Closing the Loop: Reducing Greenhouse Gas Emissions and Sequestering Carbon from Organic Wastes through Regenerative Agriculture and Climate Smart Ethanol, Compost and Foods

I. Executive Summary

i. Contact information

PI: David Blume, CEO, Blume Industries and Whiskey Hill Farms, 371 Calabasas Road, Watsonville, California, 95076; 831-722-4455, farmerdave@permaculture.com
Proposal preparer: Dr. Ronnie D. Lipschutz, Senior Analyst, Sustainable Systems Research Foundation, 2861 Mission Street, 2961 Mission Street, Santa Cruz, 95060;8 31-588-7625; rlipsch@ucsc.edu.

ii. Project Partners/minority partners: Blume Industries partners with regional food processors and local jurisdictions by transforming their organic wastes to produce organic Climate Smart ethanol, compost, food, fertilizer and valuable byproducts recycled into distillation. Partners avoid landfill tipping fees, greenhouse gas emissions from landfilling of wastes, and costs of transporting waste out of county. Past and current waste providers include: the City of Watsonville, S. Martinelli & Company, Fruition Brewery, Royal Oaks Farms, Bay View Farms, Gizdich Ranch and Medina Berry Farm. Medina is the only minority partner involved in this project so far.

iv. Compelling need for the project: The United States faces two energy-related challenges over the coming decades. First, the United States consumes almost 3 billion barrels of gasoline annually, whose combustion generates more than more than one billion tons of carbon dioxide equivalent emissions. Second, according to the EPA (2020), the U.S. produces more than 100 million tons per year of food wastes. If landfilled, these wastes would generate 40 million tons of carbon dioxide equivalent (Nordahl, 2020). These food wastes could be converted into 38 million barrels of bioethanol plus compost and valuable byproducts, significantly reduce transport and landfill emissions and increase energy security, soil regeneration and carbon sequestration.

In California, moreover, there is an urgent need to address the organic waste diversion problem. California's Senate Bill 1383 mandates a 75% reduction in methane by 2023 from household, business and agricultural waste in landfills by 2023, primarily through composting. California disposed of almost 13 million tons of compostable organic waste in landfills in 2018. Waste management entities are required to provide households, businesses, farms and industries with individual organic waste containers, to collect these materials and to compost them. In many instances, composting facilities are located far from wastes' point of origin, and the final product is not returned to the community in which it was produced.

The Blume Distillation "Closing the Loop" project will transform 10,000 tons of locally generated organic waste per year into 500,000 gallons of climate smart bioethanol per year, as well as high value industrial green chemicals, dry ice, sanitizer and natural fertilizers for enhanced food production and regeneration of damaged soil. The project PI is David Blume, CEO of Blume Industries and Whiskey Hill Farms, two highly innovative operations. He is author of *Alcohol Can be a Gas! Fueling an Ethanol Revolution for the 21st Century* (2007).

v. Approach to minimizing transaction costs: Partners are responsible only for providing organic waste and not directly involved in the production or marketing of ethanol and associated products. The only direct transaction cost involved is moving the locally generated organic wastes from point of origin to the biorefinery. A significant fraction of these wastes will be moved by private and municipal waste management operators, the remainder by our own vehicles.

vi. Approach to reducing barriers to marketing products: The scale of the biorefinery is such that markets for climate safe products are primarily regional. We propose to create a marketing group composed of local waste providers and develop a regional brand for biorefinery products.

vii. Geographic focus: Monterey, Santa Cruz and San Benito Counties, California

viii. Project management capacity of partners and experience: David Blume is the owner of a 14-acre, organic farm which is home to 2 businesses, Blume Distillation (established 2008) and Whiskey Hill Farms (established 2013). One of the driving forces behind Whiskey Hill Farm is integration of plant-based fuel production with mechanical fuel production (see below). The two businesses generate millions of dollars in revenues per year. Project partners are all well-established and operate their own plants and farms.

II. Plan to pilot CSAF practices

a. CSAF practices employed

Goal: Build a pilot biorefinery with the capacity to transform 10,000 tons of organic wastes into 500,000 gallons per year of climate smart ethanol and ancillary products, 3 million gallons of liquid fertilizer, 50,000 pounds of organic food, fruit and cosmetic crops and valuable byproducts that are recycled into the biorefinery, compost and farm operation.

Problem: The United States faces two energy-related challenges over the coming decades. First, the U.S. consumes almost 3 billion barrels of gasoline annually, whose combustion generates more than one billion tons of carbon dioxide equivalent emissions (source). Second, according to the EPA (2020), the U.S. produces more than 100 million tons per year of food wastes. In addition, there is an urgent need to address the organic waste diversion problem as soon as possible in order to combat climate change. California's Senate Bill 1383 mandates a 75% reduction in methane by 2023 from household, business and agricultural waste in landfills by 2023, primarily through composting. Waste management entities are required to provide households, businesses, farms and industries with individual organic waste containers, to collect these materials and to compost them. In many instances, composting facilities are located far from wastes' point of origin, and the final product is not returned to the community in which it was produced.

If landfilled, the Nation's organic wastes would generate 40 million tons of carbon dioxide equivalent (Nordahl, 2020). The Nation's organic wastes could be converted into almost 100 million barrels of bioethanol plus compost, fertilizer and valuable byproducts (California disposed of almost 13 million tons of compostable organic waste in landfills in 2018, which could produce 12 million barrels of ethanol). Such biorefining could significantly reduce transport and landfill emissions associated with waste disposal, transport and fossil fuel emissions from producing corn ethanol and moving it across the country, and increase energy and food security, soil regeneration and carbon sequestration. The wastes could be transformed into valuable green products that recycle greenhouse gasses into the production process rather than releasing them into the air.

Our solution: Turn organic wastes into climate smart products, including green ethanol, fertilizer and compost, and climate-smart foods, fruits and cosmetics. This solution is being demonstrated by Monterey Bay Renewable Fuels, (MBRF), as Special Purpose Vehicle operated by Blume Industries (BI) in Watsonville, California. MBRF currently produces 10,000 gallons of climate smart bioethanol per year, as well as high value industrial green chemicals, dry ice, sanitizer and natural fertilizers for enhanced food production and regeneration of damaged soil. Over the past three years, the BI biorefinery has produced ethanol and other products from a variety of feedstocks (Table 1). Burning the bioethanol as fuel releases no additional carbon dioxide into the atmosphere, since it utilizes no fossil fuels in production. Converting the wastes reduces methane emissions by diverting them from landfills. The residual mash from the refinery is turned into carbon-sequestering compost and liquid fertilizer that will regenerate soil and feed crops. Carbon dioxide produced during fermentation is turned into dry ice, using energy generated by methane produced in a biodigester from fermentation mash, and is also used to feed greenhouse crops. Process heat and hot water from the biorefinery is stored and piped into greenhouses to warm the soil and keep the greenhouses war during the winter, reducing the costs and emissions from conventional methods of heating the structures with natural gas (Figure 1 and Table 2).

Table 1: Ethanol production from selected feedstocks

Feedstock	**Output (Gallons/ton**
Molasses from sugar refining	**65.5**
Spoiled strawberries	**8.2**
Apple pomace	**17.8**
Municipal wastes	39.4
Spoiled food processing wastes	40

Bold numbers are from actual experience; the others are from Huang, et al, 2015 and Gupta & Verma, 2015.

We propose to build and operate a 500,000-gallon per year pilot bioethanol refinery at Whiskey Hill Farms. BI will sell finished products to local cities and counties, industries, businesses and consumers. Non-recurring capital and other costs of the pilot biorefinery are roughly $6,500,000 and recurring costs are roughly $9,000,000 (see budget attachment for details). With a USDA grant, BI will be able to secure a 7-year cofinancing loan for 40% of project cost (see attached letter from Santa Cruz Community Bank). Over 15 years, the pilot will produce bioethanol at an average cost of $2.60 per gallon. Depending on the product mix—sanitizer, pharmaceutical and market grade alcohol, organic fertilizer liquor and fuel—gross revenues per gallon of alcohol produced ranges from $2.50 to $125. Assuming an average revenue of $15/gallon, simple project payback is one year (Table 2). Our goal is open a functioning facility by 2025. Figures 2 and 3 below show components and process flows for the 10,000-gallon pilot plant and proposed 500,000-gallon plant.

Figure 1: Process diagram for production of climate smart commodities

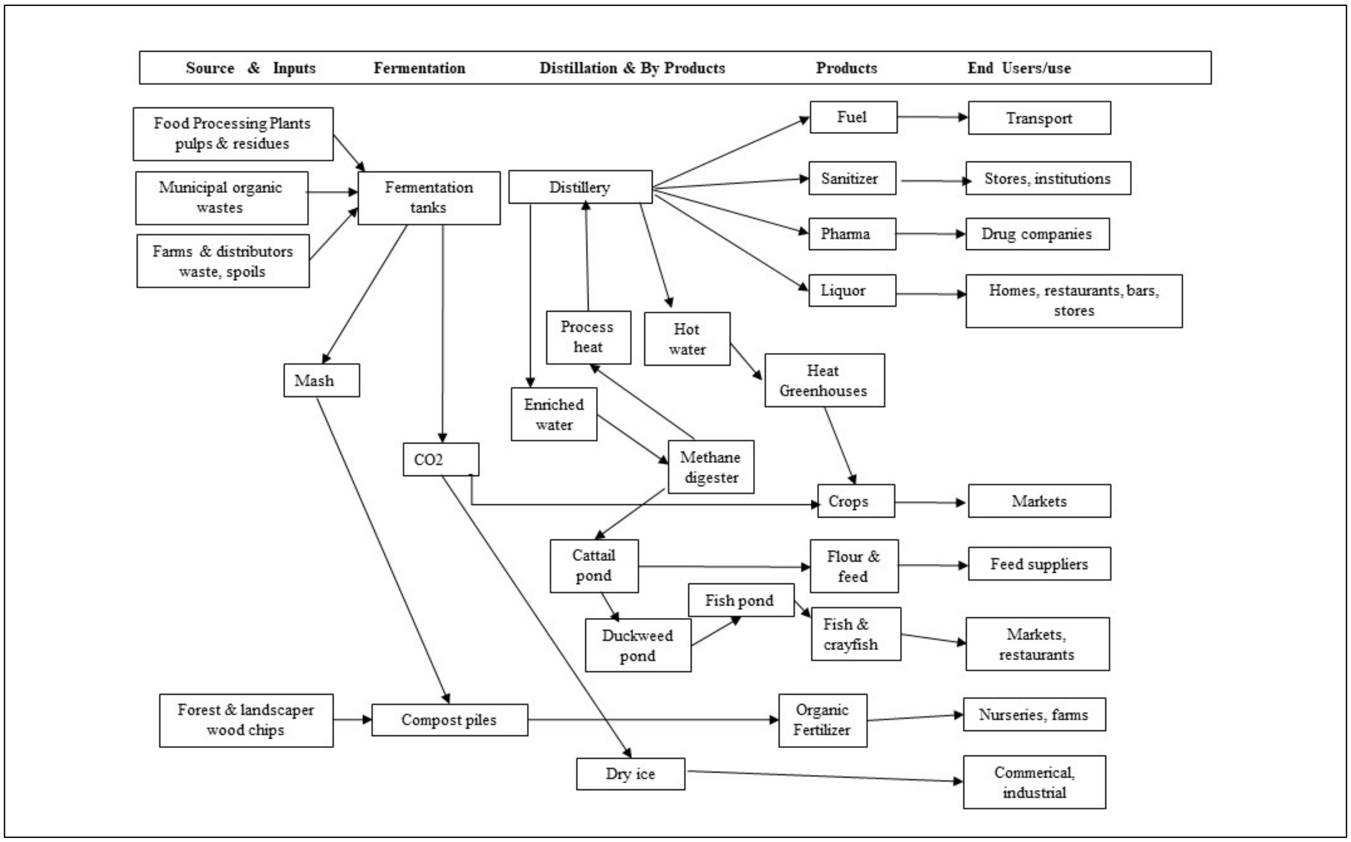


Table 2: Potential revenues generated by the pilot plant

Product	**U.S. Retail price ($/gal)**	**% of output**	**Gallons produced**	**Notional revenue****
Organic sanitizer	$100	10	50,000	$5,000,000
Pharma-grade alcohol	$80	20	100,000	$8,000,000
Liquor	$35	5	25,000	$875,000
Fuel	$6	65	325,000	$1,950,000
Fertilizer	$15	byproduct	50,000	$750,000
Total/year			500,000	$16,575,000
Production cost	($2.60)		500,000	($1,300,000)
Profit				$15,275,000
First year project cost				**$15,212,290**
Simple payback				12 months

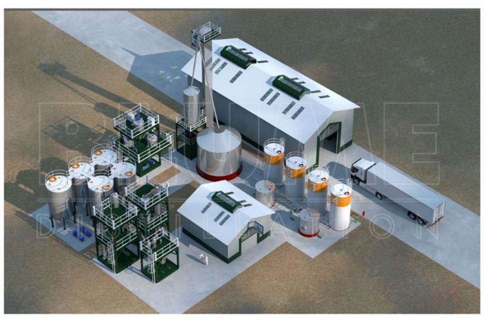
* For 500,000 gallon per year biorefinery. **Assumes production cost of $2.60 per gallon

Table 3: Bioethanol refinery & farm inputs, outputs & avoided emissions

Process Inputs	**Destination**	**Emissions/emissions avoided**
Food processing wastes, e.g. Apple pulp; fruit skins; nut hulls	Fermentation tanks	(CH_4 & CO_2)
Spoiled & returned crops, e.g., unsold & low quality produce	Fermentation tanks	(CH_4 & CO_2)
Municipal organic waste, e.g., Spoiled & leftover food; paper	Fermentation tanks & composing	(CH_4 & CO_2)
Wood chips & residues	Composting	(CO_2)
Fermentation		
Fermented liquids	Distillery	No net emissions
Off-gases (CO_2)	Feed crop production, dry ice & food-grade CO_2	No net emissions
Mash	Methane digestion pond	No net CH_4 emissions (bio-methane captured for process heat)
Distillation		
Bioethanol	Fuel, other products	(Landfill methane)
Digester residues	Organic compost & fertilizer	(CO_2 by sequestration, avoided by fertilizer emissions)
Enriched wastewater	Methane digester & ponds	(CH_4 captured for process heat, avoided nutrient runoff)
Hot water	Holding tank	No net emissions
Greenhouses & fields		
Cattail pond	Water purification & food/feed production	(CO_2, avoided nutrient runoff)
Duckweed pond	Duckweed for catfish & crayfish	(CO_2, avoided nutrient runoff)
Fish pond	Catfish & crayfish	(avoided emissions from commercial feed)
Food & fruit	Markets & consumers	(CO_2, avoided fertilizer emissions)
Agricultural residues	Composting	(avoided CH_4; CO_2)

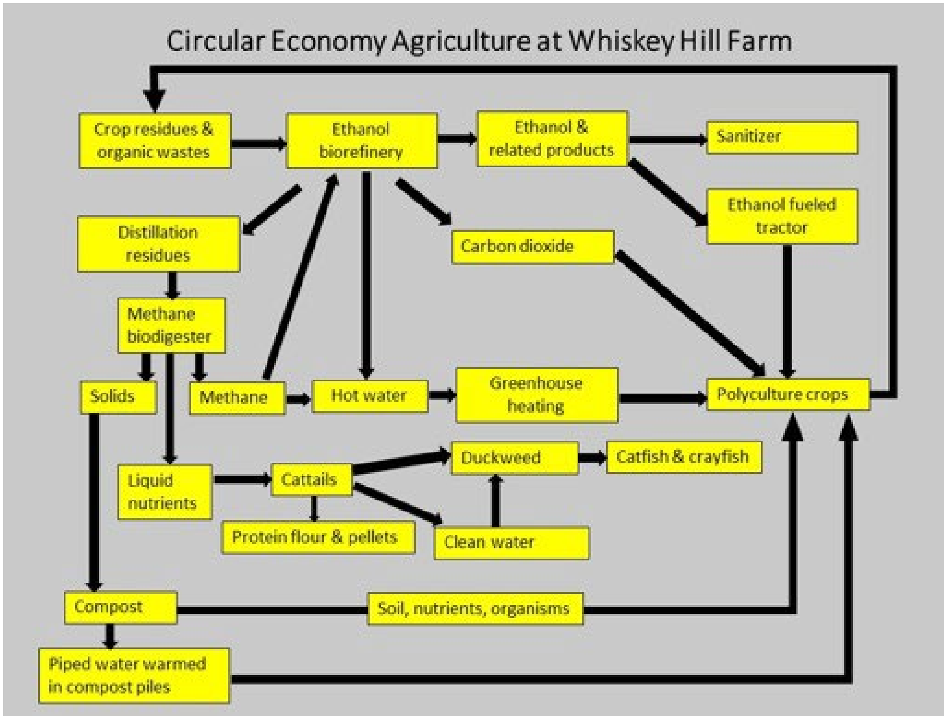
Figures 2a & 2b: Inside views of BI's 10,000-gallon biorefinery

Figures 3a & 3b: Conceptual drawings of the 500,000-gallon plant



BI operates at the same site and in conjunction with Whiskey Hill Farms, a 14-acre organic farm pioneer in developing a systems approach to agricultural technology by recycling and reusing various inputs and outputs in farming and demonstrating the technology and best practices of a circular, closed-loop food economy (see Figure 4). The organic by-products of the biorefinery are recycled into the farm's greenhouses to collect bio-based commercial CO2 and CH4 products, enhance crop growth, and grow in-house feed for aquaculture operationsh. Solid and liquid organic wastes are captured in a large methane digester. Liquid outputs are piped into ponds to grow cattails that are turned into feed pellets and other products while eliminating nutrient runoff. Digester solid residues are turned into rich compost which is then worked into the soil, increasing soil productivity and carbon sequestration capacity. Crops are grown with vertical polyculture techniques, with tall plants providing shade for low ones. Hot water from the distillation system is piped through drip irrigation lines to warm the soil and encourage growth. Carbon dioxide from the distillation process is also piped into greenhouses, via the same drip irrigation lines, to maintain high CO-2 levels that feed plants and increase growth.

Figure 4: The Circular Economy at Whiskey Hill Farms



Resource/feedstock: As noted above, the US produces more than 100 million tons of organic waste annually (approximately 0.3 tons per capita). Within Santa Cruz, Monterey and San Benito Counties, there are 775,000 residents, 18 cities, 36 unincorporated communities, 4,067 farmers, 2,340 farms, about 2,000 restaurants, 140 food distribution and processing companies and many other producers of organic wastes. If we conservatively assume the same per capita average organic waste for the three counties as for the US (surely higher in agricultural counties such as Santa Cruz, San Benito, and Monterey Counties),around 235,000 tons of organic wastes are produced every year, enough to supply more than 20 half million-gallon plants. Diverting that quantity of waste would eliminate nearly 92,000 tons of carbon dioxide equivalent annually. If this biomass were wholly converted into ethanol for vehicle fuel, CO2e reductions could be in the range of 63,750 tons of CO2e (bioethanol combustion does not generate any net additional CO2e). Additional emission reductions come from shorter shipping distances, elimination of fossil fuel use on farms growing crops for ethanol, and recycling of waste byproducts at the biorefinery (Table 4 shows where emissions take place and where they are internalized).

b. Recruitment plan: BI and WHF currently partner with a number of food processing firms, crop aggregators and breweries that provide organic waste to the bioethanol refinery and will sign up additional waste suppliers and municipalities. Suppliers will need to take no special actions by waste suppliers except to arrange for shipment to the bioethanol refinery site at Whiskey Hill Farms.

c. Technical assistance, outreach, and training: Not applicable.

d. Financial assistance plan: Not applicable.

e. Minority partner enrollment: At the present time, the only minority partner enrolled in Medina Berry Farm. However, the three counties are centers of food processing industry, the site of more than 2,000 farms and 51 cities and unincorporated communities, and the Spanish-speaking population approaches 50% of the total. Enrolling minority partners will not be difficult.

III. Monitoring, reporting & verification plan

i. Approach to GG benefit quantification: There are currently no emission quantification programs or models that address the full process described here. COMET and WARM do not explicitly address the greenhouse gas reduction benefits of bioethanol from organic wastes; GREET only analysis ethanol for vehicles. Consequently, we will develop an Excel model which builds on available models and research and operating data and real-time biorefinery production monitoring to calculate emission costs and benefits from inputs and outputs. The model input and output parameters are shown in Table 4. Process flow sensors installed throughout the biorefinery and farm will be used to validate model results.

ii. Monitoring of practice implementation: The climate safe practice involved here is diversion of organic wastes from landfill to the biorefinery. We will ask organic waste suppliers to keep records of tons of waste diverted from landfill to the biorefinery and tons of waste not provided to the biorefinery but diverted to landfill or industrial composting. We will assign staff to track supplies, diversions and benefits and ownership through supply chains (see below). Parameters are shown in Table 5.

iii. Verification of greenhouse gas benefits: We will contract with an independent 3rd party certifier to do the following:
a. Review and evaluate the basic life cycle analysis process model developed for this project, the steps involved in greenhouse gas emissions and benefits monitoring, measurement and benefits, and that measurement, analytical methods and data collection are adequate and properly implemented.
b. Apply relevant test methods and standards, calculations, modeling, and statistical methods to assess calculations of performance metrics and uncertainties.
c. Provide quality evidence that the technology is operational and reliable, and that observation of its operation supports the team claims that it can achieve specified levels of performance.
d. Ensure that performance and impact can be measured and evaluated, that the data collected and submitted to document the claimed technology performance are comprehensive and collected using acceptable and defensible methods, approaches, and test equipment, resulting in high quality data, that measurements and calculations are performed correctly; and
e. Review performance data collected during the observation period to ensure that the performance claims are supported by the observed process in operation.

Table 4: Parameters for modeling of emissions & quantification

Process	**Material inputs**	**GG gas outputs**	**Metrics**
Feedstock inputs	Waste vs. dedicated corn feedstock	Fossil fuel inputs to fuel crop production	Emissions per ton of feedstock
Transportation of product to bioethanol refinery	From food waste production site to refinery vs. corn ethanol	Fossil fuel inputs to moving feedstock & product	Emissions/ton-mile; gallons of conventional fuel consumed
Diversion of wastes	To plant vs landfill	Reductions in CH4 & other gases	Emissions/ton
Fermentation	Emissions produced & captured for reuse	Bio-CO2 captured;	Emissions/ton
Distillation	Ethanol produced vs. corn	GHG captured	Emissions per gal & ton of fuel and feed byproduct
Byproducts			
Mash	Fermentation residues	Tons of Carbon sequestered in soil	Tons C sequestered per ton of residue
CO2	CO2 captured	Feed crops; dry ice; compressed CO2	Bio-CO2 released, consumed
Hot Water	CH4	Heated process water	Tons of CH4 offset
Ponds			
Digester Pond	CH4 from mash	Captured for process heating	CH4 captured vs. released in tons
Cattail pond	CO2	Flour & feed	Tons C and nutrients captured/sequestered
Duckweed pond	CO2	Fish food	Tons C and nutrients captured/sequestered
Commodities			
Fuel	Production inputs & combustion in vehicles	Bioethanol vs. gasoline	Emission offsets per gallon & ton
Sanitizer & pharma-grade alcohol	Emissions from containers & end use	Compared to alcohol sources	Packaging; evaporation of bioethanol
Liquor	Alcohol content & digestion	Compared to other sources	
Dry ice	C sequestered	Compared to other sources	Emission reductions/ton
Compost	C sequestered	Vs. landfill	C/ton
Fertilizer	C sequestered	Vs. landfill	C/ton
Crops	C sequestered		C/ton
Hot water from aerobic compost	CH4 burned	Vs. natural gas	CO2 reduction per unit
Packaging			
Shipment of commodities	Emissions from transport to end-user	Alcohol vs. gasoline	Emissions/ton-mile
Disposition	Mash residues	Landfill vs. compost	Emissions/ton

Table 5. Template for Measurement & Monitoring of practice implementation (diversion of organic wastes & reporting & tracking of benefits

	Quantity	CO2e reduction Benefits	Custodian	Longevity of benefits
Tons of organic waste feedstock diverted per year to biorefinery				
Total number of organic waste suppliers				
Tons of waste per supplier				
Tons of waste for other treatment				
Value of products				
Reductions per dollar expended on plant				

Table 6: Tracking GHG benefits & ownership through supply chain & chain of custody

Supply chain step	GHG benefit	Notional owner
Diversion from landfill	GG emissions avoided	Feedstock producer or supplier
Distillation	GG emissions captured & recycled	Blume Industries
Composting	Carbon sequestered	Blume Industries
Crops	Hot water energy, carbon sequestered	Blume Industries
Products	GG emissions avoided by displacing alternative production methods	Blume Industries
Shipping & distribution	GG emissions avoided if bioethanol replaces gasoline	Shipping & distribution companies
Retailers & consumers	GG emissions avoided in selling & buying climate safe products	Customer
Disposal	GG emissions avoided by recycling & diversion	Waste Haulers

IV. Plan to develop & expand markets

i. Partnerships designed to market CS commodities: Beginning in March 2020, in response to the PPP needs triggered by the COVID-19 pandemic, BI shifted its primary bioethanol production stream from fuel to sanitizer. The value per ounce of sanitizer compared to fuel is enormous (Table 6), although the long-term market for the product remains uncertain. The pilot plant can produce ethanol for both distilled spirits and liquid fertilizer in volume. The market for the project's climate smart products and byproducts is primarily regional and will be sold through local distributors to local markets and jurisdictions to fuel their vehicles. Food crops and other products will be branded as "Climate Safe!" ("greenhouse emission free").

ii. Plan to track commodities through supply chains: BI will take ownership of the initial carbon emission credits from waste diversion and composting and may split them with partner waste suppliers. Subsequent emission reductions in the supply chain due to sale of climate smart commodities will be transferred to the purchaser at the time of commodity transfer, in proportion to the post-production volume or value of product transferred. The initial supply of commodities produced by the biorefinery and farm are expected to be consumed in the tri-county area, making it relatively straightforward to keep records and track transactions.

iii. Estimated economic benefits for participating producers, including market returns. Participating waste suppliers will realize initial economic benefits from avoiding disposal and tipping fees paid to waste collection companies and landfill operators. They will also be able to advertise their climate safe practices and products to customers. Under some circumstances, BI may have to pay suppliers for their organic wastes. If the pilot is successful, reproducible and scalable (all of which we anticipate), there may be competition for waste for which biorefineries will have to pay.

iv. Post project potential: As noted above, a combination of factors—emissions reductions, organic waste diversion, bio-carbon and bio-methane cycling, nutrient runoff diversion, fertilizer production offsets and energy supply—make this pilot system and process replicable and scalable. Although various programs seek to reduce organic waste volumes—especially food waste—it is unlikely that they will be eliminated, making future supply fairly reliable. Every food processor, city and county in the nation generates organic wastes and will be facing increasing pressure to divert them from landfills. Many of these jurisdictions will send the wastes to relatively inefficient industrial-scale composting facilities, which will not take advantage of their full value. Once replicability has been established, the potentially high returns on products and byproducts will make these ethanol bio-refineries especially attractive to investors, jurisdictions, waste haulers and farmers. The scale of 500,000-5,000,000 gallons for a bio-refinery and the rapid payback make them practical in urban and rural areas. We anticipate that plants on the lower end of the scale will be attractive to countries across the Global South.