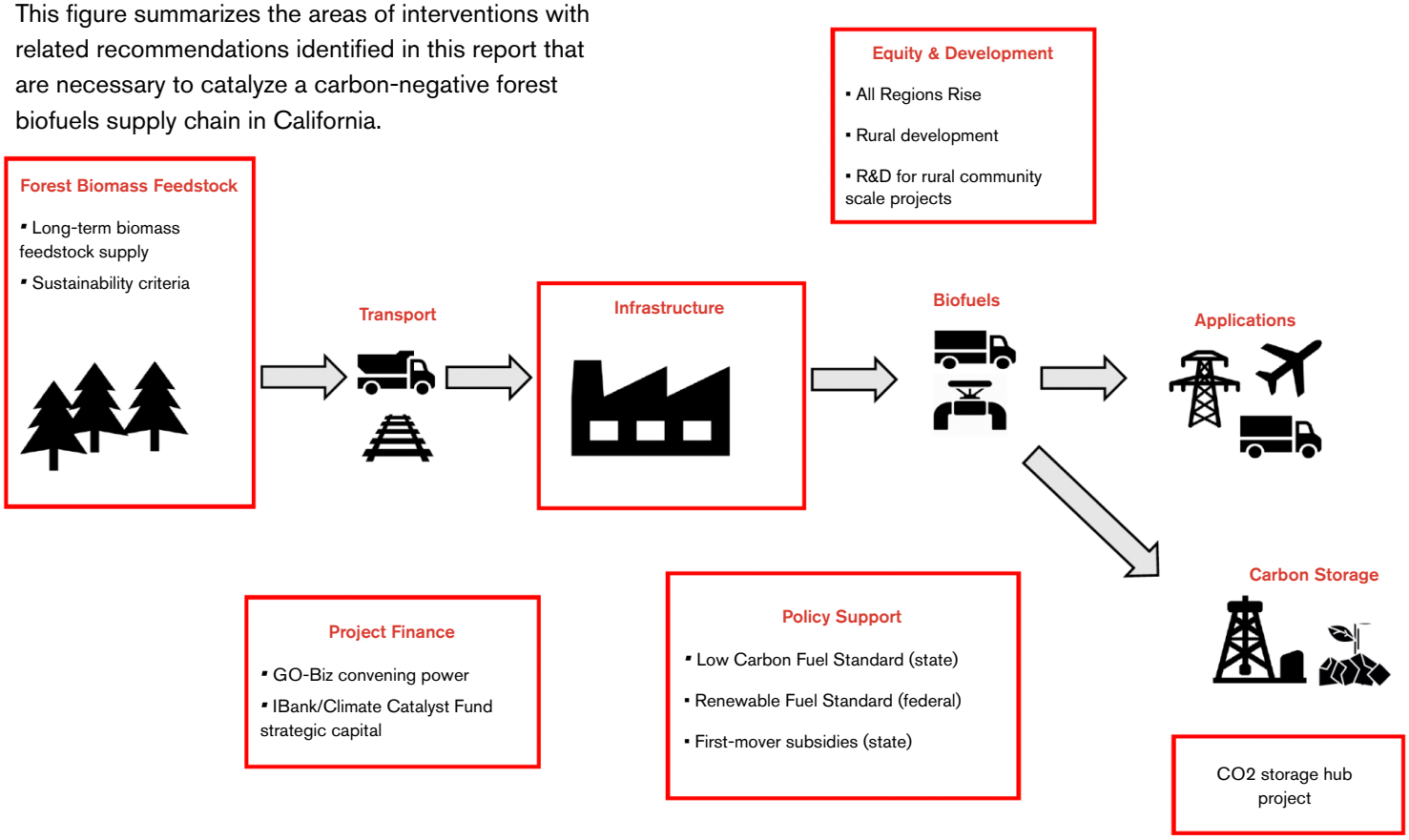
(b) Improve mapping tools and data accuracy to enable consideration of underserved communities under this new definition.

» Direct public investments in ways that aim to achieve sustainable watershed, forest and community benefit.

» Allocate public funds to demonstrate rural, community-scale hydrogen. There are significant anticipated benefits of such a model, including rural energy security, replacement of fossil fuels in rural and Tribal lands, and rural economic resilience.

FIGURE 1:

This figure summarizes the areas of interventions with related recommendations identified in this report that are necessary to catalyze a carbon-negative forest biofuels supply chain in California.



Executive Summary

California is the largest consumer of both motor gasoline and jet fuel in the United States. In 2020, gasoline consumption in California was over 11.3 billion gallons and jet fuel consumption was 5 billion gallons of gasoline equivalent (gge). Markets for alternative and low-carbon fuels such as hydrogen and renewable diesel are expected to grow significantly by 2030 in the state, largely because of policy support under the state's Low Carbon Fuels Standard (LCFS). If California's large demand for low-carbon fuels can be paired with action to develop forest biofuels, there is the possibility to promote forest restoration, strengthen regional capacity, support innovation, reduce vulnerability to wildfire and wildfire intensity, and promote carbon storage in long-lived products.

The 2021-22 state budget makes foundational investments in forest biofuels. This includes $47 million for the Climate Catalyst Fund within the California Infrastructure and Economic Development Bank (IBank) to support wildfire and forest resilience. The budget also includes $50 million to the Department of Conservation for a forest biofuels pilot program including carbon capture and storage. Yet successful commercialization of low- and carbon-negative fuels from forest biomass is far from certain, despite existing policy support.

Further action is necessary to promote policy and market development for forest biofuels across California. This report's findings are broken into five categories (Infrastructure, Supportive Policy, Feedstock Supply, Equity and Development, and Project Finance), with the following recommendations identified:

Infrastructure

Supply chain maps were developed to define forest-to-biofuel infrastructure needs. Four fuel types (hydrogen, ethanol, drop-in gasoline/diesel, and renewable natural gas (RNG)) were also assessed for current demand, future demand, and to determine how much forest biofuel could feasibly be used in the fuels industry.

Numerous gaseous and liquid fuels can be produced from forest biomass at a scale sufficient to meet California's transportation and climate goals. The appropriate fuel product will likely be dictated by regional infrastructure constraints and markets. Forest biomass resources are typically distant from expected sources of biofuel demand in the state. The distance is most prominent for hydrogen demand, which exists primarily at refineries, renewable diesel facilities, and hydrogen refueling stations. It is unlikely that a hydrogen production facility would be sited in a rural community.

Instead, long-distance transport of biomass to the hydrogen facility at a centralized location is likely. Inclusion of carbon capture and storage (CCS) will increase the prevalence of centralized facilities in the Central Valley or urban areas. Similarly, drop-in gasoline and diesel will likely be produced at a centralized location since economies-of-scale and the need for conventional refining of the fuel product make community-scale production uneconomical. Ethanol plants could be potentially easier to site at the community scale or closer to forested ecosystems since there are some fuel terminals that are more proximate to those locations.

Policy Support

Six policy recommendations were identified to support a sustainable, carbon-negative forest biofuels supply chain. These include priority administrative and regulatory changes, as well as initial state and federal agency investments that could establish the conditions for self-sustaining markets. Recommendations include:

- Catalyze first-mover projects with direct state support to overcome logistical barriers and demonstrate forest biomass supply chains to provide a foundation for markets to scale.
- Update the federal Renewable Fuel Standard program to reflect the modern day threat of catastrophic wildfire in the American West.
- Adopt changes in the state's Low Carbon Fuel Standard program to incentivize forest biofuels projects.
- Facilitate regulatory coordination and develop bold new policies to advance carbon dioxide removal as a climate solution.
- Establish and support new flexible, regional entities to overcome barriers to long-term forest biomass feedstock supply.
- Support research into sustainability criteria for out-of-state projects to ensure that all forest biofuels supplied into California meet equally high environmental standards.

Feedstock Supply

Recommendations related to the upcoming Governor's Office of Planning and Research (OPR) pilot project program were proposed that focus on publicly-supported regional approaches to forest biomass feedstock supply chain management.

The OPR recommendations include requiring each pilot project to complete a narrative that describes the vision of how to improve biomass feedstock supply chain logistics within a target region through partnerships, collaboration and information sharing with local government, including cities, counties, or special districts. In addition, pilot projects should demonstrate institutional arrangements, collaboration with the private sector, landowners and community participation and provide tangible deliverables.

The subgroup also recommends improvements to the administrative practices of the U.S. Forest Service (USFS). In particular, the appraisal process should be reviewed and improved, consistent with the goals of heightened pace and scale of fire threat reduction through fuels treatment work.

This includes establishing fair market value through an open and competitive bidding request, developing long-term stewardship contracts to facilitate investment in expanding biomass harvesting and utilization capacity establishing clear policies and practices for the use of the streamlined process for resource surveys and reporting.

Equity and Development

Recommendations were developed to enable public funding related to forest biofuels projects to deliver a more equitable distribution of economic and environmental outcomes across the state's populations while driving speed and scale of forest restoration in the state.

To this end, the report offers 5 specific recommendations to enable resilience and reduce vulnerability in the state. Our recommendations prioritize (1) the creation of substantial public benefits ranging from reduced vulnerability to wildfire and climate to socio-economic resilience and sustainability and (2) the use of public capital to realize these public benefits, particularly where private markets will not otherwise place value.

Recommendations include:

- Enable and ensure consistency with the Governor's All Regions Rise dictum.
- Accurately capture rural forest community conditions and vulnerability status, via improved metrics, tools and definitions built to specifically and exclusively guide non-CCI state monies directed at forest biofuels and forest restoration in California.
  - Existing definitions of 'underserved' in the state of California do not effectively target those communities which are disproportionately impacted by wildfire, by forest biofuels use, and by sustainable forest restoration. This causes associated funds and regulatory measures to ineffectively address the climate and wildfire vulnerability and socio-economic resilience of these communities. Two pathways to address this include:
    - Develop a specific definition of "underserved" – solely for the purpose of guiding non-California Climate Investments (CCI) state monies which target forest biofuels and forest restoration.
    - Improve mapping tools and data accuracy to enable prioritization of underserved communities under this new definition.
- Direct public investments in ways that aim to achieve sustainable watershed, forest and community benefit.
- Allocate funds to demonstrate rural, community-scale hydrogen. There are significant anticipated benefits of such a model, including rural energy security, replacement of fossil fuels in rural and Tribal lands, and rural economic resilience. These public benefits represent significant externalities not priced by private markets.

Photo Credit Repotec

Project Finance

The scale of climate, carbon, and wildfire abatement is so large that public-sector finance alone is insufficient to fund the necessary bioenergy production. For instance, at the scale of biomass utilization contemplated in this report (aggregate scale of approximately 10 million BDT per year), the capital cost of the facilities would exceed $20B. Therefore, public policy needs to be structured with an eye toward attracting private finance.

In particular, we target a lower-cost, more-risk-averse form of finance known as 'infrastructure finance' or 'project finance'. Case studies of financial risks were performed to inform project finance for a small-scale (<$25M) bioenergy project, a small-scale biofuels project (<$25M) and a large-scale ($100M+) biofuel project.

Since every project--including its community, investors, technology, and products--are different, there are no silver bullet solutions. Rather, the subgroup recommends a central convening hub that would share best practices and connect project developers, capital, and the necessary corporate and community partnerships required for a successful bioenergy project.

The hub would necessarily have multi-disciplinary expertise in the relevant technologies, state & federal policies, and project finance.

Given this broad remit, there's no perfect convener for such a hub, but the Governor's Office of Business and Economic Development (GO-Biz), with additional staffing, could serve the purpose. Since GO-Biz is a state agency, it could also serve as an integrated channel for state aid to bioenergy development.

While these recommendations are primarily focused on liquid and gaseous transportation fuels, we recognize that other energy (e.g., biomass to electricity) and non-energy uses for woody biomass may be more applicable in some cases and play key roles in ensuring that climate mitigation and forest restoration goals are met simultaneously. In addition, direct state support may be a more effective and straightforward strategy in some situations (e.g., where there are extremely isolated communities). Nevertheless, establishing the conditions to attract private investment is necessary to provide a biomass management infrastructure that could support the state's long-term forest restoration goals.

Photo Credit Bodie Cabiyo, Univ of CA-Berkeley

1 INTRODUCTION

California is facing a growing forest health and wildfire crisis, caused in part by a history of fire suppression policies and exacerbated by the effects of climate change (Williams et al. 2019).

Seventeen of the state's 20 largest fires on record have occurred in the past two decades (Forest Management Task Force, 2021). These catastrophic stand-replacing fires damage the forests so severely damaged that they are unable to rejuvenate post-fire and are often replaced with shrubs (Stevens et al. 2017). At the same time, natural and cultural fire has been a fundamental part of California's natural environment for millennia, with research indicating that about 4-12 million acres burned in the state each year prior to European settlement (Little Hoover Commission 2018).

In response, the state has set a goal to increase the pace and scale of forest treatments to 1 million acres per year by 2025 (Forest Management Task Force, 2021; FCAT 2018). This goal was set in partnership with the United States Forest Service (USFS), who owns 57% of forested lands in California. To achieve the goal, the United States Forest Service (USFS) and the state are each responsible for treating 500,000 acres. The state intends to achieve its target by facilitating treatments across both state- and privately-owned lands.

Forest biomass is a byproduct of sustainable forest activities. Currently, this biomass is mostly open burned or left in the forest to decompose.

Photo Credit UCLA

These approaches result in substantial greenhouse gas (GHG) emissions, including climate "super pollutants" in the forms of methane and black carbon. At the scale of treating one million acres per year, which is anticipated to generate hundreds of millions of new tons of biomass over the next 1-2 decades, such approaches could undermine the state's ambition to achieve net-zero GHG emissions by 2045 (Baker et al. 2019). Adopting new policies that support the robust management and use of biomass waste are essential to align the state's forest health, climate and air quality goals.

Collecting and converting forest biomass into bioenergy, notably liquid and gaseous fuels including hydrogen, renewable natural gas, sustainable aviation fuel, renewable diesel, synthetic hydrocarbons, and ethanol, presents a promising alternative to current practices (Sanchez et al. 2020; Gilani & Sanchez 2021a). Low-carbon transportation fuels are high value, owing to large incentives available under California's Low Carbon Fuel Standard (LCFS) and the federal government's Renewable Fuel Standard (RFS) programs. These incentives present an opportunity to overcome the challenging economics that affect forest biomass projects.

Some fuels can even be carbon-negative when combined with carbon capture and storage (CCS), which the California Air Resources Board (CARB) has identified as a key technology and strategy for achieving net-zero GHG emissions by 2045. Lawrence Livermore National Laboratory identified the potential for 70 million tons of greenhouse gas (GHG) mitigation, equal to over 15% of the state's GHG inventory, by collecting and converting California's forest biomass waste into hydrogen with CCS. In addition, in a recent study Princeton University highlighted the essential role of large-scale biofuels with CCS deployment for the United States to achieve net-zero GHG emissions by 2050, including in California (Larson et al. 2020).

> **"Inclusion of carbon capture and storage (CCS) will increase the prevalence of centralized facilities."**

California's liquid fuels end market is extremely large and established. In the near term, renewable liquid and gaseous fuels can displace fossil fuels in many transportation applications, helping reduce emissions while the state transitions to a predominantly zero-emission transportation system. In the long term, biofuels from forest biomass offer the potential to achieve near-zero, or even below-zero emissions in a diversity of hard-to-electrify applications, including aviation, shipping, some long-haul transport and some industrial processes, thereby supporting California's transition to net-zero GHG emissions.

Due to incentives available under the state's Low Carbon Fuel Standard (LCFS) and the federal government's Renewable Fuel Standard (RFS) programs, biofuels (including hydrogen) are afforded a price premium to alternative biomass-based products and can therefore support a higher price for the biomass while maintaining profitability (Sanchez et al 2021; Gilani & Sanchez 2021b). This can substantially improve the financial viability of biofuels projects; and therefore, support the long-term availability of biomass management infrastructure to process residues resulting from the planned expansion in forest restoration.

Carbon dioxide removal (CDR) has been identified by CARB as a key strategy to achieve net-zero GHG emissions by 2045 (CARB 2020; CARB 2021a&b). Biofuels production can become carbon-negative when combined with carbon capture and storage (CCS). Such CDR strategies are routinely identified by the IPCC and IEA as necessary to achieve global climate goals. Carbon-negative biofuels strategies are also essential for achieving national deep decarbonization goals.

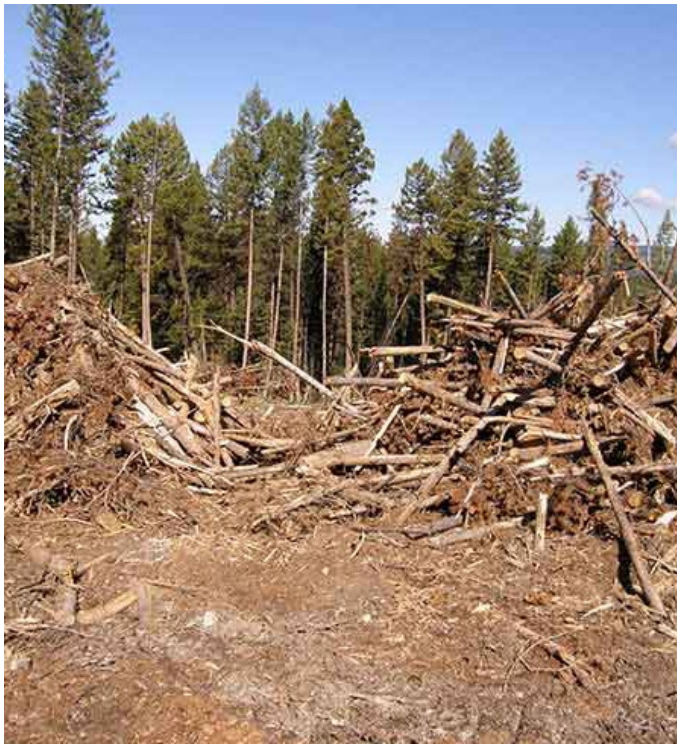


Photo Credit Biomass Magazine

A recent study explored alternative scenarios for the United States to achieve net-zero GHG emissions by 2050 at an unprecedented level of spatial, temporal, and sectoral resolution (Larson et al. 2020). The study found that large-scale deployment of biofuels with CCS was essential in all scenarios. As a sign of federal commitment, Secretary of Energy Jennifer Granholm recently launched an "Carbon Negative Shot" initiative focused on accelerating breakthroughs in the production of carbon dioxide removal technologies (DOE 2021).

The Joint Institute of Wood Products Innovation supported the University of California, Berkeley to establish and convene a state-wide Forest Biofuels Working Group and provide recommendations to support industry development by March 2022.

To understand the range of perspectives (financial, policy, social, environmental, and climate change) and consider the interplay between them, a diverse and disparate state-wide group of representatives from industry, private, government, and non-profit organizations met for six months.

Online meetings, case studies, and guest speakers from the industry as well as academia helped to inform the group and spur conversation. The findings from this report are intended to assist in the development of state-wide policies and strategies that foster a range of biofuels being established that use non-merchantable forest biomass. Each section of the report describes the findings and recommendations of each subgroup.

The working group had near consensus that utilizing non-merchantable forest biomass to produce gaseous and liquid fuels in California could provide many key benefits to the state, including meeting state's climate goals and wildfire reduction. However, there are barriers to achieving these goals that must be addressed, such as exclusion of forest biomass from public lands under the federal Renewable Fuels Standard, an absence of investment-grade feedstock suppliers, supply from municipal and agricultural biomass markets, and a lack of biofuels infrastructure.

Photo Credit USFS

2 INFRASTRUCTURE

The infrastructure subgroup performed a supply chain mapping exercise to understand what forest-to-biofuel infrastructure would require. The subgroup also examined the market outlook for four types of fuels: hydrogen, RNG, ethanol and drop in gas/diesel. The purpose of the market outlook was to assess current demand, future demand, and to realistically determine how much forest biomass can be absorbed into the market.

2.1 Supply Chain Mapping

The infrastructure subgroup produced a series of state-wide maps examining the potential biofuels supply chain for both gaseous and liquid fuels in the state of California. Existing and idle wood processing facilities such as sawmills and bioenergy facilities could be suitable sites for biofuel manufacturers looking to use forest fuel. Most of these locations are located within economical distance to available forest biomass, have existing relationships with forest managers, and have professional wood fiber procurement staff. Many of these facilities have access to rail and natural gas lines. Companies interested in producing biofuels from forest biomass in California could capitalize on these existing facilities to remove some infrastructure barriers.

> **“Existing and idle wood processing facilities such as sawmills and bioenergy facilities could be suitable sites for biofuel manufacturers looking to use forest fuel.”**

2.1.1 Hydrogen

As shown in the maps below, there is a lack of co-location of forest biomass supply and hydrogen demand in the state, making it unlikely that the biofuels facility would be located in the rural community *(Figure 2)*. As moving hydrogen is costly, lower-cost operations can be achieved by moving biomass to a hydrogen facility where it would be delivered to fuel stations and refineries using a centralized infrastructure. Advances in hydrogen transport include rail transport, conversion to ammonia, and improved trucking and liquefaction; however, these are relatively nascent fields.

2.1.2 Hydrogen with CCS

Inclusion of CCS will increase the prevalence of centralized facilities in the central valley or urban areas of California *(Figure 3)*. Forested communities will likely need to transport CO2 for geologic storage (e.g., in deep sedimentary basins). One example of a geologic storage opportunity in forested areas is the Eel River basin near Eureka, California. Additional geologic storage opportunities may be possible in forested communities; however, additional research would be necessary to determine if such options were feasible. A lack of refueling capacity in forested communities also poses challenges. If solutions to those limitations are identified, community-scale development opportunities would be possible.

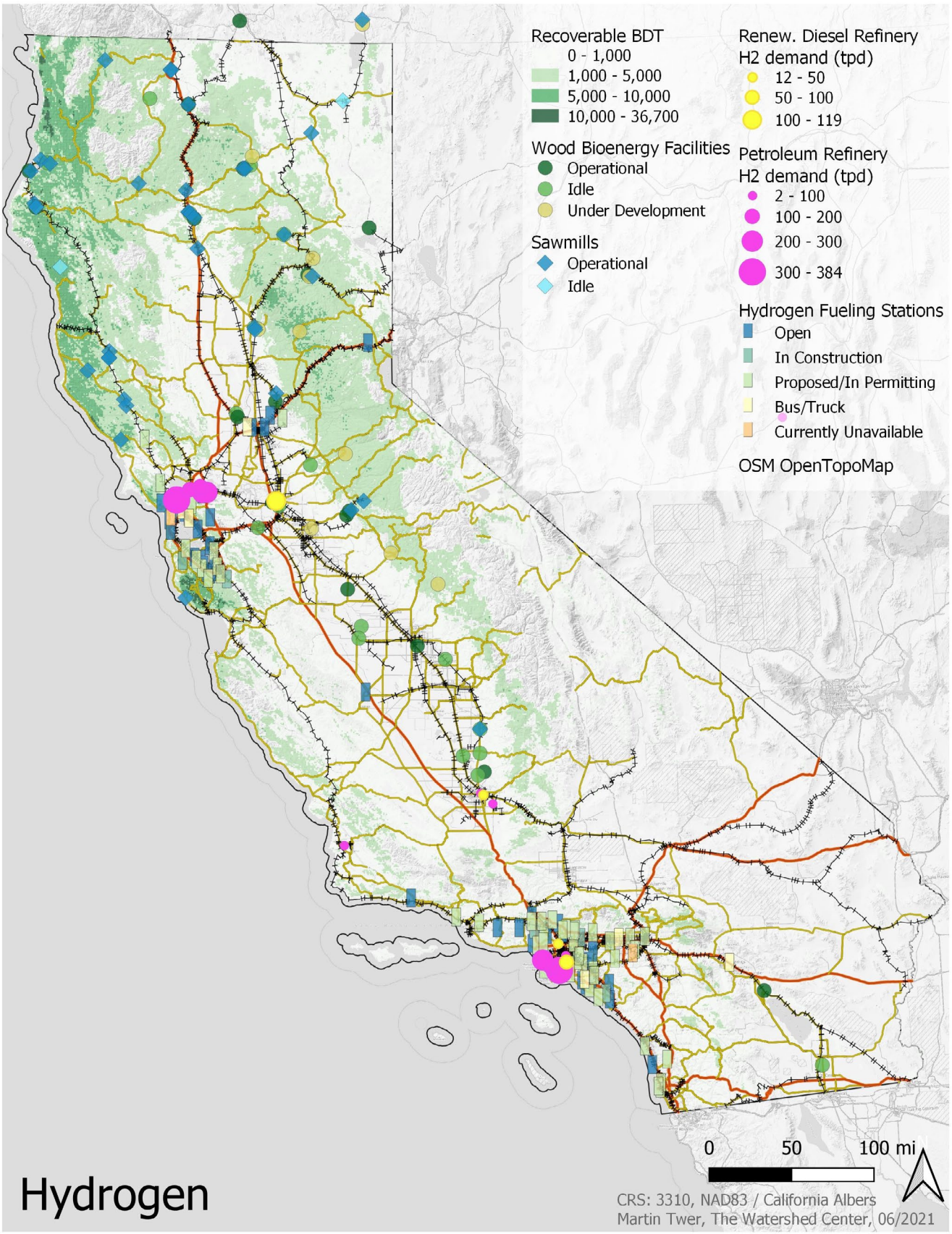


FIGURE 2:

The potential supply chain for hydrogen in California (Credit: Martin Twer, the Watershed Center, 06/2021).

2.1.3 Ethanol

Ethanol will ultimately need to be blended at a fuel terminal. This is potentially easier to site at the community-scale or closer to forested ecosystems since there are some fuel terminals that are more proximate to those locations. For example, the Chico terminal is the northernmost extent of the petroleum product pipeline system in the state and Fresno terminal is the southernmost extent of the petroleum product pipeline system *(Figure 5)*. In addition, interstate pipelines are used to export transportation fuels to Nevada, which receives over 90% of its transportation supply from California.

2.1.4 Drop-in Gasoline/Diesel/Jet Fuel

The drop-in gasoline and diesel will likely need to be produced at a centralized location near urban centers or the Central Valley *(Figure 6)*. While the fuel terminals could also accept drop-in gasoline/diesel, the most likely solution would be to transport intermediate products derived from woody biomass to oil refineries for blending. Furthermore, production of highly specific liquid fuels requires complexly integrated biorefineries, which are only economical at larger scales, reinforcing the need for centralized locations.

2.1.5 Renewable Natural Gas (RNG)

There might be an opportunity to inject RNG into natural gas pipelines that run through or near the forested communities in California. However, there is uncertainty about the suitability for pipeline injections which may need to be investigated further. RNG has benefited greatly from "virtual contracting" or "book-and-claim accounting" in which RNG is injected into the gas grid at some location (even out of state) while the customer pulls RNG in another location from the interconnected grid. Ultimately, the contract is essentially a transfer of "carbon attributes" while the underlying molecule is identical. As with hydrogen, there is a lack of RNG refueling capacity in forested communities, though that does not need to be addressed prior to community-scale development given the possibility of virtual contracting.

> **"...successful commercialization of low- and carbon-negative fuels from forest biomass is far from certain, despite existing policy support."**

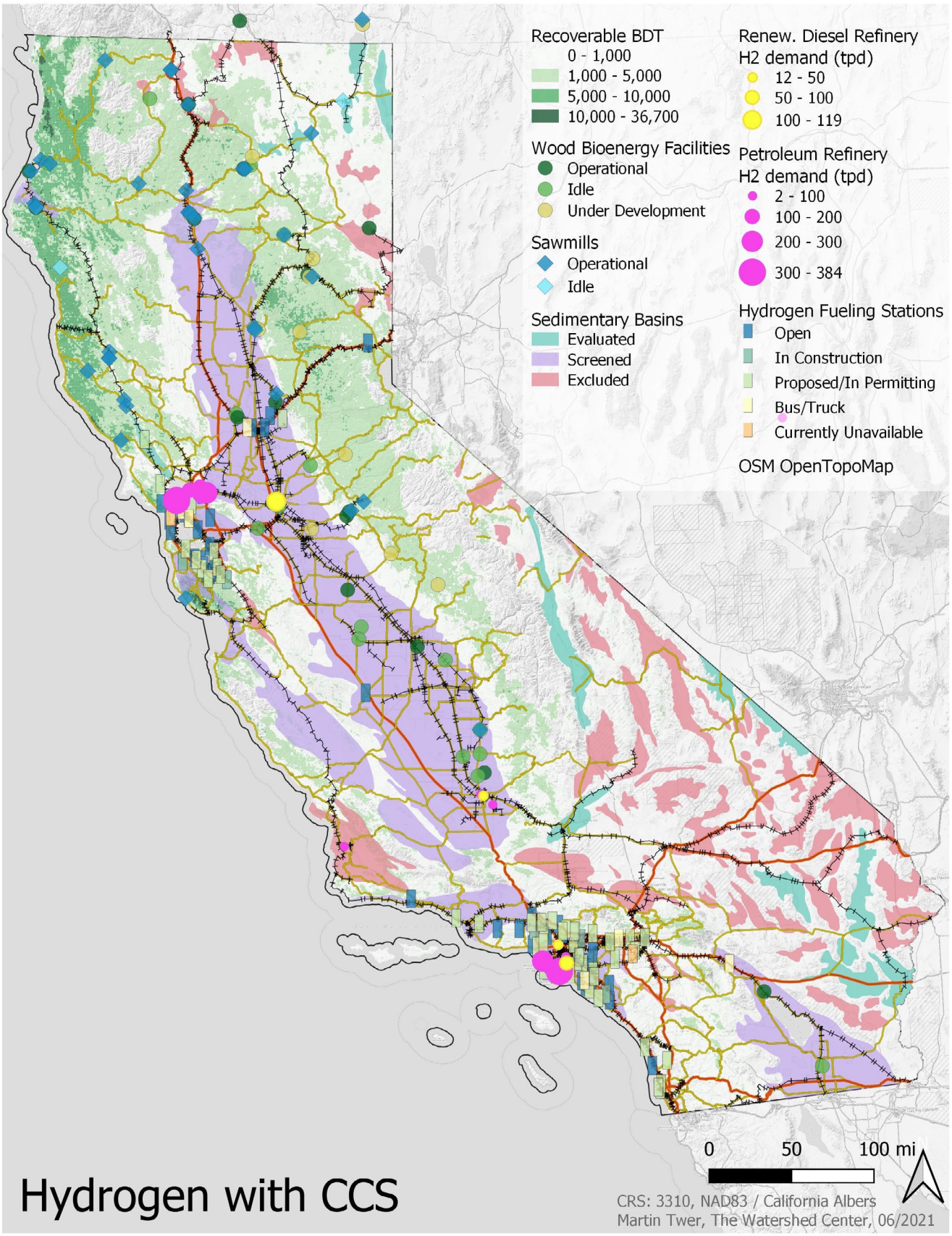


FIGURE 3:

The potential supply chain for hydrogen with CCS in California.

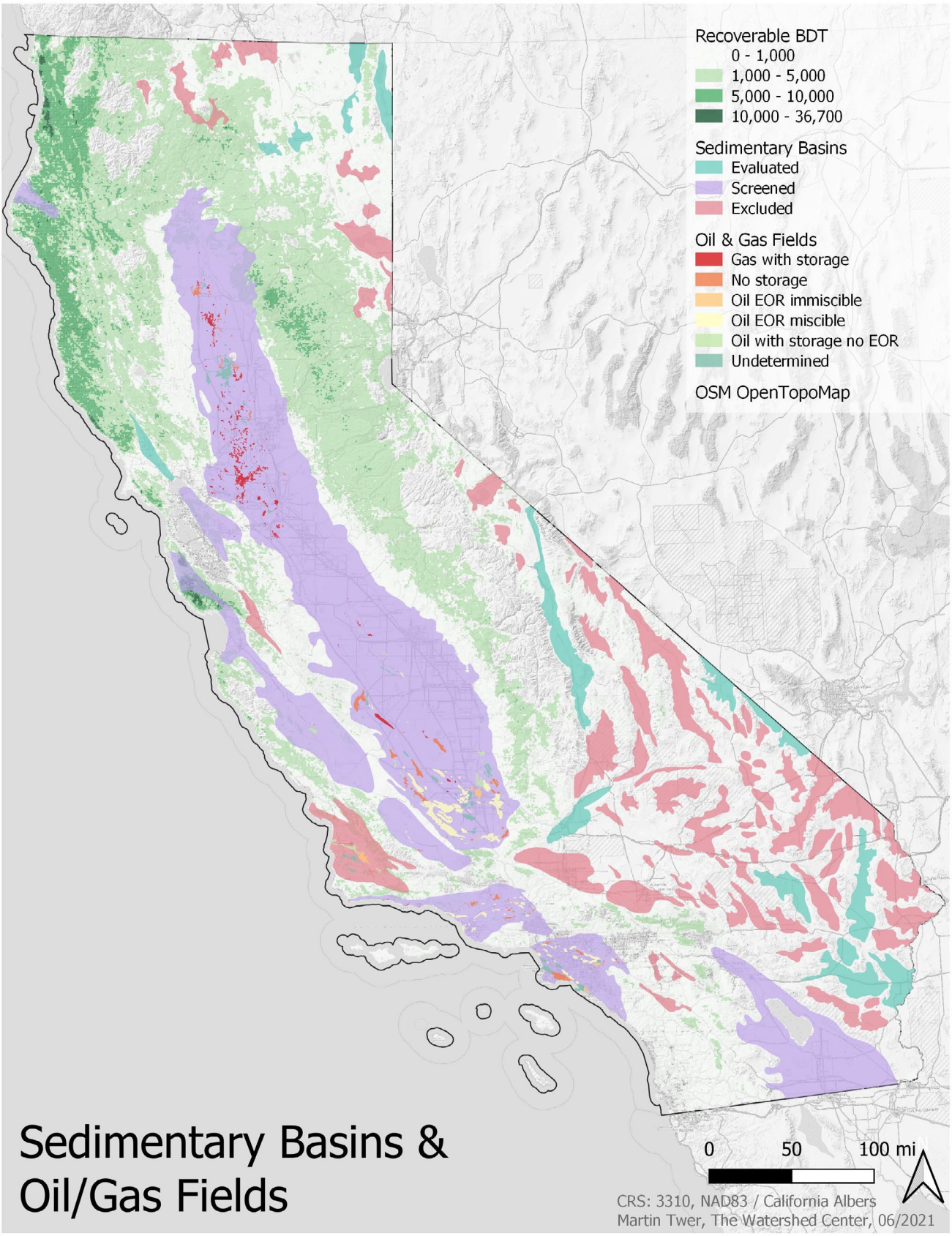


FIGURE 4:

Potential CO2 storage opportunities in California (California Geological Survey 2006)

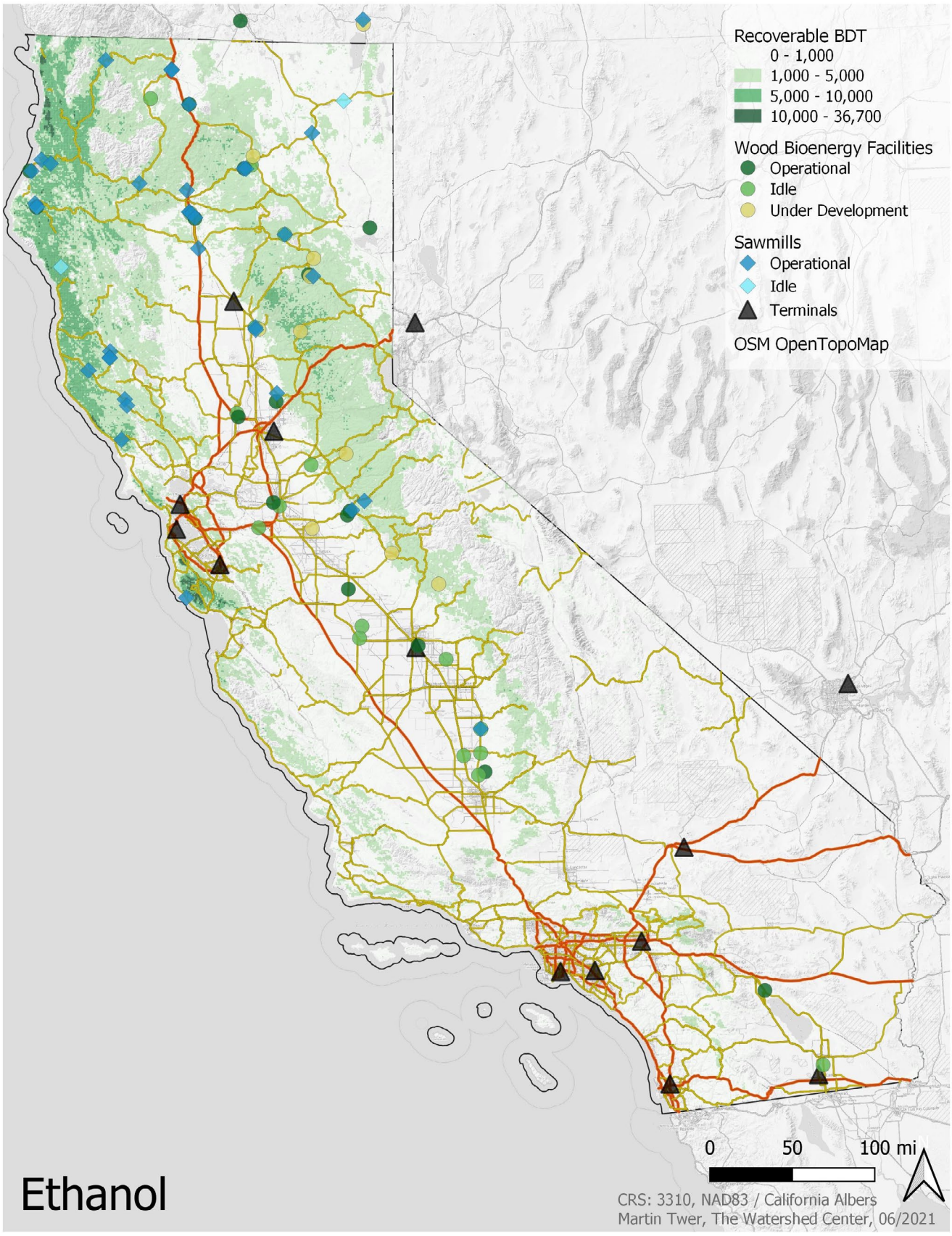


FIGURE 5:

The potential supply chain for ethanol in California

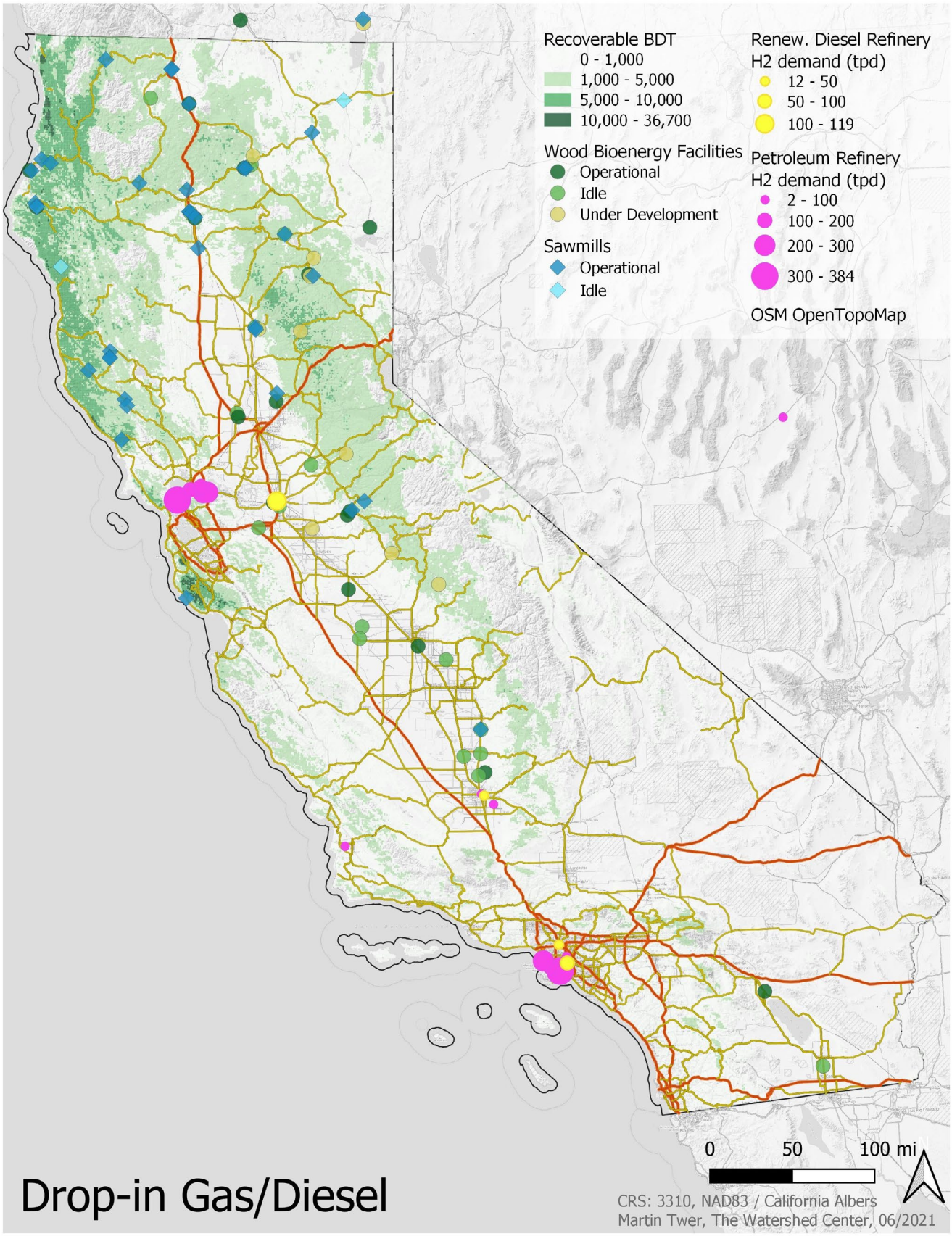


FIGURE 6:

The potential supply chain for drop-in gas/diesel in California.

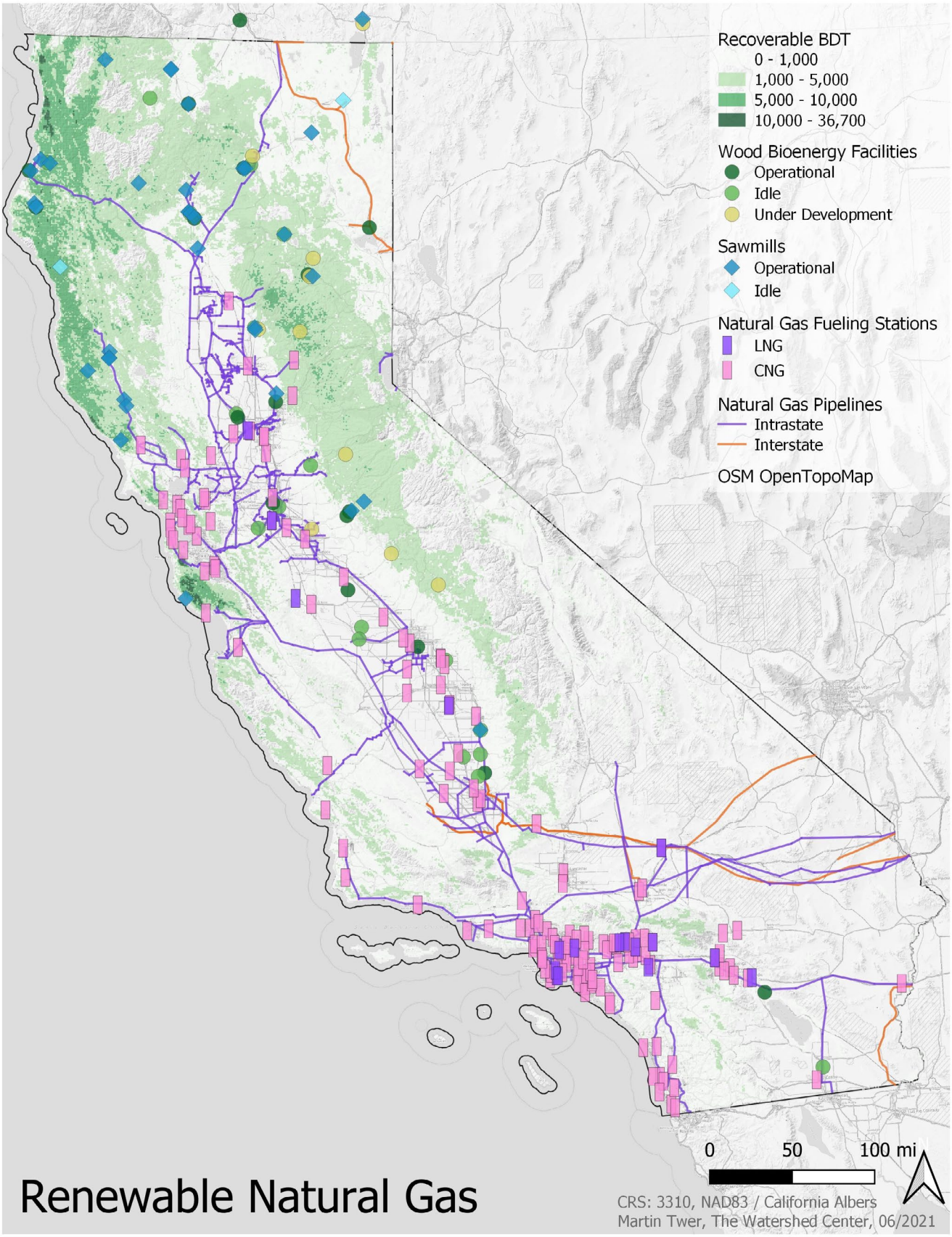


FIGURE 7:

The potential supply chain for RNG in California.

2.2 Market Size

Transportation accounts for the largest share of the state's energy consumption. California is the largest consumer of both motor gasoline and jet fuel and among the 50 states and consumed over 11 billion gallons of gasoline and 5 billion gge of jet fuel in 2020 *(Table 1)*. This accounted for 11% of the nation's motor gasoline consumption and 17% of jet fuel consumption.

Diesel fuel is the third largest transportation fuel used in California with over 3 billion gge consumption in 2020. Diesel is the fuel of choice because it has 12% more energy per gallon than gasoline and has fuel properties that prolong engine life making it ideal for heavy duty vehicle applications.

In recent years, the state has shifted its focus to a number of alternative fuels such as ethanol, renewable diesel, and RNG that reduce the levels of GHG emissions in the production. There are five ethanol production plants in the state. However, California consumed 885 million gge ethanol in 2020, which is one-ninth of the nation's fuel ethanol supply and more than seven times the amount of ethanol the state produces.

Renewable Diesel, predominantly made from plant oil and animal fats where the finished fuel is nearly identical to petroleum-based diesel, was introduced in California in 2012. California accounts for almost all of the renewable diesel consumed in the United States, largely because of the LCFS incentives.

California's natural gas production is less than one-tenth of state demand. In 2020, California's transportation sector consumed over 187 million gge which is roughly only 1% of the total natural gas end-use consumption in the state. Of that, 173 million gge were renewable.

While RNG use may not expand in the transportation sector, it can be used for electricity generation and other industrial applications. California accounts for less than 1% of total United States natural gas reserves and production. Several interstate natural gas pipelines enter the state from Arizona, Nevada, and Oregon and bring natural gas into California from the southwest, the Rocky Mountain region, and western Canada. Ninety-two (92) percent of all on-road fuel used in natural gas vehicles in California in 2020 was RNG. RNG use as a transportation fuel in California grew 177 percent over the last five years. Production capacity of RNG in California is 4.2 million gge *(Table 2)*. In 2020 a total of 187 million gge of natural gas were used as motor fuel in the state.

This section discusses markets on an energy/volume basis, which is not the sole determinant of competitiveness. Rather, LCFS has led to California's market being sorted for greenest fuel in each segment. For instance, if forest biomass were converted into RNG, it may be unable to compete in LCFS market with manure-based RNG since the CI of forest biomass-derived RNG is unlikely to be comparable to manure-based RNG.

"California is the largest consumer of both motor gasoline and jet fuel and among the 50 states and consumed over 11 billion gallons of gasoline and 5 billion gge of jet fuel in 2020."

TABLE 1:

California Fuel Consumption.

California Consumption	2020	Units*
Gasoline	*11.3 billion*	*GGE*
Ethanol	*885 million*	*GGE*
Diesel	*3.09 billion*	*GGE*
Jet Fuel	*5.09 billion*	*GGE*
Natural Gas for Transport	*187.2 million*	*GGE*
RNG Share	*173.1 million*	*GGE*

As part of the rulemaking process to adopt the 2018 proposed amendments for the LCFS program, CARB developed several compliance scenarios (e.g., volumes and credits generated by alternative fuels as well as credits generated through petroleum projects) that were used to conduct economic analysis to support the rulemaking process. *Table 3* shows the estimated fuel volumes for the four types of fuels we considered in this working group based on the 2018 LCFS Illustrative Compliance Scenario Calculator (CARB, 2018)[1] . Market trends for each fuel type are shown in *Table 4*.

**All fuel volumes have been converted to an energy equivalent basis.*

[1] Low Demand Scenario; Supply Scenario: Project/LD/Low ZEV/20%/infra.

TABLE 2:

Renewable Natural Gas Infrastructure in California.

Total RNG Facilities Nationally	157 Units	
Production Capacity	*518.6 million*	*GGE*
Production Capacity in CA	*4.4 million*	*GGE*
Facilities in Development	*155*	

TABLE 3:

LCFS Illustrative Compliance Scenario Calculator (mm GGE).

Fuel Volume	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Gasoline	*13,600*	*13,185*	*12,778*	*12,369*	*11,908*	*11,475*	*11,073*	*10,661*	*10,253*	*9,944*	*9,677*	*9,447*	*9,246*
Ethanol	*1 ,047*	*1,018*	*990*	*962*	*931*	*902*	*876*	*848*	*822*	*803*	*788*	*775*	*766*
Hydrogen	*1*	*1*	*2*	*4*	*6*	*9*	*13*	*17*	*22*	*26*	*31*	*35*	*40*
Diesel	*3,438*	*3,225*	*3,024*	*2,857*	*2,691*	*2,671*	*2,617*	*2,582*	*2,542*	*2,457*	*2,378*	*2,364*	*2,245*
Renewable Diesel share	*489*	*598*	*707*	*816*	*924*	*979*	*979*	*979*	*979*	*1,033*	*1,088*	*1,088*	*1,196*
RNG	*121*	*153*	*170*	*188*	*207*	*225*	*251*	*254*	*260*	*267*	*271*	*276*	*282*
Alternative Jet Fuel	*21*	*21*	*42*	*85*	*159*	*185*	*185*	*185*	*185*	*185*	*211*	*211*	*238*

TABLE 4:

Market Size Trend.

Fuel	Market Size *	Increase/ Decrease
Gasoline	*Large*	*Decrease*
Ethanol	*Medium*	*Decrease*
Hydrogen	*Medium*	*Increase*
Diesel	*Large*	*Decrease*
Renewable Diesel	*Medium*	*Increase*
RNG	*Small*	*Increase*
Alternative Jet Fuel	*Small*	*Increase*

**Market size:*
0-200 mm gge = Small;
201-1000 mm gge = Medium;
1001-10,000 mm gge = Large

Photo Credit Daniel Sanchez, Univ of CA-Berkeley

3 **POLICY SUPPORT**

Policy intervention can help overcome existing barriers and enable a sustainable carbon-negative forest biofuels supply chain. Below, we summarize the findings of the policy subgroup, including the identification of six key policy recommendations. We also highlight what we consider to be priority recommendations for immediate action (i.e., within the next 6 months).

In general, the recommendations identify select administrative and regulatory changes, as well as initial investments from state and federal agencies that could establish the conditions for self-sustaining markets. Biofuels economics are substantially enhanced when coupled with CCS (i.e. by increasing the LCFS credit and also providing access to the federal 45Q tax credit). Such incentives can help offset biomass transportation costs; and overtime, feasibly contribute to forest treatment costs. Relevant federal agencies including US EPA and USFS as well as state entities such as CARB, the California Natural Resources Agency (CNRA), the Department of Conservation (DOC), the California Energy Commission (CEC), the Board of Forestry (BOF), and the Joint Institute for Wood Products Innovation can play a role in implementing the recommendations. CARB is viewed as having a particularly important role via its management of the LCFS program, as well as administration of other climate policy and air quality programs.

Without these interventions, it is unlikely that very low-carbon and carbon-negative forest biofuels pathways will form in a timely and sustainable manner, with strong environmental safeguards, and at a sufficient scale to support the state's ambitious goals.

While these recommendations are primarily focused on forest biofuels (as a subset of bioenergy), we recognize that other energy (e.g., biomass to electricity) and non-energy uses for woody biomass may be more applicable in some cases and play key roles in ensuring that climate mitigation and sustainable forest restoration goals are met simultaneously. In addition, there may be some situations (e.g., extremely isolated communities) where direct state support is a more effective and straightforward strategy. Nevertheless, to provide a biomass management infrastructure that could support the scale of the state's long-term sustainable forest management goals will require establishing conditions that attract private investment. This is the key context and framing for developing the below policy recommendations.

Recommendation 1

State of California should underwrite the collection and delivery of a total of 15 million bone dry tons of forest biomass for low-carbon and carbon-negative bioenergy, with a preference for feedstock sourced from public and non-industrial private lands.

At present, there are estimated to be several millions of tons of forest biomass residues accumulated in large piles throughout California's forests each year. These piles not only present an immediate wildfire threat, and as they decompose, release methane (Schatz Energy Research Center 2021), which has a global warming potential 28 times more powerful than carbon dioxide over a 100-year time horizon. These piles reflect the severely underdeveloped forest biomass supply chain in California. One key obstacle to effectively utilizing them is the cost of conversion, loading and transportation, since forested areas tend to be mountainous and remote (e.g., see Baribault et al. 2020).

This recommendation aims to deliberately kickstart this supply chain in California, particularly for forest biomass residues sourced from public and non-industrial private lands. Together, these lands comprise 85% of total forested lands in the state, yet present notable feedstock sourcing difficulties (for further background on this issue, see Recommendation #5, below). This is a critical bottleneck to both increasing the pace and scale of forest treatments and expanding forest biofuels end markets in California.

This recommendation could be administered in a number of different ways. For example, the state (e.g., CARB; GO-Biz; OPR; IBank) could administer a reverse auction to cost-effectively underwrite biomass collection and delivery costs. A reverse auction is a process by which an entity, generally the government, announces that it wants to purchase a certain amount of a product or service — in this case biomass — and solicits competitive bids so as to acquire it at the lowest cost. Alternatively, the state could simply offer direct awards for projects that meet priority criteria, such as: low lifecycle GHG emissions; demonstrated execution of long-term (e.g., 10-year) offtake agreements; and anticipated meaningful public health, community, and ecosystem services benefits.

Finally, we note that this recommendation is proposed on the basis that the state would also take other, more substantive, and long-term oriented measures (e.g., recommendations #2-#6, below). Subsidies alone are wholly insufficient to solve the systemic issues that underlie what is a multi-decadal, multi-billion dollar problem. Deeper and more structural policy fixes to correct these issues and support market development are required. This one-off recommendation is designed to support early supply chain learning-by-doing that, in conjunction with structural policy fixes, provide a pathway to a robust solution.

Recommendation 2

US Environmental Protection Agency (EPA) should undertake the following administrative actions related to the Renewable Fuels Standard (RFS) program:

- Revise definitions as contained in Title 40, Section 80.1401 (Renewable Fuel Standard) of the Code of Federal Regulations as follows:
  - Areas at risk of wildfire: By wholly revising this definition, as "Areas at risk of wildfire are determined on an ongoing basis by the government agency with primary authority for managing wildfire risk, including the United States Forest Service, other federal agencies, tribal authorities, and state and local fire agencies. Eligible renewable biomass can be gathered from areas at risk of wildfire so long as the biomass is obtained in compliance with an approved wildfire risk management activity approved by the responsible government agency."
  - Renewable biomass: By partly revising paragraph (5), as "Biomass obtained from the immediate vicinity of buildings and other areas regularly occupied by people, or of public infrastructure including access roads and utility lines, at risk of wildfire."
  - Slash: By partly revising this definition, as "Slash is the residue including treetops, branches, and bark, left on the ground after logging or accumulating as a result of a storm, fire, delimbing, or other similar disturbance, as well as whole dead or dying trees determined by the government agency with primary authority for managing wildfire risk to provide limited ecological benefit and otherwise create a high wildfire risk".
- Develop new guidance that outlines a pathway for sawmill residues from sawmills that purchase some non-qualifying wood and therefore incur a blanket disqualification under the RFS, to qualify as renewable biomass under the RFS through the use of inventory accounting methods that provide RIN crediting for the portion of the finished fuel that has been produced from qualifying renewable biomass.

> **Without these interventions, it is unlikely that very low-carbon and carbon-negative forest biofuels pathways will form in a timely and sustainable manner, with strong environmental safeguards, and at a sufficient scale to support the state's ambitious goals.**

The RFS program is a market-based federal program that provides incentives to low-carbon biofuels projects. The incentives are awarded in categories (called "D-Codes") based on the type of feedstock used and renewable fuel produced and provided the lifecycle carbon accounting is below a certain threshold.

For example, D-3 cellulosic biofuel pathways must demonstrate at least a 60% lifecycle GHG reduction. The RFS program was created under the Energy Policy Act of 2005, and further amended under the Energy Independence and Security Act of 2007 (EISA). EISA requires that cellulosic biofuels be derived from "renewable biomass". As it relates to forestry residues, EISA defines renewable biomass as "slash and pre-commercial thinning that is from non-federal forest lands", as well as "biomass obtained from the immediate vicinity of buildings and other areas regularly occupied by people, or of public infrastructure, at risk from wildfire".

The latter definition is especially relevant to California, given the majority of the state's forests are federal lands (almost 60%), with the key qualifying term being "areas at risk from wildfire". This term is not defined in statute and is instead defined in the Code of Federal Regulations (CFR) as "those areas in the wildland-urban interface". Areas deemed to meet this criterion are determined based on modeling performed by the University of Wisconsin-Madison (2017). This modeling, which is based on historic data up to 2010 only, excludes large swathes of the American West, which faces a highly severe, contemporary threat of wildfire (see Appendix A for a summary of the wildland-urban interface map).

In other words, by virtue of this historic modeling the accessibility of RFS incentives is limited in California.

We recommend that the US EPA revise the definition of "areas at risk of wildfire" to instead simply provide the public agencies that are responsible for wildfire management in a given region the authority to determine areas at risk of wildfire. As the responsible entity with much more intimate knowledge of the landscape as well as on-the-ground experience, these agencies (i.e., USFS, other federal agencies, tribal authorities, state, and local fire agencies) are better placed to make such assessments. These agencies include USFS, other federal agencies, tribal authorities, state and local fire agencies.

In addition, we recommend that clarifying amendments be made to the definitions of "renewable biomass" and "slash" in the CFR. Specifically, we recommend that the preclusion of biomass beyond 200 feet be removed, which is arbitrary and can limit what would otherwise constitute an ecological forest treatment in certain circumstances.

By adding access roads and utility lines, agencies will also be provided an incentive to address these high-risk areas. In addition, we recommend that the US EPA incorporate "whole dead and dying trees" into the definition of slash. A limited number of whole dead or dying trees per acre can provide ecological value in the form of habitat (North 2012; North et al. 2009), but otherwise may create a high wildfire risk and limitations upon the effectiveness of possible reforestation efforts.

In California (notably the southern Sierra Nevada), hundreds of millions of dead and dying trees are present on the landscape, largely the result of overgrown and unhealthy forests, pest infestations (bark beetle), and drought (SNC 2017). This addition would provide an incentive to perform ecological forest treatments in such forests.

Finally, mill residues such as sawdust and shavings could be used to make renewable fuels under the RFS. However, sawmills that obtain any non-qualifying wood in their operations (e.g. from federal lands deemed not at risk from wildfire) may be disqualified from participating. The US EPA could provide an administrative statement showing a path for sawmills that buy some federal or other non-qualifying wood to sell RFS-qualifying residuals to biofuel facilities.

For example, a mill could use an accounting system to show what percentage of qualifying wood that they process, similar to what some mills already do for third party certification and establish a qualifying threshold on this basis.

Similarly, a fraction of their residues proportional to the amount of qualifying wood they receive could be certified for the purpose. A similar approach has been used within California's BioRAM program and could be considered.

Recommendation 3

CARB should undertake the following actions related to the LCFS program:

- Support research and adopt a simplified forest biomass feedstock calculator for CA-GREET which estimates emissions savings from mobilizing in-state woody wastes and residues relative to the counterfactual fate of these feedstocks. (priority recommendation)
- Consider additional, targeted incentives for fuel pathways making use of in-state woody wastes and residues from fire management and forest restoration activities, such as credit carve-outs.
- Support research to quantify upstream and process emissions stemming from in-state forest restoration activities as well as other environmental and public health benefits.

California's LCFS program is a market-based program that provides incentives to low-carbon and carbon-negative biofuels projects. These incentives are based on lifecycle carbon accounting to determine the carbon intensity (CI) of pathways. Pathways generate LCFS credits to the extent the calculated CI score is lower than the comparable CI benchmark. In general, pathways that provide relatively high 'avoided emissions' (i.e., the level of emissions that would have occurred in the absence of fuels creation, e.g. field burning of agricultural residues) generate relatively low CI scores and high LCFS credits.

Pathways that also apply CCS (making them carbon-negative) can generate extremely low, and even negative, CI scores.

There is currently no approved forest biofuels pathway under the LCFS, creating a high barrier-to-entry for prospective project developers. This is due to two factors. First, from a commercial perspective forest biomass is a relatively expensive feedstock compared to alternative options such as agricultural residues or municipal solid waste. Consequently, biofuels developers without additional incentives are predisposed towards other feedstocks, of which there is an abundance in California (Baker et al. 2019).

Second, lifecycle carbon accounting for forest biofuels pathways is highly technical, requiring consideration of complex factors including avoided wildfire emissions and residue decomposition rates. This makes the exploration of such pathways expensive, time-consuming, and uncertain for developers.

CARB can take proactive measures to overcome each of these barriers, thereby limiting (if not completely avoiding) 'special fixes' to the LCFS, which can create unintended consequences.

As a matter of first priority, CARB could adopt a forest biomass feedstock calculator which estimates the GHG emissions savings from mobilizing in-state forest residues relative to the counterfactual fate of these feedstocks. The research needs to develop this calculator are expected to be low, with the existing California Biomass Residue Emissions Characterization (C-BREC) model available (Schatz Energy Research Center 2021; CAL FIRE 2021). A central assumption within C-BREC is that the forest biomass is a waste or residue. This is an important assumption that has lifecycle carbon accounting implications, while also providing an implicit environmental safeguard against driving unsustainable forest harvest practices (for further discussion on this issue, see recommendation #6, below). CARB may need to consider a quantitative or qualitative methodology that can be used to establish in-state forest biomass as wastes and residues relative to primary products.

Available guidance is provided by ICF International (2015), Roundtable on Sustainable Biomaterials (2020), UK Department of Transport (2021) (in relation to the Renewable Transport Fuel Obligation (RTFO) program), and others. As C-BREC was developed in the context of electricity generation, CARB will need to integrate C-BREC or other forest biomass feedstock models with the existing CA-GREET model that estimates emissions from a broad range of transportation fuels that can be derived from biomass for the purpose of developing LCFS pathway CI scores.

Adopting a simplified feedstock calculator would allow potential developers to cost-effectively to explore the possible revenues that could be obtained via forest biofuels projects. In addition, it would also provide clarity to prospective developers around the state's interpretation of critical assumptions, such as avoided wildfire.

Finally, it would provide a baseline for CARB and the state to assess the relative competitiveness of forest biofuels compared to alternative biofuels pathways or other uses for woody biomass as well as the possible need for additional incentives or policy support to attract interest from the private sector.

We consider this first step to be the most important short-term policy action that could be taken to advance forest biofuels in California. It is a low-hanging-fruit opportunity that could unlock a bottleneck preventing project exploration and development.

The cost and uncertainty involved in estimating the carbon intensity of forest biofuels presents a major obstacle to project development. Adopting a standardized, transparent, and science-based calculator removes a critical barrier to entry into this space. We emphasize that there is also a risk that, without prioritizing this work in the next 6-12 months, CARB and the state may miss the opportunity for forest biofuels to be properly considered as part of the ongoing 2022 Scoping Plan and LCFS regulatory proceedings. This could stunt forest biofuels progress in California (and by extension proactive strategies to address the issues of accumulating forest biomass and wildfire) for multiple years.

If it is decided that additional incentives are needed to catalyze forest biofuels adoption in California, CARB staff could consider various options, including (but not limited to) credit carve-outs or a multiplier. Recent publications by Sanchez et. al. (2021) and Uden et al. (2020) explores some of these considerations.

Finally, we recommend that CARB initiate research to estimate upstream and process emissions associated with in-state forest restoration activities. This research should in no way slow the adoption of the simplified feedstock calculator, which is related to waste and residue, meaning that upstream and process emissions would not be allocated to these fuel pathways (ICF International 2015; UK Department of Transport 2021; Roundtable on Sustainable Biofuels 2020). However, and for example it is plausible in the future that the economic value of biofuels (or captured CO2) will increase to a degree that such end products should be considered by-products of forest management *(Table 5)*.

By-products are still secondary products, meaning that they are not driving forest management (i.e., "inelastic supply"), but owing to their higher value are allocated some portion of process emissions (e.g., from thinning activities). As such carbon accounting is challenging, CARB should initiate this research in the near-term.

TABLE 5:

Biofuel feedstock categories [adapted from ICF International (2015)]

Feedstock category for biofuel production	Definition	Direct emissions estimation method
Primary product(s) and co-products[2]	*Main product(s) of the production process with elastic supply*	*Allocation of upstream and process emissions*
By-products[3]	*Secondary product with inelastic supply and significant economic value*	*Allocation of process emissions to directly produce the feedstock; no upstream emissions*
Wastes and residues	*Secondary product with inelastic supply and little to no economic value*	*No upstream emissions; credits for diversion*

[2] Primary products are any unmanufactured part of a tree and wood chips and biomass produced at or on the harvest site. Co-product is the material produced during the process of primary manufacturing of another (principal) product, from the same input.

[3] By-product is the material produced as the unavoidable result of processing, but the production of which is not of itself an objective.

Recommendation 4

The California Natural Resources Agency (CNRA), in collaboration with Department of Conservation (DOC), CA Energy Commission (CEC) and CA Air Resources Board (CARB) should undertake the following actions related to advancing carbon dioxide removal (CDR) as a mitigation option in California:

- Establish inter-agency project delivery teams responsible for coordinating and expediting environmental review and permitting for carbon capture & storage (CCS) projects in California across state, federal, local, and tribal governments.
- Coordinate with the Governor's Office and Legislators to:
  - Develop and introduce an enabling legislative package that establishes: (i) at least one CO2 storage site capable of sequestering at least 5 Mt CO2 per year by 2028; (ii) a new public authority to design, build and operate the storage hub(s); and (iii) clarifies pore-space ownership and other subsurface regulations that support other storage projects.
  - Identify a funding source that supports the capital outlay of the CO2 storage hub project. This could include a combination of state and federal funds.
- CARB - Fund research evaluating the CDR potential of biochar and consider developing into a biochar protocol for adoption under the LCFS or cap-and-trade.

CDR has routinely been identified by leading authorities including the IPCC and International Energy Agency (IEA) as a key strategy to achieve global climate change mitigation goals (IPCC 2018; IEA 2021). CDR has also been identified as a key strategy for California to achieve net-zero GHG emissions by 2045 (Uden et al.; E3 2020; Baker et al 2019). Carbon-negative forest biofuels have been identified by Lawrence Livermore National Laboratory (LLNL) as the state's largest potential CDR pathway. As highlighted above, this pathway could also feasibly provide many co-benefits, including reduced wildfire risk and increased water supply due to forest health (Little Hoover Commission. 2018; Governor's Forest Management Task Force. 2021; Roche et al. 2020). Other CDR pathways include carbon-negative biofuels derived from agricultural or municipal solid wastes, as well as direct air capture (DAC) technology, which refers to purpose-built machines that suck CO2 directly out of the atmosphere. LLNL estimates that 125 Mt of mitigation could be derived from CDR strategies in California, or the last approximately 20-30% of the state's deep decarbonization goal (Baker et al. 2019). CDR is also necessary for California to achieve and maintain economy-wide net-negative emissions.

There is a compelling ethical argument that countries that are most responsible for climate change ought to take the lead to commercialize CDR technologies for global benefit, and target net-negative ambitions (Batres et al. 2021).

The key challenge of CDR is performing CCS. By way of comparison, CCS is widely performed to support enhanced oil recovery (EOR) in the United States, where tens of millions of tons of CO2 is geologically sequestered each year (NETL 2021). EOR projects have benefited from the value of the produced oil to drive their economics, which doesn't apply to CDR projects targeting permanent geologic storage. CCS in the context of CDR is challenging to execute as such projects are difficult to vertically-integrate, creating counterparty risk (Greig & Uden 2021). CO2 capture entities (e.g., bioenergy developers) usually lack the capability to develop CO2 storage; and so need to rely on partnerships with CO2 storage developers to perform this function. Meanwhile, CO2 storage developers are reluctant to invest without an assurance of long-term CO2 supply. At present, it appears that available incentives under the LCFS and federal 45Q are insufficient to break such first-mover stalemates. Since the LCFS is currently only authorized through 2030, and 45Q credits have a 12-year maximum applicability per project, there's a lack of long-term funding certainty for CCS, which creates projects that are by-nature going to be operated for multiple decades (storage, plus post-injection monitoring).

This is the rationale that underlies the recommendation that the state finance, build, and operate, either one or more CO2 storage hubs, with an aggregate capacity of 5 Mt CO2 per year, for at least 20 years. The state could establish such hubs with a primary goal to support CDR pathways in California, which is necessary to achieve net-negative emissions. In the near-term, such hubs could be used to support hard-to-abate industrial sector decarbonization (e.g., cement production), which produces sufficient volumes of CO2 to justify the creation of a large-scale storage site(s). Over time, as CDR pathways are brought to scale, these pathways would provide an increasingly large volume of CO2 supply. The state could take other steps to support CO2 storage projects more broadly, including establishing interagency project delivery teams to expedite environmental review, as well as clarifying pore-space ownership and other sub-surface regulations. We see these as two key steps needed to clarify the complex and uncertain CCS permitting processes in California. Further exploration of these issues and additional recommendations can be found in a recent review by Peridas (2021).

While outside the scope of this report, we recommend that any legislative package that is introduced on this topic also make robust considerations related to equity and labor, in recognition of the potential negative effect of energy transitions on some industries and communities. The recent Climate and Equitable Jobs Act (SB 2408) passed in Illinois provides some model examples of potential actions (Kibbey 2021).

Recommendation 5

State of California should appropriate an additional $5 million to Governor's Office of Planning and Research (OPR) for the implementation of recommendations related to, and as previously approved by BOF for the establishment of regional wood waste management entities ("CAL FRAME") that enable long-term feedstock supply of woody residuals from forested lands in California.

In order to borrow capital to build a new facility, biofuels developers must demonstrate access to a reliable, investment-grade supply of feedstock for the long-term (up to 20 years). While this is not problematic for agricultural and municipal solid waste feedstocks, it is problematic for forest residues. This is because most forested lands in California are owned and managed by the United States Forest Service (USFS), for which it is generally not possible for private companies to enter into long-term feedstock supply contracts.

This is a well-known issue among stakeholders. In recent years, various proposals have been put forward that seek to address this problem. One concept developed by the California Forest Management Task Force (FMTF) was for wood waste management entities (known as "Forest Resilience Authorities" or "CAL FRAME" entities)[4] to operate on a regional basis as a feedstock broker between landholders and wood product businesses (CSG 2020). Public agencies (e.g., joint powers entities, state conservancies, or special districts), are likely to be able to enter into long-term agreements with USFS. The goal is to fully utilize Stewardship or Good Neighbor Agreement authorities, so that more treatments will move forward on federal lands located in California.

For large-scale projects contemplated for biofuels production, large volumes of sustainably-sourced feedstock from federal lands may be ideal. Using this concept, CAL FRAME entities of various legal forms could be established on a regional basis with an express mission to support regional forest management objectives via biomass management. CAL FRAME entities would enter into up to 20-year agreements with USFS. CAL FRAME entities would then signal an intention to periodically enter into associated feedstock contracts with the USFS anticipated to correspond to the time period of regional forest management plans[5]. Prospective developers that site facilities in the region could then do so in the knowledge that the CAL FRAME entity would provide access to a steady, reliable feedstock supply.

The structure would also provide USFS flexibility to participate in the forest management project oversight to ensure sustainability or operating standards.

4 CAL FRAME stands for "California Forest Residuals Aggregation and Market Enhancement".

5 For further information, see the Regional Forest and Fire Capacity Program: https://www.conservation.ca.gov/dlrp/grant-programs/Pages/Regional-Forest-and-Fire-Capacity-Program.aspx.

Based on discussions with financiers, stakeholders have learned that federal feedstock supply contracts developed in this manner would typically be welcomed by many who provide capital to bioenergy businesses (and would likely be helpful for biofuels businesses as well).

Of course, the process of developing and scaling such CAL FRAME entities is likely to be iterative in nature; whereby signals from local communities, landholders, and prospective developers would need to be interpreted together, and a strategy to sequence project development with an increase in the pace and scale of sustainable forest treatments adopted. It should be noted that CAL FRAME entities would not be limited to supporting feedstock supply from federal lands but could support feedstock collection and delivery from state and private lands. For example, CAL FRAME entities could perform an aggregation function to convert multiple low volume feedstock supply sources from private non-industrial lands to support a single contract with a biofuels developer in a region. This concept is of interest to stakeholders, as 8 million acres of California's forested lands are owned by individuals on properties of less than 50 acres.

In 2020, the BOF endorsed a series of recommendations related to expanding biomass utilization and wood products markets in California that supported the CAL FRAME concept (Joint Institute 2020). In the 2020-21 budget, California allocated $3 million to OPR to support the development of five CAL FRAME pilots. This recommendation seeks to build on this progress, by allocating an additional $5 million to OPR to support a phase two of CAL FRAME pilot project development.

The CAL FRAME concept may be viewed as a biomass management mechanism that works in tandem with private-sector solutions like insurance & other financial instruments to meet the needs of bioenergy project finance. For example, since joint power entities based on cooperation between rural counties are unlikely to have the investment-grade credit rating required of investors, insurance companies and other financial institutions can insure the volume and price of supply from the CAL FRAME entity in a way that is acceptable to financial markets.

> **"...barriers to achieving these goals that must be addressed, such as exclusion of forest biomass from public lands under the federal Renewable Fuels Standard, an absence of investment-grade feedstock suppliers, supply from municipal and agricultural biomass markets, and a lack of biofuels infrastructure."**

Recommendation 6

CNRA, in collaboration with OPR and BOF should develop a white paper that recommends (or outlines) sustainability criteria and forest biomass feedstock sourcing guidelines for out-of-state projects that would deem these projects equivalent to meeting California's in-state environmental protections. White paper development should follow a public process and allow for stakeholder input.

Healthy forests provide multiple environmental and social benefits, including related to water supply, water quality, endangered species habitat, recreation, carbon sequestration, and more. California maintains very high standards to protect these multiple forest ecosystem services, including via the California Environmental Quality Act (CEQA) and Z'berg-Nejedly Forest Practice Act, and for federal lands National Environmental Policy Act, National Historic Preservation Act, Endangered Species Act and National Forest Management Act. These standards assure that incentives to mobilize in-state forest waste and residue from sustainable forest management will promote forest health and wildfire resilience and safeguard against mismanagement.

However, there are numerous examples of unsustainable forest management for bioenergy production (e.g. Buchholz & Gunn, 2015, Booth & Mitchell, 2020) and since the LCFS cannot discriminate against fuels or feedstocks based on where they were produced, a system of sustainability guidelines can help ensure that the above recommendations do not inadvertently support unsustainable forest management practices.

Consequently, it is recommended that CNRA, in collaboration with OPR and BOF, synthesize the latest available scientific research and develop a white paper that recommends sustainability criteria and forest biomass feedstock sourcing guidelines for out-of-state projects. This may be applied to projects, which right now can access LCFS credits under a 'Tier 2' pathway (but also feasibly, in the future, a simplified calculator), and maintain an equally high level of environmental protections. As the main concern regarding bioenergy as a viable climate solution is land management (and the threat of land mismanagement that only prioritizes GHG benefits), it is crucial that such standards are analyzed, discussed, developed, and upheld.

4 **FEEDSTOCK SUPPLY**

Despite a large volume of dead trees, brush and small diameter wood that needs to be removed from California's forests, existing and proposed wood waste utilization projects face significant challenge in demonstrating sufficient and long-term access to woody feedstock sources.

There are several reasons why an investment-grade feedstock agreement is difficult to obtain: (1) volatile markets, (2) declining USFS budgets and staffing capacity, (3) the low value of biomass as compared to its high transportation costs, (4) administrative challenges of contract management, and (5) few investment-grade entities in the supply chain with the balance sheet strength to support bankable agreements. All these factors lead to the vexing reality that while feedstock agreements are a necessary component to securing finance for new wood product businesses, they are difficult to obtain.

In response to this challenge, a new concept was proposed and has since been the subject of several convening workgroups over the last several years to improve forest supply chain logistics, including the FMTF Rural Economic Development Strategic Wood Utilization Group (REDS WUG) and the Joint Institute for Wood Products Innovation (JIPWI) Biofuels Feedstock subgroup. More recently referred to as the CAL FRAME model, the concept proposes to centralize an efficient biomass removal and utilization process for forest health projects using a new and transparent intergovernmental framework.

This process will bundle feedstock agreements for wood-based businesses to secure reliable, long term feedstock supply while providing an economically viable outlet for forest health and fuel reduction projects in California's forests.

The Feedstock Supply subgroup identified two main areas of work that could support woody residuals/ biomass availability for biofuels projects. First, the subgroup developed recommendations for the upcoming OPR pilot project program that begins in 2021. OPR was interested in receiving feedback about the pilot program in order to ensure that the recipients of grant funding through the program were clear about their goals, assets and teams, and program deliverables. Second, the subgroup looked at recommendations that could be made to the US Forest Service to improve contracting for long term feedstock supply contracts. Both of these topics help shed light on important barriers to successful biofuels project implementation.

A central theme of the subgroup's work was the development of recommendations to OPR. OPR received funds for five pilot projects that explore publicly managed regional approaches to handle forest biomass feedstock supply chain management and was looking for advice on how to proceed with the new funds distribution.

> **Numerous gaseous and liquid fuels can be produced from forest biomass at a scale sufficient to meet California's transportation and climate goals.**

The focus of this set of the recommendations included requiring each pilot project to complete a narrative that describes the vision of how to improve biomass feedstock supply chain logistics within a target region through partnerships, collaboration and information sharing with local government, which could include cities, counties or special districts.

The subgroup recommends that the applicants demonstrate some interaction with the private sector and encouraged the requirement of letters of support from licensed professionals who are actively working within the target region such as Registered Professional Forester, Licensed Timber Operator, wood products business or other private industry partner.

Other letters of support from public and/private timberland owners within the target region (can include USFS, CAL FIRE or other state agencies, or private owners) were also recommended. The subgroup also emphasized the need for the applicants to deliver tangible deliverables that will be provided throughout the grant term, and more specifically studies and analysis that would allow for the state to determine how best to move forward.

The subgroup also emphasized that each pilot needed a formal lead organization who would have the legal and administrative capacity to administer the grant.

After describing the basic requirements for a pilot project participant, the subgroup described some essential topic areas that it envisioned should be the focus of the work of the pilot projects. The most important question to ask the groups was identified as "What are the institutional arrangements that the projects will consider, such as a JPA, Community Services District or a newly created special district?"

Also, the pilots should clarify if they were planning on prioritizing private, public or a combination of both types of landowners in the region. Existing feedstock supply challenges specific to the pilot's region were also identified as a key area for research, and, how the state's plans to increase pace and scale of forest restoration and fuel reduction would impact these systems. Other questions centered around the impact of recent wildfires on biomass supply, taking into account the anticipated fluctuation in markets due to post-wildfire salvage becoming common in recent years and a future with many more acres needing management with younger stand conditions.

Understanding landowner participation in the program was also identified as an important aspect of the pilot programs. Working with federal landowners and USFS, was seen as a pivotal component of future success. At the same time, there is significant interest in helping prioritize landowners in the wildland urban interface areas and analyzing how to get landowners to feel confident to begin to offer longer term contracts.

Exploring other services related to insurance, preparation of environmental review for forest management projects, and computer modeling related services were also reviewed and recommended to be part of the pilot program.

The subgroup analyzed the issues facing local government actors who may want to get involved in the FRAME model-for example: How can the project minimize costs to taxpayers while maximizing public resources? Additionally, the subgroup identified that it would be critical to overcome complications of bringing in existing private industry into this public process and create a process to vet new businesses to provide assurance that they can be competent partners within the process. The subgroup also recommended that the pilots consider the feedstock requirements of programs like California Public Utilities Commission's BioMAT program and the LCFS, and the state's designated high hazard zones: how should these requirements play a role in the activities of this entity?

Finally, the subgroup tackled the last critical issue of financing these new proposed entities that the pilots would be exploring. The subgroup considered the unique sources of revenue this model might be able to tap into that can help fund operations and offer a subsidized process to offset biomass utilization prices to enable forest health work to be completed.

The subgroup evaluated a range of different financing mechanisms including the use of Bonds and Tax Increment Financing (TIF), member dues, payment for ecosystem services, certifications, and insurance services. Considerations of how to monetize future value of forest health to overcome the lack of immediate funding and the possible designation of natural infrastructure that might be able to improve property value in order to pay back bonds.

Other key questions were "How will the model be able to maintain constancy and employ contingency measures to ensure a long-term reliable supply of feedstock?" and "How can contract offerings and feedstock acquisition strategy overcome low profit margins from timber sales with high amounts of biomass?" Ultimately, the questions regarding the potential economic viability of the concepts were identified as critical.

4.1 The Challenges of Biomass Supply from Federal Lands

Development of the forest feedstock supply chain is critical to the successful deployment of forest biofuels production facilities in California.

Similarly, securing long-term forest feedstock supply agreements from a variety of investment grade feedstock suppliers is key to securing project financing.

In August 2020, the state of California and the USFS signed a Shared Stewardship Agreement (SSA) to increase the pace and scale of forest restoration by treating 1 million acres of forest per year across forest land ownerships in the state of California (MOU 2020). Major tenants of the SSA include development of a 20-year project plan (across all forest ownerships) by 2021 and increased vegetation treatments targeting 1 million acres/year of forestland by 2025. Approximately 500,000 acres/year of treatments will be conducted on federal lands. Implementation of the SSA could produce significant volumes of by-product potentially available as feedstock. Removing barriers impeding the forest feedstock supply chain should be addressed well ahead of the 2025, 1 M acres/year treatment benchmark so that the woody residual biomass does not contribute to climate change, exacerbate wildfire, or negatively impact ecosystems, recreation, and aesthetics of our forested lands.

4.2 Appraisal Process Recommendation

The Feedstock subgroup provides specific recommendations related to improvements of the administrative practices of the USFS and discusses how those might be resolved. Many of these recommendations mirror the work of The Nature Conservancy in its recent report (TNC 2020).

The primary recommendation centered around the appraisal process, which should be reviewed and improved, consistent with the goals of heightened pace and scale of fire threat reduction through fuels treatment work.

Product value within partnership agreements (e.g., Master Stewardship Agreements and Good Neighbor Authority) is a formal and legal process needed to determine the appropriate rate the partner should recover when working with sawn timber and/or biomass. Fair Market Value is a term that the USFS uses to appropriately determine product value. Forest Service Handbook 2409.18, chapter 40 defines fair market value as "the value at which property (timber) would change hands between a willing and knowledgeable seller and a willing and knowledgeable buyer, neither under compulsion to sell or buy and both having reasonable knowledge of the relevant facts.

In addition to type, quality, and quantity of timber, fair market value reflects the time of sale, the highest and most profitable use, the location, a reasonable time to find a purchaser, and an open and competitive market. It can be viewed as an estimate of market value that reflects the price an operator of average efficiency who is able to pay that price and retain sufficient profit to maintain long-run operations is willing to pay."

> **"If California's large demand for low-carbon fuels can be paired with action to develop forest biofuels, there is the possibility to promote forest restoration, strengthen regional capacity, support innovation, reduce vulnerability to wildfire and wildfire intensity, and promote carbon storage in long-lived products."**

USFS utilizes the appraisal process formally known as the Transaction Evidence Appraisal (TEA) method to determine fair market value. This method utilizes the current base period market price for timber and biomass and adjusts these values up or down based on site condition, road maintenance, haul costs, and other contractor costs (example-specialized machinery needed to complete the project). The USFS must utilize this process when moving projects through a contracting mechanism to determine fair market value because a single contractor can be awarded a USFS contract. The USFS contract only covers the removal of the timber and biomass by the Contractor.

The Contractor is then responsible for developing a purchase agreement for the product with local mills. Partners can approach fair market value differently (Forest Service Handbook 2008). Partnership agreements could showcase a different strategy to traditional USFS projects because the partner is not the formal contractor.

This means that the partner is not in competition with the Forest Service or the local market to profit off individual agreements. Rather, the partner can use their own procurement policy to complete the project and ensure fair market value.

Fair market value by the Partners could be established through an open and competitive bidding request. Since the partner itself is not the buyer (end use facility) or the seller (USFS), Fair market value can be achieved by utilizing a process to allow an open and competitive process, such as a request for bids (RFB). Such a package could account for the existing local market supply and demand, timing of operations and delivery, quality of the property, and highest and best use, consistent with the Forests Fair Market Value Handbook definition quoted above. Once a value has been assigned utilizing the "Fair Market Value" process, the Partner can disclose the process to the USFS representative for review. At that point after approval from the USFS, the partner could contract with all the parties involved. This new approach could significantly improve the current USFS business practice.

4.3 Other Recommendations

The subgroup also emphasized the need to expand the use of third party National Environmental Policy Act (NEPA) subcontractors, which has been mentioned in a recent report by Edelson et al. (2019). Other specific recommendations made to USFS business practices include developing or commitment to developing long-term (up to 20 year) stewardship contracts to facilitate investment in expanding biomass harvesting and utilization capacity. Working towards these contracts would increase reliability and confidence in biomass markets.

Finally, the subgroup recommends that attention be placed on how resource inventories and surveys are conducted and reported, and how operating periods are determined in these projects. Protocol level resource surveys and reporting requirements have been established but are not always conducted consistently.

This is particularly true for archeological surveys and reporting. The subgroup recommends that clearer policies and practices be established for the use of the streamlined process for resource surveys and reporting.

Second, the subgroup recommends that project designers who are putting together NEPA documents allow for Limited Operating Periods to be set based on surveys, rather than just implementing the timing as described in the guideline documents. Some projects could begin months earlier if they have the resources to conduct a survey to determine if the species of concern is not present in the area, or other changes have occurred (e.g., species has raised young and left the area). The use of streamlined options and flexibility in determining Limited Operating Periods could significantly improve project timelines and lead to more productive achievements.

5 EQUITY AND DEVELOPMENT

The emphasis on equity and development in this report is aimed at enabling public funding to deliver an equitable distribution of the economic and environmental outcomes of sustainable forestry and biofuels industries in the state, particularly where private funding would otherwise not prioritize these outcomes.

To this end, we offer five recommendations with the intention of guiding state funds which are specifically directed at enabling the growth of the biofuels industry in California to uplift equity, enable socio-economic resilience and reduce vulnerability in the state.

Importantly, our recommendations are intended to sit alongside those of the other working groups and to underscore the opportunities for state capital to unlock equity challenges in the development of a statewide forest biofuels industry. Where we place a particular emphasis on rural or community-scale research and demonstration, this should be undertaken alongside more centralized or larger-scale research and distribution, not in lieu. Our aim is to offer clarity and specificity regarding tools, regulation, expenditures and research which can enable more equitable outcomes across California's population – including the reduction of climate vulnerability among our rural communities.

5.1 Summary of Findings

Enabling and ensuring the equitable, inclusive, and sustainable growth of biofuels industries in the state will require a shared set of guiding principles. These include a focus on resilient economic development, sustainable land use, sustainable transportation planning, consideration of environmental burden (both historic and forecasted), economic and climate resilience for underserved communities, impact on rural and forested communities, and wildfire vulnerability.

The following principles are developed to guide both (1) state funding allocations associated with forest biomass use and forest restoration and (2) future research focused on forest biofuels use and forest biofuels markets.

1. Ensure that sustainable forest restoration, economic feasibility, and environmental and social equity are weighted equally in each recommendation.

2. Ensure rural, community-scale economic development alongside sustainable forest management.

3. Ensure projects are compatible with surrounding land use and communities.

4. Enable restorative outcomes for under-resourced and under-served communities.

Metrics of evaluation for environmental vulnerability, socioeconomic status and demography play an important role the delineation of public funds for sustainable forest restoration and wildfire prevention and mitigation in the state. However, rural communities in headwaters regions face a unique suite of socioeconomic and environmental burdens which are not accounted for under existing tools. As a result, public investment in biofuels industry growth and sustainable forest restoration will benefit from more effective tools to enable sustainable forest management, reduction of community climate and wildfire vulnerability, and promotion of rural economic resilience. There is a research gap in understanding the overlay of vulnerability to wildfire, economic resilience, and environmental burden associated with sustainable forest management and biofuels industries.

By identifying those socio-economically challenged communities at risk of wildfire where sustainable forest restoration projects are feasible, decision makers would be better informed as to where biofuels industry development should be prioritized.

Lastly, there are significant anticipated benefits of community-scale biofuels facilities – including rural energy security, replacement of fossil fuels in rural and Tribal lands, and rural economic and climate resilience, sustainable and family-sustaining job opportunities, economic diversification in regions often over-levered to single industries, and more.

These substantial public benefits represent significant value to the State which is not priced by private markets. We therefore recommend public investment to support demonstration, technology improvement and/por piloting of community-scale hydrogen production.

Recommendation 1

Adhere to the following equity and development guiding principles to enable consistency with the Governor's All Regions Rise dictum, which is a high road vision for inclusive and sustainable economic development across California's diverse and interconnected regions.

Principle # 1

Ensure that sustainable forest management, economic feasibility and environmental and social equity are weighed equally in all recommendations.

- Projects and work that benefit underserved and historically marginalized forested communities or groups are critical for socio-economic resilience and equity.
- Projects and work that address economic and wildfire vulnerability in underserved regions will deliver greater socio-economic and climate resilience.
- Safe, reliable jobs with family-sustaining wages and appropriate labor standards will enable equitable, sustainable industry development.
- Appropriate job training and, importantly, training credits, should be incorporated consistently across projects.

Principle # 2

Ensure rural, community-scale economic development alongside sustainable resource management.

- Rural forested communities which supply sustainable forest biomass material should benefit directly from the state's biofuels and forest management actions.
- Funded biofuels projects should be tied to regional land capacity, community well-being, sustainable resource management.
- Economic and environmental benefits of biofuels production and sustainable resource management should be reflected in feedstock and labor source communities Consideration of alternative governance structures to distribute benefit along the supply chain, such as cooperative ownership, may deliver these outcomes.
- Facilities should be appropriately scaled to what can be produced long-term.

Principle # 3

Confirm projects are compatible with surrounding land use and communities

- » Recommendations should be consistent with regulatory feasibility.
- » Avoid environmental harm to communities where projects are located.
- » Advance clean and appropriate-scale recommendations that meet climate targets, and adhere to criteria air pollution controls and noise abatement measures.
- » Include communities in project planning to ensure public buy in and project success
- » Evaluate the potential of adaptive brownfield redevelopment.

Principle # 4

Enable restorative outcomes for under-resourced regions and underserved communities

- » Advance tribal communities as workers and beneficiaries of biofuels projects from biomass sourced regions.
- » Advance projects and work that specifically target underserved forested. communities and regions as clear economic and environmental beneficiaries.
- » Ensure any negative externalities do not disproportionately affect underserved communities.

Recommendation 2

Identify and develop improved measures that accurately capture rural forest community conditions, needs, and socio-economic status.

This may best be achieved through partnership with OPR as the agency is undergoing a similar effort to address vulnerability and will benefit from expertise regarding the targeting of climate and wildfire vulnerable populations.

The California Communities Environmental Health Screening Tool (CalEnviroScreen), which is used to implement SB 535 and AB 1550, does not explicitly take into account the impacts of wildfire smoke as a form of pollution (Monserrat, 2015b; CalEPA, 2017) nor does it account for intermittent pollution bursts, lack of access to egress or health care facilities and other factors unique to rural and forested communities. It was created to direct investments of cap-and-trade (CCI) capital into clean energy projects which reduce pollution in historically burdened communities – and thus does not take into account those climate and wildfire vulnerabilities unique to rural and forested regions which are most directly impacted by forest restoration and forest biofuels industries.

Consequently, communities experiencing intermittent pollution bursts, limited health care access, high smoke exposure, and other factors characteristic of underserved and vulnerable forested communities, will not necessarily be designated as disadvantaged under CalEnviroScreen – and are therefore less likely to receive state funding for environmental and climate investments (CalEPA, 2017).

CCI monies are necessarily tied to the use of CalEnviroScreen.

However, there are substantial non-CCI funding streams which focus specifically on the development of sustainable forest biofuels industries, wildfire mitigation and forest restoration for which improved metrics will be paramount.

OPR's Vulnerable Communities tool, which is currently under review and improvement, is likely to be the most effective tool to improve upon and utilize in place of CalEnviroScreen for relevant non-CCI funding – engaging directly with OPR to support this process, to improve the efficacy and accuracy of the tool, and to enable it's usage for relevant non-CCI monies would be a important contribution to the development of a sustainable, equitable biofuels industry.

Recommendation Objective: Ensure that relevant non-CCI funding streams utilize more effective metrics to target vulnerable and underserved communities.

Target Audience: State funding agencies, biofuels industry, forested communities.

TABLE 6:

Examples of relevant, excluded criteria .

Category/ Burden	CalEnviroScreen Indicator	Excluded criteria which are specifically relevant to forested and wildfire vulnerable community
Air Quality	*PM2.5*	*-Account for the episodic nature of wildfire smoke by altering the calculation of the PM2.5 indicator, which is currently an annual mean over a three-year period* *-Differentiate wildfire PM2.5 exposure from other sources of ambient emission*
Water Quality	*Drinking H2O*	*Increase score for communities that have physically burned* *-Monitor concentrations of benzene in communities that have physically burned.* *-Examine concentrations of sediments, suspended soils, heavy metals, and algal toxins in reservoir sources resulting from wildfire impacts* *-Account for gaps in rural water infrastructure capacity to handle treatment of episodic bursts of contaminants (i.e., sediment, suspended soils, and heavy metal concentrations from wildfire erosion)*
General	*N/A*	*-Incorporate data regarding community vulnerability to wildfire*
Health Care Infrastructure	*Asthma + Cardiovascular*	*-Incorporate metrics outside of ER visits, given that these are likely underestimated in rural areas*
Health Care Infrastructure	*N/A*	*Account for disparities in access to health care through metrics such as financial and travel barriers to proper health care access, as well as capacity of health care facilities (i.e., number of doctors relative to the population)*

Recommendation 3

Develop a new, appropriate definition of underserved to specifically guide non-California Climate Investments (CCI) state monies which target forest restoration and support forest biofuels.

Again this may best be achieved through partnership with OPR to both improve upon existing processes and to ensure the definition is distributed effectively to agencies allocating relevant funding streams. The State employs a suite of definitions of 'disadvantaged', 'underserved' and 'disproportionately impacted' across its agencies to guide public investments. A review of current definitions reveals a gap in accounting for the socio-economic and environmental concerns specific to forested, rural communities.

The California Air Resources Board (CARB) priority populations definition, which is intended to "provide benefits to populations which are economically disadvantaged, exposed to multiple sources of pollution, or are especially vulnerable to the effects of pollution in a changing climate" relies on CalEnviroScreen, which results in the exclusion of rural and forested communities.

The California Department of Insurance 'underserved communities' definition, which is intended to 'address the issue of availability of insurance in underserved communities and promote anti-discrimination so that all have equal access to insurance in California" excludes the zip codes belonging to all but 2 of the 18 Sierra Nevada counties in the State (Commissioners Report, 2015).

Alpine, Amador, Butte, Calaveras, El Dorado, Mariposa, Madera, Mono, Nevada, Placer, Plumas, Sierra, Yuba, Tulare, Tuolumne, and Placer counties – meanwhile these counties face substantial economic, environmental and health vulnerability in the face of wildfire risk. The Department of Water Resources 'disadvantaged communities' map, which is designed to assist with responsibilities related to IRWM, SGMA and the CA Water Plan, relies on median household income alone as its primary indicator which fails to account for gaps in rural water infrastructure and episodic contamination bursts due to wildfire (for example, heavy metal concentrations from post-fire erosion).

As a result, each of these definitions fails to effectively target the most vulnerable Sierra communities.

A new definition of underserved will enable relevant, non-CCI State funds to deliver an equitable distribution of economic and environmental outcomes for all communities. This will likely include the overlay of economic resilience, climate and wildfire vulnerability and pollution burden.

The Sierra Climate Vulnerability Assessment offers metrics for inclusion (reference), among them: local health care capacity, climate and wildfire vulnerability, loss of infrastructure, jobs and environmental or economic resilience post-fire

Recommendation objective: Ensure that public funds related to sustainable forestry and forest biofuels deliver an equitable distribution of economic and environmental outcomes.

Target audience: Managers of funds which target forest biofuels and forest restoration activities, including:

- Infrastructure development to speed sustainable forest management (e.g., transportation subsidies, reverse-auction or other feedstock purchase subsidies, loans and guarantees for biofuels projects)
- Workforce development to speed sustainable forest management (e.g., restoration workforce training; community capacity building; biofuels labor force development, including remediation, hauling and processing).

Recommendation 4

Improve mapping tools and data accuracy to effectively target underserved forested communities.

The most promising tool to improve upon with improved indicators and definitions in order to effectively visualize and target vulnerable and underserved communities may be the California Department of Public Health (CDPH) Climate Change and Health Vulnerability Indicators tool.

California does not have a tool that points to where to invest in forested areas for sustainable forest management which includes any effective measure of equity and economic resilience. The tools that do exist fail to include critical criteria uniquely relevant to forested and rural communities. A mapping tool is needed that incorporates improved metrics (recommendation #2) and an effective definition of underserved (recommendation #3) to accurately address economic vulnerability, pollution burden, and climate and wildfire vulnerability measures across the state.

We evaluated a suite of existing tools including the California Health Places Index, UC Davis' California Regional Opportunity Index, the Climate Change and Health Vulnerability Indicators for California (a tool of the California Department of Public Health, CDPH)[6].

The latter is the most nimble tool and does include a measure of population sensitivity and adaptive capacity to wildfire or other climate threats – although none of the four tools incorporate those indicators which would most effectively address the vulnerabilities of rural and forested California communities.

Examples indicators to incorporate into an effective tool include: extreme smoke risk, smoke from open burns, wildfire vulnerability, economic vulnerability including industry diversity, asthma rates, employment rates, water quality vulnerability, health care vulnerability, housing stock quality, and intermittent pollution bursts as opposed to averages.

Important factors to consider when improving upon an existing tool for us in biofuels investment targeting include data limitations and monitoring accuracy in rural census regions[6].

Recommendation Objective: Incorporate measures of wildfire ad climate vulnerability into an existing tool to create an improved tool which is relevant for funding allocations in the biofuels and forest management space. One potential tool for improvement is the CDPH Vulnerability Assessment tool.

Target Audience: Relevant agencies with mandate to increase pace and scale of sustainable forest management, upper watershed infrastructure management, and forest biofuels use.

[6] *Population & environmental data is frequently collected at too large a spatial scale to reflect community needs. California's regulatory air monitors are sparsely located in rural and mountain regions. Population data is often aggregated on a census tract basis. Rural census tracts are much larger than urban census tracts and there may be large variations in population and environmental characteristics across these large regions. In some cases, existing tools and frameworks could be adapted to census block groups (rather than census tracts) to identify variations within large, rural census tract. However, the range of uncertainty in these areas is also high and focusing on the block group scale might increase the error in this approach. Unknown reliability of low-cost air quality monitor data (research underway, South Coast AQD).*

Recommendation 5

Public investment should be directed in ways to best achieve watershed, forest health, wildfire resilience and community benefits.

Community-scale project development alongside larger facilities can be one of the most effective ways of achieving this.

California watersheds are critical infrastructure for State water reserves. Investment in community-scale facilities will encourage restoration at a watershed-scale. Relevant funding guidelines address GHG reduction, wildfire risk reduction and green infrastructure improvements but do not explicitly encourage the maximizing of economic, environmental and public health benefits alongside these other important factors.

This should be addressed, in order to best ensure biofuels-focused funds create significant and lasting benefits. Investment in community-scale project development can be one of the most effective ways of achieving this.

Opportunities to achieve watershed, forest health, wildfire resilience and community benefits include:

- Set-Aside for Engagement Activities: grant guidelines should require an engagement plan to access targeted planning funds and projects should include the resources to assure underserved community members are able to participate in planning efforts.
- Prioritization of community partnerships: To speed project adoption and ensure authentic community engagement, grant guidelines should prioritize projects developed in close partnership with grassroots community organizations.
- Set-Aside for Co-Benefits: public monies can set-aside a portion of funds for maximization of co-benefits -- or a threshold percentage of applications 'points' for the maximization of co-benefits of forest biofuels work including those listed above.
- Leverage of high-road training programs / high-road labor ordinances.
- Leverage anti-displacement measures by prioritizing investments in local jurisdictions with existing inclusionary housing ordinances.
- Require large-scale projects receiving funds to provide a resiliency analysis and incorporate mitigation measures, similar to the requirements of an Environmental Impact Report.

Outcomes of community-scale project investment for State public health and public benefit goals:

- Water: Investments in community-scale solutions are upper watershed / green infrastructure investments.
- Speed to action: community willingness is higher in regions with greater awareness and need (relative to larger population centers with historic pollution burden; less willingness/understanding of biofuels use).
- Feedstock competition: Forest regions will not confront competition with cheaper feedstock sources in MSW / Ag-adjacent facilities.
- Economic resilience: Distributed / community-scale models will meet the state's mandate to address economic and environmental resilience for its underserved populations.
- Emissions reductions: Reduced vehicle miles; lower transportation costs and emissions.
- Improved energy resilience: Rural power back up, economic resilience in regions most vulnerable to power loss.
- Improved economic resilience: Diversity of industry in regions overleveraged to tourism, family-sustaining wages in underserved regions.

Recommendation Objective: Ensuring the public capital delivers equitable distribution of economic and environmental outcomes will ultimately benefit all Californians.

Target Audience: Relevant agencies with mandate to increase pace and scale of sustainable forest management, upper watershed infrastructure management, forest biofuels use.

Recommendation 6

Allocate funds for research and demonstration of rural, community-scale hydrogen and other biofuel production and consumption.

Hydrogen holds significant potential to pave the pathway to carbon neutrality in California. Captive hydrogen (hydrogen consumed at the site of production) has little demand at a rural, distributed scale. However, production of hydrogen from sustainably-sourced forest biofuels could fail to achieve lasting and significant economic and environmental resilience for climate-and-wildfire vulnerable communities, unless sited close to rural, forested communities.

Distributed hydrogen production and consumption could uplift economic and environmental resilience, secure back-up grid power from non-diesel sources, and replace fossil fuels in medium to heavy duty equipment. Research and pilot program demonstration for distributed hydrogen production will prove out costs, technology readiness and the potential for the state to truly address economic and environmental equity and resilience while uplifting a forest biofuels industry.

Opportunities for demonstration of rural-scale hydrogen or other biofuel include:

- Diversify BioMAT projects: This may be an opportunity to diversify BioMAT projects in the state.
- Re-Fueling: Medium and heavy-duty equipment operations are significant in rural regions of the state, re-fueling may be a high-volume application for distributed hydrogen.
- Technology readiness: Projects have attempted distributed, rural hydrogen production in the past, but technology has progressed rapidly in the years since that time.
- Rural backup grid power: vulnerability to outages is significant in rural regions of the state, caused by forced shutoffs to reduce wildfire risk and/or directly by fire. Backup power through locally produced hydrogen would encourage rural energy resilience, economic resilience and environmental resilience. (H fuel cells for microgrids).
- Replacement of diesel generators: tribal lands frequently the first to lose power and last to receive it back. They are also home to myriad diesel back-up generators for casinos and other operations; replacement of these generators with hydrogen back-up power would be of significant and lasting value to Tribal communities.

Recommendation Objective: Accelerate the pathway to hydrogen while maximizing co-benefits of biofuels use. Encourage allocation of applied R&D funding to prove out the potential of distributed hydrogen production and consumption as back-up grid power and as a refueling alternative to diesel.

Target Audience: Relevant agencies with mandate to increase pace and scale of sustainable forest management and forest biofuels use, e.g. CEC and CPUC applied research and development funds; Department of Defense (DOD) and USDA loan guarantees.

6 **PROJECT FINANCE**

The project finance subgroup members comprised active project developers in the California bioenergy sector who shared their decades of first-person successes and challenges bringing projects to fruition.

The subgroup also utilized case studies, scientific publications, government statistics and market research reports. These challenges are presented below in *Table 8* and *Table 9*.

To convert the volumes of forest biomass contemplated (e.g 10 million BDT per year supply) requires infrastructure exceeding $20B, far outstripping the capacity of public finance alone. For this reason, the project finance subgroup focused on how to attract additional, appropriate private capital to the California bioenergy sector. In particular, the subgroup focused on the different types of capital that contribute to a project financing (segmented by construction phase and risk position in *Figure 8).*

The subgroup grouped projects into three different classes, each with its own business model and challenges *(Table 7)*. The three categories of projects analyzed include BioMAT projects (e.g., Hat Creek, Blue Mountain and North Fork); small-scale biofuels projects (NuFuel); and large-scale biofuels projects (Allotrope Axens Futurol, Aemetis Riverbank, Red Rock Biofuels). The project finance subgroup also produced qualitative information about barriers and possible solutions according to the project size *(Table 8, Table 9)*.

Nevertheless, subgroup conversations showed that no two projects are alike, and therefore the most impactful support also varies.

> **“Yet successful commercialization of low- and carbon-negative fuels from forest biomass is far from certain, despite existing policy support.**
>
> **Further action is necessary to promote policy and market development for forest biofuels across California.”**

FIGURE 8:

Project Finance Phases.

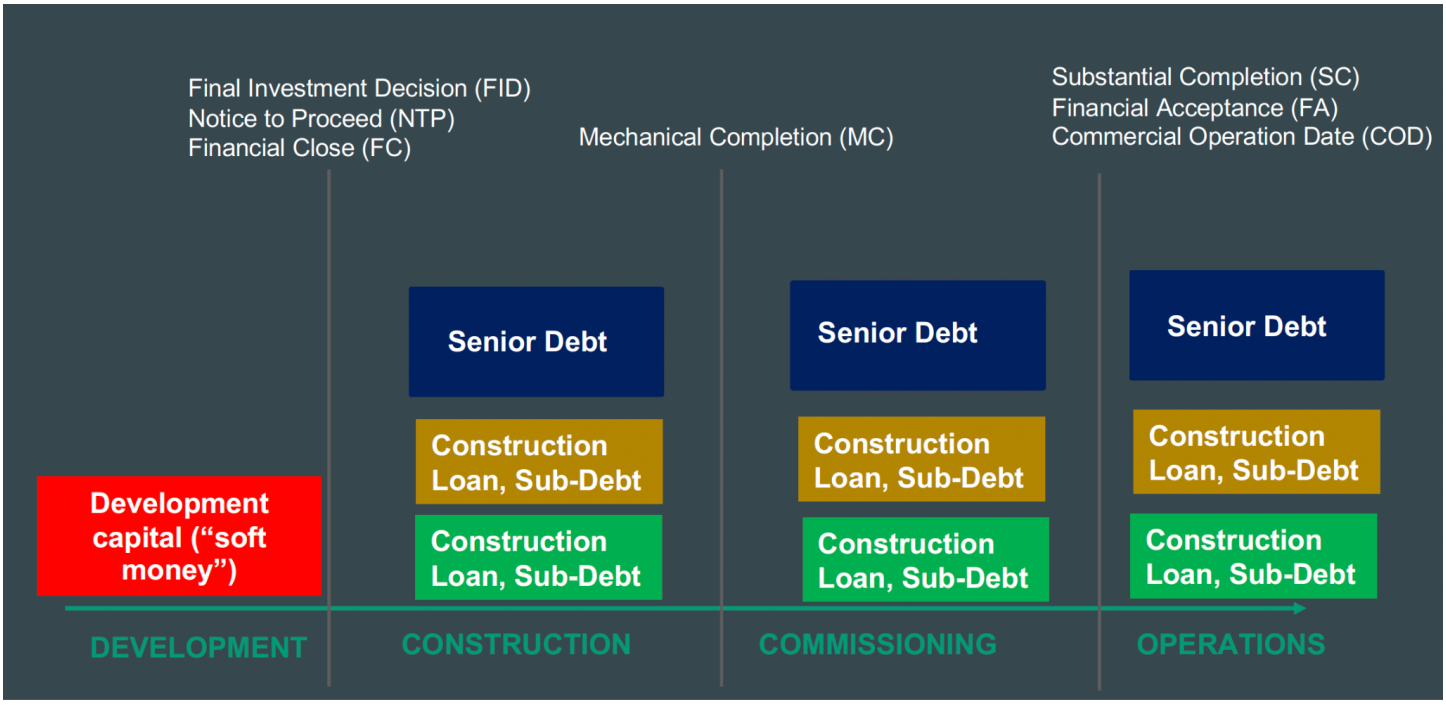


TABLE 7:

The Three project classes.

	Small BioMAT Project	Small Biofuel Project	Large Biofuel Project
Characteristics	*<$25 M* *<3 MWe* *20-year utility PPA*	*<$25 M* *Various products (hydrogen, pellets, firewood, char)*	*>$100 M* *Various products (FT distillate, Ethanol)*
Examples	▪ *Hat Creek (nearing NTP)* ▪ *Blue Mountain (nearing NTP)* ▪ *North Fork (construction)*	▪ *NuFuel first project (pre-FID)*	▪ *Allotrope Axens Futurol, ethanol (pre-FID)* ▪ *Aemetis, ethanol* ▪ *Red Rock Biofuels, FT distillate (construction)*

TABLE 8:

The Three project classes.

Additional Challenge	Potential Solution(s)
No offtake, Project financings are defined through a long-term, creditworthy buyer. It's not clear that certain products (biochar, wood pellets, firewood) can find such an offtake.	*▪ Change the capital structure* *▪ Change product* *▪ Get a hedge* *▪ Sell forward: pre-purchase agreements are blunt but create demand without exposure to buyer credit.* *▪ State procurement: some variant of "buy green", either for state use or state-intermediated distribution*
Contracted revenue cannot be locked-in before NTP. Other revenue streams, like SGIP, cannot be secured until the project commissions.	*▪ This can be solved through insurance, public capital and social organizations e.g., FRAME entities*
Products have unclear market. Some products (biochar, wood pellets, firewood) don't have transparent markets. Unclear if additional volumes can be absorbed and at what price elasticity.	*▪ Third party study: Market sizing studies can help address this.* *▪ Distribution partners: Developers likely need to identify and cultivate distributors and others with market knowledge & access. The distributors won't be investment-grade, but will presumably have historic sales and demand precedent.* *▪ Pick a new product: no question that electricity and liquid fuels are scalable commodities*
Very highly levered capital structures. Reliance on debt and insufficient equity.	*▪ Grants to front-subsidize project and displace debt* *▪ More equity (if available)* *▪ Subordinated debt, or preferred equity.*
Need tax equity. Big banks don't do such small deals. Tax equity capacity is fixed and with solar & wind credits being extended there's lots of competition for those tax equity dollars.	*▪ Since tax equity requirements are small, family offices or other non-traditional sources with tax liability could bridge this gap.* *▪ Requires bridge/construction/"mezz debt" financing*
Novel technology. At least in the eyes of local lenders/ investors.	*▪ Solved through insurance wrap on feedstock contracts and off-take contracts, or alternative sources of public capital.*
Lack of "soft money" (development capital)	*▪ Developers need to present plausible multi-site plans to justify non-collateralized, high-risk capital into their development companies.* *▪ Longer term, this is typically addressed by project developers extracting a "development fee" from the proceeds of project financial closing. The development fee from one project fronts the next project.*

TABLE 9:

Large Biofuel Project Challenges and Possible Solutions.

Challenge	Potential Solution(s)
Feedstock volumes are higher. Investors need assurances regarding a reliable amount of available feedstock on a long-term basis.	*▪ Private insurance, public capital, and social organizations, e.g. FRAME entities.*
Few if any feedstock providers are investment-grade. This poses a challenge to investors who question the reliability of the supplier.	*▪ This can be solved through insurance working together with public capital.*
Novel technology.	*▪ Solved through insurance (technology performance insurance) or alternative sources of public capital.*
Need project equity. Too risky for conventional project finance (i.e. no fixed price PPA) and check sizes are quite large.	*▪ A hub can assist with institutional investor education and project vetting.* *▪ State support such as grants can reduce, but not eliminate, equity check size.*

Recommendation 1

Subgroup meetings identified a variety of challenges accessing different types of capital required for a project financing.

Since each developer and project met different challenges, the subgroup decided the best support would be a hub that would convene stakeholders to share best practices and provide support across the various aspects of project development--commercial, technological, and financial--required for a successful financing.

There was active discussion about the best way to structure such a hub, but the subgroup settled on project-specific support. This could be structured like a startup accelerator with bespoke mentoring and support for the developer.

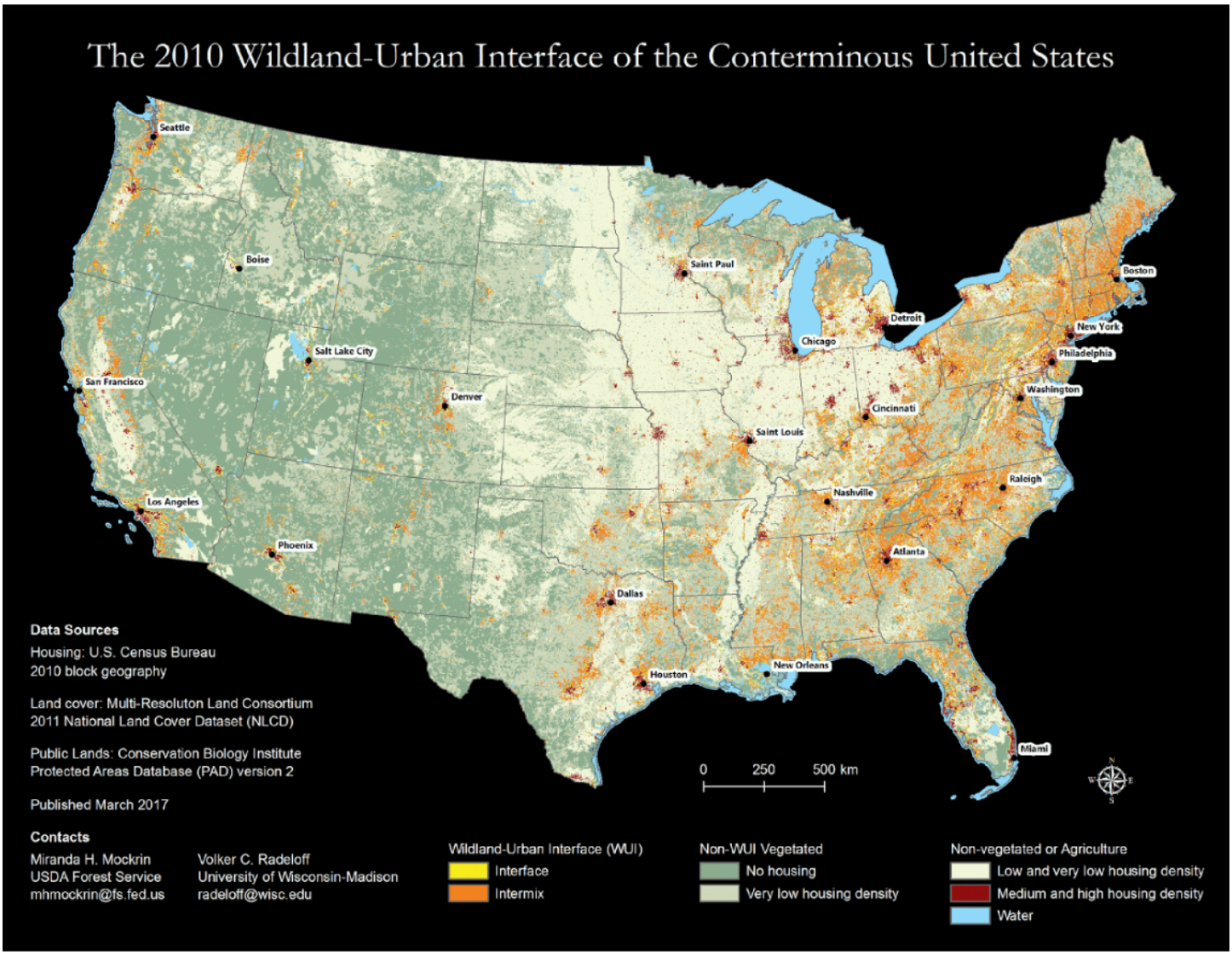
Equally important, the subgroup emphasized the need for the hub to be a convener to facilitate sharing of best practices and expertise across the multiple disciplines required for project development. In fact, the subgroup participants appreciated meeting each other as part of this Joint Institute of Wood Products Innovation's process and were seeking an ongoing opportunity for collaboration. Moreover, the hub can serve as a 'front door' to bioenergy development, which is still a small sector.

The ideal convener was difficult to identify. Non-profits typically lack the knowledge and connections to the capital markets. For-profits or consultants presented challenges around conflict-of-interest and concerns about not being sufficiently cognizant of diversity & equity issues. We ultimately recommend that a state agency would be ideal so the hub can double as a conduit for state aid. Since the hub will be intimately involved in project development, it will be best placed to understand the necessary support, avoiding over- or under-subsidizing the project in question. GO-Biz could serve as the hub convener. Via the I-bank, it already has some capital markets and project finance experience. Additional staffing could support the technology and commercial aspects of bioenergy project development.

> **"GO-Biz could serve as the hub convener. Via the I-bank, it already has some capital markets and project finance experience."**

Appendix A

University of Wisconsin-Madison Wildland-Urban Interface (WUI) zones.



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