



A WHITE PAPER FOR POLICY MAKERS

APRIL 2022

Turning Wildfire Tinder Into Low Carbon Fuels

Lead Author: Graham Noyes, Noyes Law Corporation

Report Contributors: Alfredo Arredondo, Haris Gilani PhD, Dan Sanchez PhD, Robin Vercruse



With Recognition and Thanks to:

Joint Institute for Wood Products Innovation, California Board of Forestry and Forest Protection, and University of California, Berkeley

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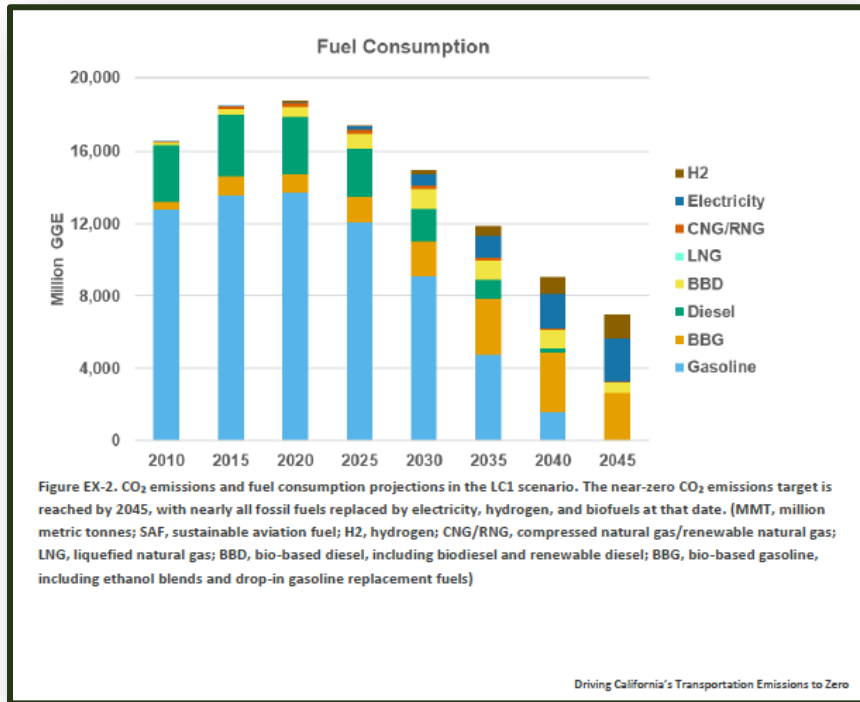
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OVERVIEW

This Woody Biomass Fuels Industry White Paper has been developed to assist California and federal policymakers chart an environmentally and economically sound course toward wildfire risk reduction and carbon neutrality. This proposed course of action maximizes the highest and best use of woody biomass generated by forest management activities: producing low-carbon transportation fuels using advanced processing technologies. The production of transportation fuels is the highest and best use of woody biomass because this feedstock is abundant and reliable, advanced technologies drastically reduce criteria pollutants and greenhouse gas (GHG) emissions relative to fossil fuel refining, and transportation is the hardest economic sector to decarbonize.

Based on the work of the Institute for Transportation Studies pursuant to AB 74, to achieve carbon neutrality by 2045, California must transition completely from fossil fuels to bio-based alternatives.¹



Producing low, very low, and zero-carbon fuels from woody biomass provides California with the opportunity to reap the jobs and economic benefits of fuel production that other states are currently enjoying. While California leads the nation in decarbonizing its transportation fuels, this has been achieved primarily through the importation of liquid fuels from other states and countries, with California currently importing over 90% of its low carbon liquid fuels.² In dramatic contrast to other feedstocks suitable for producing low carbon liquid

¹ Institute of Transportation Studies, "Driving California's Transportation Emissions to Zero," (April 2021), available at <https://escholarship.org/uc/item/3np3p2t0>

² California Air Resources, Board, Low Carbon Fuel Standard (LCFS) Data Dashboard, Figure 10, at <https://ww2.arb.ca.gov/resources/documents/lcfs-data-dashboard>

fuels, California currently possesses forest woody biomass in overabundance.

The scientific feasibility of deploying forest woody biomass in transportation has been validated by the second Carbon-Reduction Pillar of the Lawrence Livermore National Laboratory's Getting to Neutral Report:

Convert Waste Biomass to Fuels and Store CO₂

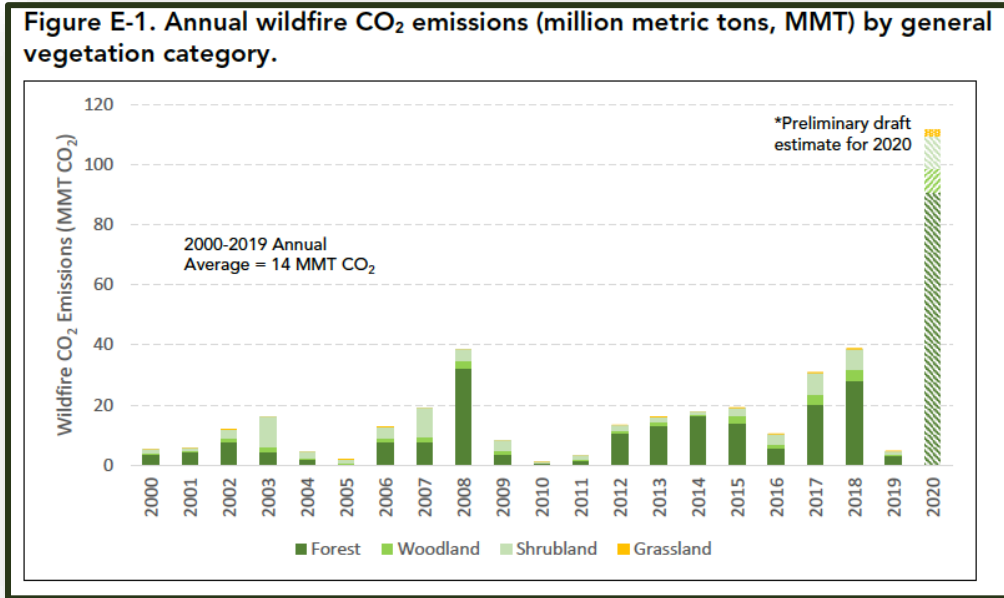
“Waste biomass is widely available across California, with about 56 million bone dry tons per year available from trash, agricultural waste, sewage and manure, logging, and fire prevention activities (...). Today, this biomass returns its carbon to the atmosphere when it decays or burns in prescribed fires or wildfires, or is used to produce energy at a power plant that vents its carbon emissions. (...)

*Converting this biomass (primarily forest biomass) into fuels with simultaneous capture of the process CO₂ emissions holds the greatest potential for negative emissions in the State. A broad array of processing options is available, and includes (...) conversion of woody biomass to liquid fuels and biochar through pyrolysis; and conversion of woody biomass gaseous fuels through gasification.”(...)*³

As a result of the changed conditions in the forests coupled with climate change, California's forests have changed from a carbon sink to a carbon source. Wildfires nationwide have drastically increased in intensity and frequency in recent years, creating not only increasing risk to life, health and property but also generating substantial GHG emissions to exacerbate the effects of climate change.⁴ The national trend is particularly acute in California. However, due to its novelty and uncertainty, the new reality of wildfire GHG emissions from forests has not yet been integrated into California's climate policy.

³ Sarah E. Baker, Joshua K. Stolaroff, George Peridas, Simon H. Pang, Hannah M. Goldstein, Felicia R. Lucci, Wenqin Li, Eric W. Slessarev, Jennifer Pett-Ridge, Frederick J. Ryerson, Jeff L. Wagoner, Whitney Kirkendall, Roger D. Aines, Daniel L. Sanchez, Bodie Cabiyo, Joffre Baker, Sean McCoy, Sam Uden, Ron Runnebaum, Jennifer Wilcox, Peter C. Psarras, Hélène Pilorgé, Noah McQueen, Daniel Maynard, Colin McCormick, Getting to Neutral: Options for Negative Carbon Emissions in California, January, 2020, Lawrence Livermore National Laboratory, LLNL-TR-796100 , at https://www-gs.llnl.gov/content/assets/docs/energy/Getting_to_Neutral.pdf , (hereafter Getting to Neutral Report) at p. 4.

⁴ California Air Resources Board https://ww3.arb.ca.gov/cc/inventory/pubs/ca_ghg_wildfire_forestmanagement.pdf and <https://ww2.arb.ca.gov/wildfire-emissions>



California’s forests cover large areas of the State and are a mix of private, federal and state lands. As such, the solution to California’s wildfire crisis requires an unprecedented level of coordination between state and federal policymakers, and also between agencies. This White Paper is intended to facilitate and support that coordination. The authors and industry participants are fully available for additional engagement.

The White Paper’s recommendations were developed based on the input of eight companies developing real-world commercial facilities that convert woody biomass to hydrogen, renewable natural gas, and drop-in liquid replacement fuels for petroleum-based gasoline, diesel and jet fuel. The policy recommendations of this report have been derived in part from and informed by the California Joint Institute for Wood Products Innovation’s 50-member working group on “Advancing collaborative action on forest biofuels” to promote policy and market development for forest biofuels. (**“Forest Biofuels Report”**).⁵

The White Paper is organized as follows:

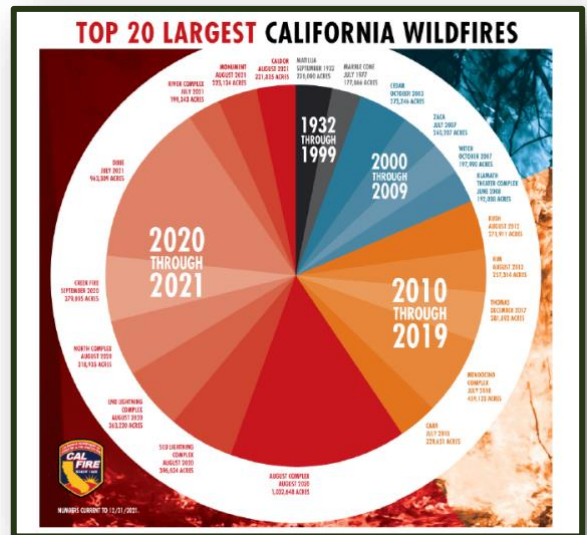
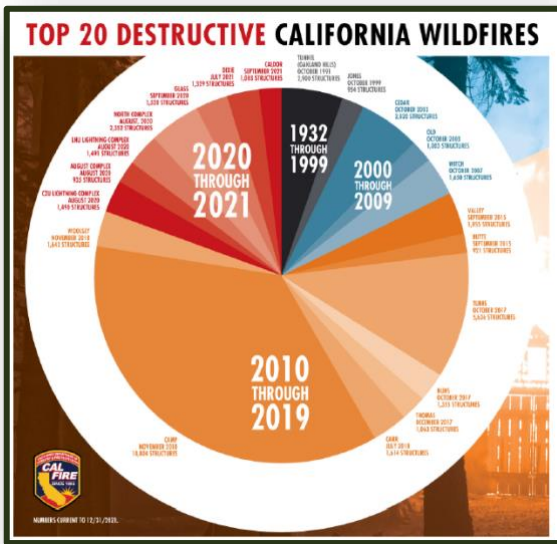
- Overview
- Challenges
- Summary of Recommendations
- Detailed Policy Recommendations
- Forecasted Market Growth with Policy Support
- Summary for Policymakers from the Joint Institute for Wood Products Innovation Report
- Company Profiles of the Nine Consortium Companies with Facility and Process Details

⁵ Joint Institute for Woody Products Innovation, California Board of Forestry and Fire Protection, posted in 2022 Reports, website at <https://bof.fire.ca.gov/board-committees/joint-institute-for-wood-products-innovation/>, report at https://bof.fire.ca.gov/media/mn5gzmxv/joint-institute-forest-biofuels_final_2022_ada.pdf

CHALLENGES

Challenge #1—California’s Wildfire Crisis is Immediate and Massive

In May of 2018, Governor Jerry Brown issued an Executive Order stating, in part, “recent wildfires have been the largest, deadliest, most destructive and costliest in history,” and establishing the Joint Institute for Wood Products Innovation to “accelerate research, development and adoption of advanced forest management and wood products manufacturing.”⁶ The risks that Governor Brown identified in 2018 have only worsened in subsequent years.⁷ It is only due to the exhaustive, brave and capable work of CalFire, the US Forest Service, and the Brown and Newsom Administrations that the California mega-fires of 2020 and 2021 did not wreak a comparable toll of death and destruction as did the Tubbs and Camp fires.



Challenge #2—It will require a tremendous effort to scale California’s forest management to the joint State/Federal goal of one million acres treated/year by 2025, which is estimated to yield about 24M bone dry tons (BDT) of biomass per year.⁸

As stated by the US Forest Service in its Wildfire Crisis Strategy:

“Wildfires have been growing in size, duration, and destructivity over the past 20 years. Growing wildfire risk is due to accumulating fuels, a warming climate, and expanding development in the wildland-urban interface. The risk has reached crisis proportions in the West, calling for decisive action

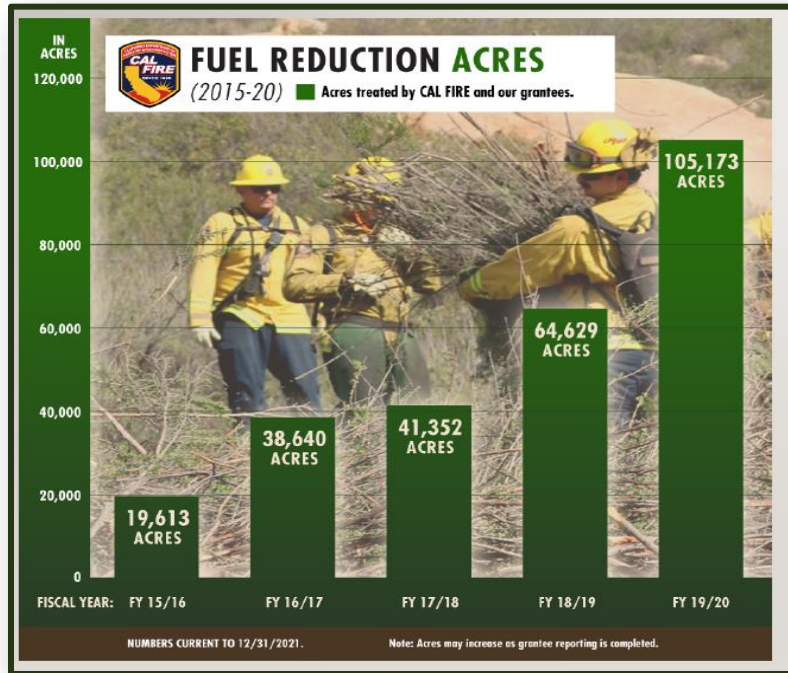
⁶ Governor Edmund G. Brown Jr., Executive Order B-52-18, at <https://www.ca.gov/archive/gov39/wp-content/uploads/2018/05/5.10.18-Forest-EO.pdf>

⁷ CalFire Staff Chief Tim Robards, “The Urgency and Scope of the Problem,” Presentation to the Department of Conservation’s Forest Biofuels Gasification Pilot Program, (April 5, 2022).

⁸ Getting to Neutral Report, at Table 8, p.31.

to protect people and communities and improve forest health and resilience. It will take a paradigm shift in land management across jurisdictional boundaries to reduce risk and restore fire-adapted landscapes.⁹

In order to achieve this dramatic expansion, California must sustain the rapid growth curve of forest treatment that has been established over the past five years.¹⁰



Challenge #3—The woody biomass fuels industry is in the early stages of commercialization and requires long-term favorable business conditions to meet the twin goals of establishing substantial demand for woody biomass feedstock and providing a reliable supply of low carbon bio-based fuels.

As has been demonstrated by the slow growth of the cellulosic ethanol industry, it is technically challenging to convert cellulosic materials including wood into liquid fuels. While there are multiple technologies that have now proven capable of converting woody biomass to transportation fuels, the woody biomass fuels industry is currently in scale-up mode.¹¹ The available technologies require high capital expenditures (CapEx) relative to the facility’s annual production capacity. All of the companies

⁹ Forest Service for the US Department of Agriculture, Confronting the Wildfire Crisis, at <https://www.fs.usda.gov/sites/default/files/Confronting-Wildfire-Crisis.pdf> at p. 3.

¹⁰ CalFire Staff Chief Tim Robards, “The Urgency and Scope of the Problem,” Presentation to the Department of Conservation’s Forest Biofuels Gasification Pilot Program, (April 5, 2022).

¹¹ For insight into the current status of industry development, see the nine Company Profiles contained as an Appendix to this White Paper.

involved in the development of this White Paper have direct experience with this challenge. The policy recommendations presented here are all principally directed at overcoming this central challenge.

The solution to these challenges is to craft policy solutions that remove current barriers and enable the rapid scale-up of the industry:

Permitting—California imports 90% of its liquid low carbon fuels not just because it has limited feedstocks, but also due to State’s uncertain and lengthy permitting process.

Revenue—California’s Low Carbon Fuel Standard (LCFS) and the federal Renewable Fuel Standard (RFS) are the most important fuel policies because each program provides long-term predictable revenue that enables return on investment (ROI) and thereby attracts investment for CapEx. Both the LCFS and RFS currently contain policy flaws impeding revenue. These flaws can be fixed by regulatory action.

Feedstock—The industry requires reliable, long-term sources of feedstock at predictable pricing. Since National Forests are at high risk, woody biomass from National Forests must be an eligible feedstock.

Appropriations—In concert with the other policy recommendations, sustained and strategic state and federal funding over the next decade will accelerate the scaling of the industry.

SUMMARY OF RECOMMENDATIONS

The California Woody Biomass Policy Consortium (“Consortium”) is composed of nine companies engaged in the development, commercialization and deployment of advanced technologies that convert woody biomass into low carbon transportation fuels (“industry”). Through this White Paper, the Consortium seeks to share with policymakers the potential of this industry to expand rapidly to simultaneously create demand for woody biomass generated by wildfire risk reduction programs and increase the supply of low carbon transportation fuels. The growth forecasts in this White Paper are premised upon the approval and implementation of four critical policy measures:

1. Update California State Policy

The California Air Resources Board (CARB) in concert with CalFire to utilize its existing regulatory authority to modify the LCFS to recognize the massive release of greenhouse gas and criteria pollutant emissions now resulting from California wildfires, prescribed burns, and citizen open burning, and to take action to reduce those emissions by providing avoided GHG emission credits within the CA-GREET model for fuels produced from qualifying woody biomass gathered from areas at risk of wildfire and open burn areas.

2. Support Revisions to Federal Policy

The U.S. Environmental Protection Agency (EPA) to utilize its existing regulatory authority to modify the RFS to recognize the peril of wildfires in the National Forests of the western U.S., and to take action in concert with the U.S. Forest Service to reduce that peril by authorizing RFS credit generation for fuels produced from qualifying woody biomass gathered from areas at risk of wildfire.

3. Expedite State Permitting

The California Legislature to pass legislation to facilitate state agency coordination and priority review of permits for facilities that produce fuels from qualifying woody biomass.

4. Direct Appropriations

To achieve the targeted growth of the industry, the California and federal governments should appropriate matching funds throughout the 2020s totalling one billion dollars to place the industry on track to create demand for 20 million bone dry tons of woody biomass in California by 2030. Particularly in the early years, a substantial portion of these funds should be dedicated to expanding staff capacity and resources at relevant departments and agencies.

DETAILED POLICY RECOMMENDATIONS

Background: The Consortium expresses its gratitude for the diligent work of the Forest Biofuels Working Group that was convened by the California Board of Forestry and Fire Protection and the Joint Institute for Wood Products Innovation, and that developed the comprehensive Forest Biofuels Report.¹² The authors of the Forest Biofuels Report 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 the working group allowed cross-pollination of ideas and opportunities across sectors, engagement of community members and practitioners capable of implementing recommendations directly.

The Forest Biofuels Report provided the starting point for this White Paper, and the Summary for Policymakers contained in that report is replicated here in its entirety as an Appendix to this White Paper. The Summary provides an excellent analysis of California’s critical forest wildfire problem and the potential solution that a vibrant forest biofuels industry could deliver to the State, its residents, and its forests. We also thank the principal authors of the Forest Biofuels Report, Dr. Daniel Sanchez and Dr. Haris Gilani of the University of California, Berkeley, for their close collaboration in the development of this White Paper and in particular the modeling work that underlies the Industry Forecast section.

Due to the fact that the recommendations from the Forest Biofuels Report were the product of a collaborative effort with extensive input from policymakers, industry members, non-governmental organizations, technical experts, academics, and other stakeholders, the following two recommendations have been integrated into this White Paper without modification to preserve the full benefit of that input.

1. LCFS Recommendation

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.
- 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.

2. RFS Recommendation

The EPA should undertake the following administrative actions related to the 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

¹² Joint Institute for Woody Products Innovation, California Board of Forestry and Fire Protection, posted in 2022 Reports, website at <https://bof.fire.ca.gov/board-committees/joint-institute-for-wood-products-innovation/> , report at https://bof.fire.ca.gov/media/mn5gzmxv/joint-institute-forest-biofuels_final_2022_ada.pdf

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, delimiting, 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.

SUPPLEMENTAL POLICY RECOMMENDATIONS

Supplemental Policy Recommendations: In addition to endorsing the LCFS and RFS Recommendations contained in the Joint Institute’s Forest Biofuels Report, the California Woody Biomass Policy Consortium has identified the following two additional policy measures as critical to rapid industry growth.

3. California Legislature and State Agencies to Establish and Implement Mechanisms to Expedite State Permitting

The California Legislature to pass legislation to facilitate state agency coordination and priority review of permits for facilities that produce fuels from qualifying woody biomass.

It is well-known that siting industrial facilities in California present substantial permitting challenges. This is driven by California’s extensive regulatory protections that include stringent protections for air, water and soil; demanding process requirements; and increasing recognition of the need to protect local communities and enhance environmental justice. The Consortium recognizes the vital importance of these objectives and does not recommend weakening the protections. However, due to the urgent and recurring risk of wildfire and open burning to human life, property, air quality and wildlife flora and fauna, there is strong impetus for the State to expedite the review and permitting of facilities to better mitigate these risks. This can be achieved by enhancing inter-agency coordination and expediting permit review for qualifying facilities with advanced technologies that utilize woody biomass to produce transportation fuels.

The following summary of best practices provides concrete examples of how California and other states have facilitated agency coordination and priority review of qualifying facilities, all of which should be applied to the permitting of facilities utilizing woody biomass to produce transportation fuels:

- Form interagency partnerships, coordinate agency reviews, set joint-agency working groups, and

publish model agency decisions. See the California Governor’s Office of Business and Economic Development, [Hydrogen Station Permitting Guidebook](#)

- Launch permitting first through efficient pre-application meetings – as an example, see the [Oregon Regional Solutions Program Overview](#)
- Develop programs and initiatives to facilitate industry expansion – examples from [the Indiana Economic Development Corporation](#) include:
 - [Regulatory Affairs](#)
 - [Opportunity Zones](#)
 - [Technology Parks](#)
- Provide a central resource site for exploring incentives: [Nevada Governor’s Office of Economic Development](#))

4. California and Federal Legislature and Agencies to Direct Appropriations to Support Robust Industry Expansion to Create Demand for Woody Biomass and Supply of Low Carbon Fuels

To achieve the targeted growth of the industry, the California and federal governments should appropriate matching funds throughout the 2020s totaling one billion dollars to place the industry on track to create demand for 20 million bone dry tons of woody biomass in California by 2030. Particularly in the early years, a substantial portion of these funds should be dedicated to expanding staff capacity and resources at relevant departments and agencies.

The final recommendation of the California Woody Biomass Policy Consortium is the development of a long-term plan for both federal and state appropriations for the industry. In order to achieve the target of creating demand for 20 million BDTs of woody biomass in California by 2030, the Consortium determined that approximately one billion dollars in funding would be required in the 2020s. This would include both federal and state funding streams. Specific to facility financing, Consortium members agreed that a modest 5% level of CapEx support would enable more companies to benefit from grants, grow more capacity, and not cause the market distortions likely to result from larger grants to fewer companies.

In the short term, the Consortium recommends the rapid expansion of agency capacity. To meet the daunting new challenge of prolonged and extreme wildfire risk necessitates the development of a well-resourced, efficient, and innovative network of agencies. This network will plan and supervise a comprehensive program of forest management activities coupled with the rapid expansion and growth of the woody biomass to the transportation fuels sector. Additional staff capacity within state government is crucial to enable the inter-agency coordination that will be necessary for success. These efforts will be limited by a lack of dedicated staff focused on this issue, therefore, the State Legislature and Administration should ensure that additional staff capacity is hired and resources are made available to the relevant departments, boards, and agencies that are crucial to the effort (CalFire, Department of Conservation, Energy Commission, GoBiz, CARB, etc). Due to the dominance of National Forests in California, it will also be necessary for California and the federal government to establish permanent frameworks to enable close planning and coordination between California and the relevant federal agencies (US Forest Service, US EPA, etc.).

INTERDEPENDENCE OF THE POLICY RECOMMENDATIONS

To rapidly scale the industry, each of the four policy recommendations must be implemented. The LCFS and RFS programs provide substantial supplemental revenue streams for the production of low carbon transportation fuels, fundamentally changing the economics of converting woody biomass to fuel and significantly advancing GHG emissions reduction while creating a sustainable market that supports wildfire risk reduction. Until the economics of converting woody biomass to fuel are favorable for investors, growth will be slow-going and will require government support. Once favorable returns are achieved, private investment will flow into the sector.

The regulatory changes proposed in this White Paper would address distinct major limitations that prevent the use of woody biomass for low carbon transportation fuels. Specific to the LCFS, CARB has not yet recognized the GHG value of avoided wildfires, burn piles or open burning in its CA-GREET model and has thereby undercut the program's effectiveness to drive demand for woody biomass. The current regulatory language of the RFS effectively excludes biomass from national forests from being an eligible feedstock for transportation fuels, thereby precluding the most valuable federal low carbon fuels program from creating market demand for biomass from necessary forest treatments. Turning to permitting, California's long-wait times, complexities and uncertainties have caused several of the world's leading low carbon fuel producers to build facilities in neighboring states. However, due to the high cost of transporting woody biomass, and in order to derive maximum benefit and commercial value from forest management activities, California needs to have distributed facilities in-state rather than elsewhere. In order to achieve this goal and to attract jobs and economic development to the State, California must address its permitting timeline. Finally, long-term appropriations of state and federal dollars will speed industry expansion by creating new agency capabilities to address the extreme risk of wildfire and by establishing funds that facilities can use for capital expenditures.

Significant industry expansion in support of both GHG reductions and wildfire protection could be achieved by implementing the four recommended policies. The next section of this White Paper describes the anticipated transformation and decarbonization of California's transportation sector that successful implementation of these policies would achieve.

FORECASTED INDUSTRY GROWTH WITH IMPLEMENTATION OF POLICY FRAMEWORK

Adoption and implementation of the four policies recommended by this White Paper are projected to enable the expansion of the industry rapidly to create 20 M BDT of demand for woody biomass in California by 2030. This section of this White Paper describes the methodology and factors underlying the modeling of industry expansion. This modeling is largely consistent with the approaches taken in the Lawrence Livermore National Laboratory’s Getting to Neutral Report and the Joint Institute’s Forest Biofuels Report. In addition to the work of Dr. Sanchez and Dr. Gilani, this section benefits from the extensive work that CARB has done in evaluating the diversification of fuel supply that has been achieved to date in California due to the network of vehicle and fuel policies that the State has developed. Through the LCFS, Scoping Plan and other proceedings, CARB has scoped the anticipated transformation of California’s transportation sector.

In particular, we use measures of different scenarios laid out by CARB in their illustrative compliance scenario calculator¹³ (ICS) to quantify the total investment needed to scale up the forest biofuels industry in California. The ICS estimates fuel supply and credit generation scenarios for the LCFS to 2030. The CARB illustrative compliance scenarios for 2030 assume that 90-100% of natural gas supply to Californian transportation will be renewable by 2030, and forecasts 11.9 billion gallons of gasoline, 2 billion gallons of diesel and 319 million diesel gallons equivalent (DGE) of natural gas consumption by 2030 (Table 1).

Table 1: 2030 market size with capital cost of forest biofuels facilities

Fuel	Units	2030 market size	% share forest biofuels	Capacity in 2030	Facility size	Number of facilities	Capital cost (million\$ / facility)	Total capital cost
Ethanol	mm gal	1,418	25%	354	40	9	500	4,500
Gasoline	mm gal	11,906	5%	595	100	6	1000	6,000
Renewable Natural Gas	mm DGE	319	25%	79	50	2	750	1,500
Diesel	mm gal	2,023	10%	202	100	2	1000	2,000
Alternative Jet Fuel	mm gal	225	50%	112	50	2	750	1,500
Hydrogen	mm kg	43	50%	21	3	7	100	700
Electricity	1000 MWH	7,576	10%	757	140	5	150	750

¹³ California Air Resources Board, LCFS Regulation page at <https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/lcfs-regulation>, see Low Demand Scenario; Supply Scenario:Project/LD/Low ZEV/20%/infra, at https://www.arb.ca.gov/fuels/lcfs/2018-0815_illustrative_compliance_scenario_calc.xlsx

Using the forecasted market size in 2030, we estimated the percentage share of forest biofuels to be between 5% and 50% across different fuel types. Biofuels such as hydrogen and Sustainable Aviation Fuels from forest biomass may have a higher penetration of up to 50% in the existing fuel markets compared to gasoline or diesel where forest biofuels could contribute up to 5% and 10% respectively. By calculating the capacity in 2030 and facility size for each fuel, we estimated the total number of biofuels facilities in California to be 33. We estimated the capital cost for each facility type by reviewing previous literature and in consultation with the technology providers and financiers. Based on capital cost estimates, we modeled the 5% cost share proposed in the Recommendations of this White Paper and calculated the proportion of the total expenditure (\$847 million), resulting in federal and state contributions of \$423 million each. Using woody biomass conversion factors (Shelly 2007), we estimated the total biomass utilization to be 20 million bone dry tons per year in California's forest biofuels sector.

SUMMARY FOR POLICYMAKERS FROM THE JOINT INSTITUTE FOR WOOD PRODUCTS INNOVATION’S FOREST BIOFUELS REPORT

The following is an excerpt from the California Joint Institute for Wood Products Innovation’s 50-member working group on “Advancing collaborative action on forest biofuels” to promote policy and market development for forest biofuels. (“Forest Biofuels Report”).¹⁴

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

¹⁴ Joint Institute for Woody Products Innovation, California Board of Forestry and Fire Protection, posted in 2022 Reports, website at <https://bof.fire.ca.gov/board-committees/joint-institute-for-wood-products-innovation/>, report at https://bof.fire.ca.gov/media/mn5gzmxv/joint-institute-forest-biofuels_final_2022_ada.pdf

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
- 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 to 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 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.

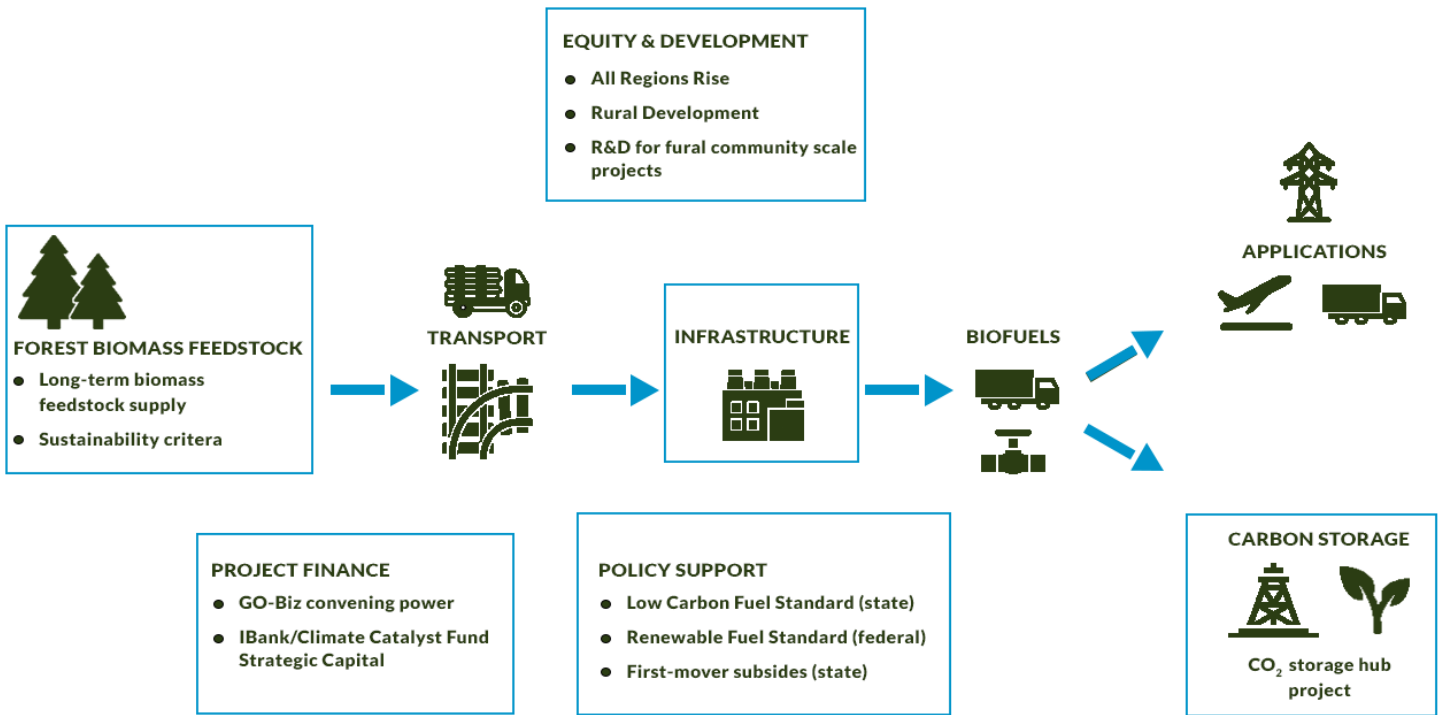
Existing definitions of 'underserved' in the state of California do not effectively target those communities which are disproportionately impacted by wildfire, forest biofuels use, and by sustainable forest restoration. This causes associated funds and regulatory measures to ineffectively address the 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 water shed, 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.



California Woody Biomass Policy Consortium Company and Project Profiles

Company Name: Alder Fuels

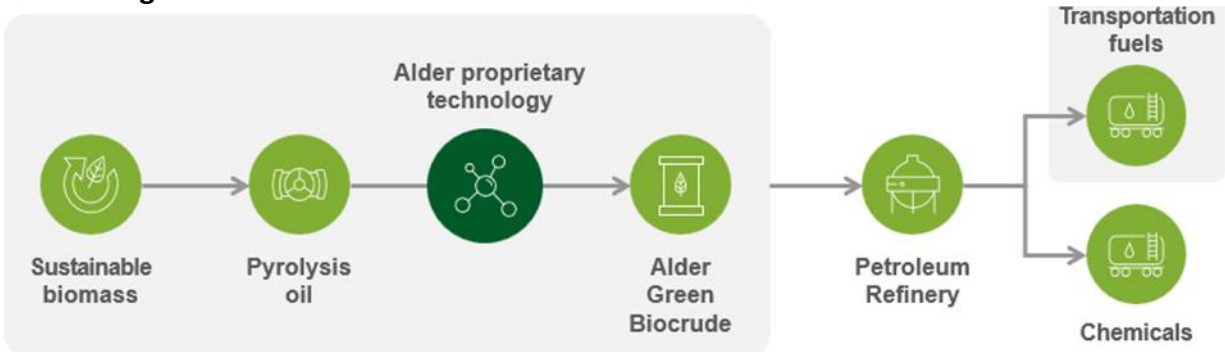
Website: www.alderfuels.com

Date Founded: 2019

Brief Description of Technology:

Alder Fuels solution maximizes the value of sustainable biomass by combining existing commercial scale processes with an elegant proprietary step to link together a complete solid biomass to liquid renewable fuel technology. The first step is converting sustainable biomass into liquid pyrolysis oil through existing technology utilized currently across North America and Europe. The second step is Alder's proprietary process to convert pyrolysis oil into separate streams including a high value green biocrude that can be sent to a petroleum refinery. The third and final step is sending the Alder green biocrude to an existing petroleum refinery for hydroprocessing into liquid transportation fuels. This commonly occurs today at refineries across North America and Europe where petroleum and liquid bio-oils are co-processed into renewable diesel, gasoline, and aviation fuels.

Process Diagram:



Feedstocks Utilized:

Alder's technology is compatible with most types of cellulosic biomass, including forest slash and timber mill residuals, agricultural harvest residuals and purpose grown or regenerative agriculture energy crops.

Products Produced:

Alder's technology produced a low carbon biocrude which is suitable for conversion into sustainable aviation fuel (SAF), renewable diesel, and renewable naphtha.

Facilities in Operation

Name	
County	
State	
Country	
Status	
Scale and Number of Facilities	
Year of commissioning	

Facilities in Development

Name	TBD
County	TBD
State	TBD
Country	USA
Status	Site finalization
Scale and Number of Facilities	TBD
Targeted Year of commissioning	2024
Technology Readiness Level (TRL)	

Estimated Future Facilities that will access California forest biomass as feedstock that will be commissioned by 2030 with optimal policy structure

Name	TBD
County	TBD
State	California
Country	USA
Status	Site Selection
Scale and Number of Facilities	TBD
Targeted Year of commissioning	2026
Current Technology Readiness Level (TRL) of Full Scale Facility Targeted for Deployment by 2030	

California Woody Biomass Policy Consortium Company and Project Profiles

Company Name: Gevo, Inc



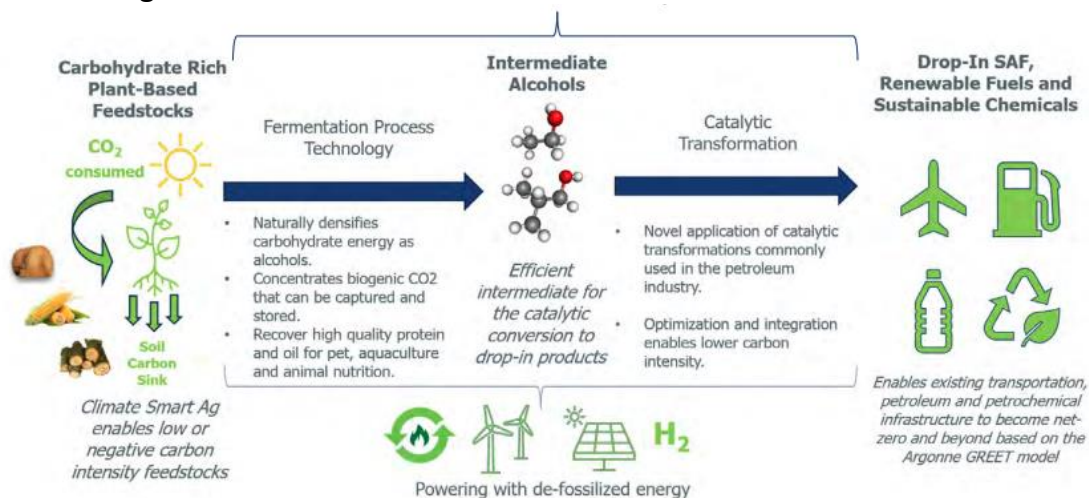
Website: www.gevo.com

Date Founded: 2005

Brief Description of Technology:

To make its energy-dense liquid hydrocarbons, Gevo uses low-carbon renewable resource-based carbohydrates as raw materials. It is also developing renewable electricity and renewable natural gas for use in its production processes, resulting in low-carbon fuels with substantially reduced carbon intensity. Gevo's proprietary technology can incorporate a variety of feedstock sources to produce fuel products.

Process Diagram:



Feedstocks Utilized:

Gevo technology utilizes regenerative agriculture energy crops such as field corn and is also compatible with most types of cellulosic and woody biomass, including forest slash and timber mill residuals and agricultural harvest residuals.

Products Produced:

Gevo's technology produces sustainable aviation fuel (SAF) and renewable gasoline. For fuel products that utilize field corn as a feedstock, high-value protein for pet nutrition and aquaculture is also produced.

Facilities in Operation

Name	Luverne, MN (Development Research Facility)
County	Rock
State	Minnesota
Country	United States
Status	Active
Scale and Number of Facilities	1.5 MGPY of IBA & 18MGPY of EtOH
Year of commissioning	Acquired for re-engineering 2010

Name	South Hampton Resources Facility in Silsbee, TX (Jet and Isooctane Biorefinery)
County	Hardin
State	Texas
Country	United States
Status	Active
Scale and Number of Facilities	100 KGPY
Year of commissioning	Operated in Partnership with South Hampton Resources, Inc. since 2011

Facilities in Development

Name	Net-Zero 1
County	Kingsbury
State	South Dakota
Country	USA
Status	In site finalization process
Scale and Number of Facilities	60MMGPY Hydrocarbon Plant Expected
Targeted Year of commissioning	2024
Technology Readiness Level (TRL)	

Estimated Future Facilities that will access California forest biomass as feedstock that will be commissioned by 2030 with an optimal policy structure

Recent Press Release: [Gevo and Sweetwater Energy Sign MoU to Supply Lignocellulosic Feedstocks to Produce Cellulosic Alcohols and Sustainable Aviation Fuel](#)

Name	TBD
County	TBD
State	TBD
Country	USA
Status	Preliminary Feasibility and Site Selection
Scale and Number of Facilities	TBD
Targeted Year of commissioning	TBD
Current Technology Readiness Level (TRL) of Full Scale Facility Targeted for Deployment by 2030	

California Woody Biomass Policy Consortium Company and Project Profiles

Company Name: H Cycle, LLC

Website: www.hcycle.com

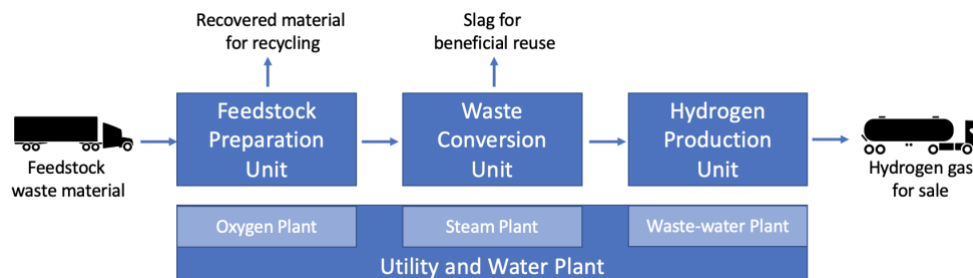
Date Founded: 2020 (Technology provider founded in 2001)

Brief Description of Technology:

H Cycle utilizes a thermochemical conversion technology from Omnivorous Conversion Technologies ('OMNI'). The OMNI system converts organic feedstock to synthetic gas (syngas), which is a mixture comprised mostly of carbon monoxide and hydrogen. A regulated input of steam, oxygen and some natural gas are utilized in the conversion process. The syngas is converted and purified to hydrogen using conventional processes, utilized in a variety of industrial applications. The conversion process involves three stages: low temperature pyrolysis, followed by an updraft gasifier for the conversion of chars leftover from the first stage, and plasma reforming to convert final tars in the syngas produced from stage one and two into additional product. Inorganic material (e.g. metals, ash) is recovered as a non-leaching slag material.

Note: H Cycle is a project developer licensing the technology from companies specialized in the development and licensing of process technologies.

Process Diagram:



Feedstocks Utilized:

Post-processed municipal solid waste (focusing on organic fractions), biomass (agriculture and forest thinnings). Can handle a high degree of contamination (e.g. metals, plastics, glass) given the technology utilized

Products Produced:

Hydrogen; can also produce renewable natural gas and liquid fuels.

A non-leaching non-hazardous slag that can be sold as road base or used at higher value as construction aggregate or in the cement industry.

Facilities in Operation

Name	Plasco Trail Road
County	Ottawa
State	Ontario
Country	Canada
Status	Shutdown (commercial demonstration)
Scale and Number of Facilities	135 MTPD (1 facility)
Year of commissioning	2006 (shutdown in 2015)

Facilities in Development

Name	TBD
County	Contra Costa, Los Angeles, Central Valley
State	California
Country	USA
Status	Site finalization
Scale and Number of Facilities	200 MTPD (3x facilities)
Targeted Year of commissioning	2025 for first one, 2026 for the next two
Technology Readiness Level (TRL)	8

Estimated Future Facilities that will access California forest biomass as feedstock that will be commissioned by 2030 with optimal policy structure

Name	TBD
County	TBD (likely Butte)
State	California
Country	USA
Status	Site Selection
Scale and Number of Facilities	200 MTPD (1 facility)
Targeted Year of commissioning	2028
Current Technology Readiness Level (TRL) of Full Scale Facility Targeted for Deployment by 2030	8 (should be 9 by then)

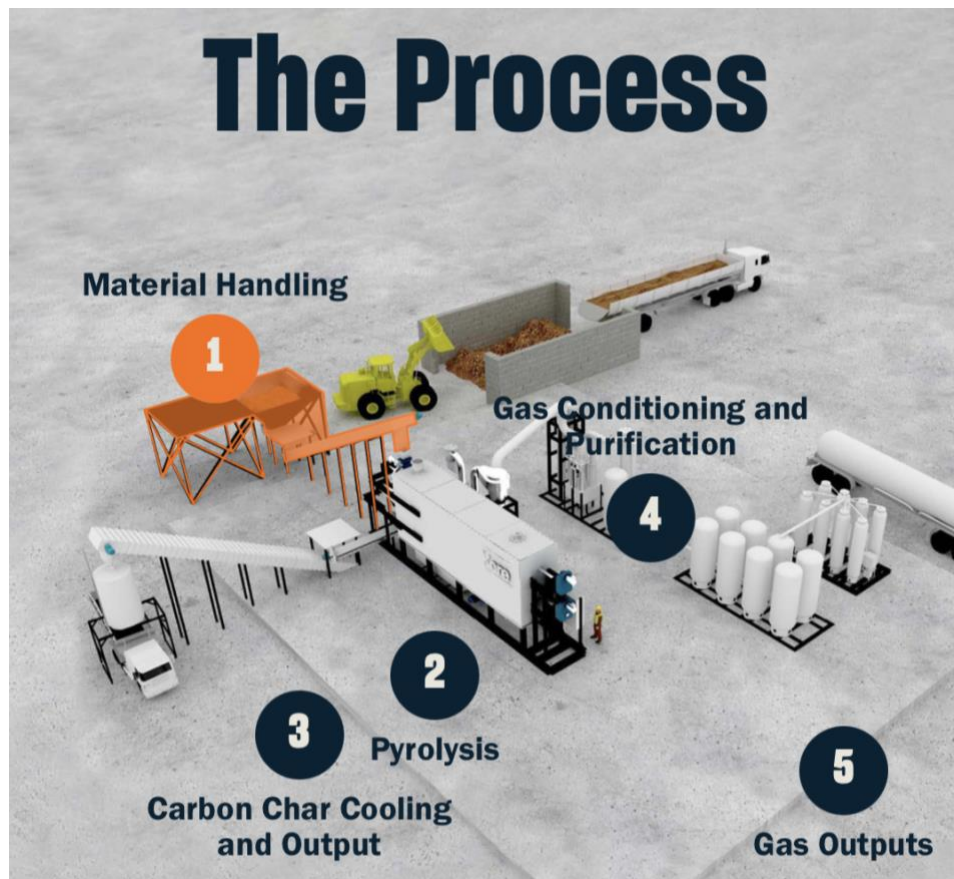
California Woody Biomass Policy Consortium Company and Project Profiles

Company Name: Kore Infrastructure (www.koreinfrastructure.com)

Date Founded: 2008

Brief Description of Technology: Kore uses High Temperature, Slow Pyrolysis to convert organic feedstocks into an energy dense biogas and a solid carbon char (biocarbon.) The biogas can be used to produce power, heat, and/or steam, or it can be upgraded to fuel cell quality hydrogen (99.999% purity) or renewable natural gas (RNG.) The biocarbon can be used as a soil amendment or coal substitute. Because the carbon in the biocarbon is very stable (will not revert to CO₂ or CH₄), the entire process is carbon negative (i.e. reduces atmospheric carbon.)

Process Diagram:



Feedstocks Utilized: Forest Thinnings, Agricultural Residuals, Urban Demolition Wood, Green Waste, Food Waste, Biosolids.

Products Produced: Energy Dense Biogas (500-600 BTU/ft³), UltraGreen™ Hydrogen, UltraGreen™ RNG, Biocarbon (elemental carbon char).

Facilities in Operation:

Kore built and is operating a commercial scale renewable energy production facility in downtown Los Angeles at a site owned by SoCalGas. The facility converts 24 tons/day of feedstock (Forest Thinnings, Ag Residuals, Urban Demolition Wood) into 240 MMBTU/day of biogas that can be upgraded to 1 metric ton/day of hydrogen or 200 MMBTU/day of RNG. The facility also generates about 5 tons/day of carbon sequestering Biocarbon.



Kore commercial scale facility in downtown Los Angeles converts 1 ton/hour of feedstock into carbon negative Biogas, Hydrogen, and RNG and Biocarbon.

Facilities in Development:

Name	California Oil Producer
County	Kern
State	California
Status	Development
Facility Size (Feedstock Flowrate)	50 tons/day
Products Produced	Biogas (to replace natural gas), Biocarbon
Targeted Year of commissioning	2023

Name	Landfill Diversion Facility
County	Kern
State	California
Status	Development
Facility Size (Feedstock Flowrate)	150 tons/day
Products Produced	Hydrogen or RNG, Biocarbon
Targeted Year of commissioning	2024

Kore is in conversation with many other California clients that could utilize thousands of tons per day of woody biomass feedstock to produce carbon negative renewable energy to decarbonize California transportation with the right policies in place.

California Woody Biomass Policy Consortium Company and Project Profiles

Company Name: **Red Rock Biofuels LLC**

Date Founded: **December 2017, commercial plant under construction in Lakeview, OR**

Brief Description of Technology: **Gasification, FT, upgrading**

Process Diagram:



- | | | |
|-------------------------------------|--------------------|-------------------------------|
| 1. Feedstock sourcing and transport | 3. Gasification | 6. Finished product transport |
| 2. Material handling | 4. Fischer-Tropsch | |
| | 5. Upgrading | |

Feedstocks Utilized: **Waste woody biomass (slash and pre-commercial thinnings).**

Products Produced: **Renewable jet (SAF), renewable diesel and naphtha fuels, biochar, cellulosic CO₂ for sequestration**

Capacity: **Approximately 20 million gallons per year of SAF, renewable diesel and naphtha fuel**

Facilities in Development

Name	Lakeview
County	Lake
State	Oregon
Country	USA
Status	Construction
Scale and Number of Facilities	1
Targeted Year of commissioning	Late 2023
Technology Readiness Level (TRL)	Under construction

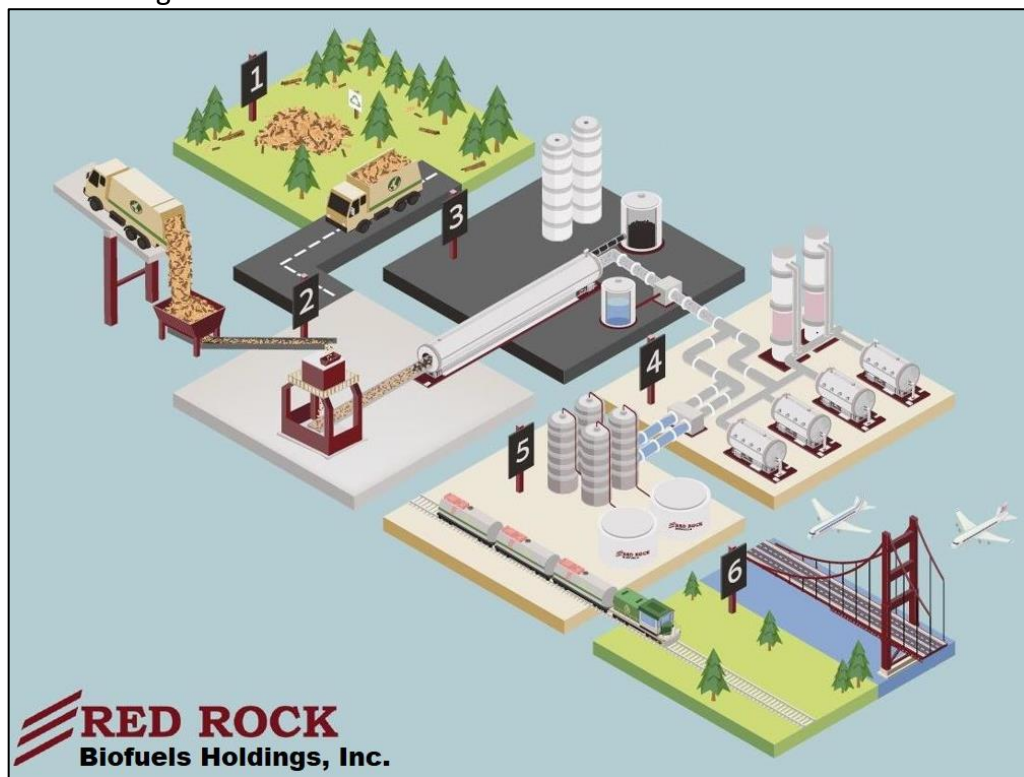
California Woody Biomass Policy Consortium Company and Project Profiles

Company Name: **Red Rock Biofuels Holdings, Inc.**

Date Founded: **2011. First commercial plant under construction in Lakeview, OR. Next plant Northern California with additional plants beyond that planned in the U.S.**

Brief Description of Technology: **Gasification, FT, upgrading**

Process Diagram:



- | | | |
|-------------------------------------|--------------------|-------------------------------|
| 1. Feedstock sourcing and transport | 3. Gasification | 6. Finished product transport |
| 2. Material handling | 4. Fischer-Tropsch | |
| | 5. Upgrading | |

Feedstocks Utilized: **Waste woody biomass (slash and pre-commercial thinnings).**

Products Produced: **Renewable jet (SAF), renewable diesel and naphtha fuels, biochar, cellulosic CO2 for sequestration**

Facilities in Operation – n/a

Facilities in Development

Name	Lakeview
County	Lake
State	Oregon
Country	USA
Status	Construction
Scale and Number of Facilities	1
Targeted Year of commissioning	2023
Technology Readiness Level (TRL)	Under construction

Facilities in Development

Name	RRBH NorCal
County	
State	California
Country	USA
Status	Development
Scale and Number of Facilities	1
Targeted Year of commissioning	2027
Technology Readiness Level (TRL)	Deploying same tech as Lakeview

Facilities in Development

Name	RRBH Oregon
County	
State	Oregon
Country	USA
Status	Development
Scale and Number of Facilities	1
Targeted Year of commissioning	2028
Technology Readiness Level (TRL)	Deploying same tech as Lakeview

Facilities in Development

Name	RRBH Washington
County	
State	Washington
Country	USA
Status	Development
Scale and Number of Facilities	1
Targeted Year of commissioning	2029
Technology Readiness Level (TRL)	Deploying same tech as Lakeview

California Woody Biomass Policy Consortium Company and Project Profiles

Company Name: Sierra Energy

Website: www.sierraenergy.com

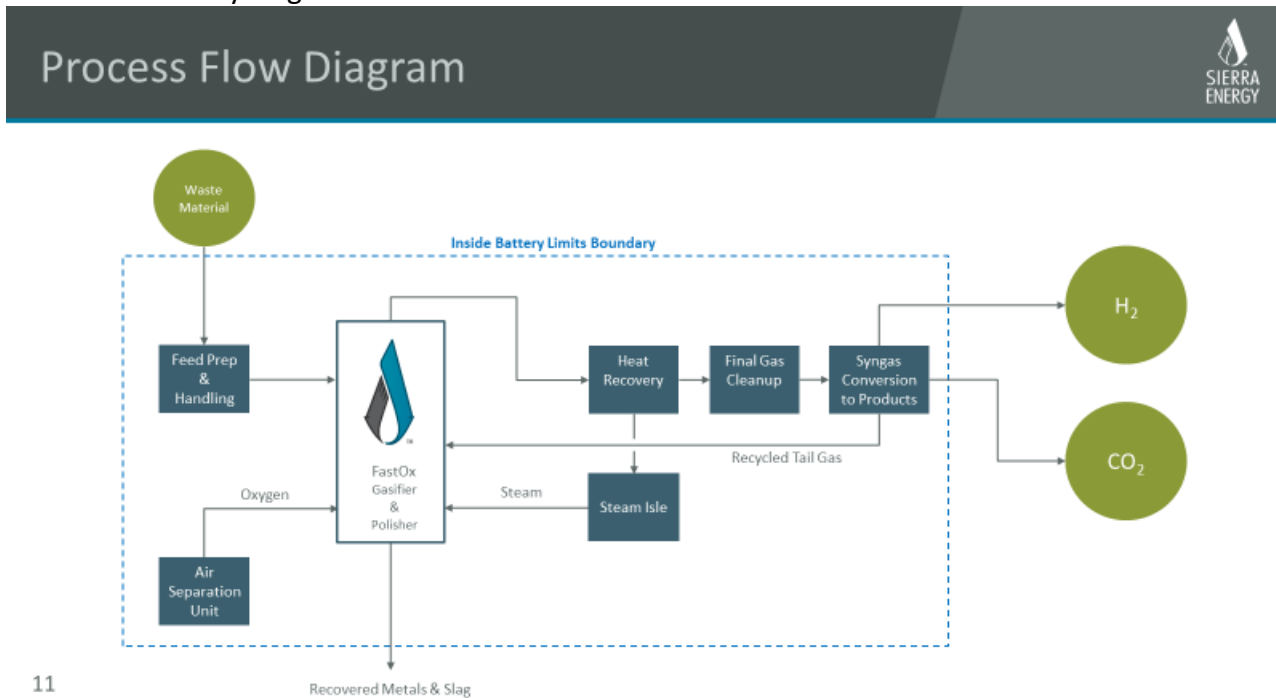
Date Founded: 2004

Brief Description of Technology:

Sierra Energy's FastOx[®] gasification turns waste into hydrogen, renewable natural gas, methanol, and other high-value end-products without burning. FastOx gasification is an ultra-high temperature updraft gasifier that uses oxygen and steam to heat waste up to 4,000°F, where waste breaks down at the molecular level. Organic material is converted into synthesis gas that is then turned into a high-value end-product. Inorganic material is recovered as either a non-leaching stone or molten metal. All outputs are saleable and there are no toxic ash or waste by-products that need to be disposed.

Process Diagram:

Process flow to hydrogen.



Feedstocks Utilized:

Biomass and post-recycled municipal solid waste. (Note: due to our high temperature operations, we can also convert more difficult feedstocks such as tires, medical waste, e-waste, and some hazardous wastes.)

Products Produced:

Hydrogen, renewable natural gas, methanol, and other liquid fuels. We also produce a non-leaching stone that can be sold as road base or used at higher value as construction aggregate or in the cement industry.

Facilities in Operation

Name	Ft. Hunter Liggett
County	Monterey
State	California
Country	USA
Status	Operational
Scale and Number of Facilities	10 MTPD (1 facility)
Year of commissioning	2020

Facilities in Development

Name	TBD
County	Sacramento
State	California
Country	USA
Status	Site finalization
Scale and Number of Facilities	100 MTPD (1 facility)
Targeted Year of commissioning	2025
Technology Readiness Level (TRL)	8

Estimated Future Facilities that will access California forest biomass as feedstock that will be commissioned by 2030 with optimal policy structure

Name	TBD
County	TBD
State	California
Country	USA
Status	Site Selection
Scale and Number of Facilities	200 MTPD (1 facility)
Targeted Year of commissioning	2027
Current Technology Readiness Level (TRL) of Full Scale Facility Targeted for Deployment by 2030	8

Note: Sierra Energy is a licensor of gasification technology. As a technology vendor, we are partnering with project developers worldwide. While the bulk of the projects using our technology will be developed by others including outside the United States, we will, in some instances including those outlined above, build, own, and operate full systems ourselves.

California Woody Biomass Policy Consortium Company and Project Profiles

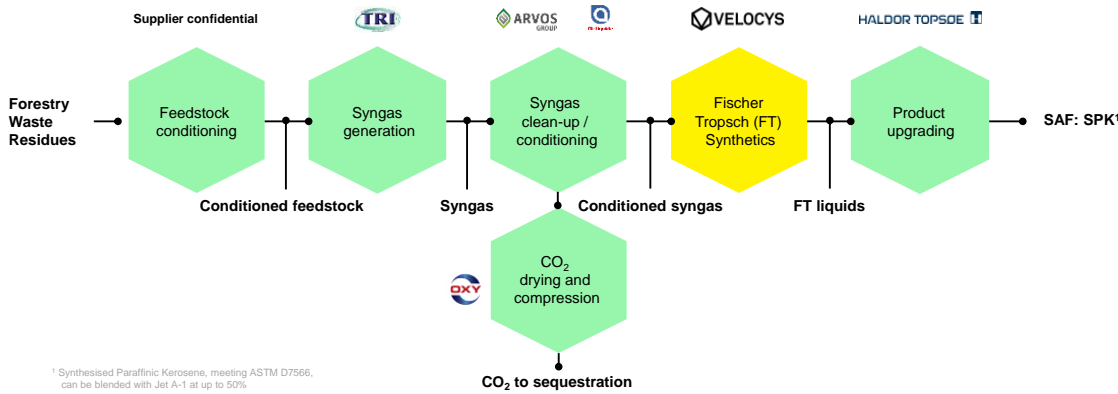
Company Name: Velocys, Inc.

Website: <https://www.velocys.com/>, <https://www.bayoufuels.com/>, and <https://www.altalto.com/>

Date Founded: 2001

Brief Description of Technology: Compact, efficient Fischer Tropsch technology. See <https://www.velocys.com/technology/> for overview.

Process Diagram:



Feedstocks Utilized: Woody biomass, Municipal Solid Waste or other cellulosic materials

Products Produced: Sustainable Aviation Fuel, Renewable Diesel and Gasoline blendstock (naphtha)

Facilities that have operated

Name	Envia Energy
County	Oklahoma County
State	Oklahoma
Country	USA
Status	Completed operations
Scale and Number of Facilities	2.7 million gallons/year
Year of commissioning	2017

Facilities in Development

Name	Bayou Fuels
County	Adams
State	Mississippi
Country	USA
Status	Engineering
Scale and Number of Facilities	35 million gallons/year
Targeted Year of commissioning	2025
Technology Readiness Level (TRL)	8

Bayou Fuels Biorefinery – Natchez, MS



Name	Altalto
County	
State	Immingham
Country	UK
Status	Engineering
Scale and Number of Facilities	20 million gallons/year
Targeted Year of commissioning	2026
Technology Readiness Level (TRL)	8

Estimated Future Facilities that will access California forest biomass as feedstock that will be commissioned by 2030 with optimal policy structure

Name	TBD
County	TBD
State	California
Country	USA
Status	Site Selection
Scale and Number of Facilities	35 million gallons/year (3)
Targeted Year of commissioning	2028 - 2030
Current Technology Readiness Level (TRL) of Full Scale Facility Targeted for Deployment by 2030	8

California Woody Biomass Policy Consortium Company and Project Profiles

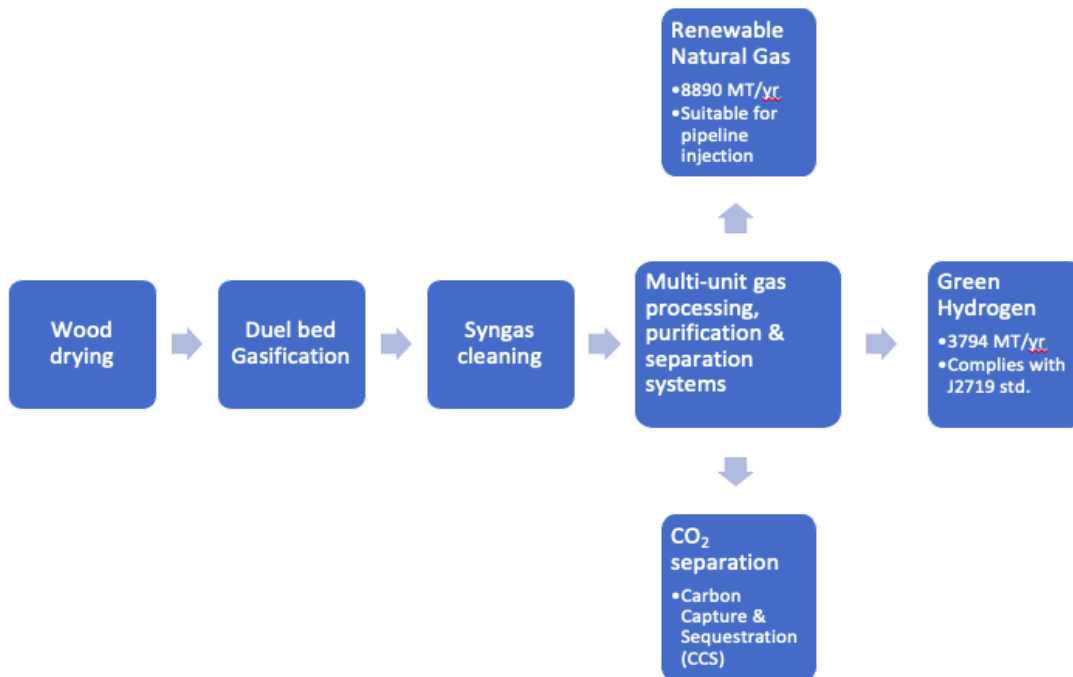
Company Name: Yosemite Clean Energy, LLC

Website: yosemitclean.com

Date Founded: 2017

Brief Description of Technology: Biomass-gasification is a commercially proven technology that has been used on an industrial scale in Europe for nearly 20 years. The technology provider selected by Yosemite, Aichernig Engineering (or “Repotec”), has successfully commercialized dual-bed biomass gasification technology since 2003 and has developed plants around the world. Repotec is based in Vienna, Austria, and utilizes technology originally developed at the Vienna University of Technology. Yosemite will employ this technology to convert biomass into syngas, with downstream conversion to green hydrogen and RNG taking place using technologies widely commercialized in the United States, supplied by companies such as Air Liquide and Chart Industries.

Process Diagram:



Feedstocks Utilized: Forest and farm wood waste

Products Produced: Renewable Natural Gas, Green Hydrogen, CO₂ CCS

Facilities in Development

Name	Oroville Biofuels Plant
County	Butte County
State	California
Country	USA
Status	FEL3 Detailed engineering and permitting
Scale and Number of Facilities	90,000BDT, 31 tons RNG, 13 tons H2
Targeted Year of commissioning	2024
Technology Readiness Level (TRL)	9

Name	Tuolumne Biofuels Plant
County	Tuolumne County
State	California
Country	USA
Status	FEL3 Detailed engineering and permitting
Scale and Number of Facilities	100,000BDT, 31 tons RNG, 13 tons H2
Targeted Year of commissioning	2025
Technology Readiness Level (TRL)	9

Name	Visalia Biofuels Plant
County	Tulare County
State	California
Country	USA
Status	FEL3 Detailed engineering
Scale and Number of Facilities	100,000BDT, 31 tons RNG, 13 tons H2
Targeted Year of commissioning	2026
Technology Readiness Level (TRL)	9

Estimated Future Facilities that will access California forest biomass as feedstock that will be commissioned by 2030 with optimal policy structure

Name	Additional Yosemite Biofuels Plants
County	Multiple
State	California
Country	USA
Status	Early stage development
Scale and Number of Facilities	7 additional facilities. 100,000BDT, 31 tons RNG, 13 tons H2 per facility
Targeted Year of commissioning	2025 through 2030
Current Technology Readiness Level (TRL) of Full Scale Facility Targeted for Deployment by 2030	9