U.S. Department of Agriculture

Research Proposal: Bioenergy for Disadvantaged Rural Communities in California

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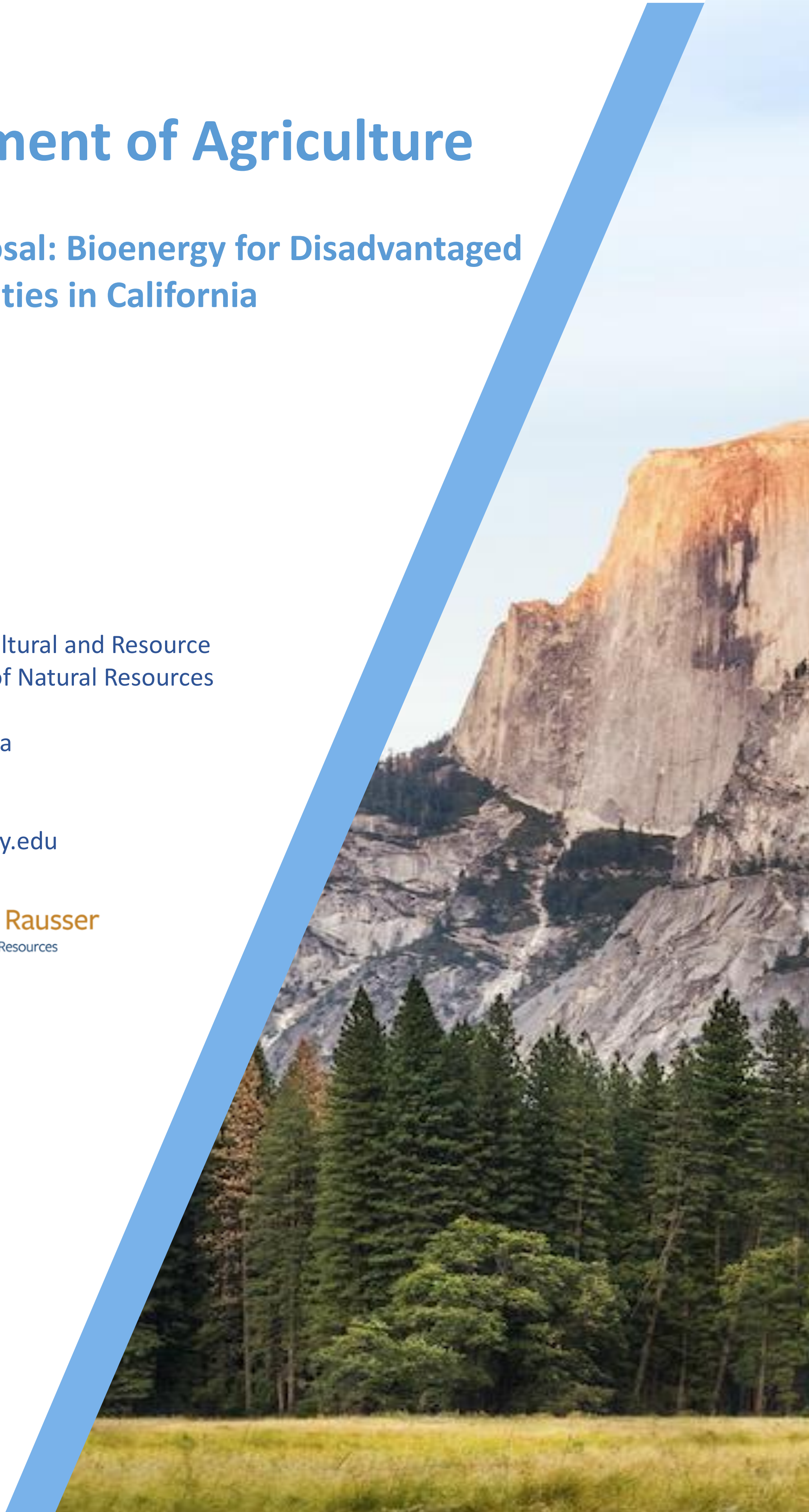


Table of Contents

1 Technical Narrative

In response to the stated objectives of the U.S. Department of Agriculture (USDA) solicitation, this proposal outlines a project to be undertaken by the Department of Agricultural and Resource Economics (ARE) to deploy a network of carbon-negative bioenergy facilities in rural California Disadvantaged Communities (DACs). These enterprises will be profitable, locally owned public entities (or held in public-private partnerships), using proven technology to convert forest and agricultural biomass into biofuels and biochar in a sustainable, carbon-negative manner. If funded, the project would advance multiple state objectives: mitigating wildfire risk, improving air and water quality, promoting skilled local workforce development, local livelihoods, and clean energy self-reliance.

1.1 Activities to be Funded

This proposal describes a 3-year strategy for community-based biofuel enterprise development, with detailed information on the first year (Phase 1) and general discussion of a two-year Phase 2 follow-up.[1] Each facility will be designed to take advantage of the many economic and social benefits of directing excess agricultural and forest biomass to a net negative carbon pathway. In addition to displacing costly, polluting fossil fuels, the project will create new local jobs and support skill-intensive workforce development. The strategic plan can be summarized as follows:

- [Year 1 / Phase 1]: Conduct a comprehensive analysis of Sierra DACs, including local institutional / infrastructure capacity, energy use patterns, and agricultural and forest biomass availability. From this baseline assessment, recruit ten pilot communities as candidates for facility development. In close collaboration with each candidate, develop implementation plans with local governments, community-based organizations, and accessible technical vocational education and training (TVET) resources (e.g., California State Universities / Junior Colleges). Deliver complete planning support to each pilot community, addressing staffing, land use, engineering, finance, marketing, and legal service needs. Detailed MOUs and implementation plans agreed with each candidate community will be the main deliverable of Phase 1. In parallel, technology testing, final TCA/LCA assessment, CEQA, and other permitting requirements will be completed.

- [Year 2 / Phase 2]: Begin implementation in the 10 target communities, leveraging community partnerships (including TVET institutions) to develop core operational staff from local labor markets. Target facilities for production commencement within six months of the Phase 2 start-date, and rigorously evaluate operational performance for the following six months. Based on these outcomes, Year 3 will target program expansion.

- [Year 3 / Phase 2]: Build on pilot results to scale up community bioenergy development and establish a non-profit California BioEnergy Network (CalBEN) to promote knowledge exchange and biofuel enterprise development in eligible communities around the state.[2] Pursue a target of 100 CalBEN members (localities with intent to implement or evaluate the technology locally) in its first year of operations.

Promoting cutting-edge clean energy technology in remote communities is challenging. Thus, our project strategy is anchored to the expertise and experience of one of the state's leading economic

[1] Phase 2 implementation is conditional on success in Phase 1

[2] Expansion could be confined to Sierra communities, since these are proximate to large volumes of agricultural and forest biomass. Extreme northern and northwestern California counties might also be considered, pending USDA approval

and technology research institutions. Primary implementation responsibility will fall to ARE, a consultancy with 20 years of domestic and international experience assessing and advising on energy, environmental, and inclusive economic development policy. For local engagement, ARE will be responsible for developing institutional relationships and recruiting community facilitators. JBEI, the premiere bioenergy research facility of the US National Laboratories, will provide all technical assistance for scaling, adaptation, and permitting of the core biomass energy conversion technology.

This project aims to establish biofuel enterprises capable of reimbursing capital expenditures in the course of facility operation. Their self-financing design relieves pressure for longer term public support while significantly improving prospects for sustained adoption and diffusion of this technology. Moreover, their local ownership creates a range of avenues by which biofuel revenues could support other local public initiatives, particularly attractive in Sierra DACs.

ARE are seeking $410,000 in USDA funding to finance Phase 1 activities (see Appendix 1). Other resources have been identified to support Phase 2 plans: the ARE project team (composed of senior UC Berkeley faculty) will be applying for (at least) matching funding from an unprecedented $100 million 2023 commitment by the State of California to UC-driven climate research. However, USDA assistance is currently the sole budgetary prospect for Phase 1. It should be noted, however, that this proposal builds on an ongoing partnership funded by CAL FIRE. Now in its third year, CAL FIRE has committed $5.7M to the development and prototyping of the carbon-negative bioenergy conversion technology that will be used in our pilots (see Section 2.4 below and Appendices 2 and 3). ARE's other partners on that project, including the patent holder (SUNY Research Foundation) and primary rights holder (CARIBOU Biofuels), are not direct participants in this USDA project – but strongly endorse the strategy described here and are soliciting their own resources for more advanced technology development. It should be emphasized that the latter are not necessary for success in our proposed implementation.

2 Project Team

2.1 Project Manager and Key Personnel

This project is a collaboration of two eminent policy research groups, UC Berkeley's Department of Agricultural and Resource Economics (ARE) and the Joint BioEnergy Institute (JBEI) of Lawrence Berkeley National Laboratory. Staff from the two organizations form a distinguished team of energy economics and technology experts, together having decades of experience managing climate policy projects with numerous California state agencies (e.g., the California Energy Commission, the California Independent Systems Operator, the California Public Utilities Commission, etc.), and other important policy partners in-state, elsewhere in the U.S., and internationally. The research team is led by three Principal Investigators, supported by subject-area veterans in impact and spatial analysis, economic forecasting, and community outreach. During the project, an array of specialist (financial, legal, etc.) experts and research assistants will be recruited to support local implementation.

David Roland-Holst, PhD – Principal Investigator (PI-1)

David Roland-Holst is a Research Professor at ARE/CNR and supervises all its research projects. Dr. Roland-Holst is a leading authority on the economics of energy and climate change, with several decades of domestic and international policy development experience. Dr. Roland-Holst will lead economic forecasting and team management for the project.

David Zilberman, PhD – Principal Investigator (PI-2)

David Zilberman is a Wolf Prize Laureate, one of the world's leading agricultural economists, and a prominent expert on biochar. He will advise the project on all aspects of biochar's contributions to forest carbon sequestration, soil health, biodiversity, water retention, and community value added.

Drew Behnke, PhD – Senior Economist, Research Associate

Drew Behnke will have primary responsibility for data development related to community assessment and facility site selection criteria. He will also assist in model calibration, analysis, and report drafting. Dr. Behnke is an expert in econometrics and data science with over a decade of experience as a professional research and policy economist. He is currently a research economist at UC Berkeley and has extensive experience with community and property development.

Sam Heft-Neal, PhD - Senior Economist, Research Associate

Sam Heft-Neal's principal responsibilities include background sector research, econometrics, and spatial data analysis. Dr. Heft-Neal possesses over 15 years of experience as a professional research and policy economist and is currently a senior researcher at Stanford University.

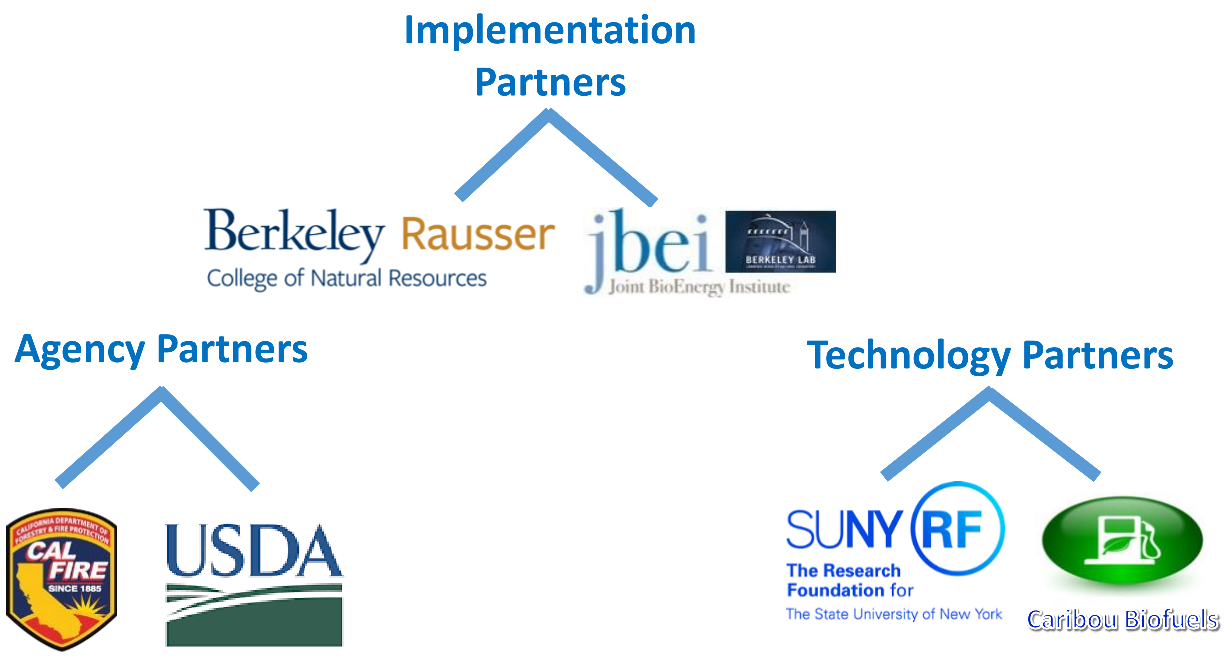
Graciela Chong, MDP/G – Community Relations Specialist

Graciela Chong has an extensive history of DAC outreach experience around California. An expert in community engagement and survey design, dissemination, and analysis, Graciela will also manage the project's administration and provide editorial support on reporting and knowledge products.

2.2 Organizational Chart

The organization for this project operates across three institutional levels, summarized schematically in Figure 1.

Figure 1: Schematic Project Organization



1.1.1 Prior / Ongoing Public Partnerships

2 UC Berkeley's Department of Agricultural and Resource Economics is one of country's most respected rural resource development research, producing myriad research and implementation projects in cooperation with domestic and international public and private agencies. Most relevant to present proposal is of course ARE's ongoing collaboration to develop and test the core bioenergy technology for CAL FIRE CAL FIRE (Grant No. 8GG196010), a three-year, $5.7M project. Other examples include Dr. Roland-Holst's economic assessment for CARB's first (2005) AB32 Scoping Plan. Over the last decade, he has also delivered the primary economic assessment of California's Renewable Portfolio Standards (RPS), a regional electricity integration plan sponsored by the California Independent Systems Operator (CAISO), and a detailed economic impact assessment of Long Term Energy Strategies for the California Energy Commission.[3] For the California Public

[3] ARE's complete project history can be found at our firm's website, www.AREecon.com

Utilities Commission, Dr. Roland-Holst recently conducted a prominent economic assessment of plans to close the Diablo Canyon Nuclear Power Plant. Finally, as it happens, he is currently performing a separate energy sector research project under sponsorship of the California Department of Conservation.[4]

2.1 Community

2.1.1 Partnership Building

Over two decades of experience with domestic and international rural development projects have given the PI's ample first-hand experience with community outreach and programs for local technology adoption. As explained below, the project's local bioenergy development strategy hinges on collaboration with community personnel and institutions. Direct and inclusive consultation with Disadvantaged Community groups will help refine engagement plans for local government, TVET institutions, and additional community organizations.

Selection of the 10 target communities will be based upon a comprehensive regional analysis of Sierra DACs in Phase 1, and ARE's outreach to local stakeholders will commence in the first year of the project. Although California is home to state-level NGOs and other groups that have demonstrated interest in biofuels and the Sierra region, ARE's primary aim is to partner with entities that have direct ties with prospective target communities (e.g., have a history of local project work and a brick-and-mortar local presence). In anticipation of Phase 1 outreach, ARE has begun to survey of prospective community-based organizations whose missions align with the goals of our biofuel enterprise strategy.

Relevant DAC partner organizations generally allocate their resources between economic development and environmental stewardship, although they differ in support capacity and approach to these issues. For example, entities like the Sierra Nevada Alliance engage in environmentally-focused workforce development, and through partnerships with state agencies (e.g., CAL FIRE) and federal ones (e.g., AmeriCorps) have associates distributed in towns across the region. Others, like the Friends of Hope Valley and Friends of the Inyo, are focused on environmental advocacy within their particular counties, and maintain visible involvement with local government. Finally, there are more commercially oriented groups, like the Sierra Business Council, that provide development services, connecting local businesses to funding opportunities and training.

2.1.2 Long-Term Commitment & Environmental Sustainability

ARE recognizes that community engagement and environmental stewardship are not just benefits in their own right, but essential contributors to the economic success of these biofuel production facilities. ARE plan to cement local participation within the enterprise structures themselves, designing the facilities to be publicly owned entities (or public-private hybrids) directly generating public income. This strategy would establish biofuel production as a community commitment to local jobs, public health/safety, and new financial resources for public goods and services.

As explained below, these proposed facilities will draw their employees from the local labor pool, leveraging accessible public TVET resources to close technical training gaps. Further, ARE's community outreach efforts will include relationship-building with both public and private entities

[4] USDA Agreement No. 2021-004.

situated upstream and downstream from bioenergy production. Doing so will ensure that, beyond any risk mitigation or long-term environmental dividends, diverse participants in the local economy will be directly linked to these facilities, materially benefiting from their long-term success.

2.1.3 Local Capacity Building

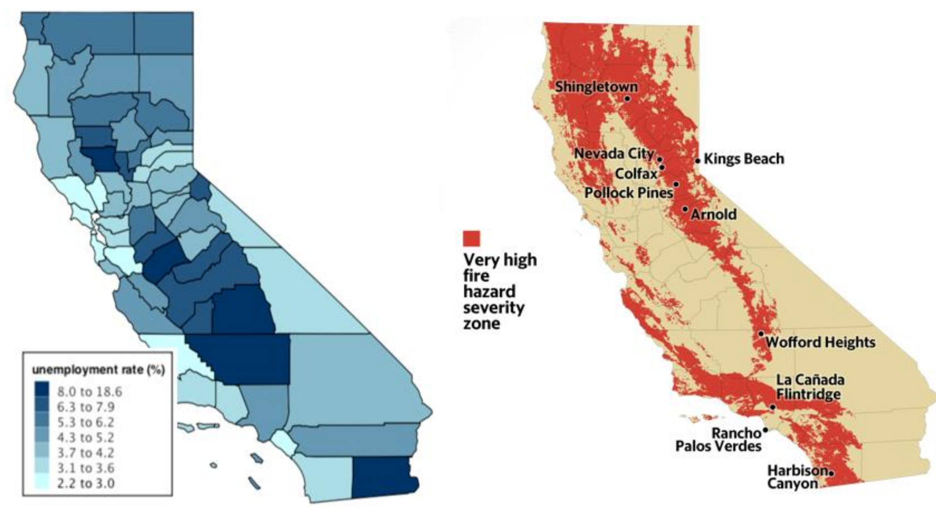
The project's facility development plan relies on community labor resources for its implementation. A number of roles within the enterprise, in spite of relatively high wages (by local standards, see the attached Techno-Economic Analysis (TEA) or the "Financial Feasibility" section below for details), will require only modest formal education and training. Some more senior roles, though, will require strong technical skills that, while needed in rural DACs, are typically recruited from more diversified urban economies. Thanks to an extensive network of California State University and Junior College (CSU / JC) campuses throughout the state, however, a wide swath of California rural communities reside within commutable distance from learning opportunities aligned with our project's operational needs. ARE's planned Phase 1 outreach work includes working with CSU / JC programs to offer relevant trainings and skill-development modules for specific biofuel facility roles.

Working in collaboration with local governments, state and federal job-training resources could be leveraged to establish appropriate training/certification programs, with prospective offers of facility employment upon successful completion. In these ways, ARE's proposed biofuel production facilities would help forge linkages between regional stakeholders, encouraging collaboration and additional benefits outside of those directly tied to biofuel enterprise operations.

2.1.4 Project Locations

California's rural communities are very diverse, but most share two relevant characteristics: significant surplus biomass and elevated wildfire risk. Because of recent bans on burning agricultural waste and limited landfill capacity, many farming communities are facing growth challenges to sustainable waste management and fire risk mitigation. Today's bioenergy conversion technology can transform these threats into opportunities – yielding direct economic benefits to workers and energy consumers, with indirect community and state-wide benefits from wildfire risk mitigation, improved air quality and livelihoods. The overlapping maps in Figure 2 illustrate the dual disadvantages that community bioenergy can address.

Figure 2: Unemployment (Left) & Wildfire Risk (Right) in California



2.2 Engineering

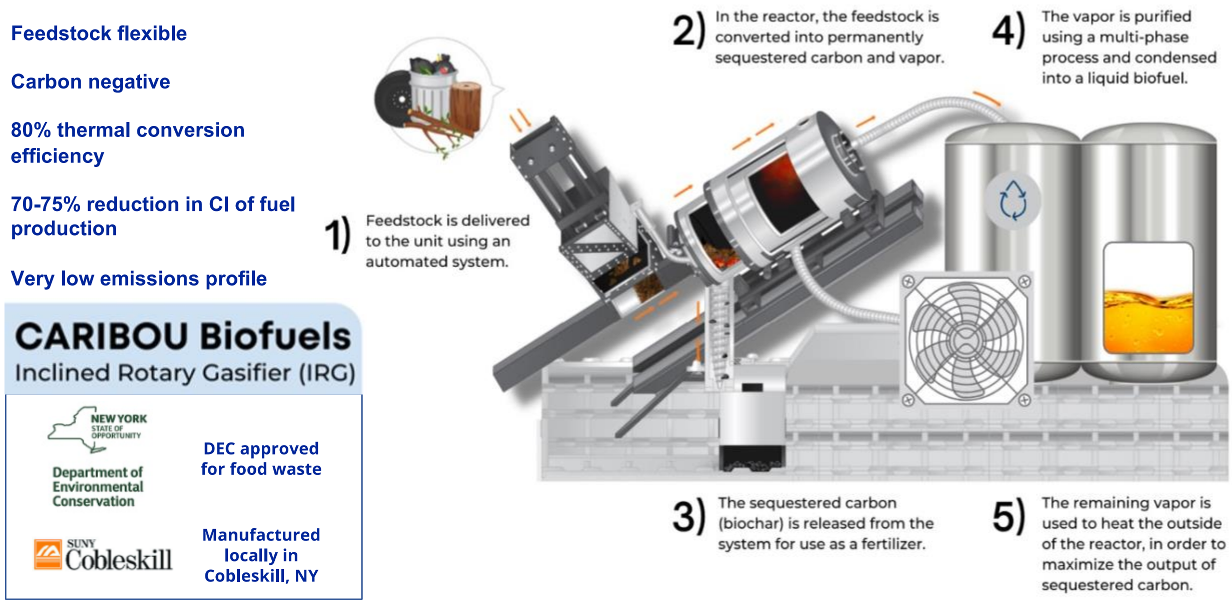
2.2.1 Basic Technology Description

The bioenergy conversion technology underpinning this proposal's community enterprise development strategy has been successfully brought to scale, field-tested, and is currently being adapted to forestry biomass applications with a 3-year, $5.7M grant from CAL FIRE. The original technology is a patented "Inclined Rotary Gasifier" (IRG) developed at the State University of New York, Cobleskill, with support from the U.S. Department of Defense.

Illustrated in Figure 3, the IRG technology uses devolatilization to convert biomass feedstock into biochar and liquid biofuel.[5] The original development goal for this technology was to offer a carbon negative alternative to mixed waste incineration, funded by the US Army to eliminate "burn pits" and produce biofuel in forward military positions. The technology is extremely versatile, capable of processing forestry waste, agricultural residue, municipal solid and other biogenic waste streams – dry, soiled, or wet. When biomass is fed into the IRG system, the reactor rotates to homogenize and tumble dry the feedstock, obviating the need for energy-intensive feedstock preparation.[6] Any unintended inert debris entering the IRG (e.g., stones, soil, metals, etc.) is discharged with the system's biochar output.

[5] Devolatilization is an anaerobic process of thermal conversion and does not require combustion or incineration of the primary feedstock.
[6] For forest clearing biomass, only relatively low energy shredding is required (see LCA for details).

Figure 1: Inclined Rotary Gasifier (IRG)



Of the biomass feedstock that enters the IRG, about 20% of its biogenic carbon is converted into liquid fuel output; 20% is recovered as biochar; 20% provides heat for devolatilization; and the final 40% is converted into syngas compounds. The latter are ideal inputs for on-site boilers or generators to deliver clean local heat and power. The IRG's innovative feedstock versatility is mirrored in the output phase: its hydrocarbon outputs require no further catalytic upgrading or post-production processing. Process emissions from the IRG system are cleaner than those of typical engines and readily capable of meeting local and state air quality mandates. Solid waste outputs include a modest quantity (<1% of feedstock input weight) of ash, easily collected and disposed of by IRG operators.

2.2.2 Technology Maturity

The IRG technology has been developed to a stage aligned with the Department of Energy's "Technology Readiness Level (TRL) 6". This was demonstrated at the State University of New York, Cobleskill, as a part of a joint Department of Defense / Environmental Protection Agency research program.[7] The system processed woody biomass feedstock at the rate of 100 lb/hr (bone-dry basis), resulting in hourly outputs of 1.7 gallons of liquid fuel, 10.9 lbs of biochar, 0.6 lbs of ash, and 33.6 kW of direct electric power. At a target processing rate of 4 T/hr (see the TEA in Appendix 3) this translates to pilot facility hourly output of 95 net gallons of liquid biofuel, 800 lbs of biochar, and 2 MW of net electric power. As part of the ongoing CAL FIRE project, technology is scheduled to be advanced to TRL 8 by the end of Phase 1, including local permitting and CEQA compliance for use in forward CAL FIRE clearing operations and other Sierra locations. This will ensure complete readiness for proposed deployment in Phase 2 of the present project.

[7] U.S. Department of Defense. 2018. *Strategic Environmental Research and Development Program.* (WP-2211). https://www.serdp-estcp.org/projects/details/394d21e3-3ac1-491e-bd01-96fdebef0ac9/wp-2211-follow-on-project-overview

2.3 Carbon Negativity

The IRG technology discussed in the "Engineering" section above captures over 80% of feedstock carbon, directing it to low and negative carbon pathways and displacing higher-carbon fossil fuel alternatives. Figure A4.3 in the TEA (see Appendix 2) illustrates the carbon cycle for the IRG process using a hypothetical biomass feedstock of Pinyon Juniper (a common Sierra Nevada tree variety) at a processing rate of 4T/hr. Figure A5.1 in Appendix 3 illustrates the Life-Cycle Analysis (LCA) and TEA system boundaries for the overall bioenergy system.

Further respecting page limits for this proposal, detailed LCA Global Warming Potential (GWP) estimates, assumptions, and references are presented in Table A5.2 of Appendix 3. Because the technology is in its final year of development under CAL FIRE sponsorship, we will not have CARB approved CI pathway statistics for this system until Phase 1 is already under way. The estimates presented here can still be considered reliable, however, having been sampled from the CAL FIRE prototype. Based on this preliminary data, the system exhibits robust carbon negativity, yielding -69.93 CO2e grams of net GWP reduction per megajoule of bioenergy production.

At this preliminary stage, our environmental accounting has been confined to carbon emissions. For ongoing Phase 1 and 2 assessments, we plan to address all EPA "Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts" (TRACI) categories of environmental damage, including criteria pollutants if the project is allowed to recognize averted burn credits. Indeed, ARE plans to discuss with state agencies the idea of "enhanced" carbon credits that recognize the additional benefits of averted biomass burning – constituting a much higher local health and wildfire risk than fossil fuel consumption.

Table 1: Carbon and GWP Accounting (see Appendix 3 for details)

					Carbon Content			GWP Contribution	
Process	Qty	/hr	Energy Flow (MJ/hr)	Energy Produced /hr	By process Co2e.g/MJ	All project Co2e.g/MJ	Percent	Co2e.g/MJ	Type of Displacement
Capital goods, Infrastructure	NA								
Harvest	8000	lb							
Transport	8000	lb	183	-	0.87	0.0053	0.0066%	5.72E-05	
Pre-treatment	8000	lb	29	-	0.14	0.0001	0.0002%	2.29E-07	
IRG fueling	800	lb	3,744	-	67.40	8.51	10.5%	0	Not displacing fossil fuel
Liquid fuel net	633	lb	12,126	12,126	60.14	24.59	30.4%	-23.38	Diesel/Gasoline equivalent
Biochar	800	lb	10,182	10,182	108.30	37.17	45.9%	-37.17	Sequestered
Electricity	3083	kW	31,711	7,356	43.10	10.69	13.2%	-9.37	CA Ave electicity equivalent
Totals			57,975	29,664		80.96	100.0%	**-69.93**	**Project GWP/MJ**

2.4 Financial Feasibility

2.4.1 Project Financial Analysis

There are two basic financial dimensions to the project: "Technology Finance", the initial capital costs of establishing each community biofuel production facility and, the primary use of USDA funds, "Program Finance" for community recruitment, planning, and implementation support. We discuss each in turn:

2.4.1.1 Technology Finance

Each prospective community bioenergy facility will be financially assessed at local market lending rates, ensuring each enterprise is designed to be profitable from inception and recover capital costs after two decades of operation. Where concessional financing is available, debt retirement will be earlier or higher net earnings can be distributed in accordance with program objectives (e.g., enhanced secondary mitigation, equity, and innovation programs).

The main financial characteristics of a typical implementation are modeled in the TEA (Table A4.2 of Attachment 1). Given the significant net earnings estimate for 20yr financing, this project should be a viable candidate for private lending, and the project will support communities approaching lenders to obtain competitive rates. We also plan to leverage loan guarantees that are now being offered by local air quality districts. As indicated in the TEA, primary bioenergy facility revenue will be generated from sales of biofuel, biochar, surplus electric power, carbon credits, and through the collection of waste disposal fees, using conservative assumptions about each.

2.4.1.2 Program Finance

Phase 1: As discussed in the "Engineering" section above, the research and development necessary to bring the IRG technology to Phase 2 readiness is already complete, funded by CAL FIRE for the express purpose of ensuring its readiness for the Sierra Nevada forestry biomass context. As itemized in the proposed budget, Phase 1 support from USDA would thus be devoted to the costs corresponding to site analysis, community outreach, financial planning, and the securing of permits and other licensing.

Phase 2: The primary use of Phase 2 funds will be for implementation support for the 10 pilot facilities and outreach to scale up the statewide community bioenergy network (CalBEN). No funds will be allocated to capital costs, and each enterprise will be structured to assume these costs subject to its own negotiated financing plan, including any concessional financing our project team can identify from public or private sector initiatives.

Concessional financing programs include enhanced loan guarantees from local Air Quality Management Districts and the "Climate Catalyst Program"[8], a loan fund within the California Infrastructure and Economic Development Bank. This Program provides, among other resources, "flexible, low-cost credit and credit support" to "projects that reduce wildfire threats through agricultural and forest biomass management and utilization." Beyond this, there are many local and private sources that might offer initial capital financing for individual community bioenergy projects. The state's Community Choice Aggregation system offers important precedence here in the context of solar energy. Many other private sources (e.g., foundations and other NGOs) provide capital

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[8] Climate Catalyst Program. 2022. *California Infrastructure and Economic Development Bank.* Retrieved from: https://www.ibank.ca.gov/climate-financing/climate-catalyst-program/

support to climate-focused activities, especially those with a strong equity dimension as included in our plan.

In addition to a range of existing state, federal, and NGO-sponsored programs (see "Project Co-Benefits" below), ARE is preparing an application for the soon-to-be-announced $100M University of California Climate Grant, aimed at supporting innovative climate mitigation and adaptation initiatives at the community level. With a team composed of UC affiliates, including prominent faculty on the current proposal, ARE will be competitive in this program. Any UC Climate Grant funds would contribute to the "matching" portion of Phase 2 funding and could significantly leverage the scale-up plan for our proposed community bioenergy network (CalBEN).

2.4.2 Business Model

The basic organizational entity for each community bioenergy facility would be a local public institution or public-private partnership (PPP) with the primary goal of delivering affordable clean energy, wildfire risk mitigation, and local workforce development. In terms of facility sites, direct land acquisition is not being considered; the intent is to negotiate beneficial use (through profit-sharing) of local community land. For feedstock resources, each community biofuel enterprise will open its operations to local private and tribal resource managers, CAL FIRE, USFS, and utilities.

The key outputs of the IRG bioenergy conversion process are liquid fuel, syngas, electricity, and biochar. For biofuels, we have an offtake agreement with a leading California buyer, but these projects are designed to meet the needs of local energy consumers (see Attachment 4). During Phase 1, our implementation plans will seek to fully utilize facility bioenergy locally. Biochar has a ready market as a soil amendment, but JBEI will be researching upgrades to higher value activated carbon, including filtration, food processing, and pharma applications.

2.4.3 Project Co-benefits

In addition to its offtake revenues, bioenergy facility operations will generate a variety of co-benefits. Some, like LCFS credits, will be monetized and factored into enterprise finances. Many others are less easily quantifiable – but clearly constitute benefits for local communities and the state.

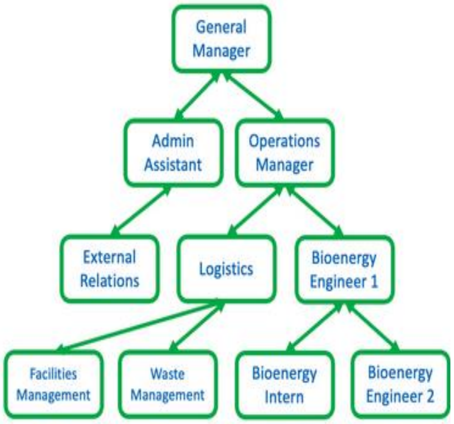
2.4.3.1 Carbon Credit Monetization

See "Technology Finance" above and the TEA (Appendix 2), for details.

2.4.3.2 Workforce Development

This project's emphasis on skilled and localized workforce development aligns it with broader state goals for equitable and inclusive development. Pilot site selection will be informed by a comprehensive baseline assessment of Sierran DACs, including access to technical and vocational, education and training (TVET) resources. Phase 1 outreach will focus on identifying local workers and accessible public education programs to staff our proposed bioenergy jobs model (Figure 4).

Figure 4: Community Bioenergy Employment Development Model



Position	Certification	Hourly	Monthly	Annual
General Manager	BA	$ 50.00	$ 8,800	$ 105,600
Administrative Assistant	AA	$ 30.00	$ 5,280	$ 63,360
Sales and External Relations Assistant	AA	$ 30.00	$ 5,280	$ 63,360
Operations Manager	TVET Certificate	$ 40.00	$ 7,040	$ 84,480
Bioenergy Engineer 1	TVET Certificate	$ 30.00	$ 5,280	$ 63,360
Bioenergy Engineer 2	TVET Certificate	$ 30.00	$ 5,280	$ 63,360
Logistics Supervisor	TVET Certificate	$ 25.00	$ 4,400	$ 52,800
Waste Management Supervisor	TVET Certificate	$ 25.00	$ 4,400	$ 52,800
Facilities Supervisor	TVET Certificate	$ 25.00	$ 4,400	$ 52,800
Bioenergy Intern/Trainee	TVET Certificate	$ 20.00	$ 3,520	$ 42,240
Compensation				*$ 644,160*
Benefits	*12.5%*			*$ 80,520*
Total Cost of Employment				*$ 724,680*

TVET partnerships will help ensure local workers are trained as necessary to occupy skilled positions in the enterprise staffing model. However, many non-technical roles are also needed for facility operations; these positions can be filled by members of the local labor pool that have not received specialized technical training. All jobs within the biofuel enterprises will be well-compensated, with wages substantially higher than state averages (emphatically so in rural labor markets).

2.4.3.3 Wildfire Risk Mitigation & Public Health Improvement

Mitigating California's wildfire risk is a critical objective of USDA's biofuel program and is central to the mission of other state bodies like CAL FIRE. Agricultural and forest biomass-based energy conversion is a viable means of advancing those aims. Clean, local bioenergy production makes sense for communities whether or not they face critical fire risk because of its many economic and other benefits. For at-risk communities, however, wildfire mitigation presents another rationale for more aggressive biomass harvesting. Reducing wildfire risk confers public health and material benefits onto Sierra communities, and it also encourages higher levels of economic investment in the region.

2.4.3.4 Advancing California's Climate Goals

California is pursuing ambitious climate goals that include significant reductions in the state's annual C02 emissions. Decarbonizing energy production is a core facet of that strategy. However, as illustrated in Figure 5, the state's current electric power mix is heavily reliant on fossil fuel sources. Bioenergy production is far below potential for a state with substantial renewable biomass resources, especially from forestry sources. Expanding the forestry biofuel sector should thus be a high priority.

Most Sierra households have below average levels of income and assets compared to the rest of the state, resulting in a high concentration of DACs (Figure 6). At the same time, heating costs and more extensive transport needs mean higher energy expenditures as a percent of income. Community bioenergy development can reduce this economic vulnerability, offering locally sourced biofuels and clean electricity at comparable cost and far lower net emissions than imported fuels and power.

Figure 5: California's Electric Power Mix & Biomass Feedstock Availability

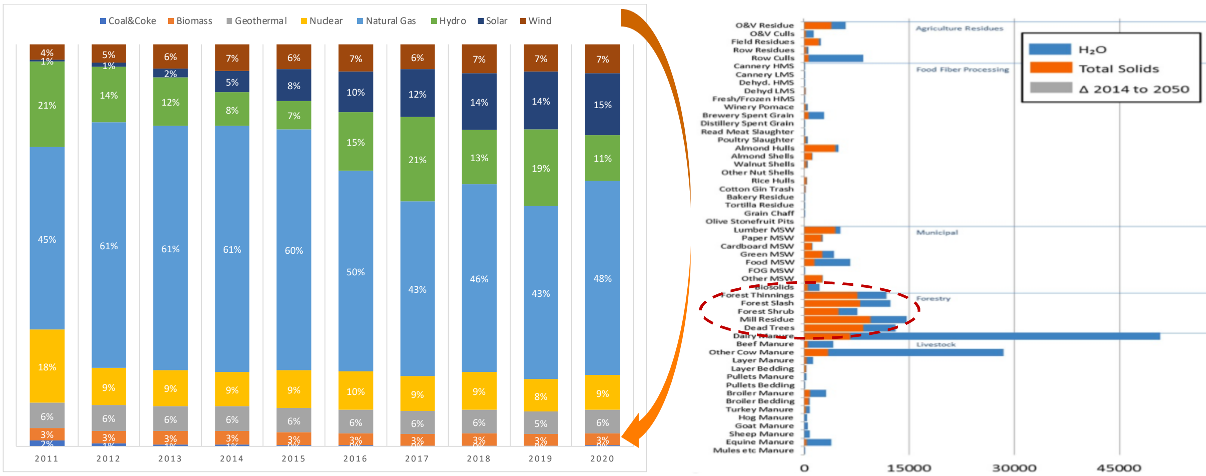
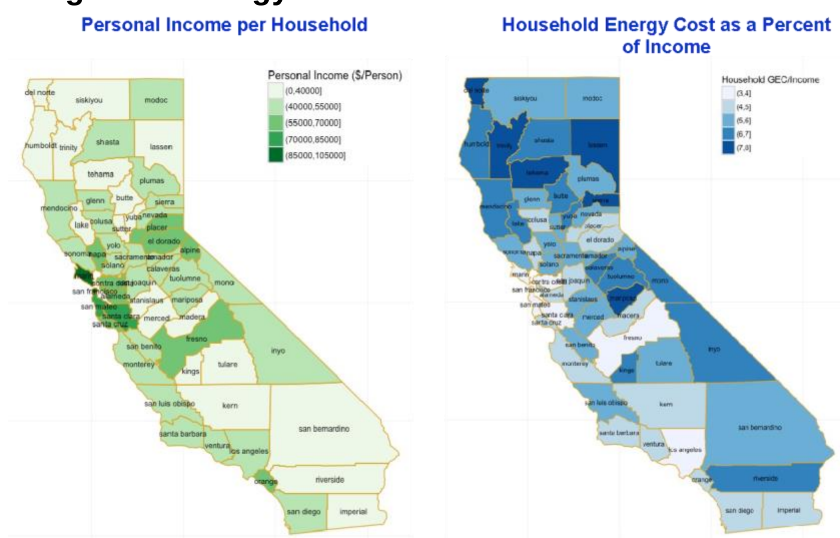


Figure 2: Energy Economics of Sierra Communities



2.4.3.5 Soil Health and Biodiversity

The environmental benefits of biochar, residual carbon harvested from biomass, are only beginning to be fully understood. Biochar as a soil amendment has a long history, but its traditional production and recycling pathways are relatively inefficient and emission intensive. By contrast, according to IPCC (2019) standards (see Appendix 3), 100% of the biochar from the proposed bioenergy technology will sequester carbon for at least 100 years. Moreover, initial testing of this high-temperature biochar reveals extremely high levels of porosity, with corresponding advantages for water retention, filtration, and microbial hosting.

2.4.4 Financial Sustainability of Carbon Sequestration

Each project will be based on a 20-year financial plan. See the TEA in Appendix 2 for details on feedstock, offtake, and financial estimates, and the LCA in Appendix 3 regarding sequestration and GWP estimates.

2.5 Execution

2.5.1 CEQA Obligations

Phase 1 project tasks will be oriented towards a comprehensive evaluation of eligible California DACs, selection of 10 pilot sites, and outreach to targeted communities. While this will entail a modest amount of staff travel in the region, Phase 1 activities constitute "feasibility or planning studies for possible future [i.e., Phase 2] actions" and do not constitute any meaningful environmental impact.

Phase 2 project tasks will involve actual site development and the commencement of facility operations. Elaborated in the "Engineering" section above, the localized and distributed environmental impact of these biofuel enterprises will be positive. Prior to ground-breaking, however, each facility will require its own CEQA that addresses planned activities within the particular local context. Because each of the 10 initial pilot sites will be selected according to a Phase 1 regional evaluation, it is not possible to anticipate the exact content of these future CEQA assessments. However, a factor in the pilot site selection rubric will be the availability of local space for facility operations in a non-environmentally sensitive location.

According to the estimated project timeline, CEQA evaluations for pilot sites will begin 9 months out from the Phase 1 start-date. This will ensure that site selection and initial outreach efforts for the 10 pilots will have already occurred, and allocate 3 months for CEQA completion in the lead-up to Phase 2 ground-breaking. As discussed in the "Project Team" section above, the ARE team is composed of energy economics and engineering experts with a lengthy professional history of collaboration with California state agencies. We have the highest confidence in our capacity to produce CEQA assessments in the lead-up to Phase 2 that will satisfy official requirements.

2.5.2 Permit Requirements

The specific set of permits required for each of the 10 pilots will thus not be established until that juncture. However, the parallel CAL FIRE project will have established precedence for permitting of the same technology in Sierra forest clearing locations, offering a sound precedent for our site approvals. Beyond this, the ARE team anticipates that many pilots will be able to avoid site development decisions (e.g., extensive construction or renovation choices) by working with local governments to repurpose existing infrastructure.

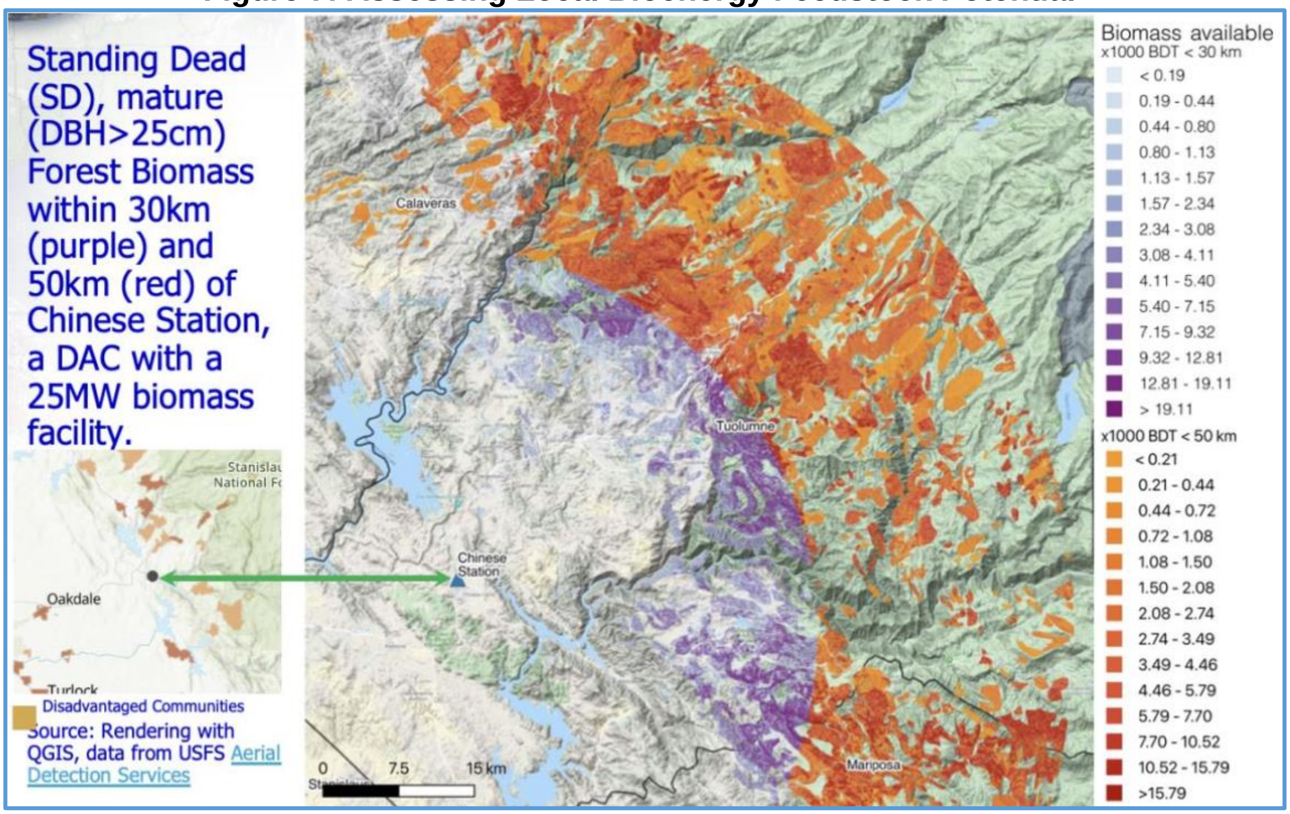
2.5.3 Land Access, Use, & Ownership

This project envisions no direct land acquisition and plans to negotiate beneficial use (through profit-sharing) of local community land pilot production sites. (See Section 2.6.2 above for more detail).

2.5.4 Feedstock Supply Description

A sustainable supply of agricultural and forest biomass is essential to the viability of each community bioenergy project, taking explicit account of the economic and environmental costs of accessing this resource. For the proposed project, we will use our own advanced GIS analysis tools to determine agricultural and forest biomass feedstock accessibility for each eligible community. ARE have significant spatial data science experience including our own search and rendering tools to support this activity. As the following figure makes clear, areas in California with high agricultural and forest biomass include many communities with relatively low incomes and high energy costs. Using a combination of USFS agricultural and forest biomass density data, socioeconomic statistics for California, and our own advanced GIS rendering tools, we can identify bioenergy feedstock quantities with a given radius of any community.

Figure 7: Assessing Local Bioenergy Feedstock Potential



2.5.5 Biogenic product offtake

As mentioned in the "Community" and "Business Model" sections, Phase 1 selection criteria will include agreements to maximize local use of project biofuels and biochar. As a backstop, the technology provider (CARIBOU biofuels) has already obtained support from Suncor, a leading North American biofuel wholesaler, but a primary objective of this project will be to localize as many benefits of clean energy self-reliance as possible.

3 References

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Appendix 1 – Draft Budget

ARE - JBEI: Disadvantaged Community Bioenergy Project

Budget

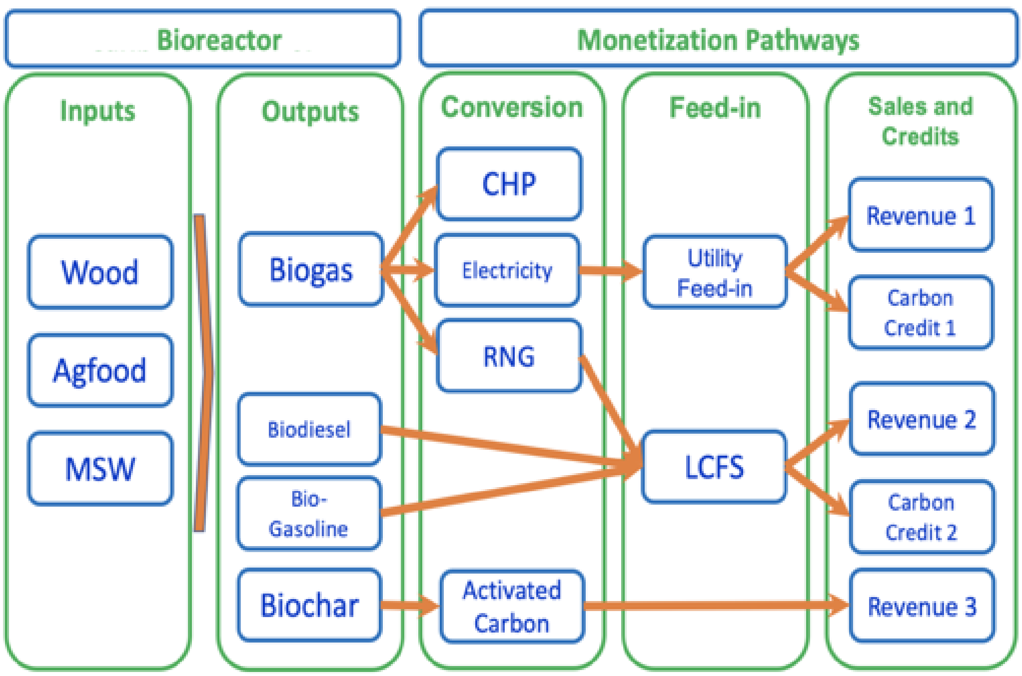
	Project Cost Allocation	Project Supervisor	Senior Economists	Senior Scientists	Community Outreach	Training Program	Admin Support	Legal Support	Organization and Training Material	ICT Expenses	Travel	Task Sub-totals
Phase 1	**Project year 1 - Statewide Assessment, System Design and Development**											
	1. Assessment of initial conditions	$ 57,000	$ 40,000	$ 40,000	$ 50,000		$ 50,000					$ 237,000
	2. Site selection for pilot communities	$ 20,000	$ 10,000	$ 10,000	$ 14,000		$ 14,000					$ 68,000
	3. Develop detailed organizational, hiring and training models	$ 10,000	$ 10,000	$ 10,000	$ 10,500	$ 10,000	$ 10,500					$ 61,000
	4. Consult with eligible communities and draft plans for pilots		$ 10,000	$ 10,000	$ 7,000	$ 10,000	$ 7,000					$ 44,000
	5. Designate 10 eligible communities for pilol implementation				$ -		$ -					
	Sub-total Year 1	**$ 87,000**	**$ 70,000**	**$ 70,000**	**$ 81,500**	**$ 20,000**	**$ 81,500**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 410,000**
Phase 2	**Project year 2 - Pilot Demonstration Projects**				$ -		$ -					
	1. Implementation of 10 local pilots, spatially diverse small (DAC) communities	$ 30,000	$ 20,000	$ 20,000	$ 24,500	$ 10,000	$ 24,500					$ 129,000
	2. Establish training program links - skills and curricular development plan		$ 10,000	$ 10,000	$ 7,000	$ 10,000	$ 7,000					$ 44,000
	3. Ongoing advisory support to eligible/interested local governments				$ -		$ -					
	a. Develop legal and financial framework	$ 20,000	$ 10,000	$ 10,000	$ 14,000		$ 14,000	$ 15,000	$ 1,000	$ 1,500		$ 85,500
	b. Secure feedstock and off-take agreements	$ 10,000	$ 10,000	$ 10,000	$ 10,500	$ 5,000	$ 10,500	$ 2,000	$ 1,000	$ 1,500		$ 60,500
	c. Recruit, train, and orient staff	$ 10,000			$ 3,500	$ 10,000	$ 3,500		$ 1,500	$ 1,500	$ 1,000	$ 31,000
	d. Site development				$ -	$ 10,000	$ -		$ 1,000	$ 1,500	$ 1,000	$ 13,500
	e.Technology adoption	$ 10,000	$ 10,000	$ 10,000	$ 10,500		$ 10,500	$ 1,000	$ 1,000	$ 1,500	$ 1,000	$ 55,500
	Sub-total Year 2	**$ 80,000**	**$ 60,000**	**$ 60,000**	**$ 70,000**	**$ 45,000**	**$ 70,000**	**$ 18,000**	**$ 5,500**	**$ 7,500**	**$ 3,000**	**$ 419,000**
	Project year 3 - Statewide Deployment				$ -		$ -					
	1. California Bioenergy Network (CalBEN) - a nonprofit corporation to				$ -		$ -					
	a. promote community bioenergy conversion				$ -		$ -		$ 2,000	$ 1,500	$ 1,000	$ 4,500
	b. active recruitment in targeted areas of need - goal of 100 members				$ -	$ 5,000	$ -		$ 2,000	$ 1,500	$ 1,000	$ 9,500
	c. advisory services on organization, technology, and finance				$ -		$ -	$ 15,000	$ 2,000	$ 1,500	$ 1,000	$ 19,500
	d. support member interests and provide cooperative services				$ -	$ 5,000	$ -		$ 2,000	$ 1,500	$ 1,000	$ 9,500
	e. policy outreach with state, local, and federal agencies				$ -	$ 5,000	$ -	$ 10,000	$ 2,000	$ 1,500	$ 1,000	$ 19,500
	f. facilitate member cooperation, including				$ -		$ -					$ -
	i. Labor training and placement coordination				$ -	$ 25,000	$ -					$ 25,000
	ii. Financial and legal service mediation				$ -		$ -	$ 15,000	$ 1,500	$ 1,000	$ 1,000	$ 18,500
	iii. Technology sharing and cross support				$ -	$ 5,000	$ -		$ 1,500	$ 1,000	$ 1,000	$ 8,500
	iv. Feedstock, fuel, and other trading				$ -		$ -		$ 1,500	$ 1,000	$ 1,000	$ 3,500
	v. Cooperative offtake contracting, utility purchasing				$ -		$ -	$ 10,000	$ 1,500	$ 1,000	$ 1,000	$ 13,500
	2. Roadmap for CalBEN expansion	$ 40,000	$ 15,000	$ 15,000	$ 24,500	$ 5,000	$ 24,500	$ 10,000	$ 1,500			$ 135,500
	3. Proposal for extension to agri-food and MSW	$ 20,000	$ 10,000	$ 10,000	$ 14,000	$ 5,000	$ 14,000	$ 5,000	$ 1,500			$ 79,500
	4. Project evaluation	$ 40,000	$ 10,000	$ 10,000	$ 21,000	$ 5,000	$ 21,000		$ 2,500			$ 109,500
	Sub-total Year 3	**$ 100,000**	**$ 35,000**	**$ 35,000**	**$ 59,500**	**$ 60,000**	**$ 59,500**	**$ 65,000**	**$ 21,500**	**$ 11,500**	**$ 9,000**	**$ 456,000**
	Project Totals	**$ 267,000**	**$ 165,000**	**$ 165,000**	**$ 211,000**	**$ 125,000**	**$ 211,000**	**$ 83,000**	**$ 27,000**	**$ 19,000**	**$ 12,000**	**$ 1,285,000**

Note: All figures provisional and subject to DOC consultation and approval.

Appendix 2 – Technoeconomic Analysis (TEA)

Technoeconomic analysis (TEA) is an empirical method for evaluating production and process systems ex ante, identifying and comparing alternative designs in terms of capital and operating costs, energy and mass balances, and other relevant technical and financial performance characteristics. In this attachment, we provide preliminary financial and system performance estimates in preliminary OPEX models and process diagrams for the proposed system. These data are based on rescaled observed data from the current CAL FIRE prototype, and will all be updated and validated during Phase 1 and Phase 2. Conservative assumptions are used for revenue potential from Carbon Credits ($0), Biochar, and waste management.

Figure A4.1: Carbon Conversion Market Pathways



Abbreviations: Combined Heat and Power (CHP), Renewable Natural Gas (RNG), Municipal Solid Waste (MSW), and Low Carbon Fuel Standard (LCFS).

Table A4.2: Preliminary TCA Income and Cost Model: Agricultural and forest biomass to Community Bioenergy Program

INCOME	QUANTITY	UNITS	UNIT VALUE	Annual
Biomass disposal cost savings	19,200	Tons	$25.00	$480,000
Carbon Credits	3,139	MT CO2e	$0.00	$ -
Biochar/Activated Carbon Sales	800	Tons	$20.00	$ 16,000
Liquid Fuel sales	454,869	Gallons	$1.50	$682,303
Surplus Electric Power	9,808,124	kWh	$0.07	$686,569
Total Revenue				**$1,864,872**
COST			**UNIT VALUE**	**Annual**
Capital Cost (IRG and generator)			**$1,500,000**	
Payment (20yr financing)		Interest	3.5%	$105,542
Floorspace			$50,000	$50,000
Insurance			$15,000	$15,000
Maintenance			$50,000	$50,000
Service Contract			$50,000	$50,000
Facility general budget			$150,000	$150,000
Compensation			$724,680	$724,680
Carbon Credit and Biofuel Mgmt			$50,000	$50,000
Total Cost				**$1,195,222**
Earnings				**$ 669,650**

Processing Assumptions	
Tons per hour	4
Hours per day	16
Days per year	300
Processing hours/yr	4,800

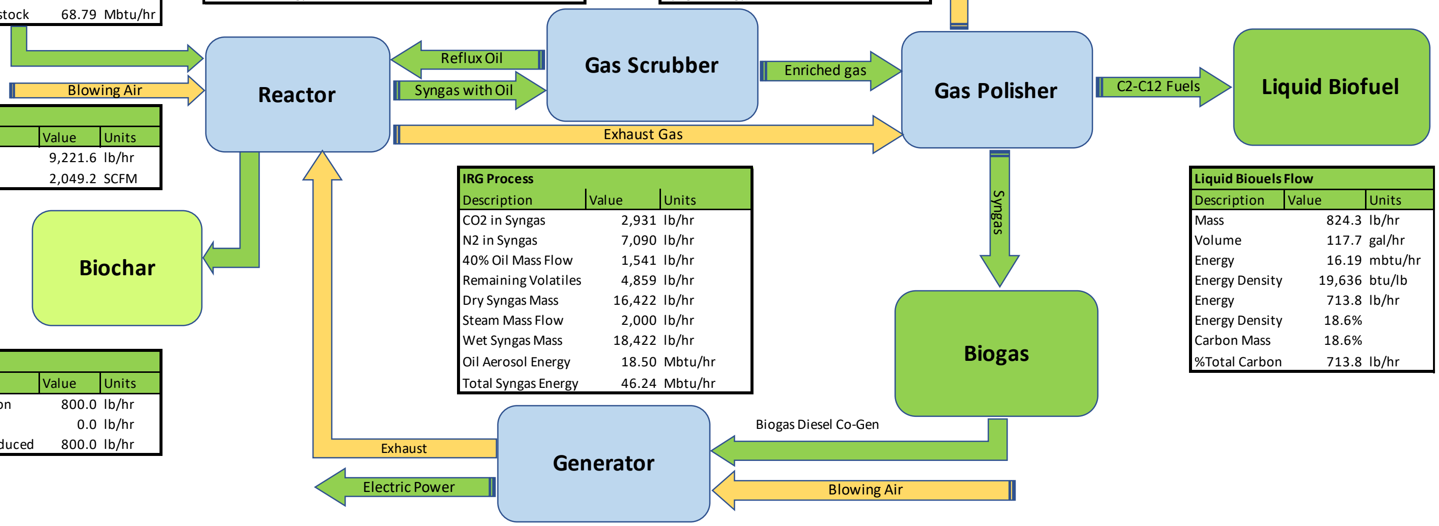
Financial Assumptions		
Biofuel price	$ 1.50	/gal
Carbon Credit	$ -	/MTCO2e
Cost of Capital	$ 1,500,000	
Reactor Cost	$ 1,000,000	

Energy Calculations		
Biofuel Output	454,869	Gal/yr
Diesel Equivalent	413,931	Gal/yr
Energy Content	54,708,304	MJ/yr
Electric Power Eqv	15,196,751	kWh/yr
CA Avg HH Elec	6,000	kWh/yr
CA Avg HH Heat	12,000	kWh/yr
Homes	844	per year

Emissions Calculations		
	7,847	MT/yr
Averted CO2e*	9.29	MT/HH
	3.13	MT/capita

* Includes biofuel and biochar mitigation.

Table A4.3: TEA Process Flow Diagram (data based on CAL FIRE CARIBOU prototype)



Feedstock

Description	Value	Units
Feed Rate Dry	8,000	lb/hr
Feed Rate Wet	10,000	lb/hr
Moisture	2,000	lb/hr
Feedstock HHV	8,598	btu/lb
Moisture	20.0%	
Volatile Matter	80.0%	
Fixed Carbon	20.0%	
Ash Content	0.0%	
Carbon	48.0%	
Hydrogen	5.5%	
Carbon	3,840.0	lb/hr
Hydrogen	440.0	lb/hr
Total Energy Feedstock	68.79	Mbtu/hr

Reactor Performance

Description	Value	Units
FC Combustion	800	lb/hr
Heat from Combustion	11.280	Mbtu/hr
% of Total Carbon Consumed	20.8%	
Heat Recovery around Shell	0.803	Mbtu/hr
Thermal Efficiency	83.6%	
Delta t lost around gasifier sh	0.0	F
FC Combustion	800	lb/hr

Reflux Oil

Description	Value	Units
Reflux Oil Mass Flow	1,541	lb/hr
Oil Energy Density	12,000	btu/lb
Reflux Oil Energy Flow	18.50	mbtu/hr

Exahust Gas Flow

Description	Value	Units
Mass	42,411	lb/hr
Net Energy	0.000	Mbtu/hr
Temperature	1,100	Deg F

C2-C5 Enriched Syngas Flow

Description	Value	Units
Dry Syngas	16,422	lb/hr
Steam Mass	2000.0	lb/hr
Syngas Energy	46.24	mbtu/hr

Flue Gas Flow

Description	Value	Units
Mass	42,411	lb/hr
Energy	-0.230	Mbtu/hr
Temperature	1,079.1	Deg F
Carbon	2,326	lb/hr
CO2	8,523	lb/hr

Reheat

Description	Value	Units
Flue Gas Heat Rec	230,000	btu/hr
Delta @Polisher	20.86	F

Blowing Air

Description	Value	Units
Mass Flow	9,221.6	lb/hr
Volumetric Flow	2,049.2	SCFM

IRG Process

Description	Value	Units
CO2 in Syngas	2,931	lb/hr
N2 in Syngas	7,090	lb/hr
40% Oil Mass Flow	1,541	lb/hr
Remaining Volatiles	4,859	lb/hr
Dry Syngas Mass	16,422	lb/hr
Steam Mass Flow	2,000	lb/hr
Wet Syngas Mass	18,422	lb/hr
Oil Aerosol Energy	18.50	Mbtu/hr
Total Syngas Energy	46.24	Mbtu/hr

Liquid Biouels Flow

Description	Value	Units
Mass	824.3	lb/hr
Volume	117.7	gal/hr
Energy	16.19	mbtu/hr
Energy Density	19,636	btu/lb
Energy	713.8	lb/hr
Energy Density	18.6%	
Carbon Mass	18.6%	
%Total Carbon	713.8	lb/hr

Biochar

Description	Value	Units
Biochar Production	800.0	lb/hr
Ash Production	0.0	lb/hr
Total Biochar Produced	800.0	lb/hr

Generator

Description	Value	Units
Generator Efficiency	35.0%	%
Generator Power	3,083.4	kW
Diesel Fueling Rate	30.0%	
Syngas Fueling Rate	70.0%	
Diesel Fueling Rate	3,156,126	btu/hr
Syngas Fueling Rate	7,364,295	btu/hr
Diesel Fueling Rate	160	lb/hr
Diesel Fueling Rate	23	gal/hr
Dry Syngas Fueling	15,597	lb/hr

Biogas Diesel Go-Gen

Description	Value	Units
Mass Syngas	15,597	lb/hr
Mass Steam	2,000	lb/hr
Net Energy	30	Mbtu/hr
Energy Dens	1,927	btu/lb
Carbon Mass	2,326	lb/hr
% Total Carbon	61%	

Blowing Air Flow

Description	Value	Units
C Mass	26,814	lb/hr
H Mass	11,318	lb/hr
Total Mass	49,571	lb/hr
Air-Fuel Ratio	3.18	:1

Generator Exhaust Flow

Description	Value	Units
Mass	42,411.1	lb/hr
Net Energy	11.358	Mbtu/hr
Temperature	1100	Deg F

Color Key

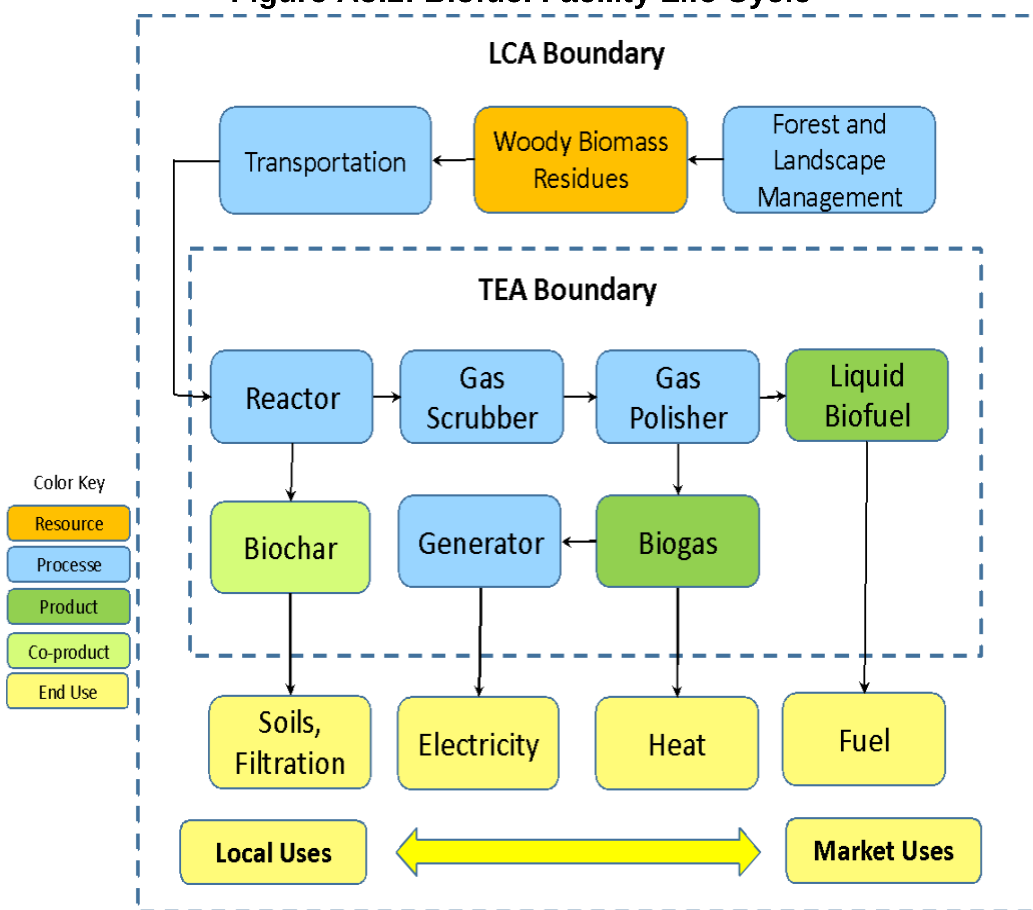
- Resource
- Process
- Product
- Co-product

Appendix 3 – Lifecycle Assessment (LCA) Calculations

Life cycle assessment extends TEA to take account of upstream and downstream linkages to the technology being considers, including feedstock supplies, output demand, and any associated economic and environmental spillovers. As such, LCA more fully accounts for the component and net impacts of a technology, but it also embodies more uncertainty regarding technical, behavioral, and market forces outside the engineering of the core technology design. This uncertainty is usually bracketed with scenario analysis, and that will be included in the comprehensive baseline and ongoing LCA assessments of Phase 1 and 2.

For this project's bioenergy technology, the LCA-TEA margin is relatively restricted, using local feedstock and producing biofuels mainly for onsite or local community bioenergy consumption with negligible waste products. These features dramatically reduce the scope and magnitude of indirect and induced GWP effects. Indeed, the primary impact outside the TEA boundary is displacement of fossil fuels, most of which are further handicapped by long supply chain linkages.

Figure A5.1: Biofuel Facility Life Cycle



These estimates rely on a series of important assumptions. Most are specified by USDA for this RFP, including the following:

1. Forest harvest carbon accounts are omitted. Presumably, these are assumed not to be differentiated across project applications.
2. Machinery and Infrastructure omitted. The RFP also notes that “The fuel system boundary may exclude emissions from manufacturing of capital goods and infrastructure.”
3. Transport estimates were based on USDA specification of 20T vehicle capacity and average round trips of 40km, based on our model of feedstock availability (Section 2.7.4).
4. Estimates of pre-treatment cost for chipping/shredding forest clippings were obtained from the forest feed-stock logistics model developed by Zamora-Cristales, Sessions, Boston & Murphy, 2015.
5. All process energy is derived in the TEA (Attachment 4).
6. For GWP assignment from process emissions, we adopt international LCA standards and guidelines, under which the release of biogenic carbon dioxide is treated as carbon neutral and does not impact the GWP assessment (BSI, 2011; EPA, 2011; ISO, 2006a; ISO, 2006b; WRI & WBCSD, 2011).
7. For biofuel, biochar, and electricity products, we assume carbon credit from fossil fuel substitution according to USDA assumptions in the RFP, weighted by energy content per MJ of bioenergy production, i.e.
    a. Diesel Life cycle EF = 77.00 gCO2e/MJ
    b. California grid electricity Life cycle EF – utility fossil gas = 71.00 gCO2e/MJ
    c. Biochar (produced at 1,000F) has 100 yr sequestration potential of 90%, following IPCC (2019): “Method for Estimating the Change in Mineral Soil Organic Carbon Stocks from Biochar Amendments”

It should be noted that the IRG technology developer, CARIBOU Biofuels, has already negotiated offtake agreements with a large California biofuel refiner (see support letter from Suncor in Attachment 10), but it is expected that most of the proposed facility outputs would be consumed locally. In addition to the immediate economic gains of a more self-reliant community energy system, this dynamic will maximize the local medium- and long-term public health benefits of displacing fossil fuels.

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College of Natural Resources

Table A5.2: Carbon and GWP Accounting

Process	Qty	/hr	Energy Flow (MJ)	Net Energy Produced	Carbon Content By process Co2e.g/MJ	Carbon Content All project Co2e.g/MJ	Carbon Content Percent	GWP Contribution Co2e.g/MJ	GWP Contribution Type of Displacement
Capital goods and Infrastructure	NA								
Harvest	8000	lb							
Transport	8000	lb	182.95	-	0.87	0.0053	0.0066%	0.0000572	
Pre-treatment	8000	lb	29.27	-	0.14	0.0001	0.0002%	0.0000002	
IRG fueling	800	lb	3,744.00	-	67.40	8.51	10.5%	0	Not displacing fossil fuel
Liquid fuel net	633	lb	12,126.00	12,126.00	60.14	24.59	30.4%	-23.38	Diesel/Gasoline equivalent
Biochar	800	lb	10,181.82	10,181.82	108.30	37.17	45.9%	-37.17	Sequestered
Electricity	3083	kW	31,710.86	7,356.09	43.10	10.69	13.2%	-9.37	CA Ave electicity equivalent
Totals			57,974.90	29,663.91		80.96	100.0%	**-69.93**	**Project GWP/MJ**