Truckee Bioenergy Feasibility Study
Final Report Summary

Prepared by:
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Truckee Tahoe Airport District Board Meeting
28 February 2024

Topics

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2. Feedstock Assessment
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Project Overview

- Seeking to utilize locally generated biomass as an alternative to onsite decay, open burning, and expensive disposal
- Partnership w/Town of Truckee, Truckee Fire, Truckee Donner PUD
- Prior scoping study identified two candidate utilization pathways
  - Biomass Power
  - Combined Heat and Biochar (CHAB)
- Air curtain burner (ACB) w/EV charging option added during FS
- Biochar market study conducted to assess value of co-products

Feedstock Assessment

- Recoverable green waste produced from multiple sources
  - Residential Programs
  - Vegetation Projects
  - Defensible Space
  - Forest Fuels Reduction
- 13,000 BDT/year produced by project partners combined
- 46% left to decay onsite; 11% burned in open combustion
- 43% delivered to ERL; $15/cy tipping fee = $98/BDT

Feedstock Assessment

Town of Truckee	Cubic Yards	Green Tons	Bone Dry Tons		Disposal Cost	
Residential Programs[1]	21,577	4,046	3,034	*98%*	$ 299,128	
Vegetation Projects	416	78	59	*2%*	$ 5,166	
2022 Total	**21,993**	**4,124**	**3,093**	***100%***	**$ 304,294**	
Annual Average (2020-2022)	**25,440**	**4,770**	**3,578**		**$ 270,703**	***28%***
[1] *Includes green cart/dumpster pick-ups and self-haul drop-offs.*						
Truckee Fire	**Acres**	**Green Tons**	**Bone Dry Tons**		**Disposal Cost**	
Defensible Space[2]	-	2,500	1,875	*22%*	$ 235,000	
Fuels Reduction[3]	600	9,000	6,750	*78%*	$ 15,000	
Annual Projected	**600**	**11,500**	**8,625**	***100%***	**$ 250,000**	***67%***
[2] *Includes 1,000 green tons/year from Tahoe Donner residential programs.*						
[3] *Assumes 15 green tons/acre @ 25% moisture; includes 100 acres/year at Tahoe Donner.*						
Truckee Airport	**Acres**	**Green Tons**	**Bone Dry Tons**		**Disposal Cost**	
Mastication[4]	20	300	225		-	
Annual Projected	**20**	**300**	**225**		**-**	***2%***
[4] *Assumes 15 green tons/acre @ 25% moisture; based on 2021 projection.*						
Truckee Donner PUD	**Cubic Yards**	**Green Tons**	**Bone Dry Tons**		**Disposal Cost**	
Removal[5]	3,500	656	492		-	
Annual Projected	**3,500**	**656**	**492**		**-**	***4%***
[5] *Includes material currently chipped, used for firewood, and taken to lumber mills.*						
PARTNER TOTAL			**12,920**	**BDT/year**		***100%***

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Siting and Utilities

- Prior scoping study focused on building cluster near Airport
  - Potential for microgrid; relatively low heating load density
  - TTAD consultant study identified significant site challenges
- Focus shifted to Truckee Public Service Center (PSC) site
  - Public Works Department and Animal Services buildings
  - Future zero-emission bus (ZEB) charging and storage facility
- Increased resiliency for Truckee public transit system
- 3 times higher annual heating costs versus Airport site

Siting and Utilities

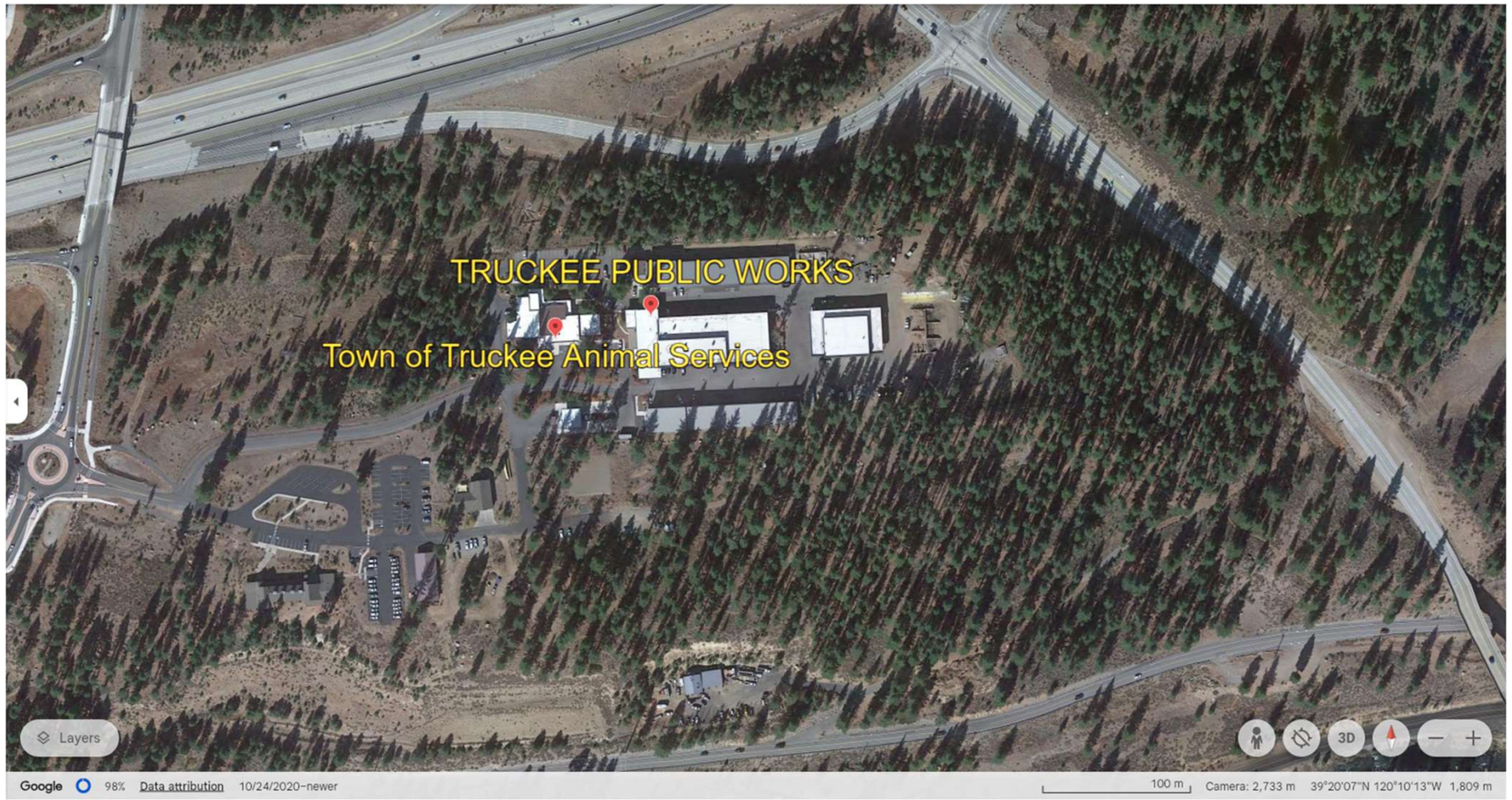

Image credit: Google Earth

Siting and Utilities

TRUCKEE PUBLIC SERVICE CENTER - ANNUAL UTILITIES								
Month	**Natural Gas**			**Electricity**			**Total Cost**	**Percentage**
	MMBtu		*$*	*kWh*		*$*	*$*	*%*
Oct-21	468	$	6,617.59	59,200	$	9,596.71	$ 16,214.30	6.4%
Nov-21	901	$	12,314.15	65,160	$	10,265.69	$ 22,579.84	9.0%
Dec-21	1,512	$	19,767.60	64,600	$	10,841.66	$ 30,609.26	12.1%
Jan-22	1,617	$	21,998.41	65,520	$	11,053.98	$ 33,052.39	13.1%
Feb-22	1,378	$	18,715.67	67,960	$	11,393.49	$ 30,109.16	11.9%
Mar-22	984	$	12,893.73	76,120	$	12,602.36	$ 25,496.09	10.1%
Apr-22	796	$	10,656.52	59,160	$	10,114.89	$ 20,771.41	8.2%
May-22	538	$	8,491.54	57,240	$	9,743.05	$ 18,234.59	7.2%
Jun-22	235	$	4,122.85	62,680	$	10,395.76	$ 14,518.61	5.8%
Jul-22	166	$	2,785.28	62,400	$	10,323.60	$ 13,108.88	5.2%
Aug-22	124	$	2,099.77	71,720	$	11,852.81	$ 13,952.58	5.5%
Sep-22	220	$	3,978.81	54,120	$	9,454.34	$ 13,433.15	5.3%
Total	**8,938**	**$**	**124,441.92**	**765,880**	**$**	**127,638.34**	**$ 252,080.26**	**100.0%**

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Unit Cost of Energy: $13.92/MMBtu (natural gas); $0.167/kWh (electricity)

Design Options

- Three bioenergy system options evaluated for PSC site
  - **Option 1A** - Combined Heat and Power (CHP)
  - **Option 1B** - Biomass Power Only
  - **Option 2** - Combined Heat and Biochar (CHAB)
- Both power-led options could support EV charging and microgrid
- CHAB system could serve small hydronic district heating loop
- PSC site will not support feedstock processing and bulk storage

Option 1A – Combined Heat and Power

- 2 x 1 MWth biomass boilers
- 2 x 75 kWe ORC generators
- Grid-connected or behind-the-meter power
- Supplemental building/slab hydronic heating
- 4,200 BDT/year feedstock (wood chips)
- Key advantages – most robust technology; meets SB 1383 target
- Key challenges – grid interconnection; net metering agreement

Option 1A – Combined Heat and Power

Image credit: ElectraTherm Inc.

Image credit: Viessmann Manufacturing Company Inc.

Option 1B – Biomass Power Only

- Air curtain burner + 100 kWe ORC generator
- Four (4) behind-the-meter EV charging stations
- Battery storage allowing overnight EV charging
- 13,000 BDT/year feedstock (trees/limbs/chips)
- Requires two full-time operators and 70,000 sf footprint
- Key advantages – avoided disposal at ERL; modular design
- Key challenges – high labor costs; 20 mph max wind speed

Option 1B – Biomass Power Only

Image credit: Air Burners, Inc.

Option 2 – Combined Heat and Biochar

- 0.6 MWth modular pyrolysis system
- Primary output is biochar (25% by weight)
- Supplemental building/process heating
- 3,300 BDT/year feedstock (wood chips)
- 830 tons/year biochar (material sales + carbon credits)
- Key advantages – carbon sequestration; highest revenues
- Key challenges – tightest fuel specification; evolving markets

Option 2 – Combined Heat and Biochar

Image credit: PYREG GmbH

Air Emissions

- Study estimated both GHG and criteria pollutant emissions
- All three options offer significant reductions in GHG emissions
  - Avoided emissions compared with business-as-usual pathways
  - Carbon sequestration in the form of biochar (Option 2 only)
- Options 1A and 2 utilize advanced emissions control systems
- Met with Northern Sierra Air Quality Management District
  - Generally very supportive of all three biomass utilization options
  - Will work collaboratively to permit any of the proposed systems

GHG Emissions

GHG EMISSIONS REDUCTION		Option 1A Boiler + ORC Generator		Option 1B ACB + ORC Generator		Option 2 Pyrolysis System	
Source	Units	Basis	MTCO2e/yr	Basis	MTCO2e/yr	Basis	MTCO2e/yr
Avoided Natural Gas Use	MMBtu/yr	2,253	119	-	-	2,253	119
Avoided Grid Electricity Use	kWh/yr	661,693	131	182,500	36	-	-
Avoided Landfill Disposal	BDT/yr	-	-	555	117	-	-
Avoided Onsite Decay	BDT/yr	2,752	3,120	6,753	7,656	1,852	2,099
Avoided Open Combustion	BDT/yr	1,448	210	1,448	210	1,448	210
Avoided Transportation	ton-mile	-	-	566,198	103	-	-
Biochar Sequestration	ton/yr	-	-	-	-	829	2,015
Total Emissions Reduction			**3,581**		**8,122**		**4,444**
Additional Electricity Use	kWh/yr	342,720	-	-	-	288,000	57
Additional Fossil Fuel Use	gal/yr	-	-	3,076	31	2,466	14
Total Emissions Increase			**0**		**31**		**71**
Net Annual GHG Reduction			**3,581**		**8,091**		**4,373**
Net Life-Cycle GHG Reduction			**89,513**		**202,271**		**109,319**

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Avoided onsite decay is largest source of available GHG emissions reductions

GHG Emissions

- Option 1B provides the greatest net reduction in GHG emissions
- Life-cycle GHG reductions for all three options would exceed annual emissions from all passenger vehicles registered in Truckee

Passenger Vehicles Per Truckee Household			
Number of Vehicles	Households[1]		Total
1	15%	886	886
2	42%	2,549	5,099
3	34%	2,040	6,119
4	10%	601	2,404
	100%	**6,070**	**14,508**
Passenger Vehicle GHG Emissions		**66,737**	**MTCO2e/yr**

[1] *https://datausa.io/profile/geo/truckee-ca*

Criteria Pollutant Emissions

	ESTIMATED CRITERIA POLLUTANT EMISSIONS FOR TRUCKEE BIOENERGY GENERATION						
	OPTION	**UNITS**	**PM**	**NOx**	**ROG**	**CO**	**SO2**
1A	**Boiler System**						
		lb/MMBtu	0.04	0.12	0.02	0.25	0.02
		lb/hr	0.27	0.83	0.12	1.70	0.17
		lb/day	6.53	19.91	2.77	40.80	4.08
		ton/yr	1.19	3.63	0.51	7.45	0.74
1B	**Air Curtain Burner**						
		lb/MMBtu	0.15	0.12	0.11	0.31	0.01
		lb/hr	10.40	8.00	7.20	20.80	0.80
		lb/day	104.00	80.00	72.00	208.00	8.00
		ton/yr	18.98	14.60	13.14	37.96	1.46
2	**Pyrolysis System**						
		lb/MMBtu	0.12	0.22	0.01	0.08	0.00
		lb/hr	0.62	1.14	0.03	0.42	0.01
		lb/day	14.88	27.36	0.72	10.08	0.24
		ton/yr	2.72	4.99	0.13	1.84	0.04
	NSAQMD						
	Level A	lb/day	<79	<24	<24	-	-
	Level B	lb/day	79-136	24-136	24-136	-	-
	Level C	lb/day	>136	>136	>136	-	-

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Emissions levels for Options 1A and 2 are mostly well below NSAQMD thresholds

Financial Analysis

- Detailed modeling produced operating and capital cost estimates for each bioenergy option
- 25-year pro forma financial analyses developed based on CAPEX and annual OPEX estimates
- Sensitivity analysis conducted to evaluate fuel price sensitivity
  - Wood fuel
  - Natural gas
  - Electricity

OPEX Summary

OPERATING EXPENSE SUMMARY		Option 1A Boiler + ORC Generator	Option 1B ACB + ORC Generator	Option 2 Pyrolysis System
Biomass Feedstock Cost	$/yr	$ 40,000	$ -	$ 30,000
Natural Gas Utility Offset	$/yr	$ (30,000)	$ -	$ (30,000)
Electric Utility Offset	$/yr	$ (170,000)	$ (30,000)	$ -
Biochar Sales Revenue	$/yr	$ -	$ -	$ (200,000)
System O&M Cost	$/yr	$ 180,000	$ 400,000	$ 290,000
Net Annual Operating Cost	**$/yr**	**$ 20,000**	**$ 370,000**	**$ 90,000**
Avoided Disposal Costs	$/yr	$ -	$ (560,000)	$ -
Avoided SB 1383 Procurement	$/yr	$ (30,000)	$ -	$ -
Carbon Credit Sales Revenue	$/yr	$ -	$ -	$ (210,000)
Value of Co-Benefits	**$/yr**	**$ (30,000)**	**$ (560,000)**	**$ (210,000)**
Net Community Benefit	**$/yr**	**$ (10,000)**	**$ (190,000)**	**$ (120,000)**

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Net community benefit is relative to business-as-usual green waste disposal pathways

CAPEX Summary

CAPITAL EXPENSE SUMMARY	Option 1A Boiler + ORC Generator	Option 1B ACB + ORC Generator	Option 2 Pyrolysis System
Direct Cost	$ 6,745,000	$ 2,265,000	$ 5,335,000
Indirect Cost	$ 1,214,100	$ 407,700	$ 960,300
TOTAL COST	**$ 7,959,100**	**$ 2,672,700**	**$ 6,295,300**
Contingency	$ 1,989,775	$ 534,540	$ 1,888,590
RISK-ADJUSTED COST	**$ 9,948,875**	**$ 3,207,240**	**$ 8,183,890**

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Bioenergy system with lowest initial CAPEX has highest annual OPEX and vice versa

ROI Summary

PAYBACK AND ROI SUMMARY	Option 1A Boiler + ORC Generator	Option 1B ACB + ORC Generator	Option 2 Pyrolysis System
25-Year Net Present Value (NPV)	$ 53,035	$ 1,662,029	$ 720,555
Discounted Payback Period (Years)	**24**	**6**	**14**
Discounted Return on Investment (ROI)	12.3%	169.3%	56.3%
Annualized Return on Investment (ROI)	**0.5%**	**4.0%**	**1.8%**

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All three options produce positive returns on investment but with very different payback periods

Sensitivity Analysis

- Options 1A and 1B on the edge of financial viability
  - Both options extremely sensitive to wood fuel unit cost
  - Increasing feedstock cost by $10/BDT returns negative NPV
- Option 1B completely insensitive to offset utility rates
- Option 2 has most flexibility in terms of energy prices
  - Produces positive NPV regardless of offset utility rates
  - Could withstand $10/BDT increase in feedstock unit cost

Biochar Markets

- Economic viability of Option 2 depends almost entirely on sale of biochar and associated carbon sequestration credits
  - 830 tons/year of high quality biochar from pyrolysis system
  - $400k in annual sales revenue from biochar + carbon credits
- Study included supplemental biochar market evaluation
- Independent markets for biochar material and carbon credits
- Material markets are regional; carbon markets are global

Material Markets

- Biochar commonly used as soil and compost amendment
  - Enhanced soil moisture and nutrient retention
  - Reduced odors and GHG emissions in compost
- Additional uses for biochar increasing steadily
  - Water/air filtration medium
  - Erosion control medium
  - Building/paving materials
  - Additive manufacturing (3D printing)

Material Markets

- Biochar material market faces significant uncertainty with respect to quality, pricing, supply chains, and end uses
- Quality and thus value of biochar co-products largely determined by bioenergy technology and feedstock composition
- Lack of standardized biochar products and established distribution networks could continue to hinder near-term market stabilization
- Two primary options for offtake: 1) developing producer-to-buyer relationships, and 2) using an experienced biochar broker

Carbon Markets

- Sale of carbon dioxide removal (CDR) credits in voluntary market likely to offer greatest economic value from biochar
- Typically sequesters about 2.5 tons CO2 per ton of biochar
- Durable carbon sequestration is a tradable commodity
  - 5.3 million metric tons of CDR credits sold to date
  - $2.1 billion in cumulative market value (since 2019)
- Value of CDR credits serves as hedge against uncertainty in biochar material markets

Carbon Markets

- Leading voluntary carbon market for biochar is Puro.earth
- Trades exclusively in carbon removal rather than offset credits

Domestic Biochar CORC Sales (Active Certified Producers)[1]					
	2021	**2022**	**2023**	**Total**	**Price**
Oregon Biochar Solutions (OR)	4,323	1,602	5,209	**11,134**	$205
Wakefield Biochar (GA)	0	0	3,424	**3,424**	$190
American BioCarbon (LA)	0	0	632	**632**	$135
Total (MTCO2/year)	**4,323**	**1,602**	**9,265**	**15,190**	**$199**

[1] *Actual sales reported on Puro.earth platform; current prices in USD/MTCO2 with weighted average total.*

ROI model conservatively assumes $110/MTCO2; $220/MTCO2 offers same payback with no material sales

Feasibility Summary

- **Economic Impacts:** positive NPV; trade-off between lower CAPEX and higher OPEX; significant wood fuel price sensitivity
- **Environmental Impacts:** 60-99% reduction in criteria pollutants; net GHG reductions could exceed 100k metric tons over 25 years
- **Social Impacts:** community-scale project could serve as catalyst for further development of circular bioeconomy in Truckee

Further Analysis

- Value engineering and/or siting studies may be needed to improve economic performance of one or more options
- Significant additional benefits may be available from hybrid design
- Combined Heat, Power, and Biochar (CHPB) system
  - Higher annual operating revenue from sales of additional CDR credits
  - Qualifying for 30% federal Investment Tax Credit (ITC) for CHP systems
  - Greater GHG emissions reductions from increased biomass utilization
- Bioenergy presents compelling opportunity for Truckee partners

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