

Biochar Demonstration Project- Economic Analysis

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I. Introduction

The Redwood Forest Foundation Inc. (RFFI) with funding from the State of California Department of Water Resources (DWR), the USDA Natural Resources Conservation Service (NRCS), the Vera Long Foundation, and small grants from the U.S. Forest Service and Community Foundation of Mendocino County, conducted a demonstration project to determine if biochar, produced from waste woody biomass (primarily tanoak), could create enough revenue to cover all costs associated with the biomass removal, processing, conversion to biochar, sales and overhead. This document shows the results of the Economic Analysis created from real data derived from the RFFI Biochar Demonstration Project.

II. Project History

Biochar Demonstration Project development, fundraising, and planning began in 2009 with the leadership of a grassroots organization called the Mendocino County Woody Biomass Working Group (WBWG). The project was developed through a series of community outreach events asking the local community for ideas about dealing with excess woody biomass and the associated negative impacts in forests in the Redwood Region.¹ The community specifically advocated for small-scale biomass utilization technologies.

After completing an initial cost versus revenue analysis on several potential small scale technologies that convert biomass to an array of value added products including, electricity, wood bricks and pellets, the WBWG found that converting biomass to biochar using the Biochar Solutions T-1000 thermal conversion unit could potentially be economically viable. Biochar is wood carbon that is created through a process called pyrolysis where biomass is heated in the absence of oxygen. Wood gasses are released leaving black, charcoal looking, wood carbon. Biochar has an array of benefits for the soil, water conservation and carbon sequestration and has a high value compared to the other value added products that were analyzed².

In 2010, RFFI volunteered to implement the communities' plan in the Usal Redwood Forest, a 50,000-acre forest purchased by RFFI in 2007 for the purpose of establishing community-based forests that provide both critical habitat for increased biodiversity and improved regional economic vitality. Thus, the Redwood Forest Foundation Inc., (RFFI) Biochar Demonstration Project was officially launched. The Biochar Conversion Unit was delivered

¹ For more information visit <http://rffi.org/Biochar.html>

² For more information about the benefits of biochar visit <http://rffi.org/Biochar.html>

to Mendocino County in October 2014.. Data presented in this analysis is based on 18 days of operation from October 2014 through February 2015.

III. Project Methodology

- * Excess woody biomass was removed from an overcrowded tanoak dominated forest stand in the Usal Redwood Forest in November 2013. The tanoak was removed based on guidelines created by Greg Giusti of the U.C. Cooperative Extension to maximize biodiversity in the forest stand. The guidelines are included in Giusti's 2014 Literature Review, "Ecological Impacts of Biomass Removal in North Coast Forests", which can be found at: http://rffi.org/Documents/Ecological_Assessment_of_Biomass_Thinning_in_Coastal_Forests.pdf
- * Tanoak removed from the stand was cut to 15-foot lengths and stacked at the landing adjacent to the demonstration plot from which the biomass was removed. Log length and pile height were determined in coordination with a chipping company to meet their equipment specifications. (At the time of log deck creation, RFFI planned to have the biochar conversion unit located in forest. Whole logs were to be chipped at the landing, then transported less than a mile to be processed.)
- * Excess woody biomass was transported to the conversion unit location for processing. RFFI decided to initially locate the biochar conversion unit at an old mill site in Branscomb, CA, before moving the unit into the forest in order to evaluate fire safety and other operating constraints. Because the tanoak logs had already been cut to 20ft lengths, a self-loader and short logger were required to move the tanoak logs to the Branscomb Mill site. These operators had to be sourced from over an hour away and represent a large percentage of over-all operational cost that can be drastically reduced in the future. Log hauling occurred on two different days approximately one month apart (referred to as Batch 1 and Batch 2).
- * A contracted chipping company chipped tanoak logs at the Branscomb Mill Site. The size of the tanoak logs (up to 14 inches) required an extremely large chipper that had to be sourced from over an hour away. If smaller diameter biomass is used in the future, a more local, less costly chipping option may be available. Chipping occurred on two days approximately one month apart (referred to as Batch 1 and Batch 2).
- * Chips created from Batch 1 were spread approximately 6 inches in depth over a large paved area to allow the material to dry. The first batch of chipped material took three 70-degree days to dry the material from 40-50% moisture to 20% and less moisture, the level required for equipment operation. The dry chips were then repled and covered. Batch 2 was chipped in early December. These chips were spread for approximately 5 days in 50 to 60 degree weather. The chips did not dry to the needed moisture level under these conditions. Batch 2 chips were repled and re-spread 3 times. Finally, favorable weather conditions in early Feb. allowed the chips to dry from 40-50% moisture to 10-15% in only three days. The cost associated with spreading, piling, covering and re-spreading is referred to as "Drying Cost" in the Economic

Analysis. This cost could have been drastically reduced or avoided if Batch 2 chipping occurred in dry months or an industrial dryer were purchased to allow for operations year round.

- * Dry tanoak chips (approximately 20% moisture or less), were fed into biochar conversion unit by the equipment operator using a small tractor with a bucket that holds approximately 1/3 yard of woody biomass. Several equipment improvements were created to allow one person to operate the machine:
 - An auger, or feeding screw attached to a foot pedal was installed in the chip holding bucket to be able to push chips out of the bucket and onto the feeding conveyer by stepping on the foot pedal.
 - A mirror was installed to be able to see inside the reaction chamber without having to climb a ladder and look in.
 - Flaps were installed around the biochar output areas so that wind could not blow the biochar as it dropped from the unit to the 55-gallon steel drums that are used as hot biochar discharge containers.
 - A timer was placed on the auger/feeding screw to release chips automatically onto the feeding conveyer.
- * The machine is now fully operational by one person who can manage feedstock as the machine is producing biochar.
- * Biochar that was produced was fed into 55-gallon steel drums, sprayed with a small amount of water, sealed and allowed to cool for two weeks before final sale.
- * Biochar was sold from the Branscomb Mill by Willits Soil Company for \$1.50 / lb. plus tax. RFFI decided to sell in bulk (110lbs. at a time or more), which does not require retail license. In addition, bulk soil amendment sales do not have labeling or fertilizer registration requirements. All shipping was provided or paid for by the purchaser.
- * The economic analysis was created based on the first 18 days of operation. The equipment operator logged how many scoops of biomass were used per day, how many drums of char were produced and the total hours of operation. This raw data was used to determine overall costs per unit of production.

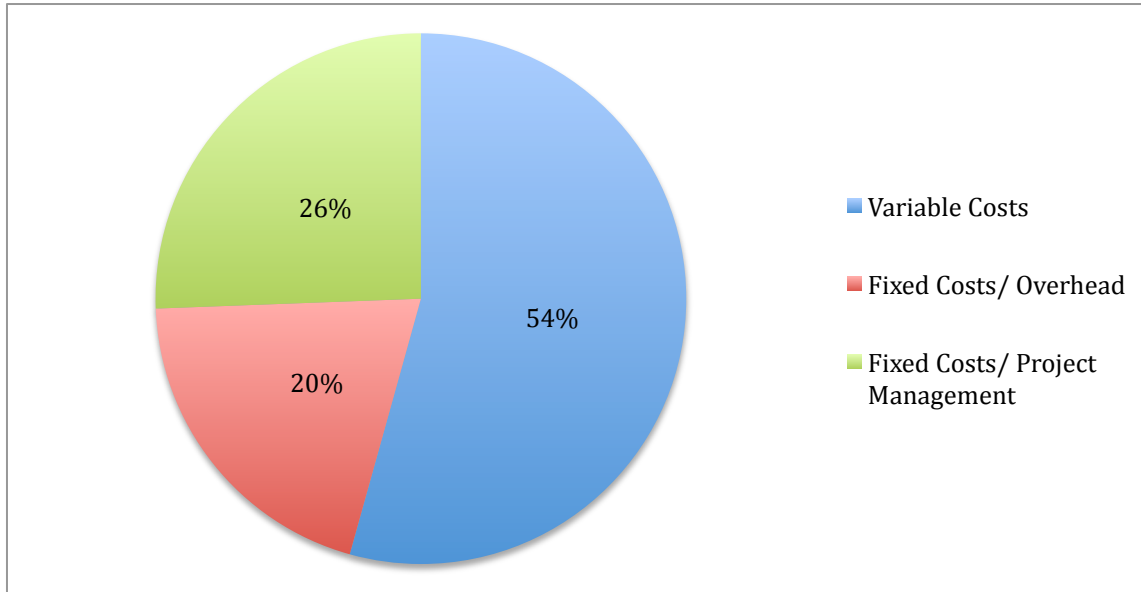
IV. Results:

Operating Costs

Appendix 2 shows all of the variable and fixed costs associated with 18 days of operations. The data shows that the break even sales price for biochar ranged from \$22.43 on the least efficient operating day to \$2.92 on the most efficient day with an average break even price of \$6.73 per lb.

These costs are broken into three categories shown in Figure 1: Variable Costs, Fixed Costs/ Overhead and Fixed Costs/ Project Management. Fixed costs do not vary based on the units of biochar produced. Variable costs are directly related to how much biochar is produced. As shown below, operational costs make up 54% of the total costs.

Figure 1- Costs as a Percentage by Type



There are several line items that are associated with variable costs. Those items are shown by percentage in Figure 2 below. The largest variable costs associated with the project are Equipment Operation (25%), Drying (21%), and Transportation (19%).

Figure 2- Variable Costs as a Percentage by Type

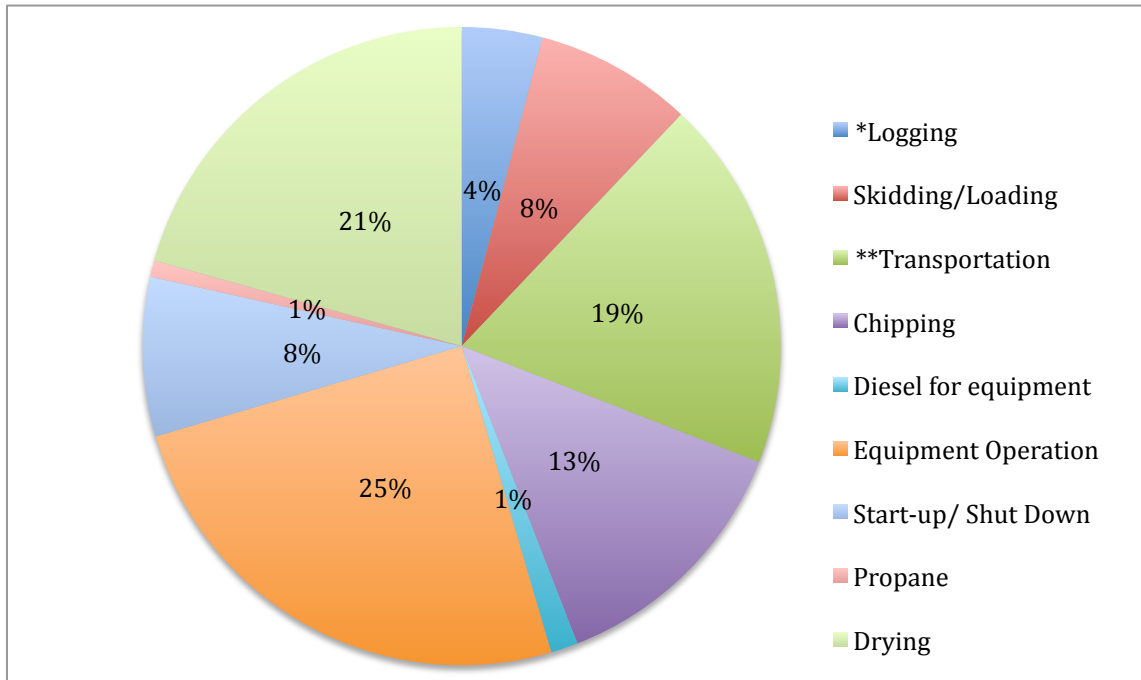


Figure 3 shows the breakdown of variable costs for each of the 18 days that biochar was produced. There is an apparent spike in drying costs for the January production days. This is related to the hours the operator spent trying to spread chips, re-pile and cover when the weather was not ideal for drying. Other than the drying anomaly and small changes in costs

over time, variable costs in Figure 3 change based on the number of units produced per day. As production increases total daily variable cost increases as well.

Figure 3- Total Variable Costs by Type per Day

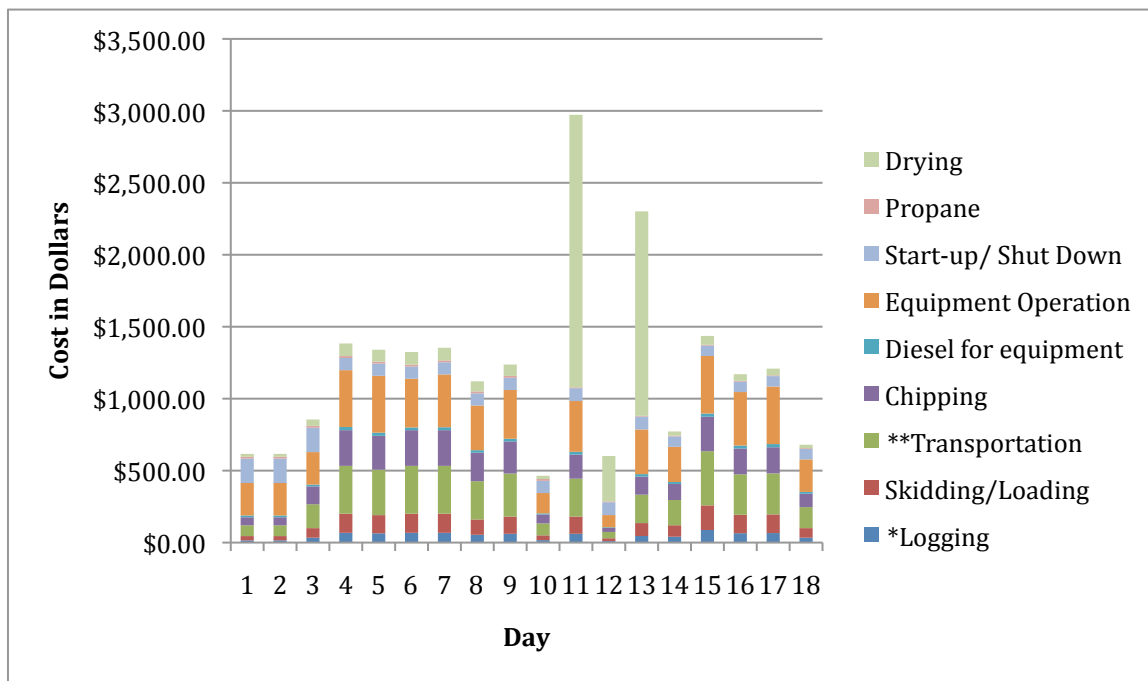
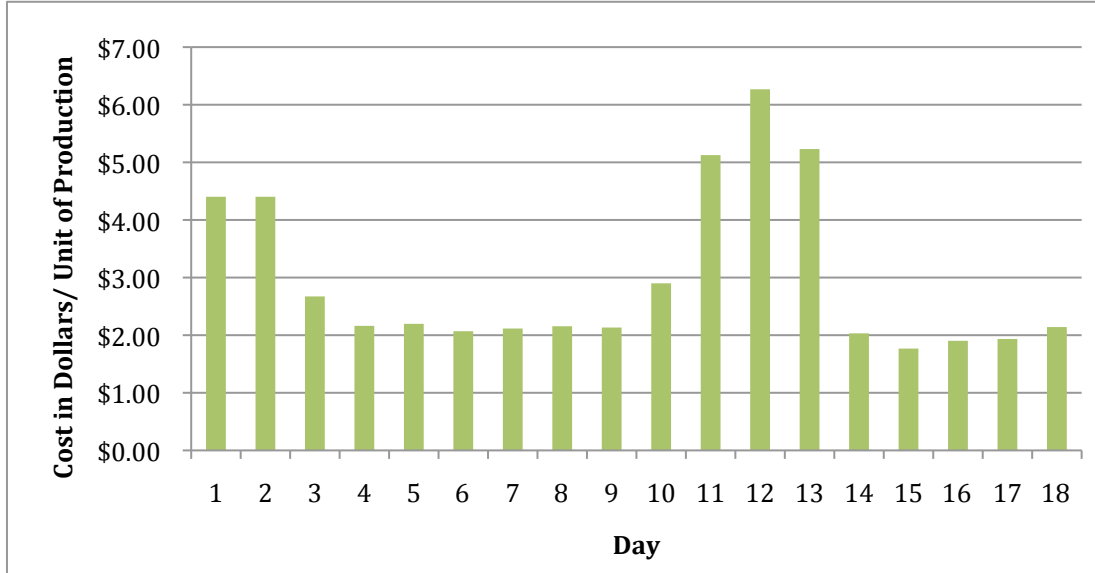


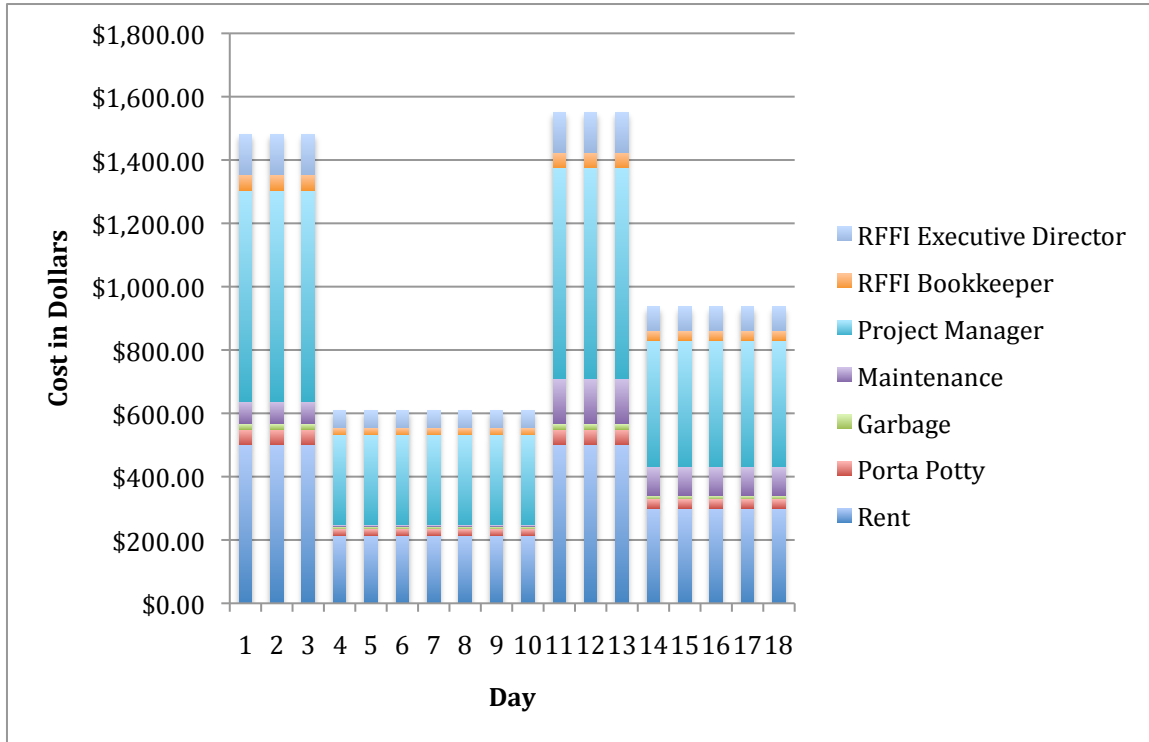
Figure 4 shows variable cost per unit of production each day. Selling biochar at this price per unit would cover operational costs each day. There are two major spikes shown in Figure 4. The first spike represents operator training, the second represents the high costs of drying in January. The remaining days show an average break-even price of about \$2.00. The project manager and equipment operator believe that efficiency could improve with experience and seasonal operation.

Figure 4- Variable Costs per Unit of Production Per Day



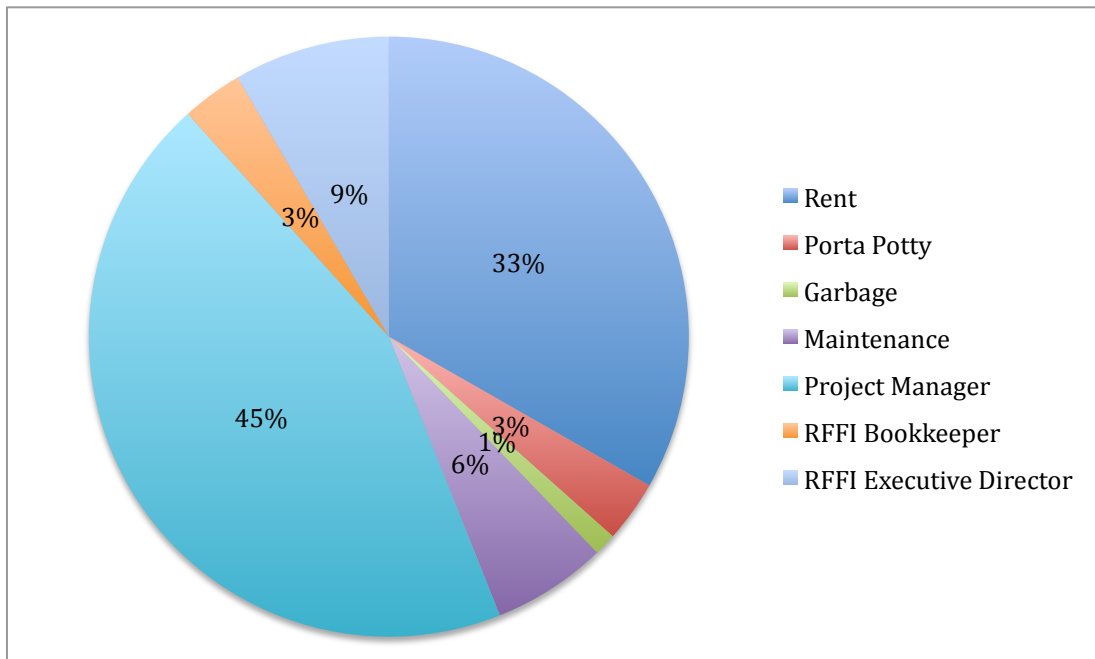
The remaining 46% of costs are incurred regardless of how many days the unit is operating and/or how many units of biochar are produced. These fixed costs are spread over the total days of operation and are then added to variable costs to determine total cost per day and per unit of biochar produced. For this analysis each fixed cost line item was totaled per month and divided by the numbers of operational days in that given month. Figure five shows all fixed costs for each operational day. The spikes represent months that fixed costs were spread over only three operational days. The shortest bars on the chart represent fixed costs for the month of November, the most productive month so far with seven days of operation. Clearly, reducing fixed costs is dependent on increasing the number of operational days.

Figure 5- Fixed Costs per Operational Day



Of the fixed costs, Figure 6 shows that Project Management (45%) and Rent (33%) were the two most expensive line items. It is important to note that the project manager took a voluntary pay cut of 30%. The numbers below represent the real costs of project management with the manager's income restored to 100%.

Figure 6- Fixed Costs by Type



The fixed and operational costs combined divided by the units of biochar produced per day represent the price that RFFI must sell their biochar for in order to cover operating costs. The most cost effective day of operation yielded a break-even price of \$2.92 per lb. It is not out of the realm of possibility to sell biochar retail at this or even higher prices, however RFFI's current wholesale model does not provide the price per pound needed to make the current operation economically feasible.

Capital Costs

Total Capital Costs are shown below:

Equipment Purchase	\$190,000.00
Equipment Improvements	\$3,357.12
55 Gallon Steel Drums	\$4,212.60
Generator	\$0.00
Equipment Installation/training	\$5,291.03
Tarps	\$664.90
Water System	\$164.09
Propane Tanks/ Torches	\$316.71
Other Equipment	\$88.87
Total =	\$204,095.32

Capital costs totaled \$204,095.32. Equipment purchase represents 93% of the total capital costs. It is important to note that RFFI did not purchase a generator for the project, which could add \$10,000 to the total capital costs for a future investor.

Revenue

To date, RFFI has sold 3,760 lbs of the total 8,256 lbs of biochar produced for \$1.50 per pound plus sales tax. RFFI expects to easily sell the remaining biochar produced during the demonstration at the \$1.50 price.

The market for biochar is in its infancy and no prevailing market price has been established industry wide. Local demand for biochar seems to greatly out-pace local supply at this time. While price could increase or decrease over time, RFFI is using the \$1.50 per pound price as the reasonably expected price for this analysis. For more information about the local market for biochar please link to our marketing study at <http://rffi.org/Biochar.html>.

V. Alternative Scenario Analysis

The Biochar Demonstration Project is intended to produce real measurable numbers to determine the economic viability of producing and selling biochar from tanoak removed from overcrowded forest stands in the North Coast. The results of the biochar demonstration project show that under current operating conditions and with a market price of \$1.50 per pound for biochar, the project is losing between \$20.93 and \$1.42 per unit of biochar produced. While these numbers clearly show that the project is not economically feasible under current circumstances, the demonstration portion of the

project can serve as a baseline to understand under what circumstances biochar production would be economically feasible. This section explores changes that could be made to make the project sustainable.

Scenario 1: RFFI Implemented Changes

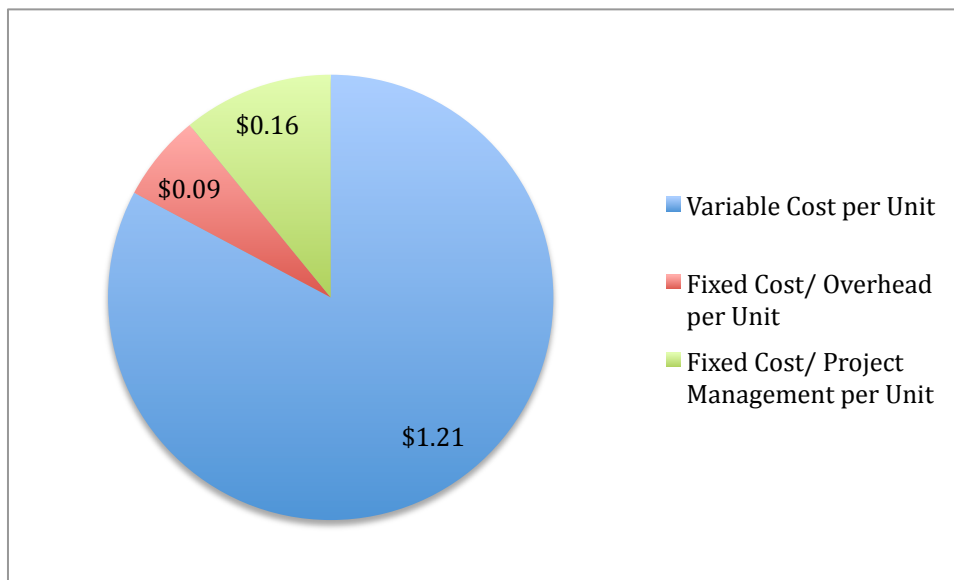
Scenario 1 uses RFFI’s current operations as a baseline and implements a series of changes that make the project economically feasible. This scenario is consistent with RFFI’s reality, but may not apply to other potential investors. For example, all capital costs, and most operating costs have been grant funded and therefore RFFI’s payback period and ROI are favorable. The numbers generated under Scenario 1 should not be used as a guide by other potential investors unless they have access to grant funds to cover capital costs.

Proposed Change	Impact	Justification
Move Unit Close to the Forest	Reduce transportation cost from \$20.68 to \$10.34 / yard	The travel time from Usal to the Branscomb Mill allows for two trips per day with the self-loader and short-logger. Locating the unit in the forest, Leggett or Piercy would reduce travel time by half allowing for twice as many loads. In addition, hauling with a full logging truck rather than a short logger can increase the volume of biomass delivered in each trip.
Operate with Dry Chips	Reduce drying cost from \$6.19 to \$1.57 / yard	RFFI can implement this step in two ways. Either close operations during wet times of year and/ or install a drying unit that uses waste heat from the biochar machine. The \$1.57 figure was calculated from Feb. drying costs, taking out the hours that the operator spent re-piling and covering because of rain.
Use Biomass from Less Costly Sources	Reduce logging and skidding costs by 50%.	If RFFI were to use slash pile material from the landing the logging cost would be zero. This change assumes that RFFI could use some slash pile material and some more expensive logged whole tanoak ultimately reducing the logging and skidding costs by half.
Reduce Operator Salary	Reduce Operator Salary from \$56.44 to \$46.44	Under the terms of RFFI’s grants the operator must be paid prevailing wage during the demonstration phase of the project. Pay rate for commercial operation is negotiable.
Operate as Efficiently in the Future as our Best Day ³	Produce 812.5 lbs of biochar in an 8 hour day of operation including start-up and shut down	The operator and project manager believe that efficiency will improve as we move forward. The three days of production that have occurred since data collection ended for this analysis were more efficient than the day on which we are basing future numbers.
Operate for 15 days	Spread all fixed	Operating for 15 days a month on average can be

a Month on Average	costs over 15 operating days	achieved easily during dry times of year. Full-time operation during dry months could allow for total shutdown during winter. RFFI could also greatly reduce fixed costs during winter months by negotiating a rent rate that is reduced when operations are halted and by stopping all non-essential project management and fixed cost services when the machine is non-operable.
Pay \$750 per month to lease a space	Reduce Lease cost to \$750/ mo	In speaking with potential leasers in Piercy this does not seem like an unreasonable price per month for rent.
Assume RFFI will Pay Salaried Employees the Same Regardless of Whether or not the Project is Active	Remove the CEO's wage as a line item	The CEO salary is included as a line item in the analysis to represent the true cost of project. However, the CEO receives the same salary whether or not the Demonstration Project is operable. Removing this line item from the analysis reflects the fact that RFFI is not actually paying any more for the CEO's work on the project.
Restore Project Manager Pay to 90% of Total Rather Than 100%	Reduce project management costs by 10%	The project manager is currently being paid 70% of her initial pay rate. The analysis assumes that the manager's pay will be restored to 100% going forward. If the pay rate were only restored to 90% this would reduce over-all project management costs.

Implementing the above changes would reduce the break-even price to \$1.46 per lb of biochar giving RFFI a \$.04 profit on each unit sold. Figure 7 shows the cost breakdown under Scenario 1.

Figure 7-Scenario 1 Costs by Type



Payback period & Return on Investment:

RFFI's total cash investment in the project to date is \$10,776.35. This expense is solely project management costs that would be covered by revenue from biochar sales under Scenario 1. If RFFI implements the Scenario 1 assumption of 15 days of production per month on average this creates net yearly revenue of \$6,220.40. Under this scenario RFFI's payback period 1.7 years. The expected return on investment (ROI) after 5 years of operation is 188.61%.

It is important to note that the favorable ROI and payback period for RFFI results directly from the fact that almost all demonstration costs were grant funded, including the large capital costs associated with purchasing the biochar conversion unit. Scenario 3 will analyze economic feasibility of purchasing and operating the biochar unit for a private non-grant funded investor.

Scenario 2: RFFI Integrating Avoided Costs

Scenario 2 takes all of the assumption that are included in Scenario 1 and includes the avoided costs associated with removing excess woody biomass to be converted to biochar rather than girdling or manual removal that would otherwise have to be paid for. Because Scenario 1 assumes that half of the material would be taken from slash piles, avoided costs are only realized for half of the biomass that would be converted to biochar. RFFI budgeted \$750.00 per acre in 2015 for biomass removal. Conservatively, Scenario 2 uses an avoided cost of \$500.00 per acre. This has the impact of reducing the cost of logging from \$2.40 to \$1.60 per yard (see the appendix for the specific calculation).

Payback period & Return on Investment:

Under Scenario 2 RFFI creates \$0.05 of net profit per unit of production. This creates a net yearly profit of \$7,859.19, a payback period of 1.37 years and a 5-year ROI of 264.65%.

Scenario 3: Internalizing externalities

Scenario 3 takes an environmental economics approach to net benefit created from long term biochar operation. This scenario includes all of the Scenario 2 changes and considers externalities. Externalities are consequences of commercial activities that impact third parties either positively or negatively that are not reflected in the price of goods. For example, Green House Gas (GHG) Emissions from industrial processes have a real economic cost to third parties, like the cost of repairing infrastructure after mega-storms linked to climate change, or the cost of crop failure due to drought linked to climate change. The carbon market integrates CO₂ into the traditional economic system by putting a price on carbon. Many other externalities do not have established markets, but like carbon emissions they do have real positive and negative economic benefits. These externalities are considered in Scenario 3.

Proposed Change	Impact	Justification
GHG Benefit of Biochar	Unknown	There is no standardized way to measure the reduction in GHG emissions per unit of biochar buried and therefore no specific carbon market value applied to biochar. Emissions savings in this project come from carbon sequestration from burying biochar, waste diversion from converting biomass that would rot or be burned into biochar, reduction in emissions related to fertilizer production because biochar reduces the amount of fertilizer required.
Increased Water Holding Capacity in Soil	Unknown	Studies show that biochar applied to soil can increase soil water holding capacity. The water savings achieved in each customer's garden or farm impact downstream water users including fish, particularly in time of drought. The range of this impact varies by study based on biochar type and initial soil condition. A field study in Finland found an 11% increase in water holding capacity ⁴ . Other studies have variable results. RFFI's biochar needs to be studied in order to make specific water savings claims.
Reduced Fertilizer Run-off	Unknown	Biochar clings to nutrients and makes them readily available for plant roots. This quality reduces the amount of fertilizer that is washed from soil during watering. Fertilizer run-off is responsible for major ecological harm to streams and tributaries, creating algae blooms that suck up oxygen from waterways and create "dead zones". There is a real benefit to local streams and tributaries and communities and wildlife that depend on them from biochar application and associated reduction in fertilizer run-off
In the forest benefits of biomass removal	Unknown	In the forest benefits of biomass removal include reduced water use by removing excess biomass, reduced risk of catastrophic forest fires, improved forest habitat, increased biodiversity and improved conditions for commercial timber growth. These combined positive impacts have a real environmental and economic value that is difficult to quantify. A 15-day a month operation will require biomass from 26.25 acres per year

⁴ Agriculture, Ecosystems & Environment Volume 140, Issues 1–2, 30 January 2011, Pages 309–313
<http://www.sciencedirect.com/science/article/pii/S0167880910003208>

		assuming biomass density per acre equal the demonstration plot density. The in the forest positive externalities will be realized on over 130 acres after 5 years.
Social and Political Capital from producing biochar and not using herbicides.	Unknown	While not directly measurable, the social and political capital derived from the biochar project is significant. The community is excited about this project and that support has created real economic benefit through a) in-kind and cash contributions from groups such as the WBWG b) RFFI's ability to raise grant money using letters of support from public representatives and others, c) multiple radio interviews and other free positive publicity. There is also a value associated with the avoided community outrage/ support for this alternative to herbicide use that could have a major impact on RFFI's community relations in the long term.

The below equation represents the positive and negative externalities laid out in Scenario 2:

Net Benefit/ Unit = (Total Revenue/ Unit - Total Cost/ Unit) + (Value of Positive Externalities)

Net Benefit/ Unit= .05 + x

Where x equals the value of Positive Externalities

The point here is that there is some value associated with these positive or avoided negative externalities and if that value could be quantified the actual net benefit of the project would be greater than what was outlined in Scenario 1 & 2. It should also be noted that agencies such as the Department of Water Resources (DWR) and Natural Resource Conservation Service (NRCS) recognize the positive externalities associated with this project which is why public funds are available through grants for projects like this that provide public benefit that is not integrated into the current economic system. In the future, the carbon sequestration benefits of biochar production will likely be internalized and create real revenue through the carbon market.

Payback period & Return on Investment:

The payback period and return on investment (ROI) under this scenario is variable depending on how you value the externalities. If we give the externalities a hypothetical value of somewhere between \$0.00 and \$0.10 the 5-year ROI would range from 264.56% to \$943.22%. The hypothetical minimum is an absolute as it assumes \$.00 in externalities while the maximum \$0.10 cents of benefit per could be an underestimate of the actual benefits per unit of biochar produced.

Scenario 3: Private Investor

Scenario 3 removes RFFI from the picture all together and looks at whether or not a private investor could create a positive ROI if he/she decided to purchase a biochar unit solely for the purpose of profit maximization. This scenario is important because RFFI is tasked with helping other landowners and entrepreneurs replicate the project if found to be economically feasible. For this scenario we will start with a fresh set of assumptions:

Proposed Change	Impact
The investor did not receive grant funding to purchase the conversion unit or other capital expenses	ROI calculations will be based on total costs including all capital expenses
The investor is not tied to biomass from any particular location- they can use the cheapest material they can find locally	Instead of logging, skidding and transportation costs, look only at delivered price of biomass = \$80 BDT the approximate market rate of delivered biomass
The investor owns his or her own lot on which to operate the machine	Rent equals \$0.00 per month
The operator is as efficient as RFFI's operator and is paid \$35.00/ hr	Labor cost is reduced to = \$35/ hr
No CEO cost; cost for project manager and bookkeeper remain	Erase CEO line item

Payback period & Return on Investment:

Under Scenario 3, the private investor has a break-even price of \$1.28 per unit of biochar sold, a much higher per unit profit than RFFI can obtain under scenarios 1 & 2. This gives the investor \$31,763.49 of net profit per year if he/she operate for 15 days a year on average and sell their biochar for \$1.50 per pound. However, in this case, the private investor must pay \$204,095⁵ in capital costs up front making the payback period 6.42 years- over five years longer than RFFI's payback period under Scenario 2. In this case the five-year ROI is negative. The ten-year ROI equals 55.63%.

VI. Discussion:

The results from the demonstration project and the above analysis of four potential scenarios for operations going forward can help RFFI and other investors decide if the project is ready for Phase II- Commercial Operation. RFFI has a distinct advantage over other potential investors because the capital costs of the project are grant funded. While a private investor is not tied to feedstock location and the expensive methods of biomass

⁵ This does not include interest payments if the investor requires a loan

removal used by RFFI to improve forest health, there is a huge risk for an investor because of the long payback period and the uncertain future price of biochar.

RFFI's payback period and return on investment are favorable, but this should not be considered a large profit-making sector of RFFI's organization. While the project is unlikely to help RFFI pay down its loan, the benefits to advancing RFFI's overall mission are significant. This project represents the 3-Es in action- restoring the forest in an economically viable way through implementing a project created by the local community. The project helps RFFI define what a community forest is- a place where well thought out solutions to some of our toughest forestry issues in the North Coast can be created by the local community, tested in a community forest, and ultimately benefit the communities who live here by providing jobs, improved ecosystem services, and in this case all of the benefits associated with local biochar use. If RFFI decides to proceed with Scenario 1 & 2 changes, the project will pay for over 26 acres per year of biomass thinning and provide a *less costly* alternative to herbicide use.

Although the above scenarios do not show huge profit making potential, the market for retail biochar is not fully explored in this analysis. Creating a label, bagging operation and pursuing a retail sales license could more than double the price per unit of biochar. Well-marketed designer biochar can sell online for over \$15.00 per pound. Pursuing this strategy is dependent of RFFI's longer-term interest in entering the biochar market, as completing these steps will require additional investment and time- likely up to a year. If RFFI does create its own North Coast Biochar label, it could be used as an umbrella label or some kind of co-op model for future biochar producers in the North Coast Region whose biochar benefits forest restoration. Removing the biochar sales barrier for future producers could spur project replication and regional in-the-forest benefits, which is the intended goal of the demonstration project.

VII. Conclusion:

The RFFI Biochar Demonstration Project successfully provides a baseline for future decision-making around commercial biochar operations on the North Coast. Biochar production not only has the potential to put economics into forest restoration, but also through agricultural water savings, more efficient use of fertilizers and carbon sequestration, it can help address the major environmental issues of our time. There is a lot of interest in biochar in the local community and beyond. Being an innovator in the use of biochar technology, gives RFFI the opportunity to tell its story to a broad audience and further enhance the RFFI mission.