FINAL REPORT | OCTOBER 2023

Woody Biomass Energy Technology Evaluation

PREPARED FOR

Yuba Water Agency

PREPARED BY

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Project No. 898-40-22-01

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LIST OF ACRONYMS AND ABBREVIATIONS

BACT	Best Available Control Technology
BDT	Bone Dry Tons
Bioenergy Team	West Yost and TSS Consultants
CDR	Carbon Dioxide Removal
CEC	California Energy Commission
CH4	Methane
CO	Carbon Monoxide
CO2	Carbon Dioxide
CPUC	California Public Utility Commission
CUP	Conditional Use Permit
DOC	Department of Conservation
EIS	Environmental Impact Statement
ESG	Environmental, Social and Corporate Governance
GHG	Greenhouse Gas
H2	Hydrogen
ICE	Internal Combustion Engine
IOUs	Investor-Owned Utilities
MOU	Memorandum of Understanding
MW	Megawatts
NEPA	National Environmental Policy Act
ORC	Organic Rankine Cycle
PG&E	Pacific Gas and Electric
PPA	Power Purchase Agreement
PSA	Pressure Swing Adsorption
RD&D	Research, Development, and Deployment
REMAT	Renewable Energy Market Adjusting Tariff
RNG	Renewable Natural Gas
ROD	Record of Decision
TRLs	Technology Readiness Levels
YWA	Yuba Water Agency

1.0 PURPOSE AND NEED FOR EVALUATION

The multiple stakeholders supporting the North Yuba Forest Partnership are undertaking a landscape scale forest restoration in an area that has seen several fires but, to date, is still mostly intact, representing a large area of highly valuable national forest, wildlife habitat, recreation sites and Sierra Communities. The North Yuba Landscape Project has eleven existing National Environmental Policy Act (NEPA) approved projects as well as a new Environmental Impact Statement (EIS) and Record of Decision (ROD) that includes several landscape scale treatments and a treatment plan for an additional high priority project. Additional RODs developed over the next two decades will include additional projects until the entire North Yuba River Watershed is in resilience and able to include fire (both natural and prescribed) as a forest management tool. As implementation funding increases the disparity in investment in essential infrastructure to support the restoration operation continues to expand. Biomass utilization infrastructure remains a primary barrier to increasing the pace and scale of forest restoration, including completing projects already funded in a timely manner. The Yuba Water Agency has commissioned this study to prepare for current, planned and future forest management operations that will support their Watershed Resilience Program, including the large North Yuba Landscape Project.

The key to addressing the biomass utilization bottleneck is the ability to efficiently determine:

- Where to process the wood, timber, biomass and other value-added products.
- How to convert the raw materials for beneficial use.
- What technologies are ready now and in the near future economically, and finally.
- When to enact plans to fully utilize the forested materials as they become available and in increasingly larger quantities.

With the short-term and long-term availability of biomass from the multiple, annual restoration projects in or near Yuba County our analyses have produced a two-prong approach regarding technology and implementation strategies. Because the next several years are estimated to bring in an increase in the amount of Bone Dry Tons (BDTs) due to more smaller projects with chipped biomass annually, a modest size low risk technology should be implemented to accommodate those amounts indefinitely. Whereas future years will likely produce more and increasing amounts of biomass annually with the larger forest restoration projects planned during those years. With that type of annual production of chipped biomass flowing it is recommended that a superior technology that is near implementation stage now, which requires larger amounts of biomass to become efficient, should be reviewed as the larger, future process for utilizing the wood material which will be generated for decades to come.

1.1 Scope of Work

West Yost, Brett Storey and TSS Consultants, Fred Tornatore, the Bioenergy Team, conducted an evaluation and review of biomass utilization technologies, including syngas, hydrogen, Renewable Natural Gas (RNG), biochar, electricity, and other potential byproducts to determine the status of these technologies and where they are successfully in operation. This information has been summarized into this report that can inform investment decisions and determine the most fruitful step for any new woody biomass utilization projects or pilot trials in Yuba County. In the evaluation of technologies, the team looked for both domestic and international examples or case studies and used the following criteria:

- Technology maturity, U.S. Department of Energy Technology Readiness Level – (TRL), see attached;
- System efficiency;
- System scalability;
- Operating requirements;
- Experience with and ability to process different types of woody biomass feedstocks;
- Environmental considerations, e.g., air emissions, water supply, wastewater;
- Estimated cost of production ($/kWh or $/MMBtu);
- Capital cost estimate;
- Operation and maintenance cost estimate;
- Marketable products and byproducts, and
- Technology vendor's capacity and willingness to contribute to the next phase of project development.

The Bioenergy Team has documented the technology and vendor evaluation process including the rationale for why the biomass utilization technology was evaluated. For this scope of work, the Bioenergy Team examined potential technologies with a TRL of seven or higher able to make use of woody biomass for energy or energy-related products. The outcomes of this investigation are presented below, and summarized in a technology evaluation matrix that will also provide a rank based on key technology attributes. The top five technologies/developers have been further discussed.

1.2 Bioenergy Technologies

Summarized below are the technology categories that were considered in this technology review.

1.2.1 Biomass to Electricity

Production of electricity from biomass combustion has been commercialized worldwide for many decades and is the most common form of woody biomass to electricity systems. Direct combustion systems feed biomass feedstock into a combustor or furnace, where the biomass is burned with excess air to heat water in a boiler to create high pressure steam. This steam drives a turbine generator to make electricity, see Figure 1 and Figure 2 below. Biomass direct combustion can also produce heat which can then be used to heat a working fluid in an Organic Rankine Cycle (ORC) turbine generator system. Such ORC systems use air cooling systems to condense the working fluid from the vapor phase back to the liquid phase in a closed loop system, thus eliminating the need for continuous water supply, for steam, and process wastewater requiring disposal, see Figure 1 and Figure 3.

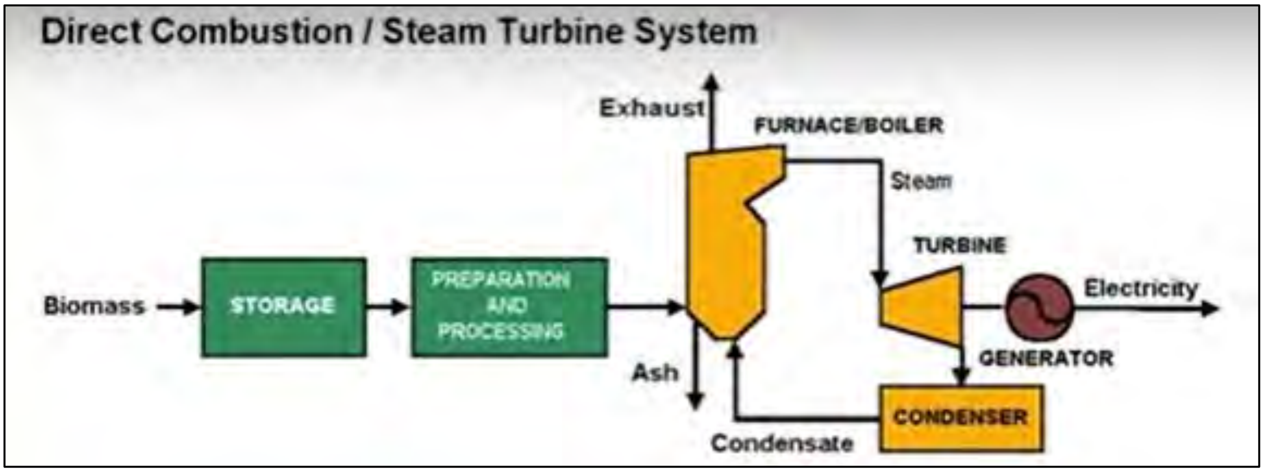

Figure 1. Biomass Direct Combustion

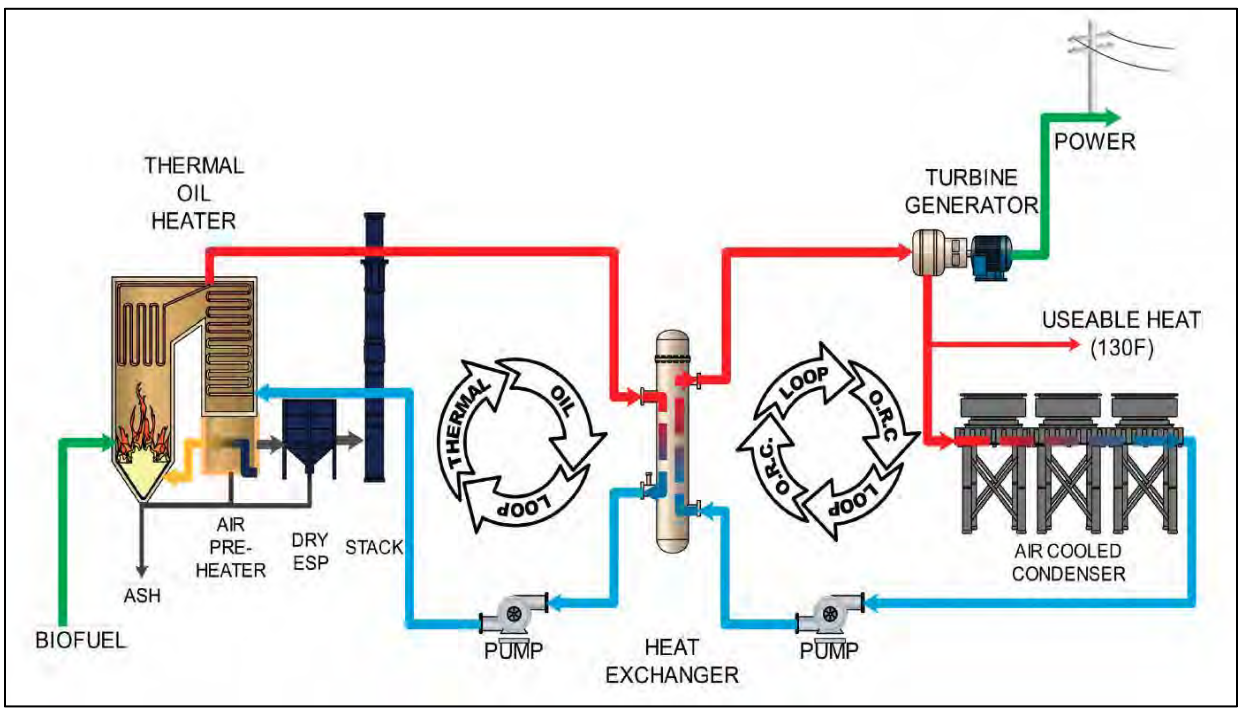

Figure 2. Small Scale Biomass Direct Combustion Power Plant

Figure 3. Biomass Direct Combustion with ORC Electricity Generation in Williams, CA

Biomass electric power systems typically use one dry ton per megawatt-hour of electricity production approximately 8,000 BDTs per megawatt-year. This approximation is typical of woody biomass systems and is useful as an indicative estimate of fuel use and storage requirements, but the actual value will vary with system efficiency.

Most wood chips produced from forest-sourced biomass will have a moisture content of 40 percent to 55 percent, wet basis, which means that a ton of green fuel will contain 800 to 1,100 pounds of water. This water will reduce the recoverable energy content of the fuel, and reduce the efficiency of the boiler, as the water must be evaporated in the first stages of combustion.

A significant consideration with forest-sourced woody biomass-fired plants are storage, handling and pre-processing of the fuel. This is the case with both small, grate-fired plants and large suspension-fired plants. Drying the biomass before combusting improves the overall process efficiency but may not be economically viable in many cases. Storage must be provided for the fuel, particularly in the winter months, when biomass may not be sourced due to inclement weather conditions. In addition, the fuel piles must be aeriated by stirring movement to keep possible combustion from happening.

Exhaust systems are used to vent combustion by-products to the environment. Emission controls might include a cyclone or multi-cyclone, a baghouse, or an electrostatic precipitator. The primary function of this equipment is particulate matter control. Cyclones and multi-cyclones can be used as pre-collectors to remove larger particles upstream of a baghouse, fabric filter, or electrostatic precipitator. Reduction in particulate can be as high as 99 percent+. In addition, emission controls for unburned hydrocarbons, oxides of nitrogen, and sulfur are generally required per local, state, and federal air quality regulations.

Gasification technology is also used to convert biomass fuels into energy. Biomass gasification systems are similar to combustion systems, except that the quantity of air is limited or totally absent to produce a fuel gas, a.k.a. producer gas with a usable heating value in contrast to combustion, in which the off gas does not have a usable heating value. This producer gas is subjected to gas clean-up to remove contaminants and compounds that foul the electrical generation system. Once cleaned and conditioned, this syngas provides the ability to power many different kinds of gas-based prime movers, such as internal combustion engines (ICE), Stirling engines, thermoelectric generators, fuel cells, and micro-turbines to produce electricity. And, as it is gas that is actually combusted or used chemically in the prime mover, emissions can be substantially less than the combustion of the solid wood fuel. A simple schematic of the gasification process is shown in Figure 4 below. It should be noted that woody biomass gasification can also be utilized to produce biofuels, biomethane, a.k.a. renewable natural gas and green hydrogen. Further discussion of biofuels is presented in the next section.

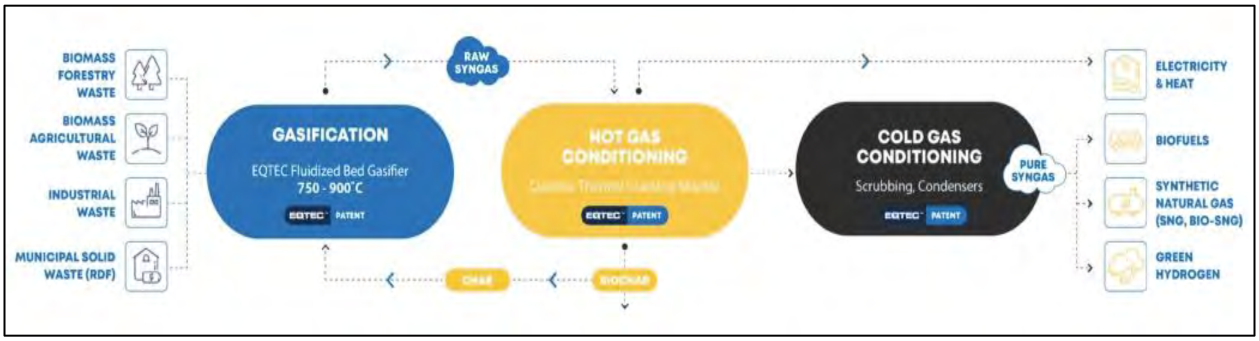

Figure 4. Biomass Gasification to Energy

1.2.2 Electricity Market

The use of forest management and hazard fuels reduction residuals in the generation of electricity for sale to Pacific Gas and Electric (PG&E) can garner a premium price. California Senate Bill 1122 was passed in 2012 and is a bioenergy specific carve out introduced by the California legislature to incubate the development of small-scale distributed generation facilities that address and support waste diversion and emissions reduction goals of the California Energy Commission (CEC), CalRecycle, and the State's Bioenergy Action Plan. The legislation further established, through public and utility deliberation by the California Public Utility Commission (CPUC)[1], BioMAT is modeled after the existing Renewable Energy Market Adjusting Tariff (REMAT) for renewables but is exclusive to small-scale bioenergy projects, i.e., 5 MW w/3 MW only for electricity export to the three major California Investor-Owned Utilities (IOUs)[2] . A total of 250 MW has been allocated to this program: 110 MW to urban sourced bioenergy (BioMAT Category 1), 90 MW to dairy and agricultural bioenergy (BioMAT Category 2), and 50 MW to forest sourced bioenergy (BioMAT Category 3). PG&E, the primary IOU for the Yuba County region, received an allotment to fill 47.5 MW of Category 3. To date, in the PG&E territory only 3 MWs of Category 3 has come online as yet (in Plumas County). There are two under construction in Madera County (2 MW) and Shasta County ,3 MW. Further, for the PG&E Category 3 allotment, there is currently 14 MWs total, which have

1 CPUC Decisions 12-08 and 15-09-004

2 These include PG&E, Southern California Edison, and San Diego Gas & Electric

a BioMAT Power Purchase Agreement (PPA). The remaining 6 MWs are for proposed projects that are in Calaveras County and Yuba County, 3 MWs each.

1.2.3 BioMAT Category 3: Byproduct of Sustainable Forest Management

For the North Yuba forest region and the forest management and thinning activities to happen for the next several years, a Category 3 facility could be a viable option. Category 3 is intended to promote the utilization of energy feedstock generated from approved fire threat reduction plans, fire safe clearance activities to comply with Public Resources Code Section 4290 and 4291, infrastructure clearance projects, and other sustainable forest management certified and approved by CalFire or another appropriate state or federal agency. Currently, a Category 3 PPA would receive $199.72 per MW hour, with PPA durations of 10, 15, or 20 years, and there are enough allotments in PG&E territory for an additional 11 Category 3 projects.

1.2.4 Project Participation and Project Development

Requirements to prepare for the BioMAT include:

- System sizing based on sustainable feedstock availability;
- Technology and vendor selection;
- Site Control;
- Negotiate Memorandum of Understanding (MOU) for project development roles and responsibilities; and
- IOU System Impact Study for interconnection.

Additional pre-development work includes:

- Feasibility Study;
- Review site zoning and apply for a Conditional Use Permit (CUP) if necessary, from the local and applicable land use agency;
- Apply for Authority to Construct air quality permit from applicable air district;
- Contract feedstock, if necessary; and
- Detailed financial model and plan to acquire financing.

Woody biomass to electricity, whether it be forest, agricultural, or urban-sourced feedstock, using direct combustion is the most mature of the wood bioenergy technologies. Wood-fired steam engines came about in the early 19th century, with electricity generation advancing throughout the 20th century with a massive deployment in California in the 1980's the advent of governmental policies and incentives for the use of waste wood from forests, agriculture, and urban settings. At the peak of the biomass industry, California's biomass power plants installed capacity totaled 800 megawatts (MW) of electricity from 66 direct combustion biomass facilities. The expiration of price support to the biomass industry is the main reason for the reduction in biomass power generation in California. Currently, there are about 30 direct-combustion biomass facility in operation with a capacity of 640 MW. The BioMAT program as described above is the more recent state government-imposed power purchase price support for the community scale biomass sector.

Gasification of wood to electricity has a shorter history than direct combustion, and when used to product syngas for the direct generation of electricity using ICE generator sets is still an emerging technology in the United States. A major part of this is due to the still evolving syngas cleanup equipment, which contain contaminants in the syngas, such as tars, can cause operating problems and costly maintenance in the ICE gensets. There is currently one gasification to ICE electricity generation project under construction in Madera County, which is being funded in part by the CEC that will in part further investigate the syngas cleanup methods and produce 2 MW of electricity under the BioMAT program, Category 3.

1.2.5 Biochar Production

Gasification, and even direct combustion, of woody biomass also results in a marketable byproduct in addition to electricity – biochar. Biochar is the lightweight black residue, made of carbon and ashes, remaining after the gasification of biomass. Biochar is defined by the International Biochar Initiative as "the solid material obtained from the thermochemical conversion of biomass in an oxygen-limited environment".

Biochar is beneficial to sequester carbon, reduces greenhouse gas (GHG) emissions and it can also improve soil moisture retention. Biochar has been also demonstrated to improve soil health and enhance agricultural productivity when applied in combination with composting. There are numerous other potential uses for biochar including, but not limited to:

1.2.5.1 Use as a Soil Conditioner

- Carbon fertilizer
- Compensatory fertilizer for trace elements
- Compost
- Water retention

1.2.5.2 Use in the Building Sector

- Insulation
- Air decontamination

1.2.5.3 Decontamination

- Soil additive for soil remediation for use in particular on former mine-works, military bases, and landfill sites.
- Soil substrates, highly adsorbing, plantable soil substrates for use in cleaning wastewater; in particular urban wastewater contaminated by heavy metals.
- A barrier preventing pesticides seeping into surface water. Sides of field and ponds can be equipped with 30-50 cm deep barriers made of biochar for filtering out pesticides.
- Treating pond and lake water. Biochar is good for adsorbing pesticides and fertilizers, as well as for improving water aeration.

1.2.5.4 Biogas production

- Biomass additive to increase biogas production

1.2.5.5 Treatment of wastewater

- Activated carbon filter
- Pre-rinsing additive
- Soil substrate for organic plant beds

1.2.5.6 Treatment of drinking water

- Micro-filtration

With some equipment modifications and loss of electrical generation efficiency biochar can also be produced in biomass direct combustion units as well. Biomass One, in Medford, Oregon produces biochar for sale.

Biochar production is generally calculated at 10 percent, plus/minus 2 percent of the input volume of woody biomass. Thus, if a biomass power plant utilizes 30,000 BDT, approximately 3,000 tons of biochar could be available for sale. Existing biochar markets are in the $500 to $1,000 per ton range, however as more and more biochar is being produced by the increasing number of biochar processors in the United States, this price is likely to go down. To be fiscally conservative, $150 to $250 per ton should be considered in any financial analysis.[3] With 3,000 tons of biochar, this could result in $450K to $750K per year in additional revenues. In addition to the selling of the biochar, the biochar could be used for carbon sequestration purposes and qualify for the sale of carbon dioxide removal (CDR) credits[4] in one of the voluntary markets, now valued at approximately $250/ton of biochar, based on $100/ton of carbon dioxide equivalent [CO2e] and a factor of 2.5 tons of sequestered CO2e per ton of biochar. This would add another $700K in potential revenue to a bioenergy project.

Both the biochar and biochar CDR credit markets are nascent and beginning to show signs of good future potential. The biochar CDR credit markets is very quickly becoming a favorable market to further monetize biochar. However, the biochar market itself still has concerns about the ultimate pricing of biochar and the availability of medium- and long-term off-take contracts. As noted above, with this lack of market maturity, potential pricing of biochar must be looked at conservatively. The biochar CDR market appears to an avenue, that due to the nature of the many of buyers of the credits, is growing rapidly. These buyers are businesses that are looking to reduce their carbon footprints per their Environmental, Social, and Corporate Governance (ESG) goals.

There are currently only a few biochar production facilities in the state, selling biochar primarily in the agricultural and composting markets. However, a vast majority of the bioenergy facilities currently proposed to convert woody biomass to electricity, hydrogen, or RNG in California will produce biochar. The larger facilities, such a proposed woody biomass to RNG facility in the San Joaquin Valley, could produce biochar in very large amounts, up to 10 to 15 percent of the feedstock input. The San Joaquin Valley facility would produce approximately 200 BDT of biochar per day.

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3 Personal communication with Tom Miles, Executive Director, U.S. Biochar Initiative, Former Chair of the International Biochar Initiative.

4 A carbon dioxide removal credit means one metric ton of carbon dioxide has been reduced or removed from the atmosphere by sequestration. Further, this reduction or removal has been certified under an internationally recognized carbon standard.

1.2.6 Biofuels Production

Biofuels, a.k.a. renewable fuels, production from forest-sourced woody biomass runs the complete gamut of low carbon transportation fuels to industrial/power generation fuels. A variety of facilities to produce fungible transportation fuels (e.g., renewable diesel, renewable gasoline, and sustainable aviation fuel – SAF) are currently under construction, using gasification of forest sourced wood waste as a key step in the biofuels production process. Woody biomass conversion technologies are also entering the marketplace that can convert wood feedstock into biomethane, aka renewable natural gas, which can be compressed and transported offsite for use in compressed natural gas vehicles. These conversion technologies are also being planned to produce hydrogen for transportation fuel and to substitute for natural gas in industrial applications in the effort to further decarbonize the energy sector. Another emerging trend for transportation fuels portfolio is the use of electricity from biomass power plants to be specifically used for electric vehicles or the production of hydrogen for fuel cell vehicles by using the bioelectricity to electrolyze water (which is split into gaseous hydrogen and oxygen – see below). These could be a much higher value proposition than biomass power to the electric grid.

The higher value of biofuels comes primarily from the various low carbon fuels programs promoted thought federal and state (California) legislative and regulatory policies. The California Low Carbon Fuels Standards, coupled with the federal Renewable Fuel Standards have created significant biofuels markets. Additional states are currently in the process of establishing similar programs. In addition to growing biofuels markets, SB 1440 (Hueso) was passed by the legislature in 2018, which required the CPUC to consider adopting biomethane targets for utilities for non-transportation uses of biomethane.

In 2022, the CPUC approved a decision adopting a 2025 goal of procuring 17.6 billion cubic feet of biomethane annually, which according to the agency would divert 8 million tons of organic waste from landfills annually. That target will be divided among utilities in proportion to their share of natural gas deliveries. By 2030, the overall target increases to 72.8 billion cubic feet annually. This amount equates to 12 percent of fossil natural gas used in California in 2020.

1.2.7 Hydrogen Production

Converting woody biomass into hydrogen typically involves a process called biomass gasification. Gasification is a thermochemical conversion process that breaks down organic materials, such as wood or other biomass, into a syngas, synthetic gas, containing hydrogen, carbon monoxide, carbon dioxide, and other components. A simple schematic of the biomass to hydrogen process is shown in Figure 5.

The process of woody biomass conversion to hydrogen conversion occurs via gasification in the following manner:

- **Feedstock Preparation**: Woody biomass is collected and prepared, just like in the direct combustion process. It is chipped or pelletized to ensure uniform size and moisture content.
- **Gasification:** The prepared woody biomass is introduced into a gasifier, a high- temperature reactor operating in a low-oxygen environment, partial oxidation. In this gasifier, the biomass undergoes a series of chemical reactions. Initially, it gets dried, and then, in the absence of sufficient oxygen, it undergoes pyrolysis, decomposition due to heat. The resulting solid char is further reacted with steam or oxygen to produce a syngas.
- **Syngas Production**: The syngas produced in the gasification process consists of hydrogen (H2), carbon monoxide (CO), carbon dioxide (CO2), methane (CH4), and other minor

components. The exact composition of the syngas depends on the gasification conditions and feedstock.

- **Syngas Cleanup**: The raw syngas may contain impurities and tar-like substances, which needs to be removed before the syngas can be used effectively. Syngas cleanup involves various processes like cooling, filtering, and catalytic conversion to remove impurities and unwanted components.
- **Hydrogen Separation**: Once the syngas is clean, the hydrogen can be separated from the gas mixture. Several methods, such as pressure swing adsorption (PSA) or membrane separation, can be used to selectively extract hydrogen from the syngas.
- **Hydrogen Utilization**: The separated hydrogen can then be used for various applications, including as a fuel for fuel cells to produce electricity, for fuel cells, and fuel cell vehicle or as a feedstock for hydrogen-based chemical processes.

Biomass gasification for hydrogen production offers several benefits, such as using a renewable resource, reducing greenhouse gas emissions when compared to fossil fuels, and providing a versatile energy carrier in the form of hydrogen. However, the process requires careful management to control gasifier conditions, optimize gas composition, handling potential environmental issues related to biomass sourcing and ash disposal, and the transportation of gaseous or liquified hydrogen to its end use. Currently there are not pipelines in California that can accommodate hydrogen gas. Additionally, the overall efficiency of the conversion process can be influenced by factors like feedstock quality and gasification technology used.

The hydrogen utilization market is still in its infancy, but numerous federal and California legislative and regulatory policies, incentive, and grant funding programs are moving both the production technology and utilization markets forward. For example, the federal Inflation Reduction Act of 2022 (IRA) includes clean energy tax credits and other provisions that would increase domestic renewable energy production. The IRA's clean energy incentives include many provisions for clean hydrogen and fuel cell technologies, either extending many existing federal tax credits, increasing existing federal tax credits, or creating new federal tax credits, including the following programs. California has been passing numerous pieces of legislation and policy directives in the attempt to significantly enhance the production, and use of hydrogen for decarbonizing the transportation and industrial sectors.

Although there are currently no operating woody biomass to hydrogen projects operating in California, or elsewhere in the United States, there are numerous projects being proposed. Both the CEC and Department of Conservation (DOC) have ongoing grant programs to encourage forest biomass in particular for conversion to hydrogen. The DOC, in particular, has recently awarded up to $500K to five forest biomasses to hydrogen projects under the first phase of its $50 MM Forest Biomass to Carbon-Negative Biofuels Pilot Program. Phase 2 of the Pilot Program will include construction of facilities that will convert Sierra Nevada forest biomass waste into carbon-negative energy. Grants awards for that second phase are expected in 2024.

There is currently a biomass to hydrogen production facility under construction in Contra Costa County, however, it only uses urban green waste, which includes woody biomass, combined with a small percentage of food waste, as its feedstock. Production is proposed to begin in later 2024. As hydrogen cannot be injected into the natural gas pipeline system in California, it is compressed and loaded into specialty truck trailer for delivery to end uses.

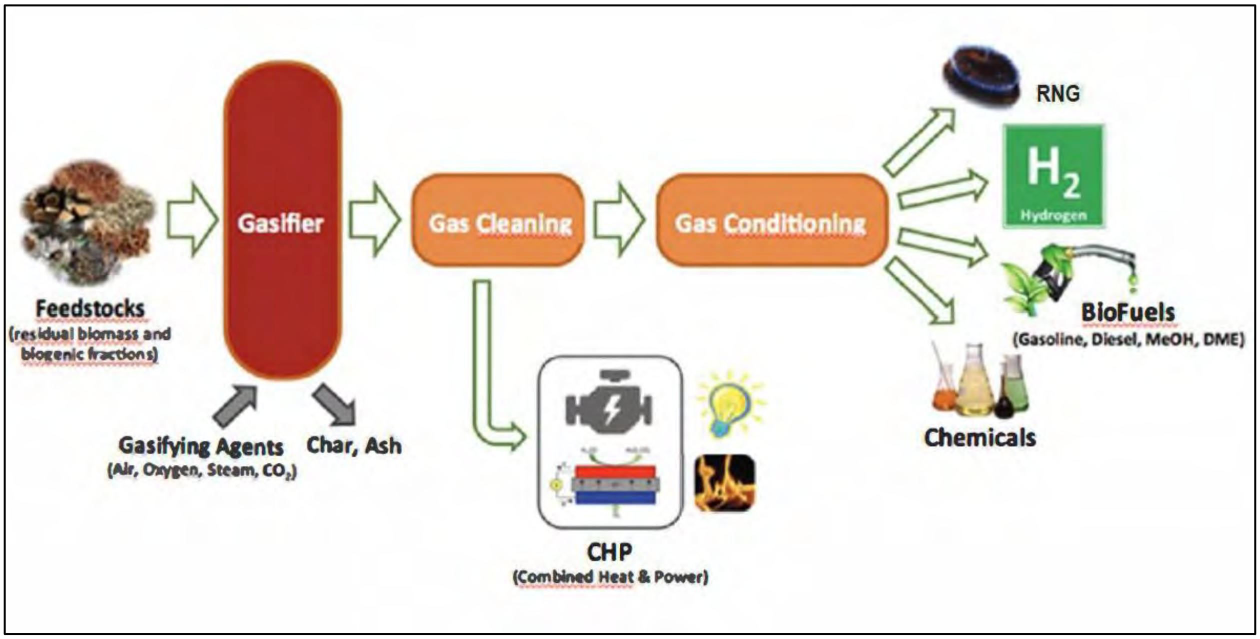

Figure 5. Woody Biomass to Hydrogen and Potentially Other Biofuels

1.2.8 Renewable Natural Gas

The production of RNG, also known as biomethane, using woody biomass is more complex than the production of hydrogen. The production of RNG from woody biomass is a complex mix of gasification, electric power production, to run the gasifiers and syngas methanation reactor where the syngas is refined to biomethane and systems to remove the CO2 component from the biomethane/syngas mixture. Then the RNG must be injected into a collocated, or nearby, natural gas line for removal at RNG fueling stations for use primarily in heavy-duty vehicles. To further lower the carbon intensity of the RNG, in fact to make it a negative biofuel, some biomass-derived RNG facilities are to construct and operate deep CO2 sequestration wells or use third-party CO2 sequestration well, to permanently "bury" the CO2. Figure 6 displays the process flow chart for such a facility planned for California's Central Valley.

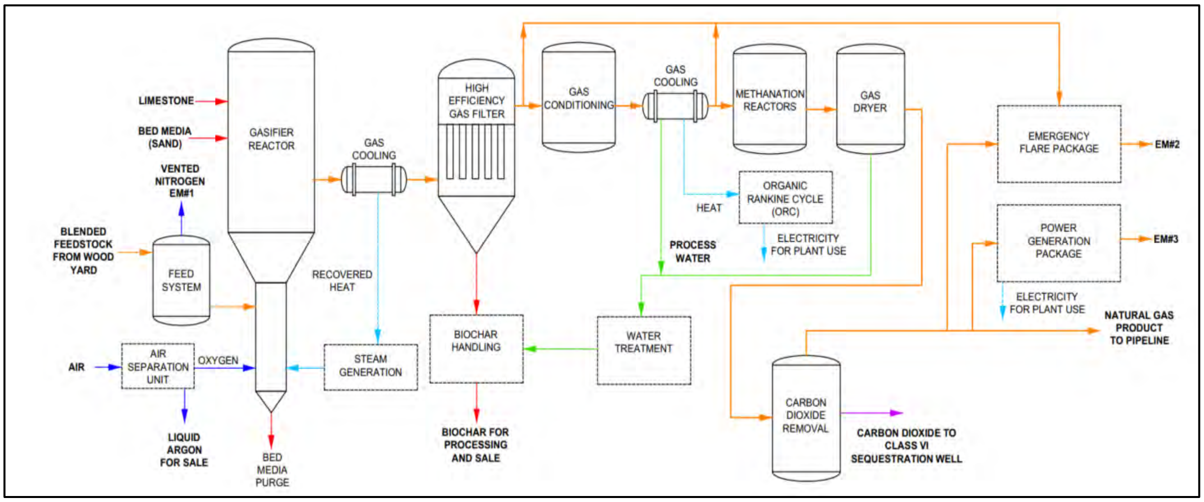

Figure 6. Woody Biomass Gasification to Renewable Natural Gas

Yuba County does possess natural gas transmission lines, primary along the State Highway 65 corridor, which could potentially accept RNG injection. Placer County was the site of a forest wood to RNG demonstration project, Figure 8, as well as feasibility investigation of full-size, commercial forest wood to RNG to be located in Placer County[5].

The pilot scale project was successful in demonstrating that forest wood from thinning activities could be converted into RNG. The RNG produced was used in a Placer County vehicle. The feasibility study that members of the Bioenergy Team participated in this study with G4, also looked at the siting of an initial commercial size unit using 30 BDT per day. G4 is a Canadian company specializing on conversion of biomass to natural gas. This siting investigation also included the need to site the facility next to an appropriately sized natural gas line. As mentioned, there is such a transmission line along the Highway 65 corridor. The G4 system was believed to be able to produce RNG, using a $50/BDT price for feedstock, in the range of $8.44 to $12.67 per MMBTU. At the time of the study during late 2014 and early 2015, the LCFS credit price was around $30. This would have provided about $2.23 per MMBTU of subsidy payment. As the price of fossil natural gas at that time was about $2.80 per MMBTU, a combined total of $5.03 per MMBTU was potentially available. This was under the range of production costs to make the project at that point in time economically viable. Given today's LCFS prices, a commercial project would have been economically viable. However, given the uncertainties of the LCFS market at that time, G4 did not move forward with a commercial project.

[5] Siting And Feasibility Study for Pilot and Commercial Scale Biomethane Facilities in California, April 2015, prepared G4 Insights, Burnaby, British Columbia. Prepared by TSS Consultants, Sacramento, CA

Figure 7. G4 Demonstration Facility in Auburn, CA

2.0 COMMERCIAL MATURITY AND VIABILITY OF BIOENERGY TECHNOLOGY

In terms of commercial maturity and viability of the above bioenergy technology using forest-sourced woody biomass, they can be ranked in the following order:

1. Direct combustion steam cycle to electricity – this technology has been commercialized since the early 19th century.
2. Direct combustion via ORC to electricity – as mentioned the direct combustion of wood has been commercialized since the early 19th century. Generating electricity via hot oil heating from the direct combustion into an ORC has been commercial for several decades. There are various companies in United States and internationally that can commercial ORC units.
3. Gasification to electricity using combustion of syngas for steam cycle or ORC – although gasification of wood to electricity has also been a potential application for nearly as long as direct combustion, only in the last 30 to 40 years has it been applied to woody biomass to produce electricity. Due to syngas cleanup issues and costs, this technology could be preferred over Item 4 below.
4. Gasification to electricity using syngas in ICE generator set – This technology application is just entering into the commercial phase in the United States. There are numerous companies claiming that it can be done commercially, but there is no long-term operating record for a system using ICE gensets.
5. Gasification to hydrogen – This technology is still non-commercial as there are no operating woody biomass to hydrogen facilities in California.
6. Gasification to liquid biofuels - This technology is still non-commercial as there are no operating woody biomass to hydrogen facilities in California.
7. Gasification to RNG - This technology is still non-commercial as there are no operating woody biomass to hydrogen facilities in California.

2.1 Candidate Technology Attributes

TSS and West Yost conducted this bioenergy technology review to seek out commercially-available conversion technologies utilizing small log and/or wood fiber feedstocks at a scale and technology type consistent with feedstock supply availability analysis and candidate site review findings. A Conversion Technology Review matrix was utilized to consider key variables such as:

- U.S. Department of Energy Technology Readiness Level – TRL should be seven or higher;
- Ability to utilize locally available woody biomass feedstocks from the Yuba region such as small logs, wood fiber, and forest slash from both hardwood and softwood species. Shells and woody biomass from almond, walnut, and pistachio orchard management was also considered;
- Technical support available once technology is deployed;
- Economic and environmental viability.

These key variables are principal to the following candidate technology attributes. The information gathered and evaluated are included in three separate tables identified below.

2.1.1 *Biomass Utilization Technology Companies*

- **Contact Information:** Company name, website, contact person with email address are provided.
- **Technology Product:** Technologies selected were direct combustion, gasification, and electricity. Some technology vendors indicated that they could produce both electricity or liquid or gaseous transportation fuels, such as biomethane, as renewable natural gas and hydrogen, as a renewable transportation fuel. Eleven of the 14 technology companies indicated they could produce biofuels and electricity, while the other three would produce only electricity.
- **Technology Maturity:** Technology maturity identification was based on the U.S. Department of Energy technology readiness assessment protocols, which were adapted from proven NASA and Department of Defense technology assessment models. A numeric value was given to each company technology, which correspond to the level of technology maturity the respective technology is believed to have achieved. Technology maturity or TRLs run from 1 to 9 with 9 being the most ready or mature. Technologies less than 7 were not considered for this report, except for two hydrogen production technologies to used forest-sourced woody biomass that were recently awarded State of California grants. The TRL matrix is attached in Appendix A and the TRL score in Table 1.
- **Experience with Woody Biomass Feedstocks and Project Locations:** Candidates were queried on their experience(s) with urban-, agricultural-, and forest-sourced woody biomass. Additional information about past and current projects is also included.

2.1.2 *Cost Estimates*

- **Estimated Cost of Production:** Where available, the cost of producing the electricity and/or biofuels was requested of the companies.
- **Capital Cost Estimate:** The capital cost was requested.
- **Operation and Maintenance Cost Estimate:** The annual cost of operating and maintaining the candidate facility was requested. Candidates replied as a percentage of the capital costs in most cases.
- **Marketable Byproducts:** Marketable byproducts, in addition to electricity or biofuels, principal products, were considered important as such byproducts could have a significant beneficial effect on revenue generation. This would be particularly important where electricity prices are low. Biochar is considered a significant byproduct as it has a market value, and currently a significant biochar voluntary carbon credit market exists and is growing.

2.1.3 *Operating and Site Parameters*

- **Operating Requirements:** Emphasis here is placed on number of employees needed to operate the facilities in total or per shift.
- **System Efficiency and Parasitic Loads:** The relative overall efficiency and parasitic load, internal use of power, was addressed.
- **Site Requirements:** Focus here is the amount of land needed for a bioenergy facility. It should be noted that all facility sites may require some access to electricity, particularly while the facility is not producing its own electricity.

- **Environmental Considerations:** All facilities will have some air pollutant emissions of some kind. Experience, however, indicates that the air emissions are generally very low with gasification systems, whether to electricity or biofuels. All candidates realized that Best Available Control Technology (BACT) would be needed[6]. Water supply and wastewater discharge needs were also considered, along with any significant solid waste disposal.
- **Involvement in Projects:** Candidates were queried as to their respective roles in the design, construction, operation, and ownership of facilities using their technologies.

Eighteen direct combustion and gasification/pyrolysis technology vendors/developers were contacted that could produce electricity, hydrogen, and/or renewable natural gas (RNG, aka biomethane), as well as biochar. Data and information on the attributes were requested for their respective technologies as indicated in the bulleted list above. The evaluated the information received from 14 candidate technologies and with the Bioenergy Team's extensive experience in the bioenergy sector, a technology evaluation matrix was prepared. There is also included explanatory text regarding the matrix information and findings, as well as the parameters and attributes, listed above, used for the matrix.

Where appropriate, the Bioenergy Team considered other factors offered by candidate technology companies during various communications, emails and conference calls, for information and data acquisition.

6 BACT means any emission control equipment or technique which the division determines to be available for maximum reduction of emissions. This determination shall consider the energy, environmental, and economic impacts on the source.

3.0 DETERMINATION OF ATTRIBUTE IMPORTANCE

In the evaluation of the candidate technologies and the attributes considered below, an importance factor was applied to each attribute. This importance level of each attribute is a qualitative value based on the Bioenergy Team's experience and consideration of the needs for Yuba Water Agency. An importance ranking of 1 to 5, 5 being of highest importance, was utilized in Table 4 below. It acts as a multiplier of the 1 to 5 values, 5 being the best obtainable value per the attribute under consideration.

3.1 Responding Technology Companies

Using standard information procurement protocol, and requirement that the bioenergy technologies should be commercial, or at least near commercial, with a U.S. Department of Energy Technology Readiness Level or 7 or higher. These companies are evaluated in Tables 1, 2, and 3 below.

- Arbor Energy – www.arbor.energy . Contact: Sutton Guldner, sutton@arbor.energy
- Aries Clean Energy – www.ariescleanenergy. Contact: Joseph Regnery, joseph.regnery@ariescleantech.com
- Biogas-Energy – www.biogas-energy.com. Contact: Brian Gannon, bgannon@biogas-energy.com
- Brad Thompson Company -www.bradco.com. Contact Dave Salem, daves@bradtco.com
- Char Technologies – www.Chartechnologies.com. Contact: Andrew Friedenthal, afriedenthal@chartechnologies.com
- Engemann Energy – engemanenergy.com. Contact: Andrew Grant, agrant@biomasspc.com
- EQTEC – www.Eqtec.com. Contact: Jeffery Vander Linden, jvanderlinden@eqtec.com
- Frontline Bioenergy – https://frontlinebioenergy.com Contact: Jerod Smeenk,
- jsmeenk@frontlinebioenergy.com
- Kore Infrastructure – http://www.koreinfrastructure.com, Contact: Steve Wirtel.
- Mote Inc. – www.motehydrogen.com, Contact: Mac Kennedy, mac@motehydrogen.com
- Raven SR – www.ravensr.com, Contact: Matt Murdock, matt.murdock@ravensr.com
- Sierra Energy – www.sierraenergy.com. Contact: Michael Kleist, mkleist@sierraengery.com
- West Biofuels – www.westbiofuels. Contact: Matt Summers, matt.summer@westbiofuels.com
- Yosemite Clean Energy – www.yosemiteclean.com . Tom Hobby, tom.hobby@yosemiteclean.com

3.2 Technology Evaluation Scoring Summary

The results of Tables 1 through 3 are summarized below in Table 4. Table 4 also displays the relative importance of each attribute, which results in weighted scores shown below.

Table 1. Biomass Utilization Technology Companies

Company	Contact Information	Technology Product(s)	Score	Technology Maturity	Score	Experience with Woody Biomass/Project Locations	Score
Arbor Energy	www.arbor.energy Sutton Guldner sutton@arbor.energy brad@arbor.energy	Electricity and hydrogen w/carbon capture and biochar credits	4	TRL: 6; Arbor is at the engineering scale/pilot scale level	1	Arbor is new to the use of woody biomass in energy production. They have begun some testing of it in their pilot scale facility. Received CA Dept. of Conservation grant for feasiblity work on forest fuels to hydrogen and electricity	1
Aries Clean Energy	www.ariescleanenergy.com Joseph Renergy, joseph.regnery@ariescleantech.com	Electricity, and biochar Gasification process with Organic Rankine Cycle engine/genset used to make electricity. Did not state how many BDT needed per MW (assume rule of thumb – 1.5 BDT per MW hour for ORC generators, with 1 BDT producing 0.67 MW).	4	TRL: 8; Aries has existing commercial unit but continues to conduct engineering work to improve overall systems.	4	Yes, with urban, agricultural, and forest wood. Operating projects in TN and FL. Projects in various stages of development in CA - one for ag wood to electricity, one for forest wood to biochar, and one for biosolids to biochar	3
Bio-Gas Energy	www.biogas-energy.com Brian Gannon bgannon@biogas-energy.com	Biofuel Currently only has 10 ton per day feed rate unit producing bio-oil (a precursor to fungible transportation fuels, or can be used as fuel oil substitute). Hoping to expand up to 200 ton/day feed rate. Conversion rate is up to 75% by mass.	4	TRL: 7; Bio-Gas has deployed a demo unit in the field	3	Yes, with ag and forest wood. Demonstration project in Northern California being funded by the CA Energy Commission (10 ton/day unit). Also received CA DOC grant to conduct feasiblity work on pyrolysis of forest wood at the East Placer County Landfill (aka Cabin Creek).	5
Brad Thompson Company	www.bradtco.com Dave Salem daves@bradtco.com	Direct Combustion Reciprocating Grate Stoker.	4	Electricity (TRL 8-9)	4	Ag wood, and forest wood.	4
CHAR Technologies	www.Chartechnologies.com Andrew Friedenthal afriedenthal@chartechnologies.com	High Temperature Pyrolysis & WGS/Methanation to produce; Renewable Natural Gas (RNG) and Biochar. Hydrogen can also be produced	5	TRL of 8-9. Will have TRL 9 project in by end of summer;	5	Experience with urban wood, Agriculture wood, and forest wood. At Kirkland Lake, 72K tons per year of wood waste into RNG; at St. Felicien, 36K tons per year of wood waste into Syngas & Biochar; at Obispo Hitachi Zosen Inova, 18K tons per year of digestate into Green Hydrogen & Biochar.	5
Engemann Energy	www.engemanenergy.com Andrew Grant agrant@biomasspc.com 330-607-4648	Direct combustion, steam cycle power plant. Technology uses commercially available components.	5	TRL: 9	5	Numerous facilities in Central and South America. Currently about to begin construction of 5 MW facility in Northern California.	5
EQTEC	www.Eqtec.com Jeffery Vander Linden jvanderlinden@eqtec.com	Gasification of biomass to create hydrogen, biochar, Renewable Natural Gas (RNG), Heat and Electricity.	4	TRL: 8	4	50,000 ton/year plant in Spain operating 7,500-8,000 hours per year since 2010. Produces 5.9 Mw electricity and heat. Plant in North Fork CA producing 2 MW electricity and heat using forest wood. Operational in 2002. Numerous plants in Europe.	5
Frontline Bioenergy	www.frontlinebioenergy.com Jerod Smeenk jsmeenk@frontlinebioenergy.com	Both gasification and pyrolysis. Electricity by steam cycle using produced gas or bio-oil; Internal combustion engine gensets using syngas; Combustion turbine using syngas; Fuel cell using RNG; Organic Rankine Cycle using producer gas or bio-oil. Specific products made are RNG, hydrogen, methanol, diesel, and jet fuel.	4	TRL: 8 for gasification.	4	Urban wood; pilot testing using agriculture and forest biomass. Previously operated a commercial scale facility in Minnesota but closed due to drop in natural gas prices.; Currently developing 1,500 BDT/day facility in the San Joaquin Valley of California to produce RNG from woody biomass.	4
Kore Infrastructure	https://koreinfrastructure.com	Pyrolysis to Hydrogen and biocarbon	4	TRL: 8 for pyrolysis of biosolids for electricity	4	Received CA DOC grant to conduct feasibility work using forest fuels to biofuel	4
Mote Inc.	https://www.motehydrogen.com	Gasification to hydrogen	4	TRL: 6: Mote appears to be at the engineering scale/pilot scale level. However they report technology uses some commercially available technology	2	Received CA DOC grant to conduct feasibility work using forest fuels to hydrogen. Teamed with Sacramento Municipal Utility District, which has land holdings for hydroelectric facilities in the Sierra Nevada Mountains. No wood experience as yet.	3
Raven SR	www.ravensr.com Matt Murdock matt.murdock@ravensr.com	Gasification to fuels or hydrogen	3	TRL: 7 Significant testing of woody biomass on small pilot scale unit in CA	3	Use of woody biomass feedstock at pilot scale facilty	3
Sierra Energy	www.sierraenergy.com Michael Kleist mkleist@sierraenergy.com	Electricity Current modular design of 1 MW units.; Conversion is about 1 BDT per MW.; Biofuels; Can produce diesel as liquid fuel, and hydrogen as gaseous fuel. Sierra Energy reportedly can produce hydrogen as gaseous fuel, creating about 50 kg of hydrogen per BDT.	4	TRL: 7 to 7. Demonstration plant constructed and undergoing testing for last few years, producing both electricity and biofuels	3	Yes, with urban, agricultural, and forest wood. 25 tons a day demonstration facility currently located in Central CA. Construction and demonstration funded in part by CA Energy Commission, and U.S. Department of Defense	4
West Biofuels	www.westbiofuels.com Matt Summers matt.summers@westbiofuels.com	Electricity; Direct combustion process with Organic Rankine Cycle engine/genset used to make electricity from 500 kw to 5 MW, 1.25 BDT per MW	5	TRL: 8 to 9 . Operating facility	5	Yes, with urban, agricultural, and forest wood. Currently developing two 3 MW electricity projects in Northern CA using forest sourced wood (undert the BioMAT program). Partially funded by the CA Energy Commission ($5MM each site). Recently constructed and commissioned a 3 MW facility using rice hulls in Northern CA. Also, recently selected to develop a 3 MW forest sourced wood facility in Mammoth Lakes (under the BioMAT program).	5
Yosemite Clean Energy	https://www.yosemiteclean.com Tom Hobby tom.hobby@yosemiteclean.com	Gasification to hydrogen	3	TRL : 8	3	Implementing a gasification system using forest wood at two sites that has an operating history in Europe. However, these projects are to produce biofuels (hydrogen) instead of electricity. Both projects received CA DOC grant funding recently.	3

Table 2. Cost Estimates

Company	Estimated Cost of Production	Score	Capital Cost Estimate	Score	Operation and Maintenance	Score	Marketable Products and Byproduct(s)	Score
Arbor Energy	Can pay for feedstock. Reported up to $50 BDT	1	Not specified	1	Likely 3 to 4% of capital cost on an annual basis	2	Electricity, hydrogen, and biochar and sequestered carbon (for credits)	5
Aries Clean Energy	Dependent on cost of feedstock , may need to be paid to take feedstock	1	$7M to $8 M per MW.	3	3.8 % of capital cost on an annual basis.	2	Biochar production is ~10% of feedstock. Expected price is $200 to $300/ton, with carbon credits worth $200 ton of carbon	4
Bio-Gas Energy	Size dependent	1	Would not state. Project dependent.	1	2.0 % of capital cost on an annual basis.	4	Biochar production – amount not yet vetted; technology vendor claims expected price is $1,000/ton	3
Brad Thompson Company	Depends heavily on fuel and interest costs, if fuel cost is $40/BDT then electricity cost is $0.12 to $0.16 per kWh.	3	$7M to $8 M per MW.	3	2.5 to 3% of capital costs on an annual basis	3	Electricity, some limited biochar	3
CHAR Technologies	Assuming no cost for feedstock, $4.42/MMBtus. However, Char confirmed that $45/BDT would work if RNG and/or Hydrogen are produced.	4	$448 per BDT of biomass throughput.	3	Station load of 350 kW, 5% of capital cost (without labor cost).	1	electricity, RNG, H2, Biochar, produced from 26 percent of BDT of biomass input.	5
Engemann Energy	Not Provided. Preference for sub-$30 BDT costs	2	$20M to $25M for 5 MW plant.	5	Expected to be 2.5% of capital costs on an annual basis	3	Electricity and biochar (Amount produced – tailored to meet local demand).	3
EQTEC	Not Provided. Assume from previous knowledge ranging $0.12 to $0.16 per kWh.	1	$8M to $10M per MW.	2	Not Provided. Assume 3% of capital cost	2	High quality biochar.	5
Frontline BioEnergy	Highly dependent on prime mover type and plant capacity. Economics also requires large-scale plant, so production costs are lower per unit	2	Highly dependent on product, and plant configuration. Engineering costs for projects design to date range from $10MM. San Joaquin Valley project installed cost is estimated at $450MM. Using 500K BDT of woody biomass, and self generating 34 MW.	2	Highly dependent on prime mover type and plant capacity. Expect up to 3% of capitol cost on annual basis not including labor.	2	RNG, methanol, gasoline, hydrogen, Diesel and jet fuel. Biochar will be approximately 10% of feedstock utilized (50K tons per year).	5
Kore Infrastructure	Not provided. Existing project with biosolids is paid to take feedstock	1	48 ton per day unit approximately $10-12MM	3	Assume 3% of capital costs per year	3	Hydrogen for transportation fuel, and biocarbon	4
Mote Inc.	Not provided	1	Not specified	1	3% of capital costs (estimated)	3	Producing carbon negative hydrogen fuel. No mention of biochar	2
Raven SR	Needs to be paid to take feedstock	1	Up to 36K of wood and green waste, capital cost high due to complexity of system	1	4 to 5% of capital costs on annual basis	1	Produces medium to low quality biochar	2
Sierra Energy	Not Provided, but likely requires tipping fee	1	$6M to $9M per MW, depending on feedstock	3	3.5% of capital cost on an annual basis.	3	Due to high operating temperature in the Sierra Energy gasifier, biochar is not produced as a byproduct.	2
West Biofuels	$0.11 to $0.12 per kWh. Both California projects to receive $0.197 (forest wood) and $0.189 (ag biomass) under California Bioenergy Market Adjusting Tariff.	5	$7 M to $8 M per MW.	4	2.0 % of capital cost on an annual basis.	5	Can be operated to produce biochar, up to 10% of feedstock input	4
Yosemite Clean Energy	Not provided	1	Not provided	1	3 to 4% of capital costs (estimated)	2	Hydrogen for transportation fuel, and biocarbon	4

Table 3. Operating and Site Parameters

Company	Operating Requirements	Score	System Efficiency & Parasitic Load	Score	Site Requirements	Score	Environmental Considerations	Score	Interest in Project	Score
Arbor Energy	2 operators per shift; 1 machinery operator (in fuel yard) per shift, plus management and admin staff;	4	Not stated. Assume 60%+	3	Energy plant main battery 1 to 2 acres, plus feedstock storage (2 to 3 acres depending on location).	4	Gasification system has no emissions. Syngas utilized in oxy-fuel combustion to minimize/eliminate NOx and Sox emissions. Torrefaction reactor and standby and emergency flare are well controlled for emissions.	4	Design – Yes; Design and Build – Yes; Design, build, operate, own – yes.	5
Aries Clean Energy	1 power plant operator per shift; 1 machinery operator (in fuel yard) per shift plus management and admin staff; Cost is location dependent.	5	Gasifier 80%; ORC – 25%; Overall efficiency is 20%; Parasitic load – 10%.	2	Power plant – 1 acre; Feedstock and byproduct storage – 2 acres.	4	Emissions control by BACT. Some wastewater; Minimal water supply needed. No solid waste generated.	4	Design – Yes; Design and Build – Yes; Design, build, operate, own - Yes.	5
Bio-Gas Energy	1-2 operator per shift; 1 machinery operator (in fuel yard) per shift plus management and admin staff; Cost is location dependent.	4	Overall efficiency 30%; Parasitic load – 5%;	4	Containerized system. Size for 200 ton a day unit not specified.	2	Low NOx burner; No water needed and no wastewater discharge. No solid waste.	4	Design – No; Design and Build – Yes. Design, build, operate, own – Yes.	4
Brad Thompson Company	3-5 Operators per shift; System operator; Mechanical and Electrical laborer.	3	12,000-16,000 Btu/kWh. Electricity parasitic load of 10%.	3	Power plant, 1-2 acres; Feedstock and feedstock storage area 5 acres.	1	Air emissions from exhaust stack and dust from the fuel yard. Water requirement depends on power cycle. Steam cycle with evaporative cooling – 75 GPM; Hybrid system – 35 GPM; dry system – 0 GPM.	2	Design – No; Design & build -Yes; Design, build, operate, and own – Yes.	4
CHAR Technologies	2 operators per shift; 1 machinery operator (in fuel yard) per shift, plus management and admin staff;	4	Not stated. Assume a low of 20%	2	2 to 4 acres	4	Pryolysis needs start up gas. Water consumption approxicmatley 3 gpm. Potential need for wastewater disposal.	3	Design – Yes; Design and Build – Yes; Design, build, operate, own – yes.	5
Engemann Energy	1-2 operators with automated remote support.	4	25-30% for 100% condensing steam turbine. 1,000-1,200 Kilowatt hours produced per BDT.	4	1 acre power plant, 3 acres+ for feedstock storage	4	Not provided. But probably higher air emissions from direct combustion. Air cooled so little water needs (water recycled).	3	Will develop, build, own and operate. (tax credits can be used by Engemann partners).	5
EQTEC	2 to 3 staff per day/evening shifts. 2 staff per night shift;	3	Not provided. Use 30% as it is gasification to IC engine gen set design	4	Power plant 1 to 2 acres, plus feedstock storage (2 to 5 acres depending on location).	3	Not provided, but given size of electricity production using gasification via new ICE gensets, air emissions should not be a significant impact.	4	Will develop, build, own and operate. And, enter into development partnerships.	4
Frontline BioEnergy	Highly dependent on plant size and level of automation. Large plants are required due to economies of scale and will require at least 5 operators at the panel and 4 operators for feedstock management per shift (3 shifts)	1	Highly dependent on prime mover and plant capacity. The planned San Joaquin Valley project will convert biomass to RNG with an estimated efficiency of 60%.	4	Highly dependent on product. One Frontline plant fit in an 80X100 foot building. Another plant (in development in the San Joaqin Valley) will require 40+ acres. Need additional acreage for feedstock receiving and storage.	2	Highly dependent on product and plant configuration; Economics require large plant with large electrical needs	2	Just Design - but not preferred; Same for design and build; Design, build, operate (and own or not) is preferred.	4
Kore Infrastructure	2 operators per shift; 1 machinery operator (in fuel yard) per shift, plus management and admin staff;	3	Not stated. Assume a low of 20%	2	Small footprint for single unit. 1 to 3 acres for facility depending on feedstock storage needs	4	Pyrolyzer has limited emissions, and have met South Coast AQMD requirements (most stringent emission requirements in California). Some bio-oil produced that may disposal	4	Design – Yes; Design and Build – Yes; Design, build, operate, own – yes.	5
Mote Inc.	Highly dependent on plant size and level of automation. Large plants are required due to economies of scale and will require at least 3-5 operators at the panel and 2 to 4 operators for feedstock management per shift (3 shifts)	1	Not stated. Assume 60%	4	20+ acres	2	Highly dependent on product and plant configuration; Economics require large plant with large electrical needs	2	Design – Yes; Design and Build – Yes; Design, build, operate, own – yes.	5
Raven SR	2 operators per shift; 1 machinery operator (in fuel yard) per shift, plus management and admin staff;	3	Gasifier 80%; ICE genset – 40%; Overall efficiency is 30%;	3	2 acres (without feedstock storage)	4	Gasification system has no emissions. Standby and emergency flare are well controlled for emissions.	4	Design – Yes; Design and Build – Yes; Design, build, operate, own – yes.	5
Sierra Energy	2 operators per shift; 1 machinery operator (in fuel yard) per shift, plus management and admin staff;	3	Gasifier 80%; ICE genset – 40%; Overall efficiency is 30%; Parasitic load – 7.5%.	3	Station – 1 acre for 3 to 5 MW. Feedstock storage dependent on forest conditions – assume 1 acre per MW.	4	Engine and flare emissions to be controlled by BACT; No water supply needed and minimal wastewater discharge. No solid waste generated	4	Design – No; Design and Build – Yes; Design, build, operate, own – Possible.	4
West Biofuels	2 operators per shift; 1 machinery operator (in fuel yard) per shift, plus management and admin staff;	3	Direct combustion unit 70%; ORC – 25%; Overall efficiency – 15 – 20%; Parasitic load – 10 – 12%;	3	Station – 0.5 to 1 acre. Feedstock storage dependent on forest conditions – assume up to 3 acres for 3 MW plant.	4	Direct combustion emissions controlled by Selective Non-Catalytic Reduction (for NOx). PM control via multiclones and bag house. Can meet air emissions criteria.	4	Design – Yes; Design and Build – Yes; Design, build, operate, own – yes.	5
Yosemite Clean Energy	Standard facility requires 30 employees for operations, maintenance, and administration (total number)	1	Not stated. Assume 60%	4	5+ acres	1	Gasification system has some emissions due to co-combustion of biochar. Standby and emergency flare are well controlled for emissions.	3	Design – Yes; Design and Build – Yes; Design, build, operate, own – yes.	5

Table 4. Technology Evaluation Scoring Summary

Company	Importance	Arbor Energy		Aries Clean Energy		Bio-Gas Energy		Brad Thompson Company		CHAR Technologies		Engemann Energy		EQTEC	
		Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Technology Product(s)	4	4	16	4	16	4	16	4	16	5	20	5	20	4	16
Technology Maturity	5	1	5	4	20	3	15	4	20	5	25	5	25	4	20
Experience with Woody Biomass/Project Locations	4	1	4	3	12	5	20	4	16	5	20	5	20	5	20
Estimated Cost of Production	5	1	5	1	5	1	5	3	15	4	20	2	10	1	5
Capital Cost Estimate	4	1	4	3	12	1	4	3	12	3	12	5	20	2	8
Operation and Maintenance	3	2	6	2	6	4	12	3	9	1	3	3	9	2	6
Marketable Products and Byproduct(s)	2	5	10	4	8	3	6	3	6	5	10	3	6	5	10
Operating Requirements	3	4	12	5	15	4	12	3	9	4	12	4	12	3	9
System Efficiency & Parasitic Load	2	3	6	2	4	4	8	3	6	2	4	4	8	4	8
Site Requirements	3	4	12	4	12	2	6	1	3	4	12	4	12	3	9
Environmental Considerations	3	4	12	4	12	4	12	2	6	3	9	3	9	4	12
Interest in Project	4	5	20	5	20	4	16	4	16	5	20	5	20	4	16
Total Weight Scored	--	--	**112**	--	**142**	--	**132**	--	**134**	--	**167**	--	**171**	--	**139**

Table 4. Technology Evaluation Scoring Summary (continued)

Company	Importance	Frontline Bioenergy		Kore Infrastructure		Mote Inc.		Raven SR		Sierra Energy		West Biofuels		Yosemite Clean Energy	
		Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Technology Product(s)	4	4	16	4	16	4	16	3	12	4	16	5	20	3	12
Technology Maturity	5	4	20	4	20	2	10	3	15	3	15	5	25	3	15
Experience with Woody Biomass/Project Locations	4	4	16	4	16	3	12	3	12	4	16	5	20	3	12
Estimated Cost of Production	5	2	10	1	5	1	5	1	5	1	5	5	25	1	5
Capital Cost Estimate	4	2	8	3	12	1	4	1	4	3	12	4	16	1	4
Operation and Maintenance	3	2	6	3	9	3	9	1	3	3	9	5	15	2	6
Marketable Products and Byproduct(s)	2	5	10	4	8	2	4	2	4	2	4	4	8	4	8
Operating Requirements	3	1	3	3	9	1	3	3	9	3	9	3	9	1	3
System Efficiency & Parasitic Load	2	4	8	2	4	4	8	3	6	3	6	3	6	4	8
Site Requirements	3	2	6	4	12	2	6	4	12	4	12	4	12	1	3
Environmental Considerations	3	2	6	4	12	2	6	4	12	4	12	4	12	3	9
Interest in Project	4	4	16	5	20	5	20	5	20	4	16	5	20	5	20
Total Weight Scored	**--**	**--**	**125**	**--**	**143**	**--**	**103**	**--**	**114**	**--**	**132**	**--**	**188**	**--**	**105**

4.0 TECHNOLOGY RANKING

The weighted scores were then tabulated in Table 5 below to determine a semi-quantitative ranking for the 14 bioenergy technologies.

Table 5. Technology Rating

Rank	Company	Total Weighted Score
1	West Biofuels	**188**
2	Engemann Energy	**171**
3	CHAR Technologies	**167**
4	Kore Infrastructure	**143**
5	Aries Clean Energy	**142**
6	EQTEC	**139**
7	Brad Thompson Company	**134**
8	Bio-Gas Energy	**132**
9	Sierra Energy	**132**
10	Frontline Bioenergy	**125**
11	Raven SR	**114**
12	Arbor Energy	**112**
13	Yosemite Clean Energy	**105**
14	Mote	**103**

4.1 Synopsis of Top 5 Technologies Evaluated

To further assist in the continuation of the process to establish a nearer- term bioenergy facility in the Yuba County area that would focus on the use of forest management and hazardous fuels residuals, the top five bioenergy technology developers are further summarized below. These summaries are based on the information in the tables above and Bioenergy Team's direct knowledge and experience with those companies.

Per discussion with the top five technologies, the first three companies further described below all have serious interest in siting a project in Yuba County. West Biofuels and Engeman Energy would be BioMAT projects, both of which these companies have experience with. If they could be persuaded to develop a project in Yuba County, in the case of Engeman Energy, another project as they are working with the Camptonville Community Partnership for a BioMAT project at the Gellerman site near Dobbins, CA, the timeline to commercial operations would be probably 24 to 36 months. Additionally, a BioMAT project could use 25,000 to 40,000+ BDT of woody biomass annually. If CHAR Technologies were engaged, along with the local developer who has described a potential project to the Bioenergy Team, that project could utilize up to 275 BDT per day, or approximately 100,000 BDT annually. However, for such a project, this amount of feedstock may be a few years away.

4.1.1 West Biofuels

West Biofuels is headquartered in Woodland, CA. Their Woodland site functions as a Research, Development, and Deployment (RD&D) facility for their development of advanced direct combustion of woody biomass to electricity, as well as for their gasification to liquid and gaseous biofuels. West Biofuels has the first Category 2, agricultural biomass, BioMAT direct combustion unit installed and operating since July 2022 in Colusa County at a rice hulling facility in Williams, see Figure 3. Using a similar design, they have two other Category 3 facilities under construction, Shasta County at the Hat Creek Construction Company on Highway 97, and Mariposa County at the Mariposa Industrial Park north of town. West Biofuels has recently been by Mono County for developing a BioMAT facility just east of the Town of Mammoth Lakes in Mono County. West Biofuels systems are using "off-the-shelf", commercial equipment at all four sites.

West Biofuels has been awarded numerous RD&D grants from the U.S. Department of Energy and the California Department of Energy. One grant in particular assisted West Biofuels in the preliminary design of their current direct combustion model[7].

A Bioenergy Team member has interacted with West Biofuels on these projects, primarily as an air quality permitting consultant. His primary contact with West Biofuels is Dr. Matt Summers. Contact information is in Table 1 above.

4.1.2 Engeman Energy USA

Engeman Energy is headquartered in Sao Paulo, Brazil with offices in Florida and California. Engeman has deployed scores of small, medium, and large, <2.5 to 50MW, units internationally. Their focus is on direct combustion, steam cycle, with air cooling to product electricity and process heat. Currently Engeman has two systems under development in California per the BioMAT program with a 5MW Category 2 facility about to be constructed in Colusa County, approximately six miles south of the community of Arbuckle at the Sun Valley Rice Cooperative rice hulling and storage facility, and a 5 MW Category 3 unit under contract for deployment in Yuba County, with the Forest Business Forest Business Center proposed BioMAT facility near Dobbins, California. Operation dates of the Arbuckle facility is later 2024, and likely early 2025 for the Dobbins site.

A Bioenergy Team member has interacted with Engeman Energy with land use and air quality permitting of their Colusa County BioMAT facility. Contact information for Joao Soares, CEO of Engeman Energy is in Table 1 above.

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[7] "Modular Biomass Power Systems to Facilitate Forest Fuel Reduction Treatment", February 2019, CEC-500-2019-019, prepared for the CA Energy Commission by West Biofuels.

4.1.3 Char Technologies

CHAR Technologies is headquartered in Toronto, Canada. They have three active projects in North America: 1) A 72,000 ton per year woody biomass to RNG and biochar under construction in Ontario; 2) A 18,000 ton per year solid digestate from an anaerobic digester conversion system in San Luis Obispo County, adjacent to the SLO County Regional Airport at the Waste Connections Materials Recovery Facility at 4300 Old Santa Fe Road, which will produce biochar and hydrogen. It is currently under the permitting process, and 3, A 9 ton per day of biosolids converted to biochar system for Synagro, which is one of the largest handlers of biosolids in the U.S. There have been discussions between CHAR and a Yuba County region company about the potential development of a 275 ton per day, forest and agricultural wood waste, in the Marysville area (along the Highway 65 corridor so as to access the PG&E natural gas transmission line). CHAR can also produce hydrogen in place of RNG.

A Bioenergy Team member has met numerous times with CHAR to discuss their technology. Contact information for Andrew White, CEO of CHAR is Table 1 above.

4.1.4 Aries Clean Energy

Aries Clean Energy is headquartered in Franklin, TN, but does have a presence in California. Although it began as a biosolids conversion, via gasification, to electricity, with biochar. Aries has been developing a BioMAT Category 2 facility, using agricultural biomass, in Kern County. This facility will gasify the biomass to produce syngas which will then be combusted to heat a working fluid for ORC generation to electricity. Aries is also planning a gasification of biosolids facility in Solano County to produce primarily biochar. However, neither one of these projects in listed on PG&E BioMAT PPA list, so when they might start operations is unknown. Aries is currently shifting from producing electricity as its main product to biochar. In a recent presentation to the California Forestry Association, they have entered into an agreement with Collins Pine, Chester, CA sawmill facility, 500 Main Street, to produce biochar for sale and acquisition of CDR credits for biochar utilization. Production date is unknown. As mentioned above Collins Pine, Chester already has an operating BioMAT Category 3 facility.

A Bioenergy Team member has met numerous times with Aries to discuss their technology. Contact information for Joseph Regnery, Director of Business Development is in Table 1 above.

4.1.5 KORE Infrastructure

KORE Infrastructure is headquartered in Bozeman, MT, but has a Southern California presence with a thermochemical conversion project which began operations in 2021 in the central Los Angeles area. This KORE fully operational commercial-scale facility in central Los Angeles, is where KORE is working with Southern California Gas, and the South Coast AQMD, utilizing a variety of woody biomass materials and biosolids, to make hydrogen, renewable biogas, biomethane, and biochar. KORE is currently taking this technology to produce hydrogen and biochar from forest-sourced woody biomass removed from the Tule River Indian Reservation in Tulare County. As mentioned in Table 1 above, KORE has received a $500K CA Dept. of Conservation grant. This grant is for the development and ultimate establishment of a KORE pyrolysis system to produce hydrogen and biochar from forest waste wood.

In regard to the other technology/developers evaluated in this investigation, although they ranked outside of the top five, they could produce breakthrough technologies with 5 years. The available grant funding by federal government and California, along with very favorable federal loan guarantees, coupled with the IRA tax and other financial incentives is creating a “goldrush” for bioenergy technologies. As noted above in the technology evaluation tables, Arbor Energy and Mote are considered by the Bioenergy Team as below TRL 7, but they appear to be advancing quickly. Yosemite Clean Energy is well funded both by private and public capital and is using a gasification technology that has operated in Europe for several years, producing syngas for electricity generation. If their current project plans come to fruition in the next two years, they have a great potential.

5.0 RECOMMENDED PATH FORWARD

Given the current projections of the amount of forest-sourced woody biomass that may result in the short-term versus long-term, and the evolution of bioenergy technologies to address the utilization of forest biomass, it is recommended that a BioMAT project be first looked at. It will likely take time for the forest management projects and infrastructure to be in place to take massive amounts of biomass out of the forest and deliver it to a bioenergy facility. The removal of forest biomass by thinning requires considerable funding, which, although might occur for the next few decades, is not a certainty. Recently, the USFS has awarded a significant amount of funding to support fuel treatments in the Yuba region and will assist in the removal of biomass to facilities. A 3 MW BioMAT would only need about 25,000 to 27,000 BDT per year for feedstock supply, and the technology vendors described above are ready to build additional BioMAT power plants. In addition, those companies are willing to take on the entire project, i.e., design, build, operate and own, working with entities that can supply the feedstock. By beginning with a 3 MW BioMAT project, there is already a viable off-take market in a long-term PPA with PG&E. This, and having them own and operate the facility helps further minimize the risk to the YWA and other partners in the North Yuba Project region.

It is recommended that YWA, with the Bioenergy Team, engage with the highest ranked bioenergy developer, West Biofuels. It is known that West Biofuels is interested in the Yuba County region and is developing a track record of BioMAT Category 3 projects in their business portfolio.

The YWA can accelerate the establishment of a BioMAT project by assisting in the predevelopment costs for such a facility. Predevelopment work necessary to begin the construction of a BioMAT facility is generally not funded by project investors or traditional loan sources. Predevelopment works includes the following, but not limited to:

- Siting and developing site control;
- Develop feedstock procurement plan and stewardship agreement with Forest Service and the National Forest Foundation;
- Interconnection and power purchase agreement with PG&E;
- Preliminary engineering and design for the project site;
- CEQA and NEPA if necessary, review of bioenergy site;
- Land use/air permitting;
- Regulatory agency and community outreach and support;
- Predevelop project management and close interface with bioenergy project developer.

The YWA can start this process by retaining a consultant that has experience with all of the above predevelopment activities and is familiar with the various technologies and project developers in this report.

Further, it is recommended that YWA also stay engaged in reviewing technology options and companies for the longer-term necessity of a much larger biomass conversion obligation in supporting the multiple forest restoration projects planned.

Appendix A

Technology Readiness Levels

Relative Level of Technology Development	Technology Readiness Level	TRL Definition	Description
System Operations	TRL 9	Actual system operated overthe full range of expected mission conditions.	The technology is in its final form and operated under the full range ofoperating mission conditions. Examples include using the actual system with the full range of wastes in hot operations.
System Commissioning	TRL 8	Actual system completed and qualified through test and demonstration.	The technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental testing and evaluation of the system with actual waste in hot commissioning. Supporting information includes operational procedures that are virtually complete. An Operational Readiness Review (ORR) has beensuccessfully completed prior to the start of hot testing.
	TRL 7	Full-scale, similar (prototypical)system demonstratedin relevant environment	This represents a major step up from TRL 6, requiring demonstrationof an actual system prototype in a relevant environment. Examples include testing full-scale prototype in the field with a range of simulants in cold commissioning [1]. Supporting information includes results from the full-scale testing and analysis of the differences between the test environment, and analysis of what the experimental results mean for the eventual operating system/environment. Final design is virtually complete.
Technology Demonstration	TRL 6	Engineering/pilot-scale, similar (prototypical) system validation in relevant environment	Engineering-scale models or prototypes are tested in a relevant environment. This represents a major step up in a technology's demonstrated readiness. Examples include testing an engineering scale prototypical system with a range of simulants. (a) Supporting information includes results from the engineering scale testing and analysis of the differences between the engineering scale, prototypicalsystem/environment, and analysis of what the experimental results mean for the eventual operating system/environment. TRL 6 begins true engineering development of the technology as an operational system. The major difference between TRL 5 and 6 is the step up from laboratory scale to engineering scale and the determination of scaling factors that will enable design of the operating system. The prototype should be capable of performing all the functions that will be required of the operational system. The operating environment for the testing should closely represent the actual operating environment.
Technology Development	TRL 5	Laboratory scale, similarsystem validation inrelevant environment	The basic technological components are integrated so that the system configuration is similar to (matches) the final application in almost allrespects. Examples include testing a high-fidelity, laboratory scale system in a simulated environment with a range of simulants (a) and actual waste (b). Supporting information includes results from the laboratory scale testing, analysis of the differences between the laboratory and eventual operating system/environment, and analysis of what the experimental results mean for the eventual operating system/environment. The major difference between TRL 4 and 5 is the increase in the fidelity of the system and environment to the actualapplication. The system tested is almost prototypical.
Technology Development	TRL 4	Component and/or systemvalidation in laboratory environment	The basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of ad hoc hardware in a laboratory and testing with a range of simulants and small-scale tests on actual waste (b). Supporting information includes the results of the integrated experiments and estimates of how the experimental components and experimental test results differ from the expected system performance goals. TRL 4-6 represent the bridge from scientific research to engineering. TRL 4 is the first step in determining whether the individual components will work together as a system. The laboratory system will probably be a mix of on hand equipment and a few special purpose components that may require special handling, calibration, or alignment to get them to function.
Research to Prove Feasibility	TRL 3	Analytical and experimental critical function and/or characteristic proof of concept	Active research and development (R&D) is initiated. This includes analytical studies and laboratory-scale studies to physically validatethe analytical predictions of separate elements of the technology. Examples include components that are not yet integrated, or representative tested with simulants. (a) Supporting information includesresults of laboratory tests performed to measure parameters of interestand comparison to analytical predictions for critical subsystems. At TRL 3 the work has moved beyond the paper phase to experimental work that verifies that the concept works as expected on simulants. Components of the technology are validated, but there is no attempt tointegrate the components into a complete system. Modeling and simulation may be used to complement physical experiments.
	TRL 2	Technology concept and/orapplication formulated	Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof ordetailed analysis to support the assumptions. Examples are still limited to analytic studies. Supporting information includes publications or other references thatoutline the application being considered and that provide analysis to support the concept. The step up from TRL 1 to TRL 2 moves the ideas from pure to applied research. Most of the work is analytical orpaper studies with the emphasis on understanding the science better. Experimental work is designed to corroborate the basic scientific observations made during TRL 1 work.
Basic Technology Research	TRL 1	Basic principles observed and reported	This is the lowest level of technology readiness. Scientific researchbegins to be translated into applied R&D. Examples might include paper studies of a technology's basic properties or experimental workthat consists mainly of observations of the physical world. Supporting Information includes published research or other references that identify the principles that underlie the technology.

(a) Simulants should match relevant chemical and physical properties.
(b) Testing with as wide a range of actual waste as practicable and consistent with waste availability, safety, ALARA, cost and project risk is highly desirable

Appendix B

Transportation Biofuels Incentives

Renewable Fuel Incentives

Production of bioenergy, including fuels and electricity used as a vehicle fuel, from forest sourced woody biomass could qualify as a renewable transportation fuel and meet the requirements for tradable carbon offset credits. Relevant incentive programs include the Federal Renewable Fuel Standard (RFS) and the California Low Carbon Fuel Standard (LCFS).

Federal Renewable Fuel Standard

The RFS was authorized under the Energy Policy Act of 2005 and expanded under the Energy Independence and Security Act of 2007. The RFS mandates that refiners and distributors of transportation fuels utilize certain types of renewable fuels and provides volumetric blending targets. It is administered by the US EPA, which updates the blending obligations for each type of renewable fuel on an annual basis.

The four renewable fuel categories under the RFS are:

- Biomass-based diesel
- Cellulosic biofuel (which includes RNG)
- Advanced biofuel
- Total renewable fuel

As shown in Table 4, the RFS program uses an accounting mechanism, Renewable Identification Numbers (RINs), to track alternative and renewable fuels. The RFS program offers a tiered system for GHG reduction value. Several relevant RIN categories are identified and described in the Table 1 below.

Table 1. Classification of RINs Credits under the RFS

Rin “D” Code	Fuel Type	GHG Reduction Requirement, percent	Fuel
D3	Cellulosic Biofuels	6	Cellulosic ethanol/naphtha/diesel, renewable CNG/LNG/electricity, etc.
D4	Biomass-Based Diesel	50	Biodiesel, renewable diesel, etc.
D5	Advanced Biofuels	50	Sugarcane ethanol, renewable heating oil, biogas, etc.
D6	Renewable Fuel	20 or less	Corn ethanol, etc.

Cellulosic biomass made from forest source woody biomass, such as forest product residues, forest thinning, and slash would meet the D3 RIN criteria. D3 RINs have the highest value, as shown in Table 2.

Table 2. Recent RIN Values ($/RIN)			
D6, dollars	D5, dollars	D4, dollars	D3, dollars
1.13	1.44	1.50	3.23
Note: https://growthenergy.org/growth-energy-ethanol-data-hub/rin-prices/			

RINs are valued as dollars per ethanol gallon equivalent. A gallon of ethanol contains 77,000 BTU/gallon. The value of RINs for a specific biofuel can be estimate using Table 3. A pathway for electricity as a RIN-generating biofuels has been adopted for biogas generators, however a project-specific thermochemical pathways have yet to be officially established pathway at this point.

Table 3. Estimate of RIN Values for Common Biofuels		
Biofuel	Energy Density	Estimated Rin Credit Value
Ethanol	77,000 BTU/gal	269.40₵/gal
Diesel	130,000 BTU/gal	454.83₵/gal
Gasoline	124,000 BTU/gal	433.84₵/gal
Hydrogen	270 BTU/scf	0.94₵/scf
Renewable Natural Gas	1,020 BTU/scf	3.57₵/scf
Electricity	3,412 BTU/kWh	11.94₵/kWh

It must be noted that forest biomass acquired from federally-managed lands (including USFS, DLM, DOD, and tribal lands) for biofuels production do not qualify to received RINs. This must be taken into account with any financial proforma evaluation.

California Low Carbon Fuel Standard

The California LCFS is a dynamic program offering transportation biofuel producers the unique ability to further monetize conversion of woody biomass to biofuel. Project developers can use this program to receive value for the GHG reductions of alternative transportation fuels.

However, the produced biofuel must be sold into the California market to take full advantage of the LCFS program and potential revenue.

Credits gained through the LCFS program can be sold to regulated entities. Currently the market is a highly fragmented spot market with almost no long-term contracts. This market uncertainty, coupled with the inability to get an offtake agreement that extends through the life of debt financing, has limited the effectiveness of the program in developing new and innovative transportation fuels. Historical pricing for LCFS credits and transaction information through July 2023 is available in Table 4.

Table 4. Historic LFCS Pricing			
Time Period	Number of Transfers	Total Volume Credit	Average Price USD/Credit, dollars
2023 (Q1 & 2)	1,810	18,309,000	77
2022	3,137	30,6241,000	125
2021	2,664	25,280,000	188
2020	2,461	21,775,000	199
2019	1,656	14,147,000	191
2018	1725	13,334,000	160
2017	1,226	8,875,000	89
2016	929	5,343,000	101
2015	578	2,852,000	62
2014	304	1,667,000	31

A credit in the LCFS program is equivalent to the reduction of one metric ton of carbon dioxide equivalents (MT CO2e). The amount of greenhouse gas (GHG) reduction per unit of fuel depends on the certified pathway. This GHG reduction is the difference between the carbon intensity (g/MJ of fuel) of the renewable fuel and the carbon intensity of the replacement fuel (e.g., diesel or gasoline).

As can be seen in Table 4 the LCFS credit price has been dropping over the last two years. This is due in large part to the significant increase in out of state renewable diesel and dairy farm RNG, coupled with a large increase in renewable.

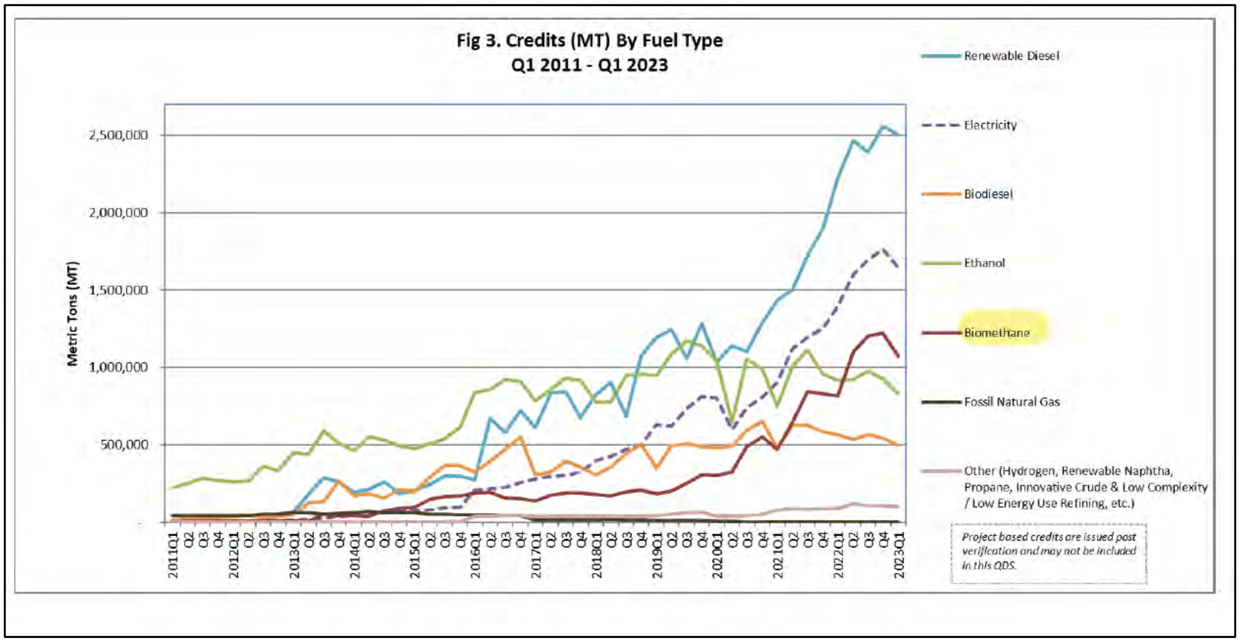

Figure 1. Credits by Fuel Type

The California Air Resources Board (CARB), the regulator of the Low Carbon Fuel Standard (LCFS) has been working to implement policy changes to boost the credit price, which has fallen from 2021 prices of about $200/metric ton (MT) to current levels below $80/MT due to above referenced credit surpluses. CARB announced in late 2022 directions the program could take given CARB's announcement that they would be raising their 2030 greenhouse gas (GHG) emissions reduction target and the need for a market signal to stop the slide in LCFS credit prices.

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