Biochar Production Facility Feasibility Study

Assessing the Potential for a New Class of High-Value Forest Products to Energize Wildfire Risk Reduction in Chelan County

Prepared for Chelan County Commissioners

C6 Forest to Farm

Delivered 2024-04-29

Version History

Version #	Release Date	Notes
1.0	2024-04-23	Released for initial review by Chelan County Economic Services Director.

Contents

Version History.......... 2
Contents.......... 2
Executive Summary..........7
Glossary of Terms.......... 12
Biochar Product and Production Terms.......... 12
Financial Terms..........12
Stakeholders and Community..........14
Stakeholder Engagement Objectives.......... 14
1. Stakeholder Engagement.......... 14
1.1. Stakeholder Groups and Mapping.......... 14
1.2. Stakeholder Engagement Approach..........15
2. Key Stakeholder Influences on the C6 Business Model.......... 16
2.1. General.......... 16
2.2. Forest to Plant..........17
2.3. Customers & Products.......... 18
2.4. Carbon Markets.......... 18
3. Key Stakeholder Influences on the C6 Facility Design.......... 19
3.1. Forest to Plant..........19
3.2. Plant..........19
3.3. Customers & Products..........22
3.4. Carbon Markets.......... 22
4. Securing Support & Resources.......... 23
5. Conclusions and Remaining Gaps.......... 23

Forest to Plant......25
Feedstock Objectives......25
1. Feedstock Profile......25
1.1. Forms......26
1.2. Forest Health Treatments......26
1.3. Species......27
1.4. Limited Haul Radius......27
1.5. Onsite Pre-Processing and Forest Products Campus......28
2. Feedstock Forecast......28
2.1. Forecast Methods......28
2.2. Forecast Scenarios......29
2.3. Forecast Results......29
2.4. Methodology 1: Mason, Bruce & Girard MBF Forecast......30
2.4.1. Methodology......31
2.4.2. Estimates......31
2.5. Methodology 2: WA DNR Landscape Evaluation Forecast......32
2.5.1. Methodology......33
2.5.2. Estimates......33
3. Landowner Alignment......34
3.1. Cost Reductions......34
3.2. Risk Reductions......35
3.3. Emissions Reductions......36
3.4. Economic Development......36
3.5. Feedstock MOU's......36
4. Alternative Feedstocks......37
5. Conclusions and Remaining Gaps......38
Plant......40
Plant Objectives......40
1. Plant Context......40
1.1. Constraining Facility Requirements......40
1.2. Biochar Production Process Functions......42
1.3. General Site Requirements & Conditions......48
1.4. Site Options......51
1.5. Winton Mill Site Constraints and Conditions......52
1.5.1. Property Owner Constraints......52
1.5.2. Site Conditions......52
1.6. Site Layout Configurations Assessed......56
1.6.1. Concept SL.1......58
1.6.2. Concept SL.2......60
1.6.3. Concept SL.3......62
2. Plant Configurations......68

2.1. Site Layout.......... 68
2.2. Plant Design Configuration Options.......... 69
2.2.1. Feedstock Format Impacts on Plant Configuration.......... 72
2.2.2. Reactor Options.......... 72
2.2.3. Co-Product Impacts on Plant Configuration.......... 74
2.2.3.1. Electricity Generation.......... 74
2.2.3.2. Bioliquids Products.......... 75
2.3. Plant Design Configuration Comparison.......... 76
3. Regulatory & Permitting Assessment.......... 79
4. Winton Mill Site Lease Findings.......... 80
4.1. Footprint.......... 80
4.2. Rent Structure.......... 81
4.3. Site Conditions & Investments.......... 81
4.4. Options to Extend.......... 82
4.5. Comparables Cost Analysis.......... 82
5. Conclusions and Remaining Gaps.......... 83
Products and Customers.......... 86
Products and Customers Objectives.......... 86
1. Potential Products for the C6 Pilot Facility.......... 86
1.1. Biochar Products.......... 90
1.2. Raw Pyrolysis Vapor & Syngas - Heat and Electricity.......... 92
1.3. Bioliquid Products.......... 93
1.4. Product Energy Balance.......... 95
2. Regional Markets & Prospective Customer Segments.......... 97
2.1. Our Process for Finding Biochar Customers.......... 97
2.2. TAM Assessment.......... 98
2.3. Identifying Agricultural Sub-Markets.......... 98
2.4. Customer Discovery Findings.......... 99
2.5. Corn/Potato/Wheat Rotations Discovery (Priority Serviceable Market).......... 99
2.6. Anaerobic Digesters (Additional Customer Discovery Required).......... 101
2.7. Manure Management (Additional Customer Discovery Required).......... 102
2.8. Vineyards Customer Discovery (Deprioritized Market).......... 103
2.9. Cannabis Customer Discovery (Deprioritized Market).......... 104
3. Serviceable Market Analysis: Potato/Corn/Wheat via Co-Compost.......... 104
3.1. Co-Compost Distribution Summary.......... 104
3.2. USDA Subsidies.......... 105
3.3. Customer ROI.......... 106
3.4. Volume Projections.......... 109
4. Other Products.......... 110
4.1. Electricity.......... 111
4.2. Bioliquids.......... 112

4.2.1. Bio-Oils....112
4.2.2. Wood Vinegar....113
5. Conclusions and Remaining Gaps....114
Carbon Markets....115
Carbon Markets Objectives....115
1. Carbon Markets....115
1.1. Focus on Voluntary Markets....116
1.2. Biochar Carbon Offsets, Strong Demand, Premium Price....116
1.3. Source of Plant Capital & Ongoing Revenues....117
2. Preliminary LCA....118
3. Standards and Carbon Market Partner Assessment....119
3.1. Carbon Market Ecosystem Summary....119
3.2. Biochar Standards....121
3.3. Go-To-Market Partner (Project Developers, Measure/Reporting/Verification Platforms)....122
4. Conclusions and Remaining Gaps....124
Recommended Configurations....125
Recommended Configurations Objectives....125
1. 9 Plant Configurations....125
1.1. Three Key Learnings....126
1.2. Key Learning #1: Pre-possessing Small Diameter Logs....127
1.3. Key Learning #2: Co-Products Outputs....131
1.4. Key Learning #3: Pilot Scale....133
2. Recommended Plant Configurations....135
2.1. Plant Configurations Assessment....136
2.2. Recommended Plant Configurations E, G and I....136
2.3. Mission Alignment....137
2.4. Risk Mitigation....137
2.5. Financial Returns....138
3. Conclusions and Remaining Gaps....139
Project Financial Projections....141
Financial Projections Objectives....141
1. Financial Statements and Terminology....141
1.1. Financial Statements....141
1.2. Project Cash Flow Categories....141
2. Base Case Financial Projections for 3 Recommended Configurations....142
2.1. Recommended Plant Configurations....142
2.2. Plant Configurations Cash Flows....143
2.2.1. Plant Configuration E - Overall Summary....144
2.2.2. Plant Configuration E - Launch Capital Summary....145
2.2.3. Plant Configuration E - Revenue, Cost Summary....145

2.2.4. Plant Configuration G - Overall Summary....146
2.2.5. Plant Configuration G - Launch Capital Summary....147
2.2.6. Plant Configuration G - Revenue, Cost Summary....147
2.2.7. Plant Configuration I - Overall Summary....148
2.2.8. Plant Configuration I - Launch Capital Summary....149
2.2.9. Plant Configuration I - Revenue, Cost Summary....150
2.3. Major Assumptions....151
3. Sensitivity Analyses....153
3.1. Biochar Price....153
3.2. Wood Vinegar Price....154
3.3. Feedstock Cost....155
4. Sources of Capital....155
4.1. Public Funding....156
4.2. Grants....157
4.3. Foundations....157
4.4. Project Finance....157
4.5. Traditional Commercial Debt....158
4.6. Equity....158
5. Conclusions and Remaining Gaps....158
Conclusions....160
1. Key Takeaways....162
2. Recommended Next Steps....162

Executive Summary

C6 Forest to Farm was started in the Methow Valley in 2019 to address the extreme wildfire risk in the area, which had materialized as a significant portion of the watershed burned since 2000 and the deaths of several firefighters. This risk, shared across much of the western US, is the result of a century of aggressive fire suppression in fire-adapted forests that are dependent on frequent low-intensity fires to maintain healthy stand densities. As these forests became denser, climate change decreased moisture levels in our forests while increasing temperatures and lengthening dry seasons. The combination of overstocked forests and more favorable burning conditions results in wildfires that more often grow rapidly to become “extreme” and very costly to attempt to control. These fires detrimentally impact local communities and ecosystems while destroying forests that could otherwise help sequester carbon in the face of climate change, creating a grim feedback loop. The associated firefighting comes at the cost of hundreds of millions of taxpayer dollars each year.

Investing in wildfire risk reduction is necessary to reduce the amount of firefighting required and maintain the health of our forests so they can continue to support us in the decades to come. After receiving significant study funding from the state of Washington in 2021, we pursued the development and funding of a biochar production facility that was both economically self-sustaining and generated a positive return on investment. **Our hypothesis was that biochar would be a high-value forest product that would allow us to buy small-diameter logs that come from forest health treatments as its feedstock, thereby helping stimulate more treatment activity.**

We started by assessing site options in the Methow Valley, which was challenging given local zoning restrictions and few practical property options. We soon began focusing on the Wenatchee Valley after being invited to learn more about the Winton mill site, knowing that the risk of extreme wildfire in that area was very high.

We assessed feedstock availability in the Wenatchee Valley and adjacent areas within a reasonable transport distance of the Winton mill site. We developed plant design concepts to establish a viable process flow in the context of the site, the feedstock available and the products we wanted to pursue. We reached out to customers in multiple markets to assess the needs they have that biochar might serve. We evaluated the voluntary carbon markets to determine the revenues and capital funding we would realize by sequestering carbon via biochar applications.

Our goal was to develop a facility configuration that was financially sustainable with positive returns at a meaningful capacity to address operational risks, so that we could justify scaling the operation, onsite and beyond. Along the way, we developed and iterated on a financial model that incorporated production volumes given the plant capacity, the revenues we thought we could realistically generate, the capital costs of the plant and operational launch, and the operating costs of the facility. As we encountered challenges with the plant’s processing complexities, capital intensity, and product pricing, we iterated toward a feasible balance.

After assessing nine potential plant configurations balancing different feedstock sources, biochar production equipment, and output products, we identified 3 key takeaways:

1. Pre-processing small diameter logs into chips onsite is capital intensive and drives incremental operating costs. At the pilot scale, the fully-burdened costs are too high to operate profitably. As a result, we believe it's best to site the biochar facility at a location where it can buy chips from another provider, either on a forest products campus or co-located near a mill or similar forest products producer.
2. Positive financial returns are dependent on finding high-value uses for the vapor stream, in addition to selling biochar products. Burning it to generate electricity will likely lead to profitable operations but a smaller facility might not achieve a positive long-term return on investment, as the upside associated with electricity generation is limited given regional electricity rates. Alternatively, capturing the bioliquid from the vapor stream and separating it into its "bio-oil" and "wood vinegar" fractions, is more capital intensive and higher risk, with a significantly higher potential return.
3. To reduce required up-front capital and give the operations an opportunity to mitigate risks, it's best to launch the facility with a single reactor before scaling reactor capacity. At launch scale, which we recommend to be between ~1.1 and ~1.5 dry tons/hr (reactor feedstock infeed), the right plant configuration would likely operate profitably and require no additional capital. However the facility is unlikely to generate a positive IRR due to underutilization of labor, fixed costs and CAPEX until its production exceeds ~1.8 dry tons/hr with the addition of a reactor.

In our customer discovery work, we also determined that the biochar market in Washington is nascent and requires further development to ensure sales volumes that justify a meaningful pilot capacity. Biochar shows promise as a valuable soil amendment for a variety of crops, but it hasn't been sufficiently demonstrated in the region to convince growers of its value.

Based on what we've learned, we conclude that a pilot biochar facility in Chelan County is feasible under limited circumstances. While the plant configuration would be limited in its feedstock sourcing, product outputs and minimum scale, the biochar market is in fundamental need of development to demonstrate a level of feasibility that justifies the overall investment.

Given this, we suggest that future biochar project developers in the region focus initially on one of two approaches to procuring or producing biochar for trials to build customer relationships and demand.

1. Build and operate a small-scale R&D system (at least ~0.11 dry tons/hr [100 dry kg/hr] feedstock, ~42 dry tons biochar/yr).
2. Form a partnership with a regional biochar producer who uses the same type of woody biomass (e.g. Restoration Fuels in John Day, OR).

Trials could start with many small plots to evaluate a variety of biochar formulations across multiple crops, and the results would inform field trials (e.g. quarter or half pivot circles) with innovative growers. Assuming positive outcomes, we recommend working with organizations like the USDA Natural Resources Conservation Service and WSU Extension Service, as well as existing, highly-respected ag consultants and sales representatives to help build demand.

Once momentum is established with prospective biochar customers, the site and pilot capacity can be determined. The site is dependent on the feedstock approach. While the Winton mill site is generally a good fit for a biochar production facility, property covenants currently prevent its use as a forest products campus that includes sawmill or woodworking operations. Buying wood chips from a co-located chip mill at a forest products campus will greatly reduce the upfront capital intensity of the pilot. The capacity to achieve a self-sustaining operation with positive returns would largely be determined by full labor utilization and the feedstock approach.

Our goal with this study was to highlight key operational considerations, opportunities, and risks of a Chelan County-based pilot biochar facility from multiple perspectives. We hope this helps enable the success of such an endeavor in the future as it is part of an overall set of solutions needed to reduce extreme wildfire risk in our region and address climate change in general. We believe it also offers opportunities to create other benefits in the region (Figure 1).

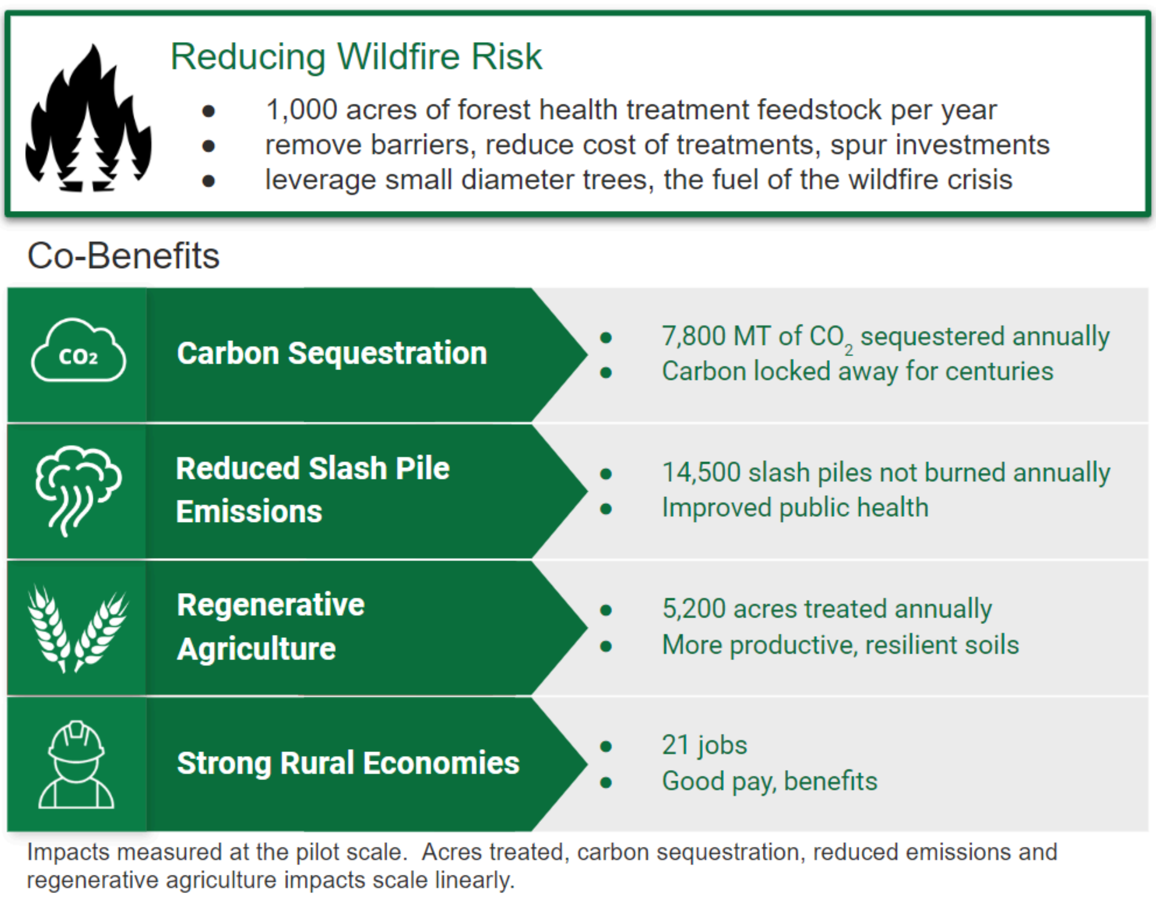


Figure 1: Total benefits of implementing a pilot biochar production facility in Central WA.

1. Wildfire Risk Reduction

The wildfires crisis is a growing problem. On average, US wildfires burn 8,000,000 acres each year, a 3X increase compared to the early 1990's[1]. Wildfires in the US have grown to the point where they account for 8% of total US GHG emissions[2]. A number of causes contribute to this problem, but there is consensus that Western US forests are overstocked with biomass, especially with small diameter trees. Removing and creating value from this biomass is one of the biggest blockers to reducing the fuel loads. Our analysis validated that our proposed biochar facility would reduce some of the blockers related to, and inject additional revenue into, forest health treatments. The pilot would consume fuels from ~1,000 acres of forest health treatments each year (15,000 acres over 15 years), and those volumes scale directly at increased biochar product levels.

2. Carbon Sequestration.

In order to keep global temperature increases below 1.5 degrees celsius, the world will need to both dramatically reduce emissions and actively remove carbon dioxide from the atmosphere. General consensus indicates that carbon dioxide removals will need to reach 3 gigatons per year by 2050[3]. Biochar is one of the most proven carbon dioxide removal technologies and has the ability to scale to material levels. Our facility concepts were designed to limit operational emissions and therefore maximize net carbon dioxide removal. Based on a 3rd-party life cycle assessment, our pilot biochar production would sequester 7,800 metric tons of CO_2e each year - that's the equivalent to the emissions of 1,700 gas powered cars. Biochar CO_2 removal is extremely verifiable and durable - locking carbon in the soil for 100's of years.

3. Slash Pile Emissions Reductions

Without the existence of a reliable market for small diameter trees, they are most commonly piled and burned. Unfortunately, slash piles result in a huge amount of emissions that include very hazardous PM2.5 particles. Slash pile emissions can reach levels that impact public health and disproportionately impact underserved communities who are more likely to work outside, as well as the elderly and young children. By paying for and removing biomass from forest health treatments, we'll eliminate the emissions from 14,500 slash piles[4].

4. Regenerative Agriculture

Conventional farming practices have depleted soil carbon levels by an estimated 30 to 50% of their original levels (source). This has made soils less productive and farmers increasingly dependent on expensive nutrient inputs. Using biochar as a soil amendment is one of the most effective ways to increase soil carbon levels and at the same time increase water retention,

---

[1] The 3X increase in acres burned is based on a 5 year average of 2018-2022 vs.1991-1995 from the National Interagency Fire Center.

[2] GHG emissions by source type are available at Google's Climate Trace.

[3] The 3 gigaton estimate is based on multiple international agencies, including Science Based Target Institute (SBTi).

[4] 14,500 piles not burned estimate is based on data from the University of Washington's Piled Fuels Biomass and Emissions Calculator. Slash piles assumed to be hand piled, conifer, 10' high, 20' wide, half sphere slash piles which the tool estimates weigh 1.36 tons.

nutrient retention, and microbial populations. Using biochar as a soil amendment reduces costs while increasing yields and resiliency to disease and drought. These are the reasons why the USDA is a strong advocate for biochar and is encouraging farmers to use it through federal subsidies.

5. Rural Economies

Over the past 30 years the forest products industry has seen a slow and steady decline in many regions of the Western US. In Chelan County, which has 1.3M acres of forested land, there are no major forest products operations. This lack of industry not only results in job losses but it increases the cost of forest health treatments due to a lack of investment and logging operators. The proposed pilot facility would be a small but important step to reverse that trend. The facility would result in 16 new forest products jobs (direct jobs), and we estimate another 4 jobs related to logging operations, logging and biochar transportation (indirect jobs).

This is the final deliverable from C6 Forest to Farm. Given acute operating and capital fundraising challenges, we are dissolving. The authors of this study, Mark Moseley (Director of Finance and Product Development) and Bret Richmond (Director of Engineering) will continue to have email access for 12 months following dissolution. If you have any questions about the study, you may contact them at mark@c6f2f.org or bret@c6f2f.org.

Glossary of Terms

Biochar Product and Production Terms

aqueous - a chemical solution in which the solvent is water (source). Used here in reference to one of two major portions of raw bioliquids captured from a pyrolysis vapor stream. This portion contains many different molecular compounds. See "wood vinegar, pyroligneous acid".

biochar - solid carbon-rich substance resulting from pyrolysis, based here on pyrolysis of woody biomass.

bioliquid - fluid resulting from capturing the condensable compounds of a pyrolytic vapor stream.

biomass - biological matter, typically used here in reference to woody materials from forest health treatments.

bio-oil, biocrude, tars - interchangeable trade terms referring to the organic fraction of pyrolytic bioliquids.

comminution - reduction of particle size (source).

co-products - used here to refer to the products that can be produced alongside biochar, namely from the pyrolysis vapor stream. Examples include electricity, bioliquids (which can be converted or refined into many products), and heat.

feedstock - raw material supplied to a machine or processing plant (source), used here to refer to the woody biomass from forest health treatments we would convert to biochar and other products.

organic - a chemical compound that contains carbon, especially in carbon-hydrogen or carbon-carbon bonds (source). Used here in reference to one of two major portions of raw bioliquids captured from a pyrolysis vapor stream. This portion contains many different molecular compounds. See "bio-oil, biocrude, tars".

pyrolysis - the thermal decomposition of materials at elevated temperatures, in the absence of oxygen (source). Used here as the core process used to convert woody biomass into biochar and raw pyrolysis vapor.

reactor - an enclosed volume in which a chemical reaction takes place (source). Used here in reference to equipment in which pyrolysis reactions generate biochar and raw pyrolysis vapor.

wood vinegar, pyroligneous acid - interchangeable trade terms referring to the aqueous fraction of pyrolytic bioliquids.

Financial Terms

CAPEX - capital expenses associated with construction of the facility.

Gross Profit - earnings before taxes.

Net Income - Gross Profit minus Taxes. We don't assume any debt financing, so there is no interest deduction.

OPEX - operating expenses associated with operation of the facility.

Profitable - the cumulative amount of net income, which includes revenues, OPEX and taxes is positive.

Positive Cash Flow - the cumulative amount of all cash flows, including CAPEX and Net Income is positive.

IRR - the discount rate used to make the present value of future cash flows zero. IRR is valuable for analyzing capital projects to understand and compare potential rates of annual return over time.

Stakeholders and Community

Given our mission to reduce wildfire risk in the region, we assumed we would need to secure broad-based support for our project. We also presumed that the local impacts of a forest product manufacturing facility could result in concerns by a variety of stakeholders. Any project of this magnitude should be underpinned by intentional stakeholder engagement to secure support and continually identify concerns in order to address them via community outreach, the business model and/or system design. We believe this approach will result in better outcomes than the delays recently experienced by some project developers in this space.

We found stakeholders to be receptive to our project and the concept of a pilot facility at the Winton mill site. While we would need to address a few stakeholder engagement gaps to pursue the project further, we don't anticipate that we would run into significant concerns or opposition.

Stakeholder Engagement Objectives

1) Determine the breadth of stakeholders who would impact or be impacted by the C6 pilot facility and operations, engage intentionally with them as a good neighbor and/or collaborative partner, and secure stakeholder support and avoid issues that might delay or block implementation.
2) Inform our approach to establishing a biochar production business in the region.
3) Inform our facility design, including processing system design, operations and logistics.
4) Secure necessary resources, including funding, partnerships, and permits.
5) Define conclusions and highlight gaps.

1. Stakeholder Engagement

We developed and maintained a list of stakeholders, categorized them into groups to help organize ongoing engagement, and engaged with stakeholders in two primary capacities. First, we engaged with specific key stakeholders as needed to inform our general approach to establishing a biochar production facility in the region, define facility constraints, and secure initial resources. Second, as a U.S. Dept. of Energy Small Business Innovation and Research (SBIR) grant partner with Forest Concepts of Auburn, WA, we engaged with a range of stakeholders specifically to inform the plant design.

1.1. Stakeholder Groups and Mapping

C6 initially systemically mapped potential stakeholders and organized them into groups. The list was maintained over time as we learned and made more connections. The primary areas of influence of our stakeholders are shown in Figure 2. Other dimensions of stakeholder influence exist, but business and product definition through production and facility definition through buildout were most helpful at this early stage of development.

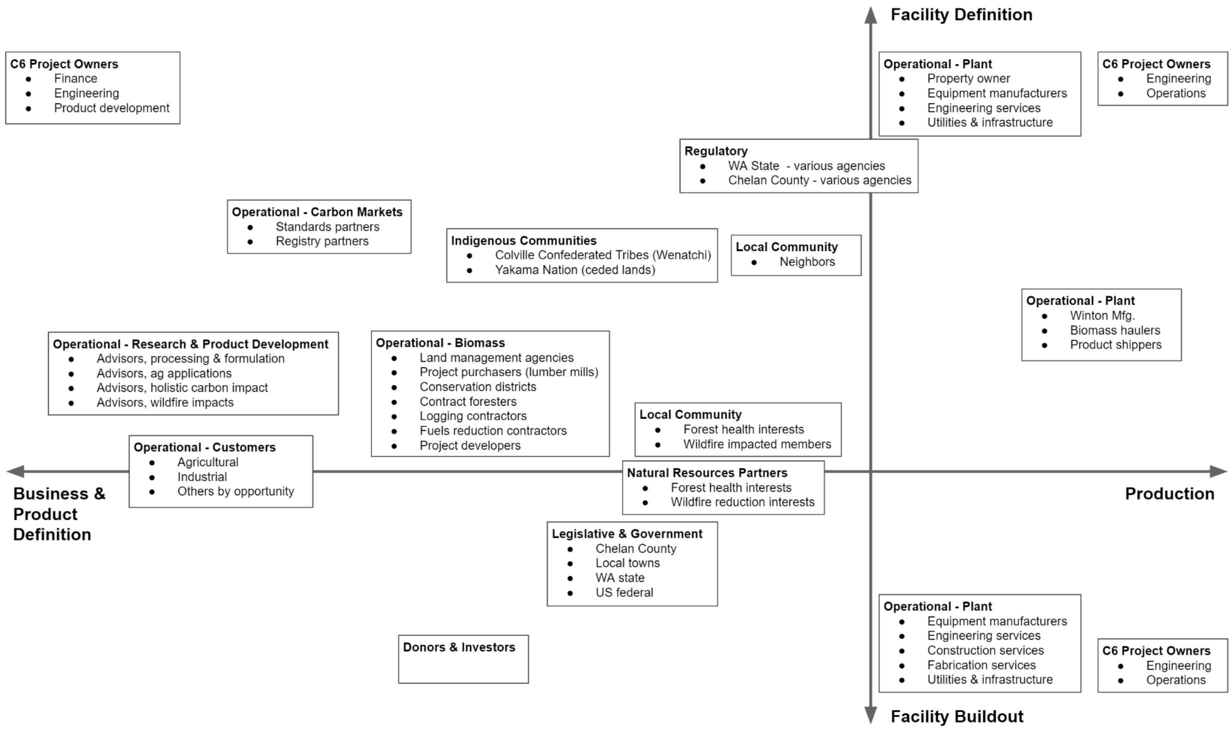


Figure 2: Stakeholder map indicating rough areas and magnitudes of influence by various stakeholder groups for the C6 Pilot Facility project.

1.2. Stakeholder Engagement Approach

Given the early-stage and uncertain nature of our project, our early stakeholder engagement was conducted on an as-needed basis. This was for a couple of reasons:

- We were heavily resource-constrained
- We felt that we shouldn't ask for people's time if we didn't have immediately important needs (e.g. research questions, subject matter expertise, process data)

Most of our stakeholder engagement was focused on direct project-related topics, using typical discussion and correspondence mechanisms. For example, we engaged with local legislators to gauge their support and determine whether they could connect us with financial and other resources. We connected with land management agencies to understand their wildfire risk reduction projects and how biomass could be made available for our operation. We connected with permitting agencies to define project constraints. And, we connected with prospective customers to understand their needs and determine potential product outlets.

We also engaged with the general community on a limited basis to build support and identify concerns. For example, when we were considering a facility in the Methow Valley, we held multiple informational sessions for the community, and C6's co-founders sat for Q&A with the local radio station. After we shifted our focus to the Wenatchee Valley and the Winton mill site, we gave presentations for community organizations (e.g. Wenatchee River Institute) and participated in multiple community events.

We also partnered with Forest Concepts, a WA-based biomass processing equipment developer and manufacturer, on a grant focused on modular, community-scale biomass pre-processing systems. The idea was to demonstrate how direct, intentional engagement with the community during system design and development would result in better outcomes than the delays and litigation some project developers have experienced recently. In this partnership, we developed, delivered, and analyzed the responses to a stakeholder survey to gauge local priorities related to this business and impressions of the operation and potential products. The findings of this survey were primarily related to the facility, looping stakeholder priorities and impressions into the system design. It was completed in the last quarter of 2022, with 14 respondents, including 3 C6 stakeholders.

2. Key Stakeholder Influences on the C6 Business Model

2.1. General

2.1.1. Wenatchee Valley community members in general, across multiple occupational, leadership and demographic dimensions, are hopeful for a solution to reduce extreme wildfire risk in the region. Local citizens face multiple wildfire-related issues that make their lives substantially more challenging - notably diminished air quality, increasing insurance rates, and the anxiety of fire season.

2.1.2. Local private landowners cannot find economical outlets for the excess forest biomass on their properties. In many cases, they are aware that their properties are overstocked and want to do something about it, but have limited resources to bear the high costs of forest biomass removal.

2.1.3. In the DOE SBIR stakeholder survey, we asked respondents to rank a list of priorities for our project. The priorities were as follows, with average ranked scores across external respondent groups (officials, partners, users) shown in Table 1:

Priority	Avg. Ranked Score
Provide markets for forest health treatment thinnings, trimmings, and brushy biomass	4.5
Reduce wildfire risks by taking in Firewise biomass for biochar or other market production	1.9
Eliminate smoke impacts on residents and businesses (from fires, prescribed burning, slash/pile burning, etc.)	2.9
Create local jobs related to forestry, wood processing, and environmental protection	4.7
Improve agricultural and forest soils through application of biochar to agricultural fields, vineyards, orchards, and forests	4.4
Address climate change by sequestering biochar produced from woody biomass (a stable form of carbon)	3.8
Monetize available carbon through participation in carbon markets as part of addressing climate change	6.0

Table 1: Summary of survey respondent priorities for the C6 project.

We were surprised by these rankings, for example how much higher carbon monetization scores related to reducing wildfire risk and eliminating smoke impacts. We also saw a significant spread of scores for each priority across respondents. Our conclusion is that these priority areas are all important, depend on stakeholder perspective, and could be emphasized in different ways with different stakeholders to help elicit support and expose concerns.

2.1.4. In the same survey, we asked respondents "What one word would you use to describe how our project will affect you?" The resulting list reinforced general support for our approach.

- Responsible
- Safer
- Opportunity
- Pioneering
- Impact
- Solutions
- Capacity
- Community-involved
- Smoke-reduction
- Synergy

2.2. Forest to Plant

2.2.1. While the area around the proposed facility site is a top US Forest Service (USFS) priority for wildfire risk reduction, limitations currently exist to making thinned biomass available for removal from USFS projects, because it isn't standard practice to include this removal in project National Environmental Policy Act (NEPA) evaluations. While this will likely change in the future due to pressure on the USFS to reduce wildfire risk and contain firefighting costs, understanding these limitations influenced C6's feedstock strategy, driving a near-term focus on county, state and private sources.

2.2.2. Local logging operators indicated that our proposed forest biomass payment price of $40/delivered ton is compelling enough for them to implement the logistics of hauling small diameter logs from local projects to the facility.

2.2.3. Cascadia Conservation District and DNR foresters shared insights from their experience working with local private landowners to assess and implement Firewise and thinning projects, which helped us understand that our biomass payments would materially reduce overall project costs for private landowners given existing subsidies from WA DNR and USDA NRCS.

2.2.4. Individuals in county, state and federal forestry agencies are motivated to help private and public landowners reduce fuel loading in their forests and reduce wildfire risk. Administrative friction is due to bureaucratic process, not individual interests.

2.3. Customers & Products

2.3.1. Our regional approach, based on biochar sales into the Columbia Basin agricultural market (~40-240 delivery miles), has been generally well-received. High level stakeholders, from legislative reps to representatives of community organizations (e.g. Chumstick Wildfire Stewardship Coalition) and landowner advocacy groups (e.g. Washington Farm Forestry Association), are motivated by the concept of removing carbon from where we have it in excess in our forests to applying it to regional agricultural soils where it is in short supply.

2.3.2. Stakeholders connected to the forestry and forest products industry have expressed skepticism about biochar as a forest product that can transform the small diameter tree market. People have been working to identify a transformative suite of forest products for some time, and biochar and its related co-products have been in that mix. The skepticism we heard, and the history it's based on, has informed our business model approach. Specifically, we have focused on maximizing revenue streams, taking advantage of carbon sequestration and associated credits, and productive use of all the biomass and the heat it generates.

2.4. Carbon Markets

2.4.1. Stakeholders from the voluntary carbon markets informed us that a feedstock strategy that leverages biomass from forest health treatments would be very marketable and attractive to offset purchasers. These highly marketable offsets would likely allow us to price at the high end of the market and potentially unlock capital to build the facility.

3. Key Stakeholder Influences on the C6 Facility Design

3.1. Forest to Plant

3.1.1. Project purchasers and logging contractors in the region indicated that if C6 wants to minimize feedstock cost and maximize the amount of biomass to be made available, then the plant should be configured to receive small-diameter logs up to 40 feet in length from standard log trucks. The form and length are key constraints for the pre-processing system design.

3.1.2. Logging contractors also indicated that minimizing hauler time on site would help drive a preference toward deliveries to the facility, which impacts logistics equipment choices and project CAPEX.

3.1.3. Local private landowners and representatives of the Chumstick Wildfire Stewardship Coalition emphasized that our ability to receive wood chips and mixed brushy Firewise material would be helpful to local residents. While we see this as a low-volume source of feedstock that is unlikely to have significant impact on wildfire risk reduction, we recognize the value in helping the local community with the challenge of disposing of their excess woody material. We initially looked at this as a later facility addition, because it would require more material handling space and equipment. However, our system layout plan changed in 2023, making it easier for us to receive and process wood chips to help the local community.

3.2. Plant

3.2.1. Building codes and permitting requirements are constraints for the facility. Officials with the following agencies (Table 2) helped us understand those constraints and plan for them:

General System Permitting Stakeholders	
Application Area	**Agency**
Critical Areas & Shorelands	Chelan County DNR WA Dept of Ecology
Building	Chelan County Community Development
Solid Waste	Chelan-Douglas Health District WA Dept of Ecology
Hazardous Waste & Toxics Reduction	WA Dept of Ecology
Air Quality	WA Dept of Ecology
Electrical	WA Dept of Labor & Industries
Fire Safety	Chelan County Fire Marshal
Noise	Chelan County Public Works
Health & Safety	WA Dept of Labor & Industries
Water Quality	WA Dept of Ecology
Domestic/Potable Water	Chelan-Douglas Health District
Septic & Sewage	Chelan-Douglas Health District

Table 2: Summary of permit application areas and stakeholder agencies.

3.2.2. The layout of our system on the site underwent multiple evolutions as we matured our design, zeroed in on the target pilot capacity, and received input from multiple stakeholders

3.2.2.1. The property owner provided preferences about which parts of the site they wanted to keep open for specific future uses.

3.2.2.2. The general manager of Winton Manufacturing provided significant input based on his knowledge of the site and experience operating there.

3.2.2.3. The Chelan County Fire Marshal provided valuable inputs as we weighed tradeoffs of operating on different parts of the site, especially for our pre-processing system.

3.2.3. In the DOE SBIR stakeholder survey, we specifically asked about dust, noise and 24/7 operation of the facility (Table 3). Note that the respondents do not include adjacent neighbors.

Question	# of Responses
What is a tolerable visible dust level and frequency to you?	*choose 1*
1 - Very limited - site footprint	3
2 - Limited - radius of 1/4 mile	3
3 - Follow OSHA AQI standards	3
4 - Not limited	1
What is a tolerable noise level from the operation to you?	*choose 1*
Operational noise acceptable 9-5 hours of operation only	5
Limited noise acceptable <85 decibels (lawnmower)	5
What kinds of noises from businesses are most obnoxious to you?	*can choose multiple*
1 - Construction Noise	7
2 - High-pitched	2
3 - Loud banging	6
Is it ok with you that some of its operations need to run 24 hours a day?	
Ok - noise-dependent	10

Table 3: Summary of stakeholder responses to questions about facility disturbances.

It's no surprise that stakeholders don't want to have dusty, noisy facilities running in their neighborhoods. What we took away from this is that the dust and noise levels absolutely must be mitigated, which we cover in more detail in the Plant section.

While the responses indicated that 24/7 operation is noise dependent, qualitative discussions also highlighted concerns about nighttime lighting at the site. Bright lights, especially those pointed away from the site, should be avoided.

3.2.4. We talked with one adjacent neighbor to the Winton mill site outside this survey. He indicated that noise from operations at the site have been acutely bothersome, and that the train noise is similarly bothersome. This further underlines the need to mitigate operational noise.

3.2.5. We didn't ask about increased truck traffic in the stakeholder survey, but it has come up in various stakeholder conversations. The volume of truck traffic we expect to support the operation is limited, especially at pilot startup scale. In context of the Winton mill site, this traffic would most likely travel directly from

U.S. Hwy. 2 to the site using Winton Mill Rd. (~⅛ mi.), and avoiding Winton Rd., the county road running to Coles Corner.

3.3. Customers & Products

3.3.1. In our customer discovery process, we talked with prospective customers from multiple industries. Biochar can be applied as a compost amendment in high volumes, especially in areas like manure composting. These volumes make delivery via commodity belt trailer preferable to delivery via bulk bags. This has impacted our biochar material handling and storage approach.

3.3.2. During our discussions with prospective customers it became clear that producing small particle biochar ($\lesssim$ 3mm or 0.13 in) would make logistics and the application of our product difficult for them, particularly since the smaller particles could tend to blow away in the wind before being mixed into compost or the soil. This learning reinforced the idea that we are better off starting with small diameter trees or chips and avoiding sawdust from mills, but there are applications in which this is less of a concern.

3.4. Carbon Markets

When a biochar producer is pursuing carbon credits for their product, biochar carbon standards drive a number of product & operational requirements.

3.4.1. Some requirements are related to biochar properties (e.g. H:C ratio, fixed carbon content), which impacts biochar production equipment selection. Most of the available equipment can operate across a range of conditions that provides flexibility to meet these requirements.

3.4.2. Some of the standards state that at least 70% of the waste heat produced in the process must be put to valuable use. This impacts the overall process design, driving heat recirculation for feedstock drying or heat sharing to adjacent operations.

3.4.3. The standards require that all energy used in the production process be included in a system Life Cycle Assessment (LCA) to account for carbon emissions vs. carbon retained in the biochar and sequestered. This has some impact on equipment decisions regarding energy sources (e.g. electricity vs. diesel) and efficiency, which in turn impacts system CAPEX and OPEX.

3.4.4. The standards require testing of the biochar products to verify properties, and measurement and tracking of product masses to establish a chain of carbon custody from biochar production to application. These requirements impact equipment selection and product logistics layout at the site (e.g., product trucks must scale).

4. Securing Support & Resources

C6's stakeholder engagement exposed us to funding and collaboration opportunities, helping us secure much-needed resources and support for early-stage operation.

- Our initial discussions with Chelan County Commissioner Bugert led us to investigate the Winton mill as a potential facility site. He and Commissioners Overbay and Gering subsequently sponsored critical funding for the completion of this study.
- Outreach to legislative representatives led to both operational and capital funding from the state of WA.
    - Our initial operational funding was via the WA Dept. of Commerce, originating from a state budget appropriation championed by our 12th District legislators, including Senator Brad Hawkins and Representatives Keith Goehner and Mike Steele.
    - Our initial capital funding was via a state capital budget appropriation, for $1.425MM, also championed by our 12th District legislators.
- Outreach to stakeholders at the USFS led to a number of grant opportunities, primarily via the USFS Region 6 Wood Innovations Program, eventually resulting in operational funding.
- Stakeholders pointed us to other grant opportunities that we pursued, and while we didn't win them, we are grateful for the opportunities.

A notable confluence of collaboration and funding opportunity is our recent collaboration with the Chumstick Wildfire Stewardship Coalition and the Chelan County Dept. of Natural Resources to propose implementation of biomass utilization elements of the Leavenworth and Chelan County Community Wildfire Protection Plans for a USFS Community Wildfire Defense Grant. If awarded, it would provide $5.4M in capital funding that would go toward our pilot facility as a long-term investment in biomass utilization for the area, as opposed to the direct funding of forest health treatments that's typical for the grant. Both organizations are critical stakeholders given their influences in the area adjacent to the Winton mill site, and we are grateful for their open collaboration.

Another notable collaboration and funding opportunity has been with the Washington Farm Forestry Association, who advocates for private forest landowners in the state. Our collaboration with them led to a proposal for the Inflation Reduction Act Small Forest Landowner grant to fund market development for biochar and associated products, along with a number of other projects related to maturing the biochar market to secure an economic outlet for small diameter trees and help small forest landowners manage the health of their holdings.

5. Conclusions and Remaining Gaps

In general, we found our stakeholders to be supportive of this project. Again and again, they suggested potential grants or other funding sources, new contacts who might be able to help us, and potential product applications. People in the region have a strong desire to find a proactive, preventive mitigation to extreme wildfire risk, especially if it involves creating local jobs and products that have a positive impact on our economy and society.

As noted above, some healthy skepticism about biochar has been demonstrated by some stakeholders. In the past few years, research on the topic has surged, and several groups across the United States and beyond have attempted to start biochar-based ventures, some successfully and some not. The contributing reasons for this are suggested in the following sections, interwoven into our own project strengths and weaknesses. Based on the track record of biochar to date, skepticism by stakeholders is reasonable and to be expected, and responses to it should be based on the specific conditions of a venture in its own proposed location with its specific feedstock sources and product outlets - just like for any business venture.

If other project developers pursue this type of project in the Wenatchee Valley, we recommend that they allocate several person-weeks over their initial year to building collaborative relationships within the stakeholder groups identified above. We recommend working initially with representative stakeholders (e.g. state legislators, county commissioners, community group leaders) to secure their support and understand their concerns as representatives of broader stakeholder groups.

Once that foundation is set and relationships are being built across more stakeholder groups we recommend addressing a couple of gaps in our stakeholder outreach. The first is outreach to local indigenous communities. We know that our past Executive Director reached out to contacts at the Yakama Forest Products group. We have some high-level indications of positive impressions, but don't have good documentation of the discussion. We believe C6's co-founders also reached out to Wenatchi representatives of the Colville Confederated Tribes, but again, we don't have any documentation of that. Dialogues should be established with these groups.

Secondly, we heard anecdotally from Winton Manufacturing that they ran into challenges with some adjacent neighbors as they were securing their conditional use permit. We engaged with only one of these neighbors after they reached out to us. We were looking for more funding certainty before we asked for the other neighbors' valuable time. This is a gap that should be addressed.

Forest to Plant

Feedstock availability is critical to any biomass utilization facility but sourcing mission-aligned feedstock is especially important to the C6 Pilot Facility due to our mission of “reducing the risk of extreme wildfire in the Pacific Northwest by advancing forest health” which intentionally limits our ability to pursue other sources of feedstock.

C6’s plan to reduce wildfire risk centers around creating a market from small diameter trees that are fueling extreme wildfires. Currently, these small diameter trees, commonly referred to as “pre-commercial”, have low or no market value. The lack of a market naturally makes treatments to remove pre-commercial trees expensive and reduces their pace & scale relative to the need. By paying for pre-commercial biomass, C6 hopes to reduce the cost of treatments and help accelerate their pace and scale.

Feedstock Objectives

1) Define what type of feedstock (aka “feedstock profile”) C6 would leverage for operations.
2) For a given feedstock profile, determine if there will be enough availability on an annual basis:
    a) to allow us to operate our pilot facility at 100% capacity.
    b) to allow us to scale operations beyond the pilot scale.
3) For the private landowners, understand:
    a) the current solutions for forest health treatments, and identify their pain points.
    b) if C6 could help address some of their pain points.
4) Formalize partnerships with landowners & landowner-facing organizations that can unlock feedstock supply.
5) Assess alternative feedstocks in the event that mission-aligned feedstock sources aren’t available or viable.

1. Feedstock Profile

When determining the target feedstock profile for the C6 Pilot Facility, we considered three factors:

1) Wildfire risk reduction
   In alignment with our mission, we focus on using feedstock that will reduce wildfire risk; this consideration eliminates orchard trimmings and other agricultural residues.

2) Operational costs
   In order to operate profitably and run a sustainable operation that can have an impact for the life of the facility (estimated at 15 plus years), we focus on feedstock that can be delivered to the plant and converted to biochar at costs that align with our business model. Thus, we focus on a denser form of locally sourced biomass that can be cost-efficiently transported using traditional logging trucks - bole wood. Initially, this eliminates using limbwood, which isn’t as dense and can’t be transported using

traditional logging trucks.

3) Product consistency
In order to produce biochar that would deliver consistent physical and chemical attributes, we focus on a limited number of tree species that have the most impact on wildfire reduction, primarily conifers like douglas fir and ponderosa pine. Initially, this eliminates using less impactful but still common species like vine maple and alder.

Based on the above factors, we prefer the following feedstock profile.

1.1. Forms

- Small Diameter Trees (primary): Small diameter trees, 12” or less diameter at breast height (DBH), produced from fuel reduction treatments, fuel breaks or stewardship treatments. Small diameter trees will be the highest priority source of feedstock due to their impact on wildfire risk reduction.
- Processed Tops & Cull Logs (secondary): Processed tops and cull logs that are typically produced from commercial logging operations will be a secondary source of feedstock. Although not as mission aligned, processed tops and cull logs can help fill gaps in feedstock availability, balance feedstock costs and reduce slash pile-related emissions.

Figure 3: Typical pile of small diameter trees

1.2. Forest Health Treatments

The following types of forest health treatments would be the primary sources of our feedstock for a C6 Pilot Facility.

- Fuel Reduction Treatments: Fuel reduction treatments, the selective thinning and removal of trees to return forest ecosystems to more natural fuel stocking levels.
- Fuel Breaks: Fuel breaks, a strip or block of land on which trees, brush and debris have been reduced and/or removed to prevent fire spread and/or for firefighting purposes.
- Commercial Stewardship Treatments: Similar in nature to fuel reduction treatments, commercial stewardship treatments are required as part of a commercial logging project.

Figure 4: Aerial view of a fuel break.

1.3. Species

In an effort to produce biochar with consistent physical and chemical properties that deliver targeted results to customers, we would primarily source biomass from conifers that are critical to reducing wildfire risk. Based on data from the USFS and natural resource consultants Mason, Bruce & Girard (MB&G), these species make up a majority of the pre-commercial biomass available in Chelan County.

- Douglas Fir (*Pseudotsuga menziesii*)
- Ponderosa Pine (*Pinus ponderosa)*
- True Firs *(Abies)*
- Western Hemlock (*Tsuga heterophylla)*

1.4. Limited Haul Radius

In an effort to reduce both the emissions associated with our operations and transportation costs, we would prioritize sourcing feedstock from a 50-mile radius from the Winton mill site.

Figure 5: Image to the left is a rough approximation of the area within the C6 haul radius with planned fuel reduction treatments.

1.5. Onsite Pre-Processing and Forest Products Campus

Onsite pre-processing of small diameter trees is both capital and labor intensive. We will cover this in more detail in later sections, but initially we'd not recommend a biochar operator make those investments with the goal of a standalone operation. Instead, we'd recommend that the pilot be located at a forest products campus where tenants source various forms of biomass from the owner operator. What we've described above in section 1 is the profile of feedstock we'd advocate to be sourced by the campus.

2. Feedstock Forecast

2.1. Forecast Methods

Due to low market values, forecasting pre-commercial feedstock volumes is challenging. If C6 had additional resources and was planning to construct our pilot biochar facility, we would invest additional resources to pay a 3rd party to provide a forecast based on more specific parameters (especially related to haul radius). However, we found two data sets (see below) that we could use to calculate two feedstock forecasts. Since these data sets weren't specifically structured to forecast small diameter tree volumes exactly matching our feedstock profile (forms, treatment sources, species, haul radius), we had to make assumptions for key inputs with imperfect information. With that in mind, we decided it was important to leverage both forecast methodologies in an effort to triangulate volumes.

- **Data Set #1:** Mason, Bruce & Girard estimate (developed for Chelan County Forest Products Campus assessment)
- **Data Set #2:** WA DNR Landscape Evaluation treatment recommendations

2.2. Forecast Scenarios

Due to the uncertainty associated with our analysis assumptions, C6 created three scenarios for each forecast methodology, summarized below.

Mason, Bruce & Girard MBF Forecast			
	Low Scenario	**Base Scenario**	**High Scenario**
Treatment Level	Aggressive	Conservative	Conservative
Operation Type	Ground Only	Ground Only	Ground+Cable

Table 4: Mason, Bruce & Girard forecasted two treatment levels for federal lands, conservative and aggressive.

Although the aggressive treatment forecast results in more board feet in total, it actually results in fewer small diameter trees being thinned and as a result less biomass that fits our feedstock profile.

WA DNR Landscape Evaluation Forecast			
	Low Scenario	**Base Scenario**	**High Scenario**
Years to Complete Treatments	20 years	16 years	10 years
Green Tons per Acre	10	15	20
DNR Proposed Treatment Level	Lowest Acres	Lowest Acres	Lowest Acres

Table 5: WA DNR forecasted treatment levels for state lands.

2.3. Forecast Results

The feedstock forecasts vary in both methodology and scenario. However, all of our forecasted scenarios resulted in estimated feedstock levels in excess of the 19,000 green tons per year required to ensure full capacity operations at the proposed pilot facility. In both the “base” and “high” scenarios, we estimate there is enough feedstock to double the pilot capacity to 38,000 green tons per year.

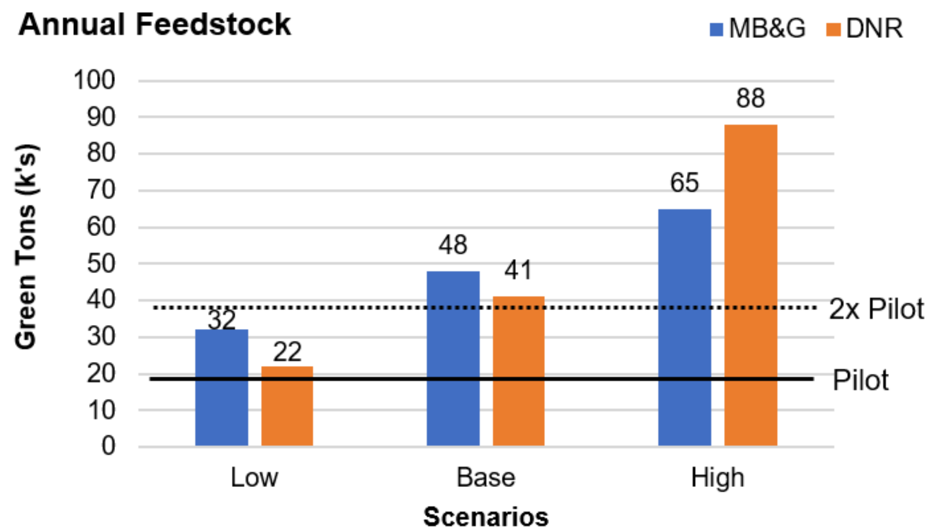


Figure 6: Summary of feedstock volumes from both data sets, across scenarios.

Estimated Annual Feedstock (green tons/yr)

	Scenarios		
Methodology	**Low**	**Base**	**High**
1. Mason, Bruce & Girard	32,000	48,000	65,000
2. WA DNR Landscape Evaluation	22,000	41,000	88,000
Average	27,000	44,500	76,500
Average Relative to Pilot	1.4	2.3	4.0

Table 6: Summary of feedstock volumes from both data sets, across scenarios.

2.4. Methodology 1: Mason, Bruce & Girard MBF Forecast

As part of the Chelan County Forest Products Campus Project, Mason, Bruce & Girard assessed the volume and location of timber in Chelan, Kittitas and Okanogan counties that might be available for harvest over the next 20 years using a publicly available forest inventory and their internal harvest methodology. Mason, Bruce & Girard subsequently provided C6 with a data file containing annual MBF harvest estimates specific to Chelan County. This data was structured by landowner type, species, and size of tree (DBH). Mason, Bruce & Girard forecasted 2 different logging operation types - ground only and ground plus cable.

In addition to the above information, Mason, Bruce & Girard provided 2 forecast scenarios:

- Scenario 1 (USFS management based on current USFS prescriptions)
- Scenario 2 (USFS managed at intensified thinning regimes).

We elected to use the more conservative Scenario 1 for our “base scenario”, and it represents a material increase in thinning by USFS compared to recent years (see below, data from Chelan, Kittitas, Okanogan Counties).

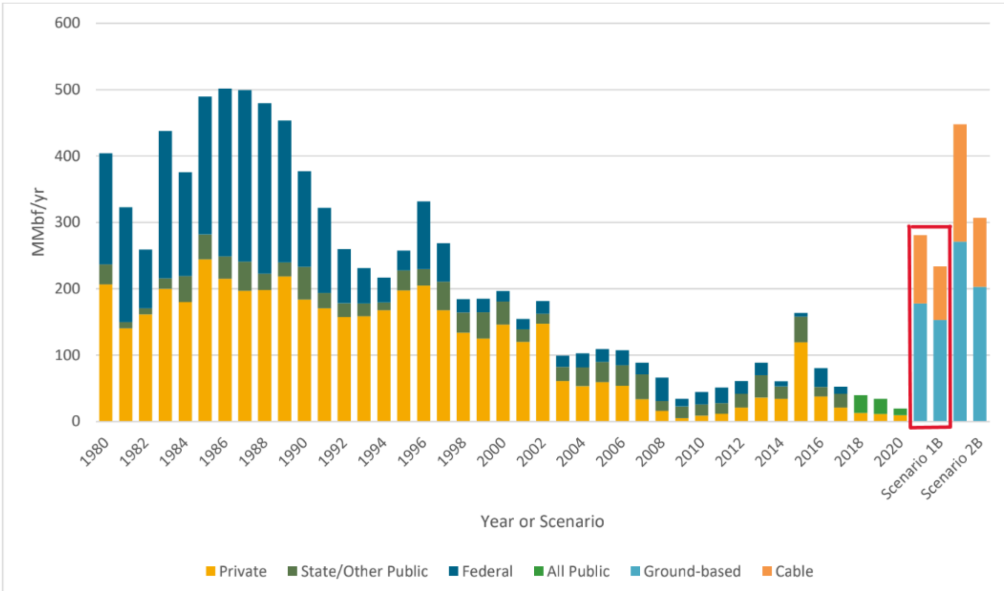


Figure 7: Mason, Bruce & Girard scenario volumes relative to historic harvest levels.

2.4.1. Methodology

Leveraging the Chelan County Mason, Bruce & Girard data, we estimated annual green tons available within our haul radius by allocating the MBF volumes to smaller polygons within Chelan County using the following drivers:

1) available forested acres (Mason, Bruce & Girard)
2) proposed treatment acres (based on DNR land evaluations)
3) green tons per MBF (Mason, Bruce & Girard)

Using this methodology, we were able to estimate how many MBF and green tons might be available for our feedstock profile (all species, DBH <= 12”), within our presumed haul radius, which is initially assumed to be three polygons (Nason Creek, Upper Wenatchee Pilot Project, Chumstick to LP).

2.4.2. Estimates

Using the methodology outlined above, C6 estimates that between 32,000 and 65,000 green tons of feedstock matching our profile are available on an annual basis. These forecasted volumes, which don’t assume any competition for feedstock, exceed the 19,000 tons required to support full operations at the C6 pilot facility by 1.7X to 3.5X.

Estimated Annual Green Tons
all species, dbh <= 12"

Polygon Name	**Low Scen**	**Base Scen**	**High Scen**
Nason Creek	4,115	5,523	7,515
Upper Wenatchee Pilot Project	9,662	12,683	17,257
Chumstick to LP	18,965	29,867	40,636
Total	**32,742**	**48,074**	**65,408**

Table 7: Summary of feedstock volumes from each applicable polygon.

2.5. Methodology 2: WA DNR Landscape Evaluation Forecast

As part of DNR's 20-Year Forest Health Strategic Plan, they conducted Landscape Evaluations for high-priority planning areas across eastern Washington. These Landscape Evaluations, which are available on DNR's "Forest Resilience Data and Mapping System", incorporate specific treatment recommendations including acres treated (see Nason Creek recommendation below).

Table 1. Summary of forest health treatment needs *(range represents low and high end of treatment need).*

Forest conditions to treat		**Treatment need (acres)**	**Current acres by major landowner***				
Type	**Size class**		**USFS**	**Industrial**	**Community**	**Private**	**DNR**
Dry Dense	Small	250 - 500	20	159	726	114	0
	Medium-Large	3,500 - 4,000	3,419	191	175	979	177
Moist Dense	Small	500 - 1,500	239	801	795	264	0
	Medium-Large	1,500 - 4,000	4,672	524	78	671	249
Dry + Moist Open	Medium-Large	1,000 - 1,500	626	846	611	300	30
Total		**6,750 - 11,500**	**These are current acres, not targets*				
Anticipated treatment type	Noncommercial thin plus fuels treatment. May be fire only (prescribed or managed wildfire).						
	Commercial thin plus fuels treatment if access exists. May be noncommercial, fire only (prescribed or managed wildfire), or regeneration treatment.						
	Maintenance treatment: prescribed fire, managed wildfire, or mechanical fuels treatment. *Target range corresponds to 50-75% of dry open and 25-50% of moist open forests.*						

Table 8: DNR treatment schedule for Nason Creek

2.5.1. Methodology

We leveraged data from 3 DNR Landscape Evaluations that are within the C6 pilot facility haul radius: Nason Creek, Upper Wenatchee Pilot Project and Chumstick to LP.

Nason Creek Example	**Lower Treatment**	**Higher Treatment**
acres	6,750	11,500
years to complete	20	20
avg. acres/yr	338	575
x % of acres accessible (1)	75%	75%
x tons per acre	15	15
avg. tons/yr	3,797	6,469
(1) % of acres thinned that are accessible for mechanical removal		

Table 9: Nason Creek example treatment schedule.

We did the same calculation for the Upper Wenatchee Pilot Project and Chumstick to LP Landscape Evaluations, then aggregated the results. We estimated multiple scenarios by modifying three variables:

1) Acres targeted for treatment (two scenarios): DNR lower treatment & DNR higher treatment
2) Years to complete (six scenarios): 10, 12, 14, 16, 18, 20
3) Tons per acres (three scenarios): 10, 15, 20

2.5.2. Estimates

Using the methodology and scenarios outlined above, our forecast had a large range. Our most pessimistic forecast resulted in an estimate of 22,000 green tons of feedstock available per year, which exceeds the needs of the pilot facility. Our most optimistic forecast resulted in 88,000 tons of feedstock per year - far in excess of what's needed, potentially allowing significant scaling of the facility. The base case scenario resulted in 41k tons per year, roughly 2X the 19k tons needed for the pilot facility.

Feedstock Forecast leveraging DNR data
lower treatment acres target
assumes 75% of acres accessible

		Low DNR Targets					
		Years to Complete					
		20	18	16	14	12	10
Tons	**10**	22,031	24,479	27,539	31,473	36,719	44,063
per	**15**	33,047	36,719	41,309	47,210	55,078	66,094
Acres	**20**	44,063	48,958	55,078	62,946	73,438	88,125

Table 10: C6 Feedstock Forecast based on DNR data.

3. Landowner Alignment

We understood that getting strong alignment with landowners was critical to accelerating the pace & scale of forest health treatments and accessing feedstock. With that in mind, we spent significant time understanding the landowner's perspective as it relates to forest health treatments and biomass removal. Based on that discovery, we believe there is strong alignment and mutual benefit to biomass removal, and more specifically biochar production. From the landowners' perspectives, a number of types of benefits were identified but they can be grouped into four main themes:

1) cost reduction,
2) risk reduction,
3) emission reduction,
4) economic development

Because of the strong alignment between C6 and landowners, we were able to sign two non-binding feedstock MOU's with critical local stakeholders: Chelan County Dept. of Natural Resources and the Cascadia Conservation District. We also developed strong relationships with other landowner-facing organizations in Chelan County, including the Chumstick Wildfire Stewardship Coalition and WA DNR Service Foresters.

3.1. Cost Reductions

Forest health treatments are expensive for all landowner types (federal, state, local, private). With the exception of private landowners that have access to cost-share programs, landowners struggle to offset these costs by selling pre-commercial small diameter trees due to a lack of local markets. The high cost of treatments limits the pace & scale of treatments, especially for private landowners. The C6 pilot facility, which would generate revenues from the sale of bio-products, electricity, and carbon offsets, could marginally help reduce the costs of treatments for the 15 plus year life of the plant.

The high cost of treatments is a challenge for all landowner types but especially for private landowners. Despite cost share programs from multiple agencies, it's not uncommon for an average-sized defensible space treatment (five acres) to cost a private landowner over $10,000 (net of cost share). That cost, especially when you factor in the ongoing maintenance, is simply too high for many rural landowners. A 2019 study by the UC Berkeley Goldman School of Public Policy found that 71% of respondents cited the "cost of defensible space maintenance for homeowners" to be the most significant challenge to landowners considering treatments (source).

Leveraging revenues from biochar and other products, the C6 pilot facility (or a forest products campus operator) would pay landowners and project implementers for delivered biomass from forest health treatments. However, the extent that these payments reduce overall costs isn't completely clear due to the incremental costs associated with delivery. Currently the most common way to dispose of this biomass is by piling & burning it, which incurs a relatively low cost. Delivering this biomass would result in incremental costs associated with processing, loading and delivering biomass. Based on our conversations with logging operators, we believe those incremental costs are less than the amount we're proposing to pay for biomass, up to $40/ton but we don't have an estimate of how much an landowner or operator would realize net of the incremental costs.

Beyond the direct impact the C6 biomass payment could have, the pilot facility might help federal, state and local governments extend their treatment budgets and improve project plans. If mills know they'll be able to sell previously unmerchantable biomass for biochar production - they might be more willing to bid on commercial projects with stewardship commitments. If local logging operators know there is a reliable source of revenue for pre-commercial biomass - they might be more likely to make investments to harvest it more cost-effectively.

3.2. Risk Reductions

Safely disposing of the hazardous fuels generated by treatments can be a challenge. Landowners need to prepare and eventually burn their piles following a long list of best practices (see below).

- locate piles correctly
- construct piles correctly
- keep the piles dry
- procure a burn permit
- burn during allowable periods, when conditions are right
- inform neighbors, especially those with breathing difficulties

- have suppression tools

For landowners, this can be overwhelming and adds friction to an already long, complex process. The C6 pilot facility would provide a safe outlet for 19,000 tons of biomass annually, which would eliminate this friction and decrease the barriers of doing forest health treatments, especially on private lands

3.3. Emissions Reductions

Currently, most small diameter trees thinned during forest health treatments are piled (slash piles) and eventually burned. These burn piles emit harmful emissions, including PM2.5 particles, which impact community health. This problem is especially acute for Chelan County where underserved members of the community are more likely to work outdoors. Private landowners are aware of this problem and mention it as a blocker for forest health treatments.

An April 2022 study published by researchers at the University of Washington School of Environmental and Forest Sciences (source) showed increased slash pile burning will result in emissions that exceed EPA's air quality standards, often reaching “very unhealthy” levels and sometimes even reaching “hazardous” levels.

With funding from Chelan County, we commissioned independent consultant CORRIM and the University of Washington to conduct a life-cycle assessment of the C6 Pilot Facility (source). The life-cycle assessment determined the pilot facility will directly eliminate 7,800 mt[5] of CO_2 emissions each year or 118,950 mt over the life of the facility due to thinned biomass not being piled and burned. The 118k mt of avoided emissions are the equivalent to the emissions of 25,500 cars. The LCA did not attempt to quantify the emissions that might be avoided due to C6’s impact on wildfires.

3.4. Economic Development

The forest products industry in North Central Washington has been in decline for decades. This decline has resulted in the loss of many good paying local jobs. Chelan County experienced this directly when the Winton mill closed in 2006 and over 100 employees were laid off. The decline is also seen in logging operations, as there are fewer loggers operating in the area. Local forest landowners all benefit from a stronger local forest products industry as it generally improves the local economy, spurs forestry-related investments and lowers their costs.

3.5. Feedstock MOU’s

In February 2023, C6 and Chelan County Natural Resources Dept (CCNRD) signed a non-binding feedstock Memorandum of Understanding (MOU). The primary

[5] All masses are reported on a short ton basis with the exception of carbon sequestration, which are reported on metric tons basis to align with international standards.

purpose of the MOU was to commit to jointly developing a "cooperative purchase arrangement for biochar feedstock derived from forest residuals generated from forest health treatments administered by CCNRD". The MOU summarized the mutual benefit of this relationship: "generating value from what has traditionally been considered waste. Doing so will extend county budgets and increase the pace and scale of treatments, thereby providing the following benefits: protecting local communities, economy, public health and safety, and natural resources, and sequestering carbon". We appreciate CCNRD's support and hope the learnings shared in our feasibility study eventually lead to the development of a biochar facility so that the benefits outlined in the C6/CCNRD MOU come to fruition.

In May of 2023, C6 and Cascadia Conservation District signed a very similar non-binding feedstock MOU. Cascadia Conservation District is an important landowner-facing organization that helps facilitate forest health treatments in Chelan County.

4. Alternative Feedstocks

Since C6's strategy to reduce wildfire risk centers on creating a market for the small diameter trees that are fueling the wildfire crisis, we are very committed to using small diameter trees as our feedstock. However we felt that it was important to explore using alternative feedstock types on a temporary basis to address risks which will be discussed in more detail below.

1) USFS Project Risk
   A large portion of the feedstock for the pilot facility would be sourced from USFS projects, which traditionally have been delayed or reduced for a number of reasons.

2) Wildfire or Disease
   Wildfire or disease could reduce or eliminate the amount of feedstock available around the pilot facility.

3) Higher than planned cost of small diameter trees
   Right now there isn't a strong market for small diameter trees in Chelan County, but that could change in the future. Limited availability of logging operators could also increase feedstock costs.

4) CAPEX associated with pre-processing small diameter trees
   Small diameter trees used as feedstock will need to be pre-processed before they can be converted into biochar. The CAPEX associated with pre-processing equipment is significant and might make the project infeasible.

To address this risk, we looked at alternative feedstock sources including agricultural waste and determined that mill waste, specifically wood chips, were the best alternative because they could seamlessly be integrated into our existing plant design and are readily available. The mission alignment of the chips depends on where they are sourced. Chips sourced as part of a larger forest products campus that prioritizes feedstock from forest health treatments would be directly aligned. Chips sourced from a traditional sawmill that could source some of their biomass from stewardship projects, and which generally support forest health through regular operation would be less directly aligned.

Working with Hampton Lumber's residuals team, we determined that we could source all the feedstock we need from the Hampton Lumber Darrington mill, in the form of wood chips. We'll cover this in more detail in the Recommended Configurations section, but buying chips dramatically reduces upfront CAPEX and ongoing OPEX, which is critical to generating positive financial returns. At the pilot scale, the cost of undelivered wood chips would support profitable operations. Unfortunately the cost of wood chips including transportation from Darrington is too high to support profitable operations. This fact makes it very important to either be part of a forest products campus or co-locate with a mill.

5. Conclusions and Remaining Gaps

Forecasting volumes for our profile of feedstock, small diameter trees that don't currently have value, is difficult. However, based on the available data, we believe that there is more than enough biomass that needs to be removed in the direct vicinity to provide the pilot facility with 19,000 tons per year for at least 15+ years. This is supported by the forecast done by Mason, Bruce & Girard as part of the Chelan County Forest Products Campus project, as well as thinning guidance included in DNR's Landscape Evaluations. Unfortunately, what treatment needs to happen and what actually will happen aren't necessarily aligned because of several risks, including USFS project delays or funding reductions. To address this and other risks, we determined we can use wood chips from an existing mill as a complement or temporary alternative feedstock.

From a landowner perspective, there is strong support for a biochar facility. A biochar facility would reduce costs, eliminate some pile burning, improve air quality and attract additional logging operators. Because of this strong alignment with landowners, we were able to sign non-binding supply MOU's with Chelan Co and Cascadia Conservation District as well as establish strong relationships with the Chumstick Wildfire Stewardship Coalition and DNR cost-share foresters.

The limited geographic and topographic granularity of the available data contributes to the difficulties of forecasting pre-commercial biomass availability. The data provided by Mason, Bruce and Girard is probably the best data source available and was very useful. Using this data, we made rough estimates of how much of Chelan County total forecasted volumes were within our haul radius. Using their GIS capabilities, Mason, Bruce & Girard could likely improve the forecast accuracy.

Another critical gap we would need to close is confirmation of the delivered cost of feedstock. Based on feedback from local logging operators, we've been told that $40/ton delivered is enough to incentivize operators to deliver feedstock to our pilot facility. Before proceeding with the project, we would work more closely with logging operators to sign purchase contracts that include pricing to help us confirm that critical cost assumption.

Finally, there are a number of risks associated with getting feedstock from USFS lands. One risk we believe can be influenced relates to mechanical removal of pre-commercial trees from USFS projects. Based on guidance from the USFS, allowing mechanical removal isn't automatically granted for all forest health treatments - it requires additional consideration in each project's NEPA analysis. If we were to move forward, we'd need to ensure mechanical removal is included in the NEPA analysis for future projects within the facility's haul radius.

Plant

The core of the C6 Pilot Facility is the plant, which will transform small diameter logs and wood chips into biochar and other products, and package those products for delivery to customers. The process design, equipment selections and subsequent detailed engineering to prepare for site modifications and system installation must be grounded in business needs, regulatory constraints, safety, functionality, performance, cost, product flexibility, etc. We found that it is feasible to build and operate a biochar production facility at the Winton mill site. However, a final determination of the plant's site, design and layout should be based on the constraints, products to be manufactured, and economic performance. The product mix and economic performance should ultimately drive the plant functionality, capacity, and scaling approach.

Plant Objectives

1) Establish context of the plant, including requirements, site conditions, and necessary process steps.
2) Illustrate plant configuration options, and explain how they compare on a techno-economic basis.
3) Summarize findings from an initial regulatory & permit assessment, and outline future steps required.
4) Summarize findings from our initial lease agreement negotiations.
5) Define conclusions and highlight gaps.

In the Conclusions section, we recommend a plant configuration and outline next steps for plant development based on the combined findings for feedstock availability, the plant and product outlets.

1. Plant Context

The biochar production plant sits within the constraining context of business needs, the site, and fundamental process functions. Once these constraints are set, configurations can be designed to fit within them and optimize for techno-economic performance.

1.1. Constraining Facility Requirements

These constraining requirements set the guardrails for system design, helping to ensure that it can be implemented successfully at a fundamental level. The following high-level topics are included in the holistic requirements set; more detailed, formalized requirements statements are available here.

Constraint Category	Requirements Topic
Business	Self-sustaining operation
	Positive annual growth rate to recoup upfront investments
	Upfront capital investment that is achievable to raise given the risk profile
Regulatory & Permitting	Facility conformance to local, state and federal code & permit compliance requirements
	- Chelan County and WA Dept. of Ecology critical areas & shorelands requirements
	- WA Dept. of Labor & Industries facility safety requirements
	- Chelan County building codes & amendments
	- International Building Code
	- International Fire Code
	- National Fire Protection Association
	- International Mechanical Code
	- International Fuel Gas Code
	- National Electrical Code and electrical permitting requirements by WA Dept. of Labor & Industries
	- Uniform Plumbing Code
	- WA State Energy Code
	- WA Dept. of Health and Chelan-Douglas Health District domestic water system requirements
	- WA Dept. of Health and Chelan-Douglas Health District septic system requirements
	Operational conformance to code & permit compliance requirements
	- WA Dept. of Labor & Industries operational safety requirements
	- WA Dept. of Ecology air quality permit requirements
	- Chelan County Public Works and WAC operational noise requirements
	- WA Dept. of Ecology and Chelan-Douglas Health District solid waste requirements for incoming feedstocks
	- WA Dept. of Ecology hazardous waste & toxics reduction regulations for products and waste streams manufactured by the facility
Safety	Unit operation design, labeling and shielding to prevent injuries via sharp edges & corners; hot surfaces; pinch points; gas, smoke or vapor inhalation; explosion; unwanted fire ignition; fall injuries; chemical exposures; and other predictable hazards
	Unit operation safety features to help ensure personnel safety during standard operation, maintenance, and hazard response (e.g. emergency stops, lockout/tagout)
	Handling of feedstock and products in the facility to prevent overflows, leaks, thermal exposures, and other stresses that create facility and personnel hazards
	Standard operating procedures for all processing and hazard response, and personnel training on the SOPs
Supply Chain	Feedstock origin as forest waste in accordance with biochar carbon crediting standards
	Feedstock formats the plant can process, based on functionality and product formulations
	Seasonality of feedstock receiving (for small-diameter logs)
Production	System production capacity to support organization’s mission and business constraints
	Chosen co-product capture & handling given relative techno-economic performance of options (e.g. capturing bioliquids for offtake vs. combusting to generate electricity)
	Packaging of biochar and co-products to support customer needs
	Measures to address neighboring stakeholder concerns (e.g. noise, dust, nighttime lighting)
Site (see Table 16, Table 17, Table 18)	Location or haul radius to minimize cost and emissions of transporting biomass to facility
	Minimum log decking space to support inventory holding for year-round operation, considering seasonality of delivery (for small-diameter logs)

Constraint Category	Requirements Topic
	Minimum pre-processing space for conversion of small-diameter logs into useful format for biochar production
	Minimum biochar production space given production capacity
	Minimum utility levels (electricity, water, sewage/septic) to reliably support operation
	Facility conditions needed for reliable operation
Functionality	Functions required to receive feedstock of each targeted format (e.g., log unloading, log decking, chip unloading)
	Functions required to convert feedstock to appropriate format for biochar production (e.g. debarking, comminution, drying)
	Functions required to convert feedstock to biochar and targeted co-products
	Functions required to capture, post-process, package and store biochar (e.g. cooling, spraying to moisturize, packaging in bulk bags)
	Functions required to capture, post-process, package and store co-products (e.g. bioliquids condensing, separation, intermediate tank storage and mixing)
	Functions required for product quality control (e.g. sampling, testing)
	Functions required for product logistics (e.g. product labeling, biochar loading onto trucks, bioliquids transfer to railcars, truck scaling)
	Functions required to maintain the facility (e.g. backup power, snow plowing, cleaning and housekeeping)

Table 11: Plant constraint requirements topics.

1.2. Biochar Production Process Functions

Biochar production requires a minimum amount of functionality. The preferred feedstock format to support our mission drives expanded functionality (e.g. log processing vs. simply receiving wood chips), as does revenue realization beyond the biochar itself. This set of functionality helps set the context for system layout on the site and some of the choices we've made along the way. We developed a list of functions, indicating which are required and which are optional (Tables 12-15).

Note that a few key decisions drive significant functionality requirements.

- Feedstock format - if the plant only receives wood chips, then significant functionality is removed - the entire pre-processing line - and the capital intensity of the operation dramatically decreases. Receiving SDTs from forest health treatments better fits with our mission, so the mission alignment and cost tradeoffs must be carefully considered.
- Debarking - if the plant receives small-diameter logs, debarking functionality requires other functions upstream and downstream in the log processing chain. If debarking is not included, product quality and consistency might suffer, but the capital intensity of the operation is significantly reduced.
- Co-products capture & handling - if electricity generation or bioliquids capture are chosen to increase revenue, then they drive significant additional functionality and capital cost.

Required functionality key:

- ✅ - required
- ❌ - not required
- ⚓ - functionality anchor that impacts up and/or downstream process decisions

Area	Function	Required for SDTs?	Required for Chips?	Comments
Feedstock pre-processing	Scale feedstock delivery trucks	✅	✅	
	Unload log trucks	✅, ⚓	❌	**THE DECISION TO RECEIVE SMALL DIAMETER TREES IS A SIGNIFICANT FUNCTIONALITY ANCHOR.**
	Load log trailers	❌	❌	This makes operations easier for log haulers
	Store stems	✅	❌	Based on seasonal variation in logging operations and desire to operate year-round
	Load stems into system	✅	❌	Loaded in batches
	Singulate stems	✅ if debarking	❌	Required if debarking, so individual stems can be cut to shorter length to decrease equipment size and cost
	Convey stems	✅	❌	
	Buck stems into shorter logs	✅ if debarking	❌	
	Capture sawdust	✅ if debarking	❌	Required by fire code, if debarking and need to cut stems
	Dispose of sawdust	✅ if debarking	❌	‘Dispose’ likely providing to adjoining Winton Mfg. compost facility
	Convey logs	✅	❌	
	Detect metal in logs	✅	❌	
	Capture reject logs	✅	❌	
	Debark logs	✅ if debarking ⚓	❌	- Highly desirable in the context of ‘engineered biochar’ products, to reduce product formulation and inconsistency risk. **- THE DECISION TO DEBARK LOGS IS A SIGNIFICANT FUNCTIONALITY ANCHOR, UPSTREAM AND DOWNSTREAM.**
	Capture & convey bark	✅ if debarking	❌	
	Dispose of bark	✅ if debarking	❌	‘Dispose’ likely providing to adjoining Winton Mfg. compost facility

Area	Function	Required for SDTs?	Required for Chips?	Comments
	Capture & singulate debarked logs	✅ if debarking	❌	
	Convey debarked logs	✅ if debarking	❌	
	Chip stems/logs	✅	❌	
	Capture & convey chips	✅	❌	
	Store chips	✅	✅	
	Control pre-processing equipment	✅	✅	

Table 12: Feedstock pre-processing functions.

Area	Function	Required?	Comments
Biochar Production	Receive chips	✅	Provides feedstock flexibility for SDT model
	Bin chips for surge events	✅	
	Convey chips	✅	Necessary multiple times
	Comminute chips	✅	Finalize wood particle size per product need
	Screen particles	✅	
	Capture & convey fine particles	✅	
	Dispose of fine particles	✅	'Dispose' likely providing to adjoining compost facility
	Recirculate oversize particles for comminution	✅	
	Convey accepted particles	✅	Necessary multiple times
	Bin particles for surge events	✅	
	Dry particles	✅	
	Control comminution, screening, drying, materials handling equipment	✅	
	Condense water from dryer exhaust vapor	❌	Not strictly necessary, but can be used to moisturize biochar and close a resource loop
	Duct dryer exhaust vapor to atmosphere	❌	If dryer exhaust is above ~120 deg. C, this will likely require additional treatment to meet air quality requirements
	Pyrolize particles	✅	
	Capture & duct pyrolysis vapor	✅	See below for where it goes under 'Co-Products Options'
	Control pyrolysis equipment	✅	
	Cool biochar	✅	
	Moisturize biochar	✅	This is necessary to reduce risk

Area	Function	Required?	Comments
			of product ignition
	Capture & convey biochar	✅	
	Bin biochar for surge events	✅	
	Package biochar	✅	
	Store biochar inventory	✅	
	Load biochar for shipping	✅	
	Scale biochar shipping vehicles	✅	
	Test biochar characteristics	✅	QC for product quality & consistency and per carbon market standard

Table 13: General biochar production process functions.

Area	Function	Required for Electricity Gen?	Required for Bioliquids Capture?	Comments
Product handling & logistics	Co-Products Option 1 - Full Combustion			
	Combust vapor	✅	✅	Minimum viable approach for the vapor stream; must be in accordance with WA Dept. of Ecology air quality requirements.
	Capture & duct flue gas exhaust	✅	✅	
	Mix flue gas stream with ambient air	✅	✅	Depends on how the particular dryer works, though closing this waste heat loop helps control operational cost.
	Control mixing gas proportions	✅	✅	
	Duct mixed gas to dryer	✅	✅	
	Exhaust surplus flue gas to atmosphere	✅	✅	
	Monitor & control combustion device	✅	✅	Combustion air intake control, temp monitoring, etc.
	Co-Products Option 2 - Electricity Generation* *based on the use of technology that transfers heat energy in flue gas to an air stream to drive a microturbine-based generator; other technologies will require different functions			
	Transfer flue gas heat energy to generator	✅	❌	This set of functions is optional, but supports a potential revenue stream.
	Capture electricity	✅	❌	
	Manage & control grid interconnect	✅	❌	
	Capture & duct cooled flue gas exhaust	✅	❌	
	Capture & duct heated air exhaust	✅	❌	
	Mix gas streams with ambient air	✅	❌	

Area	Function	Required for Electricity Gen?	Required for Bioliquids Capture?	Comments
Product handling & logistics	Control mixing gas proportions	✅	❌	Achieve appropriate gas temp and enthalpy for dryer infeed
	Duct mixed gas to dryer	✅	❌	Close waste heat loop
	Exhaust surplus flue gas to atmosphere	✅	❌	
	Co-Products Option 2 - Bioliquids Capture			
	Condense bioliquids	❌	✅	This set of functions is optional, but supports a potential revenue stream.
	Store bioliquids	❌	✅	
	Label bioliquids	❌	✅	
	Provide secondary containment for bioliquids	❌	✅	
	Manage bioliquids temp	❌	✅	
	Separate bioliquids	❌	✅	
	Store aqueous fraction	❌	✅	
	Label aqueous fraction	❌	✅	
	Provide secondary containment for aqueous fraction	❌	✅	
	Store organic fraction	❌	✅	
	Label organic fraction	❌	✅	
	Provide secondary containment for organic fraction	❌	✅	
	Manage organic fraction temp	❌	✅	
	Transfer aqueous fraction for shipping	❌	✅	
	Transfer organic fraction for shipping	❌	✅	
	Capture & duct noncondensable syngas	❌	✅	
	Combust noncondensable syngas	❌	✅	
	Monitor & control combustion device	❌	✅	
	Capture & duct flue gas exhaust	❌	✅	
	Mix flue gas stream with ambient air	❌	✅	
	Control mixing gas proportions	❌	✅	
	Duct mixed gas to dryer	❌	✅	
	Exhaust surplus flue gas to atmosphere	❌	✅	
	Test bioliquids characteristics	❌	✅	

Table 14: Co-products production and handling process functions.

Area	Function	Required?	Comments
Safety	Develop operating SOPs	✅	Standard processing, transport, health events, hazard events, etc.
	Train personnel on SOPs	✅	
	Provide appropriate equipment safety features	✅	E-stops, alarms, lockout/tagout, etc.
	Provide healthy personnel feedback channel	✅	
General operations	Provide personnel facility needs	✅	Restrooms, breakroom, etc.
	Provide backup power	✅	Required for reactor & downstream systems to ensure vapors are not left to cool, condense and foul the wrong locations
	Store and distribute propane	✅	Typical for combustion systems requiring startup & supplemental fuel
	Store and dispense diesel	✅	Required for log hauling & snow removal equip.
	Transport biomass onsite	✅	Depends on solution, could be in bulk bags, belt trailers, via wheel loader, etc.
	Transport product onsite	✅	Depends on solution, could be in bulk bags, belt trailers, via wheel loader, etc.
	Remove snow	✅	C6 is targeting year-round operations
Maintenance	Inspect & address equipment safety features	✅	
	Grind chipper knives	✅ if SDT model	Maintenance function, required ~2X/wk
	Inspect & address moving components	✅	Lubrication, replacement, etc.
	Inspect & address fluid and fuel gas connections	✅	
	Inspect & address duct connections	✅	
	Inspect & address combustion components	✅	
	Inspect & address flue gas stacks	✅	

Table 15: General biochar production process functions.

1.3. General Site Requirements & Conditions

1.3.1. Biochar Production Site Requirements

1.3.1.1. The site must be in a location that is within a reasonable haul radius (~50 miles or less) of mission-aligned biomass, to reduce feedstock cost and carbon emissions. It should also be within a reasonable distance of customers to reduce product delivery costs and carbon emissions.

1.3.1.2. The site must have the necessary space for feedstock inventory storage, pre-processing, biochar production, product storage and operational logistics (Table 16).

Site Component	Minimum Space* (sq ft) *Space minima based on 1.5 ODT/hr pyrolysis reactor infeed rate
Feedstock storage (SDT)	~35,000 sq ft, assuming - cold decks 20 ft in height (max per code) - average log length of 28 ft - 45 deg vertical stack tapers at each end - 25 ft spacing between 2 decks - ~5000 sq ft loader maneuvering space at approach ends of full decks
Feedstock storage (wood chips from SDT)	~8,000 sq ft, assuming - total storage volume of ~28,000 cu ft necessary for 24/7 operation through weekend given pre-processing only during week - storage in 10X 48 ft chip trailers of ~3,000 cu ft ea - trailers parked 4 ft apart - 18 ft clearance retained in front of trailers for low-profile yard tractors
Feedstock storage (wood chips delivered)	0 - 8,000 sq ft, depending on weekend delivery options - if deliveries made on 'as-needed' basis with a large buffer in the front end of the biochar line, then no additional storage is needed - if no delivery is available on weekend, then previous case illustrates need
Coarse pre-processing (SDT)	~25,000 sq ft, including loader approach to log infeed deck, depending on layout
Pre-processing (wood chips)	~ 850 sq ft, including chip receiving bin, infeed surge bin and conveyor, 8 ft x 24 ft comminution and screening module, and fines capture + ~550 sq ft for chip trailer parking
Final pre-processing and biochar production	~2,750 sq ft, including drying, reactor, thermal oxidizer, bulk bag packaging, truck loading - Minimum dimension to support movement of equipment housed in 40 ft. ISO containers, both X-Y translation and rotation to re-orient if needed
Product storage	Depends on packaging and inventory approach for given customer set* - bulk trailer loading - space for a commodity belt trailer to be parked while awaiting delivery to customer - bulk bag inventory - pallet rack space to hold bulk bags, plus space between for forklifts, minimum ~1000 sq ft * Note some facilities pile the product indoors or outdoors on the ground or floor to be loaded on a demand basis.
Operational logistics	Depends on facility, consider: - feedstock and product truck scaling - sufficient space between equipment for safe operation, housekeeping, maintenance access

Site Component	Minimum Space* (sq ft) *Space minima based on 1.5 ODT/hr pyrolysis reactor infeed rate
	- vehicle backing, turnaround, general maneuvering space - regulatory requirements, e.g. secondary containment for bioliquids - product loadout and shipping space - rail access for long-term shipping scale

Table 16: Space requirements for the C6 pilot facility.

1.3.2. The site must have the necessary utilities available to support the facility's operation (Table 17).

Utility	Minimum Capacity* *Utility minima based on 1.5 ODT/hr pyrolysis reactor infeed rate
Electricity - coarse pre-processing (SDT)	300 kW (~360 kVA), 480VAC 3-phase
Electricity - final pre-processing, biochar production & product handling	125 kW (~140 kVA), 240VAC 3-phase 250 kW (~260 kVA), 460VAC 3-phase provides more flexibility - This is heavily pyrolysis reactor-dependent. Some reactors use electrical heating technology to maintain the pyrolysis reaction, while others recuperate waste heat to do so
Water - pre-processing	Minimal for periodic cleaning and maintenance
Water - biochar production & product handling	~45 gallons per hour, plus periodic cleaning and maintenance - Some water needs can be met by condensing water vapor from the biomass drying operation
Water - personnel use	120 gallons per day (5 gallons per hour) - based on typical office use of ~20 gallons per day per employee (source)
Water - fire suppression	Sufficient volume and pressure to conform to IFC & NFPA regulations
Septic	Volume to support personnel water usage

Table 17: Utility requirements for the C6 pilot facility.

1.3.3. The site must be modifiable at a reasonable cost to support the facility's operations (Table 18).

Site Component	Required Condition Post-Modification
Feedstock storage (SDT)	Flat, smooth surface suitable for decking logs and operating a log unloader and/or wheel loader
Feedstock storage (wood chips)	Surface suitable for parking one or more chip trailers
Coarse pre-processing (SDT)	Smooth, appropriately graded log hauling approach surface to log infeed equipment, suitable for log unloader and/or wheel loader
	Ground conditions support reasonable piers, footings, etc. to appropriately mount & support processing equipment
Pre-processing (wood chips)	Surface suitable for parking one or more chip trailers
Final pre-processing and biochar production	Covered space, protected from precipitation, ideally indoors
	Flat, smooth floor surface suitable for appropriately mounting and

Site Component	Required Condition Post-Modification
	supporting processing equipment
	Floor drainage to support equipment cleaning
	Ceiling height to support installation of combustion stacks, overhead conveyance into bulk commodity trailers, etc.
	Ceiling and roof and/or wall construction to support pass-through ducts for combustion air feed, post-drying and post-combustion emissions and any other emissions or make-up air required
	Doors large enough in width and height to accommodate pull-through or back-in of 2 semi trucks in parallel, with reasonable spacing to support driving needs
	Sufficient lighting to support personnel travel within the space, both by foot and vehicle (forklifts, feedstock and product trucks)
Product storage	Ceiling height to allow pallet racks to hold 3 vertical levels of bulk bags, with appropriate spacing between levels
Operational logistics	Sufficient outdoor lighting to support safe operation of vehicles and equipment outside daylight hours (e.g. log unloading at morning and late afternoon on short winter days)
	Reasonably smooth driving lanes with sufficient turning radii to allow truck traffic where needed
	Truck turnarounds where needed
	Areas to place plowed snow
Common to all	Roof snow-shedding exposure only where acceptable
	Appropriate fire sprinkler systems for indoor production areas
	Water source accessible and appropriate for feedstock inventory fire suppression if needed
	Appropriate lanes for fire apparatus travel

Table 18: Site condition requirements for the C6 pilot facility.

1.3.4. Fire constraints

As mentioned in previous sections, fire codes and regulations drive facility and production constraints (Table 19). Shown here are keystone requirements, many of which require further examination of the International Fire Code and related industrial and building codes. Note that the occupancy group classification will depend on whether we're capturing bioliquids from the process, and their classification level as flammable (unlikely) or combustible liquids. This classification has not yet been completed.

Fire Safety Component	Required Conditions
Log dry decks (SDT feedstock storage)	- Maximum dimensions of 500 ft L x 300 ft W x 20 ft H - Separated by at least 100 ft - Placed at least 100 ft from 'exposures' (e.g. buildings) - IFC 2806.2
Sawdust storage	Maximum dimensions of 250 ft L x 150 ft W x 25 ft H (IFC 2808.3)
Bark storage	Maximum dimensions of 250 ft L x 150 ft W x 25 ft H (IFC 2808.3)
Wood chip storage	Maximum dimensions of 250 ft L x 150 ft W x 25 ft H (IFC 2808.3)
Biomass collection and storage	- Sawdust, bark, wood chips, screened fines and other flammable biomass shall be properly collected and stored. (IFC 2808) - Static piles of biomass shall have internal temperatures measured, with weekly monitoring and recording of temps. (2808.6)
Materials handling	Approved materials handling shall be available for moving flammable biomass during firefighting operations. (IFC 2808.9)
Occupancy group	The indoor production area shall be considered Group H-3 occupancy if bioliquids are captured and stored, assuming they are classified as Class I, II, or IIIA flammable or combustible liquids. (IFC 202) The indoor production area shall be considered Group F-1 occupancy if no bioliquids are captured and stored. (IFC 202) - To be validated by Chelan County Fire Marshal
Automatic Sprinklers	For Group H-3 occupancy, the indoor production area shall include an automatic sprinkler system. (IFC 903.2.5.1) For Group F-1 occupancy, the indoor production area shall include an automatic sprinkler system if the *fire area* exceeds 12,000 sq ft. (IFC 903.2.4)
Fire extinguishers	Appropriately rated and sized fire extinguishers shall be placed within reasonable distance for personnel access for most biomass processing equipment. (IFC 2808.8)
Access roads	Fire apparatus access roads shall be provided around the facility, and kept clear in case of fire emergency. (IFC 2803.6)

Table 19: Fire safety requirements for the C6 pilot facility.

1.4. Site Options

We initially pursued a biochar facility in the Methow Valley, where C6 Forest to Farm was founded. While its wildfire risk is very high and needs to be addressed, the Methow Valley has a very limited number of industrially zoned property options. We found a few candidate properties for lease, but all had significant drawbacks. Most were previously gravel pits with limited infrastructure, and would require significant investment just for utilities. All the properties would have required new structures to house the plant.

We were introduced to the Winton mill site as an option by former Chelan County Commissioner Bob Bugert. We began to pursue it given its past usage and clear potential for our facility. For risk management purposes, we looked briefly at other commercial and industrial properties on the market in the Wenatchee Valley, and didn't find anything that could meet our constraints while providing a lease option and appropriate existing structures to adapt for our purposes. Chelan County recently sponsored an assessment of potential forest products campus locations (source), which would be a good resource to evaluate if looking for an alternative site. We believe much of what we learned in assessing the Winton mill site could be applied to help assess other sites for their fitness for biochar production.

1.5. Winton Mill Site Constraints and Conditions

1.5.1. Property Owner Constraints

- The Winton mill property includes covenants restricting uses as a sawmill or woodworking facility, but biochar production was included in the Conditional Use Permit obtained by Winton Manufacturing.
- As we initiated the lease definition process, the property owner indicated that they wanted to be thoughtful about adjacent sections of the Winton mill building they would lease to a given tenant, so as to not break up the space and keep spaces accessible for other tenants.
- As we progressed through the lease definition process and the property owner further defined their overall leasing strategy, they indicated that they wanted to preserve a particular indoor space for multiple tenant spaces, as well as particular spaces adjacent to the building for tenant parking and access. This impacted our approach to site layout, though it did not block us from finding a solution.

1.5.2. Site Conditions

1.5.2.1. Indoor Spaces

The indoor spaces of the mill available for our consideration for biochar production are shown in Figure 8.

The primary indoor spaces we considered were A, B and E1, due to their sizes and drive access for equipment installation and operations. Spaces A and B are also adjacent to the 'courtyard' area north of the building, which we were considering early on for feedstock storage.

We didn't consider space C, given that Winton Mfg. indicated that they planned to add an operation on the north end of that space (red section in Figure 8). Spaces C and D are one contiguous 'hall', but have a number of structural columns in the middle of the layout, making drive access through the door at Space C into Spaces D and E2 tricky, especially for anything larger than a passenger vehicle. Space E2 is contiguous with E1, with the exception that its floor grade is 3 ft higher. This, combined with its remoteness from the Space E drive door limits its utility for our operation.

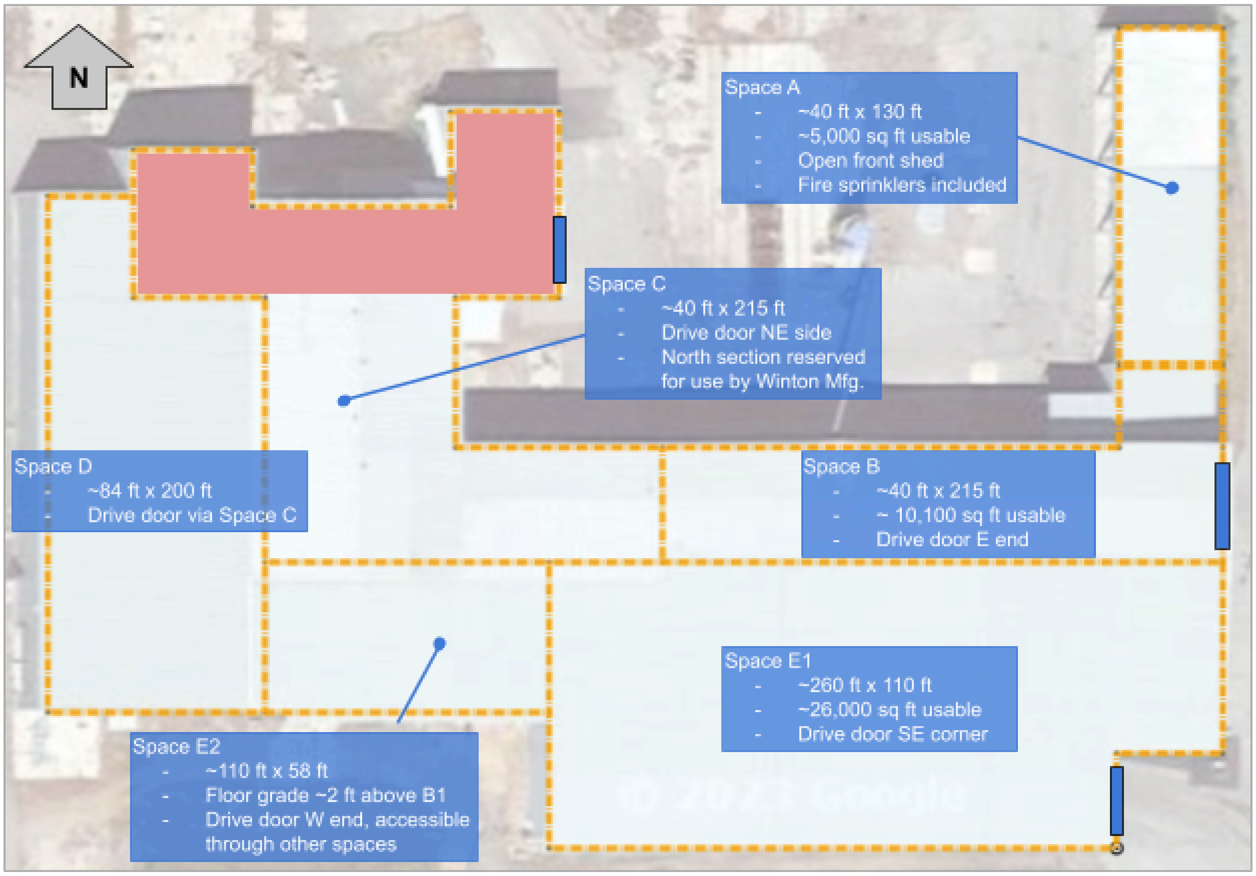


Figure 8: Winton mill site indoor spaces offered for lease consideration by the property owner.

1.5.2.2. Outdoor Spaces

We considered all the spaces shown in Figure 9 for log storage and pre-processing as our conceptual development progressed. In short, we started investigating concepts based closer to the mill building in Spaces A, Z, Y and X so that log storage, pre-processing and biochar production would be contiguous, connected via automated conveyance. Our analysis later drove us to consider spaces V and W.

We considered Space A, an open-front shed with a concrete floor, for a variety of purposes, including our pre-processing line and wood chip storage. Its south wall, shared with Space B, would allow a conveyance pass-through into the mill building. The primary challenge it poses is the posts supporting the front of the structure, but they're generally far enough apart to work between.

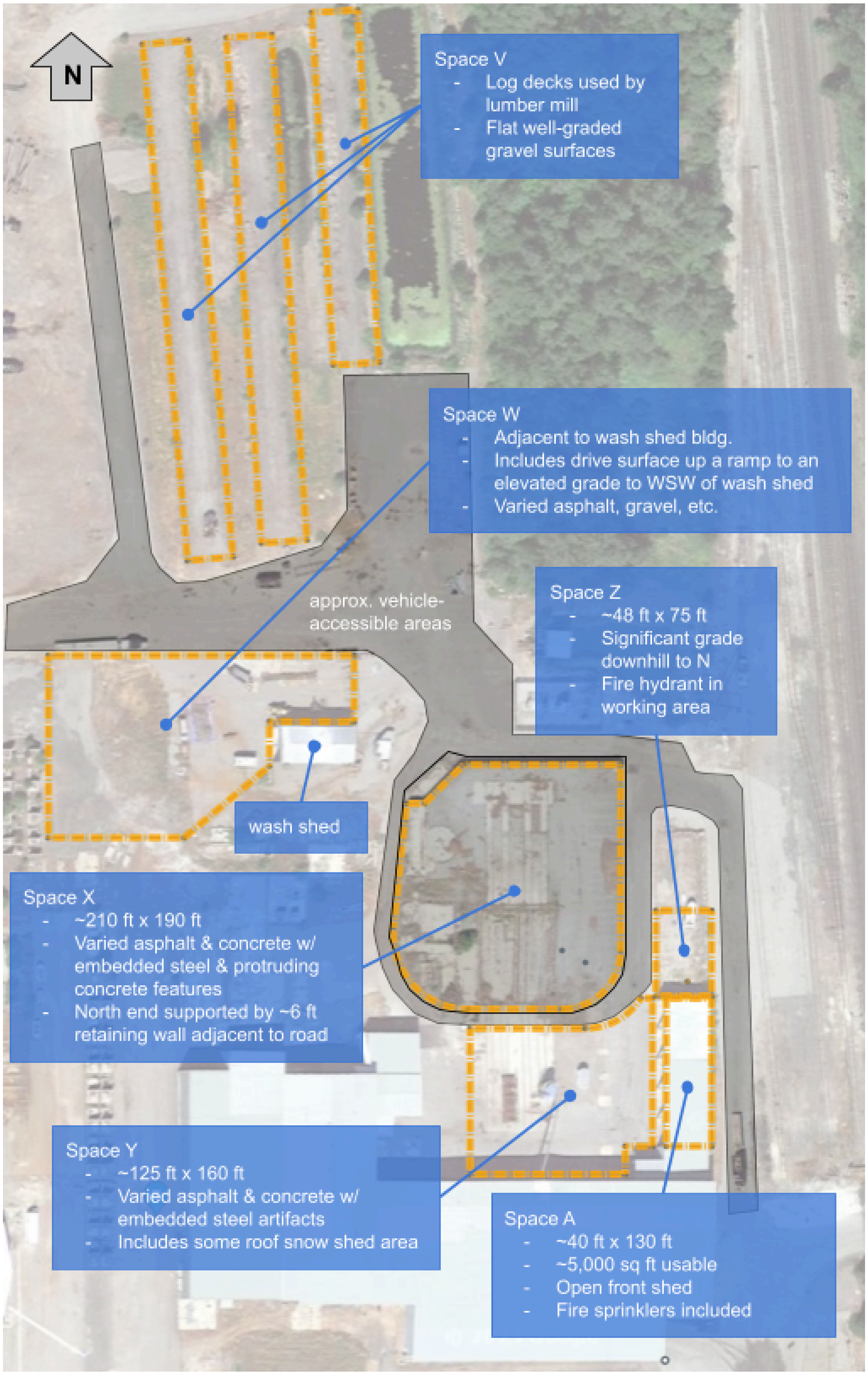


Figure 9: Outdoor spaces considered for log storage & pre-processing.

We considered Space Z as a location for a log infeed deck to serve a pre-processing line in Space A. There's about 40 ft of west-east vehicle approach to Space Z, across the lane between Space X and Space Z. It's limited by the beginning of a retaining wall on the east edge of Space X. A fire hydrant is located near the end of the Space A shed, which limits equipment placement. Space Z also has a downhill grade to the north away from the Space A shed, which would complicate equipment placement there.

We considered Space Y primarily for pre-processing, though we also briefly considered placing a chip storage system there. The north side of the mill roof sheds snow onto the south edge of this space, which essentially eliminates consideration of a ~24 ft strip along that edge. The surface is composed of a mix of asphalt, which seems to be deteriorating condition, and concrete with embedded steel features used during the mill's operation.

We considered Space X for log storage and pre-processing. We initially targeted it for log storage in conjunction with pre-processing in spaces Z, Y and A. We later determined that log cold decks must be 100' away from exposures per fire code, which eliminated much of Space X for that purpose. We then investigated using the more limited log storage in conjunction with pre-processing at the south end of the space.

Space X does have some significant challenges for these types of uses, however. The surface is mostly concrete with embedded steel features, but includes many concrete protrusions, which were likely footings and pads for past mill equipment. In order to be usable as a log cold deck space with heavy equipment travel, the concrete would have to be smoothed, or a very thick course of material would need to be added to create a smooth grade.

Later in our concept development process, we considered Spaces V and W for log storage and pre-processing. Space V was used for log storage by the mill, and includes water retention ponds between the deck lanes to serve deck sprayers that were used to prevent uneven drying and insect and weather degradation of logs. We would not need those for our feedstock, since drier is better for our process and degradation of the wood grain is not a concern. The log decks are arranged in roughly parallel lanes, about 18 feet wide, with flat gravel surfaces.

Assuming log storage at Space V, Space W would be a good adjacent location for pre-processing. It includes both asphalt and un-finished surfaces, and grade elements that would make it easier to set up a pre-processing line that includes a tall debarker. Furthermore, the wash shed could be incorporated into the operation for vehicle parking, tool storage, etc.

Across the drive lane immediately east of Space A is a rail siding, which would be beneficial for shipping logistics, especially with scaled-up operations to produce and deliver bioliquid products.

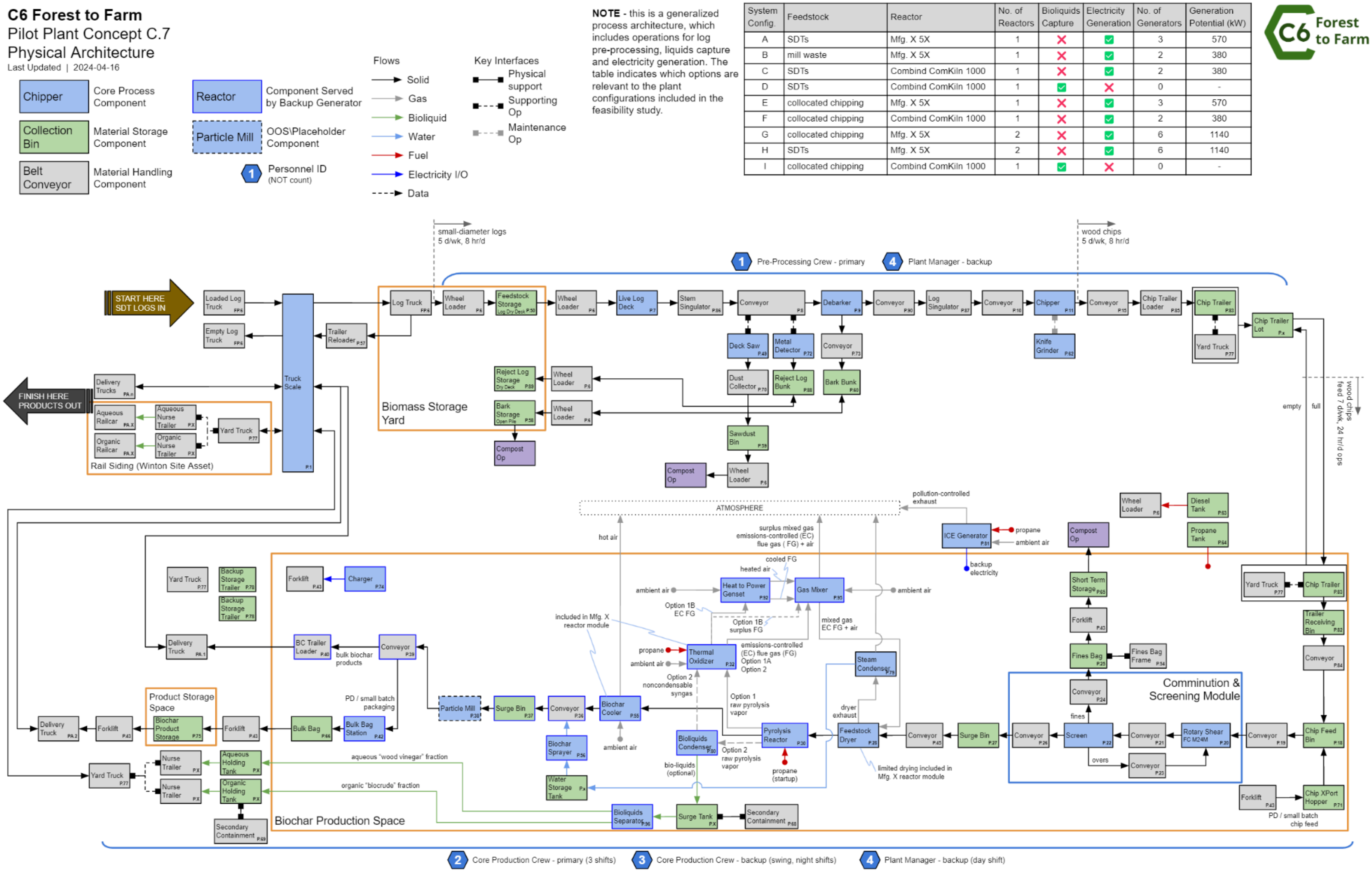
1.6. Site Layout Configurations Assessed

Following are a few of the conceptual site layout configurations we considered, based on the assumptions provided in Table 20. It's not a comprehensive list, but should illustrate the challenges and tradeoffs given the spaces available at the Winton mill site and our lack of experience with log processing.

Parameter	Assumption	Notes
Capacity	~1-1.5 ODT/hr reactor infeed	- Balance of pilot risk mitigation, desire to impact problem, equipment available - Feedstock volumes determined via upstream mass balance
Working Hours	Pre-processing - 8h/d, 5d/wk Production - 24/7	- Based on noise generated by pre-processing equipment

Table 20: Parameters underlying layout configuration assessment.

The site layouts are based on a process architecture, shown in Figure 10, that includes equipment based on the system constraints, required functionality, and site conditions. The diagram is generalized across multiple potential configurations and specific equipment selections, but should give a sense of the unit operations considered.



System Config.	Feedstock	Reactor	No. of Reactors	Bioliquids Capture	Electricity Generation	No. of Generators	Generation Potential (kW)
A	SDTs	Mfg. X 5X	1	✗	✓	3	570
B	mill waste	Mfg. X 5X	1	✗	✓	2	380
C	SDTs	Combind ComKiln 1000	1	✗	✓	2	380
D	SDTs	Combind ComKiln 1000	1	✓	✗	0	-
E	collocated chipping	Mfg. X 5X	1	✗	✓	3	570
F	collocated chipping	Combind ComKiln 1000	1	✗	✓	2	380
G	collocated chipping	Mfg. X 5X	2	✗	✓	6	1140
H	SDTs	Mfg. X 5X	2	✗	✓	6	1140
I	collocated chipping	Combind ComKiln 1000	1	✓	✗	0	-

Figure 10: Process architecture considered for site layouts and plant configurations.

1.6.1. Concept SL.1

An early concept, called Concept SL.1 for the purposes of this summary, involved storing logs in Space X, pre-processing them and storing chips in Space Y, conveying chips into Space B for biochar production, and either using Space A to inventory bulk bags of biochar or loading it directly into commodity belt trailers outside the east end of Space B (Figure 11).

If feasible, this concept would be relatively compact on the site, with the pre-processing and biochar production lines adjacent to each other. Furthermore, Space B is one of the smaller spaces within the mill building, meaning its lease cost would be lower.

However, a major challenge with this concept was the limited area in Space Y for pre-processing. Early iterations of the log processing line were based on faulty assumptions about the space and equipment elevations required, and as we learned more, this concept looked more and more unrealistic. Furthermore, the snow shedding off the north side of the roof wasn't immediately apparent to us, but would create challenges with year-round operation in this space.

Another challenge with this approach is the narrow width of Space B, especially in the context of system optimization (moving equipment) and scaling (adding equipment). Many of the biochar reactor systems on the market today are housed in 40-foot ISO containers, and the practical usable width of the hall is just under 40 feet. This means that scaling would be restricted based on limited equipment orientation options and the need to maintain reasonable equipment spacing for the operation.

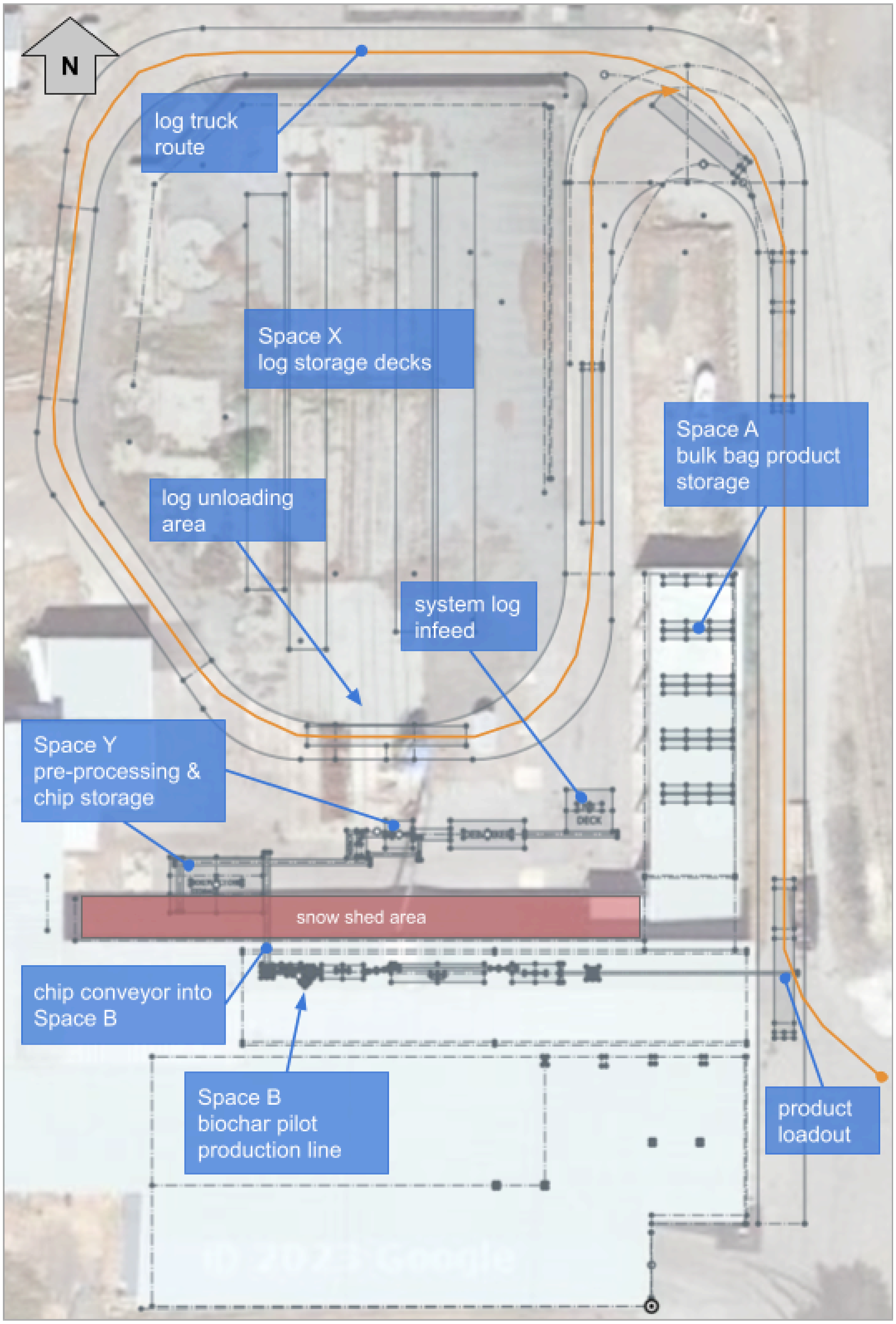


Figure 11: Concept SL.1, a site layout concept considered early in the Winton mill site analysis.

1.6.2. Concept SL.2

A concept we then evolved into, Concept SL.2, involved storing logs in the northern part of Space X, pre-processing them in the southern part of Space X, conveying chips into Space A for storage, then conveying them into the NE corner of space E1 for biochar production, loadout and inventory holding (Figure 12).

This concept incorporated new or previously unknown constraints, as well as conclusions from earlier concepts. We initially considered using the NE corner of Space E1 for our pilot biochar production line, based on a potential arrangement to initially lease a subsection of E1 and later expand into the remainder.

For pre-processing, we faced a couple of new constraints. First, a deeper dive into the fire code showed that we couldn’t place the log cold decks within 100 feet of the building (IFC 2806.2). Next, after discussions with the property owner about our initial concepts and lease details, they indicated that they’d like to keep Space B open for general tenant space, along with a sizable portion of Space Y adjacent to the building for tenant parking. For us, this aligned well with new concerns about snow shedding from the north side of the building.

We also incorporated more realistic assumptions about the equipment arrangements based on what we were learning from manufacturers and advisors, and we began using 3D modeling for our concept development to help ensure viable equipment arrangements.

This concept is generally attractive because its footprint is relatively compact. The operation is mostly contiguous, from log storage to biochar production and storage. The feedstock flows through the process after log infeed without personnel touching it. The only discontinuity is between the chip storage in Space A and biochar production in Space E1, so we would have to determine how personnel travel from the pre-processing line into the production space (breaks, etc.).

This concept has some limitations that make it difficult to pursue given our targeted capacity and desire to scale. First, the log storage area as shown marginally provides enough log inventory volume for the pilot operation.

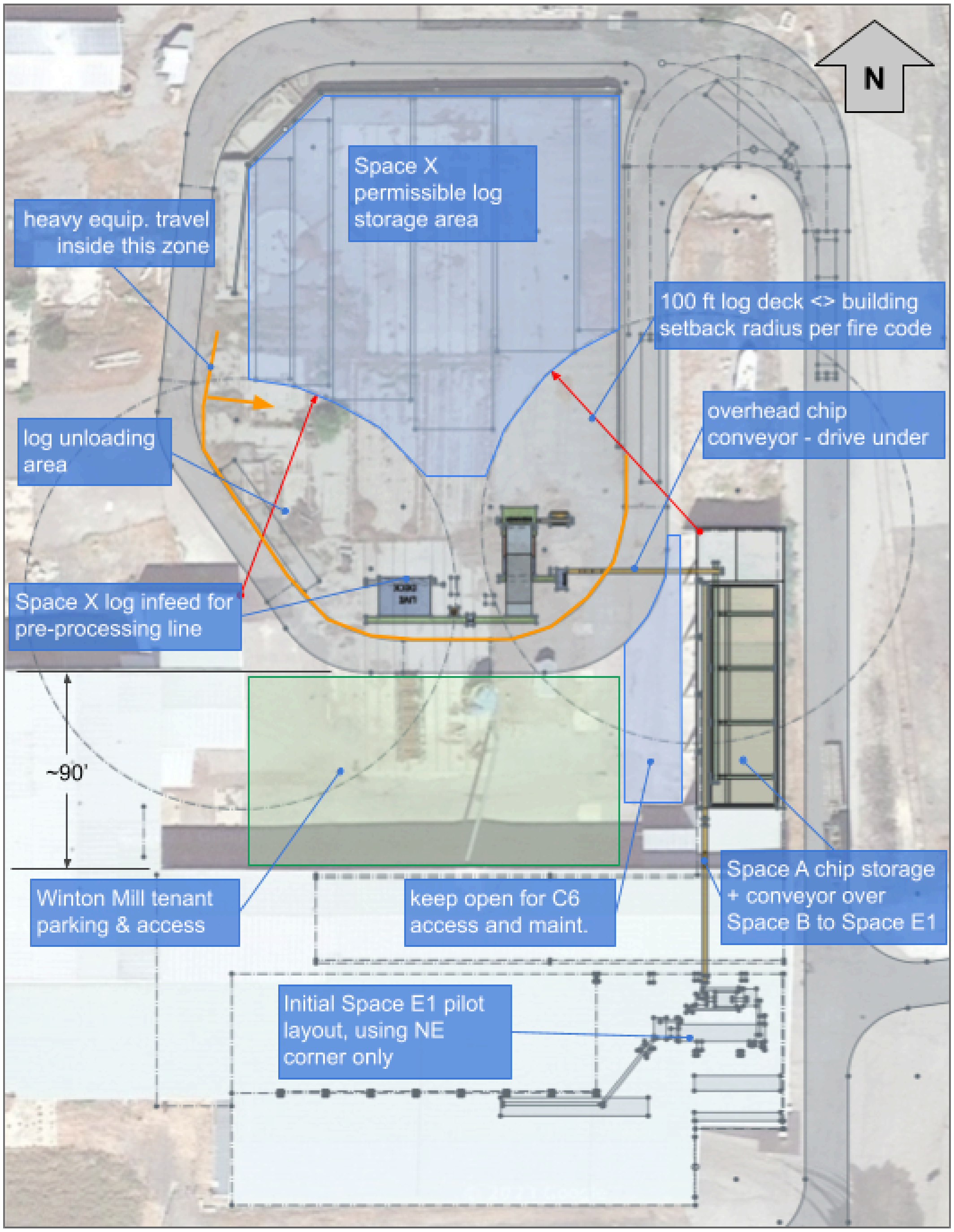


Figure 12: Evolved pre-processing and chip storage in site layout Concept SL.2, incorporating fire code and property owner constraints.

However, when we began assessing equipment paths between the log decks and the pre-processing line, we had to further erode the log storage volume to provide more space for equipment maneuvering. Further, once we begin to scale the operation, we'd have to expand into other log inventory space anyway.

Also, the pre-processing line poses elevation challenges. We included debarking functionality into this concept, and the type of debarking equipment we targeted is ~15 ft. tall and top-loading. It can't be directly loaded, because the logs are too long and need to be bucked down to a reasonable length to help control the debarker cost. This is difficult to balance with the need for the log infeed deck to be at a reasonable elevation for loading with a wheel loader or similar equipment, ~6-8 ft. Given the flat grade, in order to load bucked logs into the top of the debarker, we'd either need a tall drive ramp for loading equipment to access the log infeed deck (further eroding log storage space to provide for equipment movement), or an expensive, space-intensive inclined log conveyor.

The chip storage volume in Space A was also ultimately insufficient to support 24/7 biochar production through weekends, and it proved to be quite expensive to appropriately convert the space for this purpose.

The Chelan County Fire Marshal posed concerns with this concept about the potential for biomass ignitions so close to the main mill building, due to sawdust buildup, etc. While Space A includes a sprinkler system, storing wood chips inside at a depth approaching 12 ft was also a concern.

Finally, the arrangement to lease a subsection of Space E1 proved to be infeasible for the property owner.

Overall, Concept SL.2 *could* work at a lower pilot scale (⩽0.8-1.0 ODT/hr reactor infeed), especially if debarking and its attendant process steps are not required, but the log storage and pre-processing arrangement wouldn't support operational scaling. In short, it's an over-constrained concept that creates unnecessary expense.

1.6.3. Concept SL.3

Based on the limitations of Concept SL.2, we investigated Space V for log storage, adjacent Space W for log pre-processing and the entire Space E1 to provide plenty of room for pilot optimization and secure scaling space (Figure 13). Overall, this approach, shown in Concept SL.3, would mean breaking the operation into 2 distinct areas, with a significant distance between them.

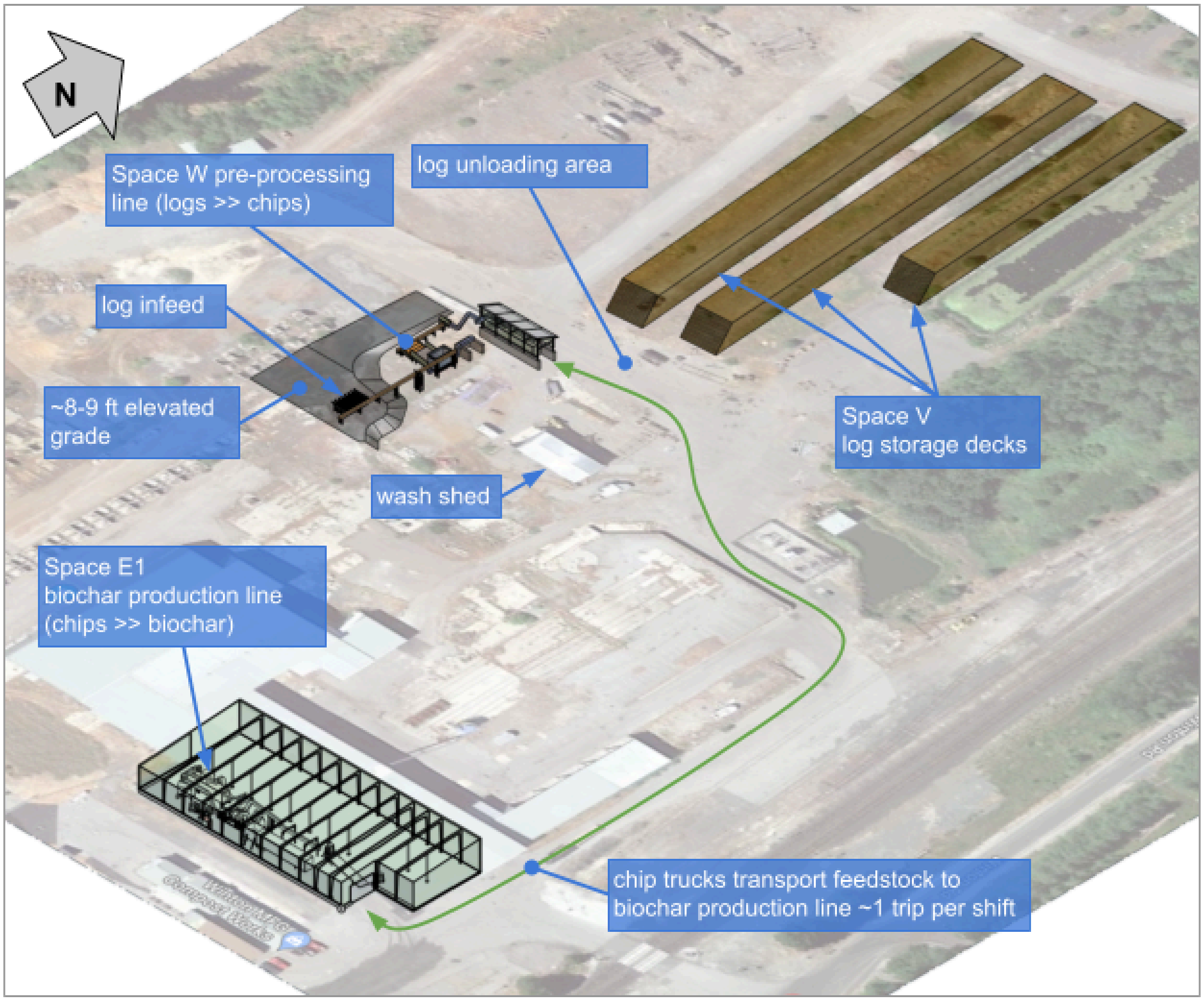


Figure 13: Site layout concept SL.3, incorporating portions of the northern part of the site.

Space V was designed and used for the purpose of log storage by the original mill, provides plenty of inventory space to support scaling the operation, and is in great condition for the purpose.

Space W provides a key benefit for the pre-processing line, which is a favorable elevation feature. The west side of the space includes a paved lane up a slope to a platform that is about 8-9 ft higher than the adjacent area next to the wash shed. This allows the log infeed deck to be at a reasonable height for loading (~6.5 ft) when placed on the elevated grade, with a flat log conveyor directed to the top of the debarker, eliminating the need for an inclined log conveyor or similar equipment (Figure 14).

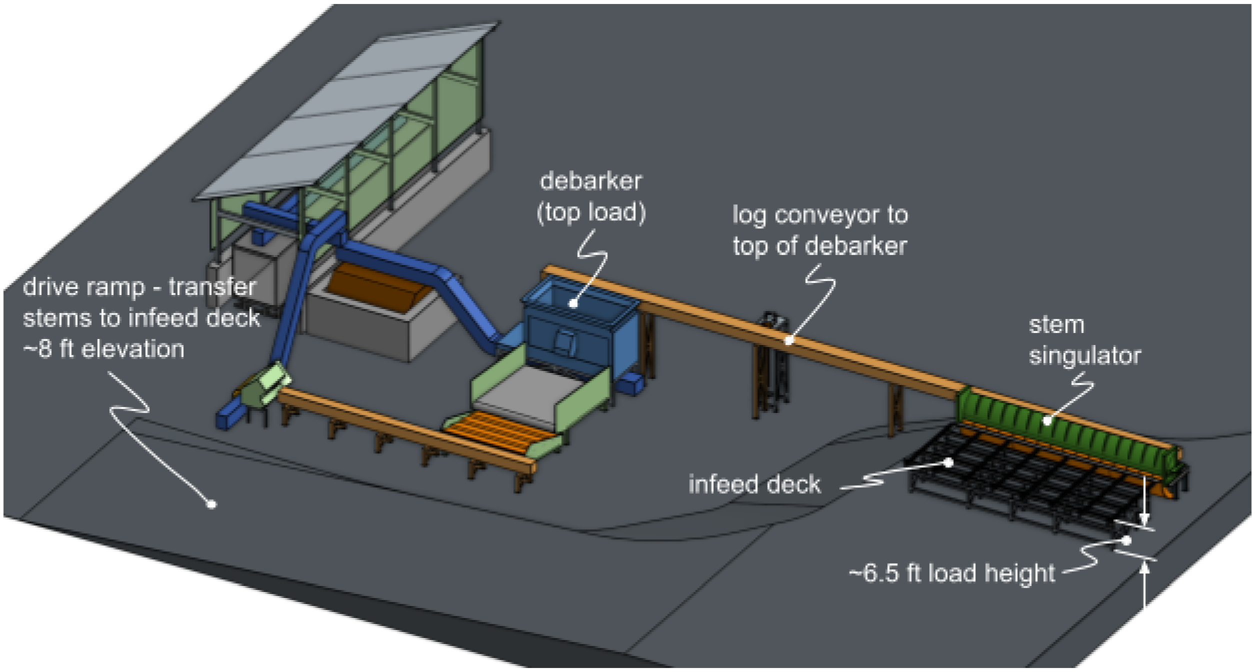


Figure 14: Pre-processing arrangement in Space W, taking advantage of elevation features.

Furthermore, Space W generally includes existing asphalt surfaces where we would want to route truck and equipment traffic. The primary exception is at the log infeed location, where the surface is uneven, but that can be easily modified.

Space W is also well away from the main mill building, which addresses concerns raised by the Chelan County Fire Marshal in reviewing the previous concept.

The primary operational implication of this layout is that the pre-processing and biochar production spaces are quite far apart. It's far enough that a conveyance system is unlikely cost-effective, at least at pilot scale, especially considering its inflexibility. Our approach would instead be to use standard chip trailers to inventory chips and transport them to the biochar production line. We anticipate this will be a challenge during winter operations due to the amount of snow removal work required. At the same time, it advantageously requires that the biochar production line start with a chip receiving solution, which would provide us with more flexibility in feedstock formats we can receive.

As shown in Figure 15, Space E1 will provide plenty of flexibility for the pilot biochar line, from chip receiving to biochar product storage. Our approach has been to place the pilot line on the south side of the posts that split the E1 space, assuming we'd later expand into the area on the north side of the posts.

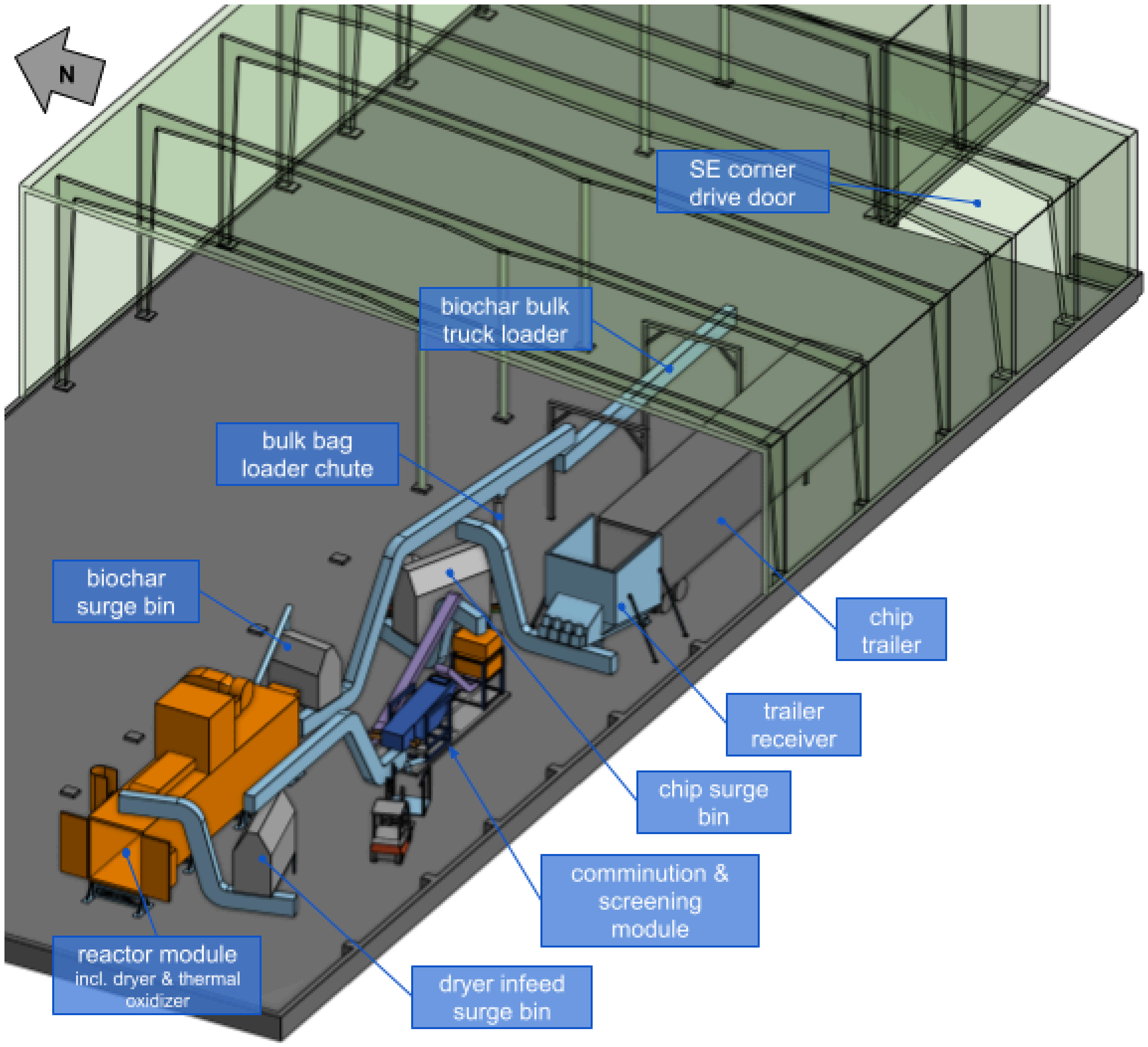


Figure 15: Pilot biochar production line concept, placed in the south section of Space E1.

A production element we didn't consider deeply during initial development of the site layouts is space required for capturing and handling biochar's optional co-products. These include the bioliquids that can be condensed from the vapor stream, and electricity that can be generated from combusting the vapor stream. At one point in late 2022, we specifically decided to push co-products considerations into the future to simplify pilot development and fundraising. However, as the techno-economic analysis progressed, it became clear that we would require the additional revenue from one or more of these co-product streams to help ensure that the operation is fully self-sustaining.

We recently assessed site layout Concept SL.3 with co-product handling in mind. With regards to electricity generation, the primary additional space needs are for the generators themselves, along with their required flue gas and air handling ductwork and gas mixing equipment to recirculate hot gases of the appropriate temperature to the feedstock dryer. Our mass and energy balance indicates that reactors of 1.5 ODT/hr infeed capacity generate enough pyrolysis vapor, and in turn, flue gas mass and heat, to support 3 “Heat2Power” generators of the type manufactured by 247 Solar and Capstone Green Energy (190kW each). We believe these three generators would fit within the southern section of Space E1, along with the pilot production line (Figure 16). We also believe at this time that the gas mixing system could be placed overhead in the facility, integrated into a duct network that would transport high-temp flue gas from the TO, the flue gas and hot air exhausts from the generators, and ambient air to achieve appropriate characteristics for dryer infeed. This concept would need more design and evaluation to validate.

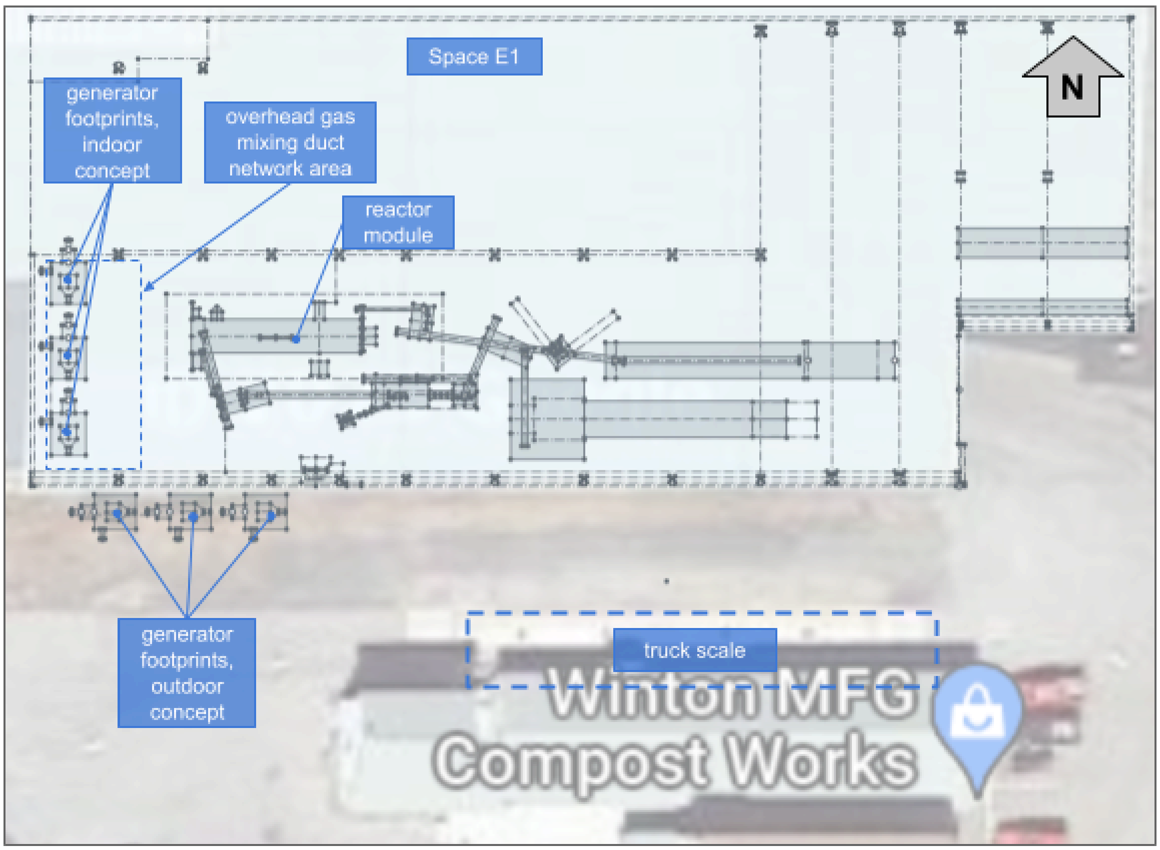


Figure 16: Potential pilot layout arrangement of generators in Space E1.

The generators could alternatively sit outside the south wall of Space E1, to the NW of the facility’s truck scale, but this arrangement hasn’t yet been proposed to the property owner and it would require more modification to the building envelope for duct passages.

With regards to bioliquids capture for product offtake, most of the required space is for storage, including best practices for dangerous wastes as defined by WA Dept. of Ecology. Once the liquids are condensed and captured, they need to be separated into their aqueous and organic phases for different products. A typical approach to shipping these products is by railcar, depending on where customers are located. The concept we outlined was to place low-volume intermediate storage and secondary containment, along with necessary thermal management and mixing, adjacent to the pilot reactor module. We would then pump the aqueous and organic fractions to larger volume intermediate static storage tanks just outside the south wall of Space E1, as shown in Figure 17. When each intermediate storage tank is full, its contents would be pumped into a small "nurse" transfer tanker trailer to be transported to the rail siding immediately to the east of the mill building for product transfer to the railcars. Note that using a more consolidated approach of storing the liquids and transferring them in large tanker trailers won't be acceptable due to fire code restrictions on using "tank vehicles" to store combustible liquids (IFC 5704.2.2). Our bioliquids haven't yet been tested for flammability and combustibility, but we expect that they'll be classified as Class II or Class III combustible liquids. We believe the approach of using static storage tanks would leave plenty of space for use of the facility's truck scale, but haven't reviewed this concept with the property owner.

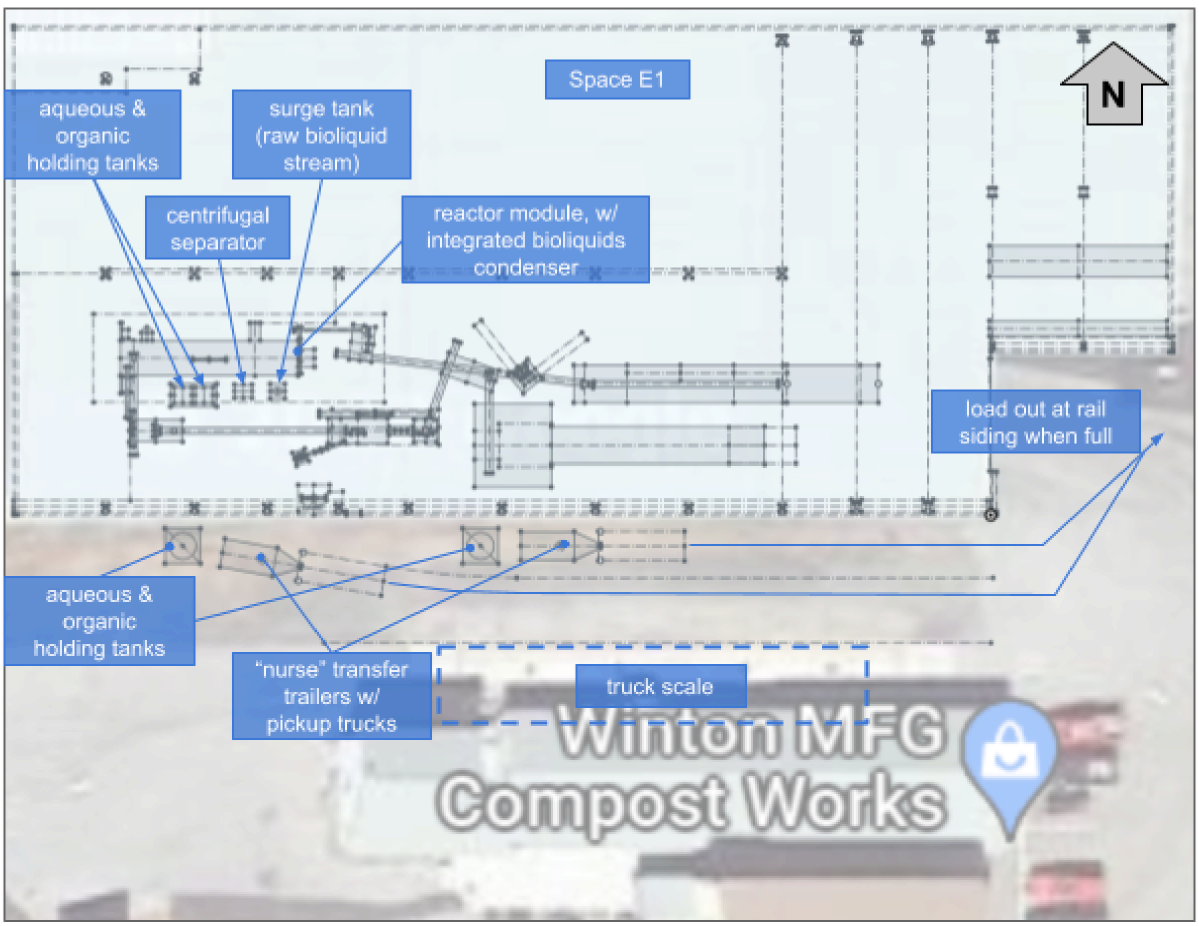


Figure 17: Potential pilot layout arrangement for bioliquids capture, separation and handling in and adjacent to Space E1.

Between the three site layout concepts presented here, several iterations were considered and determined to be infeasible due to equipment arrangement issues, capacity constraints, logistical challenges, etc. (Figure 18).

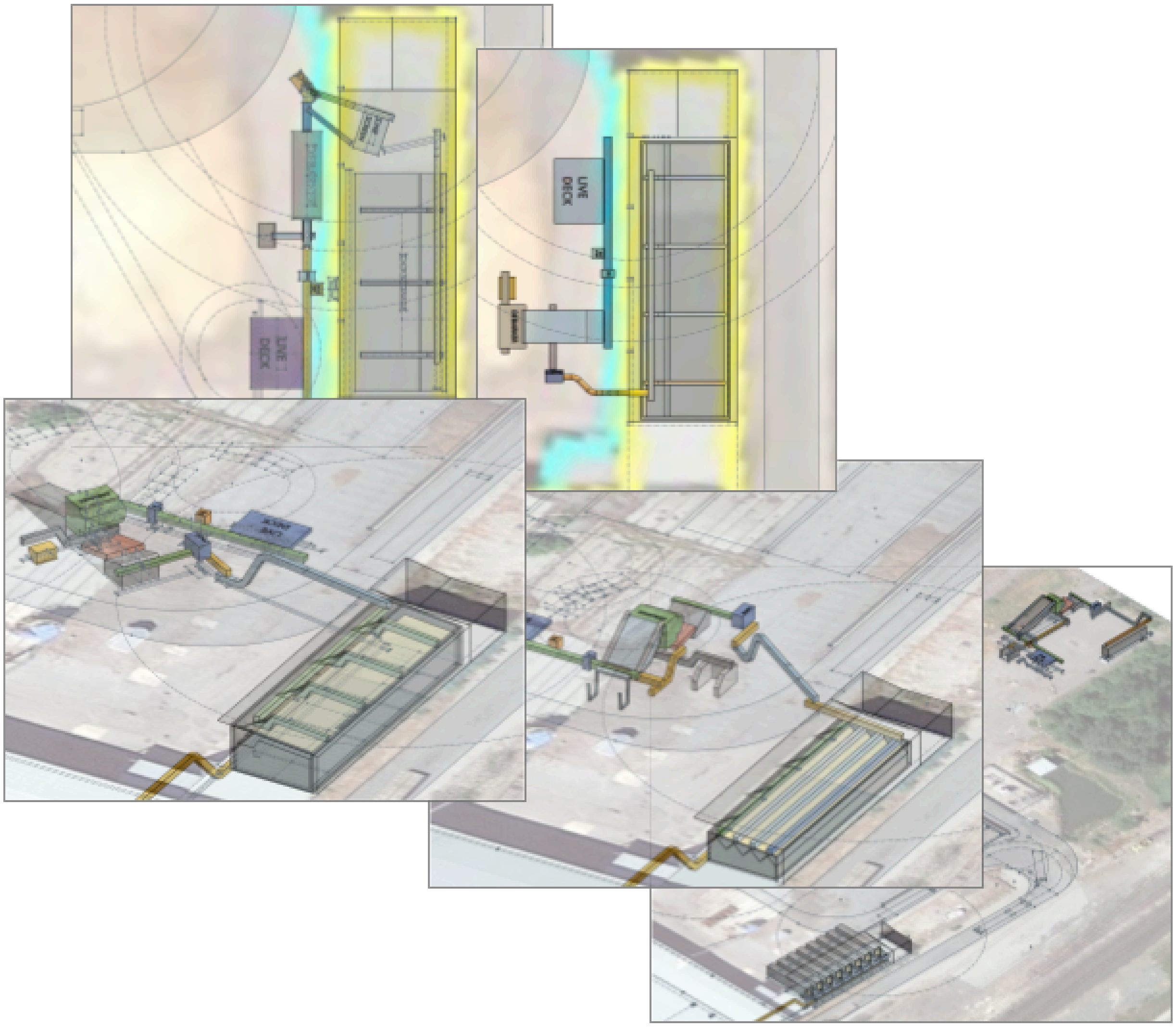


Figure 18: Snapshots of infeasible layout concepts considered in the Winton mill concept development process.

2. Plant Configurations

2.1. Site Layout

The site layout configuration concepts are summarized in Table 21.

Concept	Spaces	Advantages	Key Challenges	Feasible?
SL.1	X, Y, A, B	- Compact, adjacent pre-processing and biochar production - Lower lease cost in Space B	- Insufficient pre-processing space - Space B narrow width limiting equip. orientation & arrangement - Log storage didn't account for required distance from buildings - Fire marshal concerns with equip. adjacent to building - Little or no scale potential	**NO**
SL.2	X, A, E1	- Relatively compact, automated materials handling throughout - Provides Winton property owner with tenant flexibility for Space B	- Insufficient log storage area - Insufficient chip storage volume - Matching pre-processing equip. elevations requires high-footprint measures - FM concerns with equip. adjacent to building - Little or no scale potential	**NO**
SL.3	V, W, E1	- Log storage designed for the purpose - Pre-processing line simplified due to elevation feature in Space W - Room for pilot optimization in Space E1 - Room for co-products capture & handling in Space E1 and immediately outside on S side of building - Scale potential of ~5X - Pre-processing equip. well away from main mill building, alleviating FM concerns	- Discontinuous pre-processing & biochar production requires manual transport of chips between lines - Increased snow removal needs	**YES**

Table 21: Summary of site layout concepts.

We believe site layout Concept SL.3 would be most appropriate to support pilot operations, while providing capacity for scaling. While it poses some challenges by requiring more feedstock transport on the site, doing so at the pilot scale fits within the personnel model. It also provides more tenant flexibility for the Winton mill site owners.

2.2. Plant Design Configuration Options

In the process of determining the most advantageous way to launch the pilot facility, we assessed several plant configurations based on variations of four parameters, including feedstock source, reactor, co-product(s) and number of reactors. The parameters are summarized in Table 22, along with their general impacts on key economic factors like capital expenditures, operational expenditures and revenue.

Configuration Parameters	Options	Economic Impact Factors			Comments
		CAPEX	OPEX	Revenue	
Feedstock source	SDT	⬆️	⬆️	-	Requires expensive pre-processing system, and personnel to run it
	Mill waste	⬇️	⬆️	-	Costly feedstock due to transport; requires more energy for drying
	Collocated chipping	⬇️	⬇️	-	Similar feedstock cost to SDT, without the CAPEX
Reactor	Mfg. X 5X	⬇️	⬆️	⬆️	Requires annual maintenance plan
	Combind ComKiln 1000	⬆️	⬇️	⬇️	Lower production capacity
Co-products	Electricity	⬆️	-	⬆️	
	Bioliquids	⬆️	⬆️	⬆️	
Number of reactors	1	⬇️	-	⬇️	
	2	⬆️	-	⬆️	More fully utilizes personnel needed for single-reactor system, maximizing production level for given labor cost

Table 22: Plant configuration parameters, and their high-level relationships to economic results.

We started with our most mission-aligned feedstock format (logs from small-diameter trees), with the lower-cost reactor option and electricity generation as the co-product. We assessed it economically with our financial model, and determined that the pre-processing equipment cost and low utilization prevented it from being profitable. In the following configuration, we assessed the same reactor with electricity generation, but with mill waste as a feedstock source. This eliminated the pre-processing system, dramatically reducing the CAPEX, but came with its own issues in terms of feedstock cost and drying intensity. We followed this type of process from configuration to configuration, using what we learned to identify ways to decrease risk and increase profitability and long-term ROI as we went. The configurations we assessed are described in Figure 19 and Table 23.

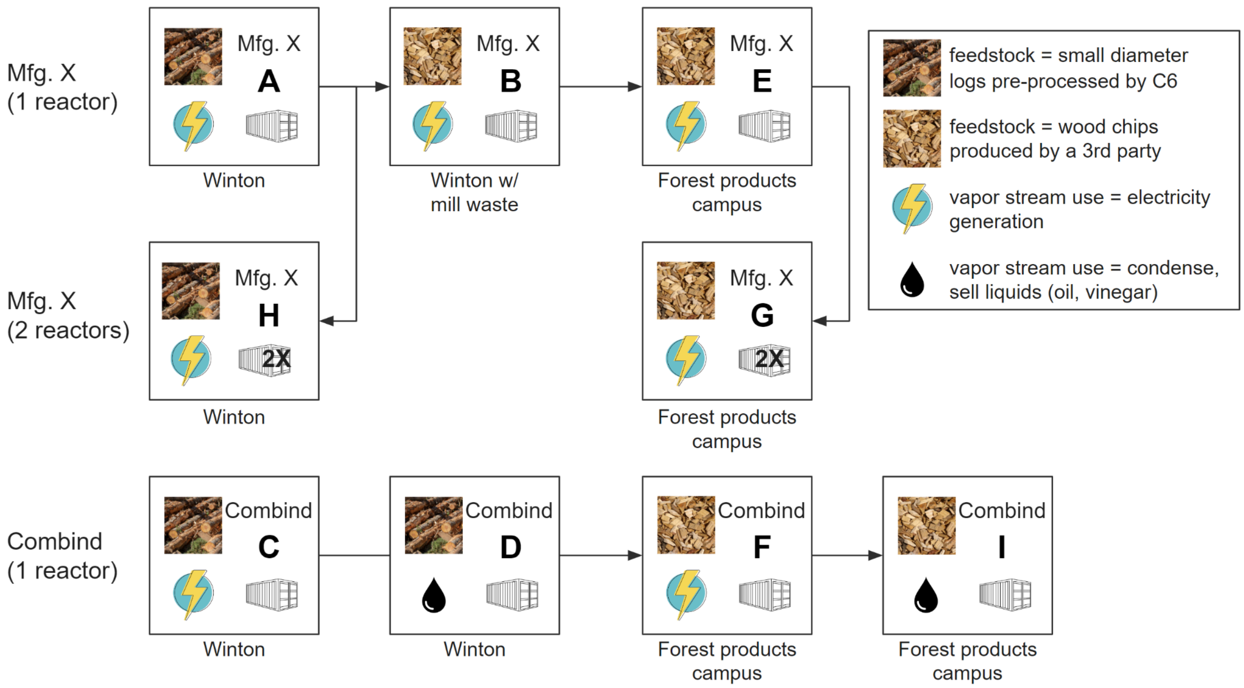


Figure 19: Plant configurations included in our detailed economic analyses.

System Config.	Feedstock	Reactor	No. of Reactors	Bioliquids Capture	Electricity Generation	No. of Generators	Generation Potential (kW)
A	SDTs	Mfg. X 5X	1	❌	✅	3	570
B	mill waste	Mfg. X 5X	1	❌	✅	2	380
C	SDTs	Combind ComKiln 1000	1	❌	✅	2	380
D	SDTs	Combind ComKiln 1000	1	✅	❌	0	-
E	collocated chipping	Mfg. X 5X	1	❌	✅	3	570
F	collocated chipping	Combind ComKiln 1000	1	❌	✅	2	380
G	collocated chipping	Mfg. X 5X	2	❌	✅	6	1140
H	SDTs	Mfg. X 5X	2	❌	✅	6	1140
I	collocated chipping	Combind ComKiln 1000	1	✅	❌	0	-

Table 23: Plant configurations included in our detailed economic analyses.

Each configuration parameter uniquely impacts the overall plant configuration.

2.2.1. Feedstock Format Impacts on Plant Configuration

Our baseline mission-aligned feedstock format, small-diameter logs from forest health treatments, requires significant capital for site modifications and pre-processing equipment. To transform logs on a truck to chips fed into the biochar production line requires a system comparable to the front end of a sawmill. The primary cost-saving option we can exercise in that pre-processing system is whether or not to debark the logs. Doing so helps maximize biochar product consistency and protect downstream equipment, and if we remove it, the pre-processing line remains quite expensive.

We considered receiving mill waste chips. This would eliminate our pre-processing line, though it would require more materials handling on the front end of the biochar production line to help ensure an adequate supply buffer in situations where we're dependent on daily deliveries from relatively long distances (>125 mi) in bad weather. While the CAPEX decrease is dramatic (~$5M), there are appreciable tradeoffs with OPEX. Because there are no sawmills in the vicinity, the cost of transporting the chips is high, elevating our feedstock costs. And, receiving chips from a mill on the west side of the Cascades (e.g. the Hampton Lumber mill in Darrington) means they will have higher moisture contents through most of the year, increasing the amount of energy needed to dry them and decreasing revenue potential from co-products.

We also evaluated the concept of launching the pilot facility in the context of a centralized forest products campus, knowing that Chelan County officials are pursuing such a campus (source). Forest products consultants at the Beck Group recommended a shared services model for the campus, where the type of log handling and pre-processing we would need for small-diameter logs (a "merchandising" line) is included on the campus (source). In this model, we assumed Chelan County would be motivated to reduce wildfire risk in alignment with our mission, and can operate a pre-processing line at full utilization to serve multiple product streams like posts & poles, firewood and wood chips. We also assumed that Chelan County and other partners in campus development would make the necessary investments in the pre-processing system, and that producers on the campus would pay fair market value for whichever form of wood they need from the pre-processing line.

2.2.2. Reactor Options

We evaluated several reactors based on cost, performance, reliability, product formulation flexibility, numbers of units in the field, engineering support provided, etc. The two reactors included in these configurations are both auger-based systems, providing sufficient process control and flexibility for product development, and are packaged similarly in ISO containers. They also offer similar biochar yields, which are lower for both systems than initially expected, decreasing biochar revenue potential and adding pressure to pursue revenue from the vapor stream. They include different integrated functions and offer trade-offs in terms of cost, performance and field exposure.

As shown in Table 24, the Mfg. X reactor has more integrated functionality at a lower price. It uses multiple parallel series of components to process the materials. While this modular approach helps control cost, it multiplies the number of high-temperature moving parts, creating concerns about reliability and uptime. The performance of the integrated dryer was not well documented, and the manufacturer indicated that a pre-dryer would likely be needed, in which case we would strongly consider moving all drying into a single unit to avoid the complexity of multiple dryers. The manufacturer also wasn't able to provide complete stack emissions data for the integrated thermal oxidizer, which would require significant further due diligence to ensure compliance with WA Dept. of Ecology air quality requirements.

They offer a bioliquids capture system that is still undergoing engineering verification, and they project that it will capture a small percentage of the condensables in the vapor stream, because the system needs the energy in the vapor stream to ensure proper combustion in their integrated thermal oxidizer. If pursuing bioliquids capture, we would evaluate the possibility of an external condenser, but their system might be fundamentally limited by their thermal oxidizer. If it's not limited, modifying the reactor to work with an external condenser module may be quite challenging from an engineering perspective and drive a price increase; we haven't yet discussed this possibility with them to validate the impact.

In terms of support, one of their customers said they'd received solid, responsive field support in operation, although the engineering support we received in the evaluation process was poor and didn't inspire confidence in selecting their equipment.

Reactor	Capacity	Drying	Bioliquids Capture	Thermal Oxidizer	Units in the Field	Price	Risk
Mfg. X* 5X	1.5 ODT/hr	Included & insufficient; pre-dryer required	Included, captures <10% of condensables; external system likely necessary	Included, performance data not provided	>10	Base: ~$1.6M Est. Pkg**: ~$2.9M	- reliability & uptime - many moving parts - performance - integrated thermal oxidizer effectiveness not provided
Combind ComKiln 1000	1.1 ODT/hr	Not included	Included, captures virtually 100%, leaving a clean syngas stream	Not included	0	Base: ~$2.2M Est. Pkg**: ~$3.9M	- not proven in the field, at the 1.1ODT/hr scale
* Mfg. X reference due to confidentiality sensitivity. ** Package includes dryer, reactor, bioliquids condenser and thermal oxidizer for more direct comparison							

Table 24: Reactors considered in the plant configurations evaluated.

The Combind ComKiln 1000 reactor comes with fewer integrated functions and a lower capacity, at a higher price point. However, it offers greater product flexibility, since its integrated condensing system is much more effective at capturing bioliquids. It also offers some features that we believe will result in more consistent products (e.g., airlocks to prevent oxygen infiltration and the baseline ability to run an inert sweep gas through the product stream during pyrolysis). While Combind does not yet have ComKiln 1000 units deployed in the field, they have been running a smaller-scale ComKiln 200 unit (~0.22 ODT/hr) for a few years, iterating the design as they encounter issues and opportunities for improvement. They have been responsive and open in their engineering support during our evaluation. They are developing a lease program, which we would consider for the pilot line, but we didn't include that option in our configuration analysis.

As shown in Table 24, we included the base price of the reactor, and also developed cost estimates for both reactors based on an all-inclusive package of dryer, reactor, bioliquids condenser and thermal oxidizer, in order to compare them on a more direct basis. The Mfg. X reactor would require a pre-dryer and an external bioliquids condenser. The Combind reactor would require a dryer and a thermal oxidizer. Based on budgetary estimates for these items, we believe the Mfg. X package would cost around $2.9M, and the Combind package would cost around $3.9M.

2.2.3. Co-Product Impacts on Plant Configuration

We evaluated several potential biochar co-products, as discussed in the Products section. The primary options - electricity generation and bioliquids capture and separation - each have specific impacts on the plant configuration.

2.2.3.1. Electricity Generation

We considered a few different generation technologies, which would have varying impacts on the plant configuration:

- A steam-based generation system, which would be most efficient if our thermal oxidizer were replaced with a steam boiler that combusts the vapor or syngas. We could then re-circulate the flue gas from the boiler's burner for dryer preparation. We haven't analyzed this process, because of the amount of equipment needed to manage the water and steam, in addition to the generator itself.
- An Organic Rankine Cycle (ORC) generator, like ElectraTherm's Power+ Generator. This would require an interface adaptation between our flue gas stream and the water circulation system they use to carry heat into their system to power the refrigerant cycle that drives the turbine. We could then re-circulate the cooled flue gas from the interface heat exchanger for dryer preparation.

- An indirect-fired microturbine, as featured in 247 Solar's Heat2Power generator. In this system, the flue gas runs through a multi-stage heat exchanger to heat and pressurize an ambient air stream that drives a microturbine generator. It exhausts cooled flue gas (~250°C) and the heated air (~625°C), which can both be re-circulated for dryer preparation. This is the option we've used for our analysis, due to its relative simplicity.

Electricity generation takes up appreciable space, especially at the pilot scale. The generators we considered have capacities lower than the generation capacity we think we can achieve, driving the need for multiple units. This is advantageous for mitigating process risk at startup, as we'd likely launch with one generator, and add more once the process proves itself. However, as shown in Figure 16, adding generators to match our prospective capacity requires an appreciable footprint (~1,200 sq ft) and a significant amount of ductwork to transport the flue gas and air streams to and from the generators. If scaling up beyond pilot, we would pursue higher-capacity systems that are more space-efficient.

These generators, with capacities of 190kW each, are projected on a budgetary basis to cost $400,000 each. Switchgear would be required to synchronize the generator output to the grid, and we received a wide range of budgetary estimates on this equipment, between $25,000 and $100,000 depending on the utility requirements. We estimated that this equipment would cost around $75,000, and projected that the equipment for a 3-generator system (570kW) would cost about $1.5M, including contingency for both the generators and the switchgear.

2.2.3.2. Bioliquids Products

Capturing bioliquids requires much less space inside the pilot facility than electricity generation, but more outside. The arrangement shown in Figure 17 would require about 400 sq ft of floor space without significantly altering the pilot line layout, and piping to transport the liquids to holding tanks or tanker trailers outside. These tanks would need about 6000 sq ft to account for approach lanes and parking space between the facility's truck scale and the south wall of Space E1.

We estimate that the cost of separating, pumping, storing, transferring and managing the temps of the liquids from the reactor to the railcars is about $420,000 including contingency, assuming a viable condensing system is included with the reactor package. The U of I chemical engineering capstone project team estimated $754,000 for the bare module cost to condense the liquids from the vapor stream, in addition to the $420,000.

Capturing the bioliquids would also add operational overhead. We would capture them as products with offtake agreements, so they wouldn't be strictly considered dangerous wastes, but we would follow the dangerous waste labeling, storage and handling requirements defined by WA Dept. of Ecology as best practices. If we experienced a sudden interruption in offtake contracts and captured liquids that we couldn't ship to a customer, we'd be in compliance with dangerous waste requirements. What this means in practice is that we would have to implement a labeling program, provide and maintain secondary containment for every liquids storage point and develop SOPs and training associated with hazards due to these liquids. Furthermore, capturing and storing the liquids dictates our fire code occupancy classification (high hazard group H-3 assuming the liquids are Class II combustible, IFC 202), which then drives additional electrical and liquids storage requirements in the facility.

Transferring the liquids from holding tanks outside the building, to transfer tankers, to railcars at the siding will require appreciable labor, multiple times per week. Given the temperature sensitivity of the organic fraction, the railcars will have to be heated periodically for much of the year to ensure that the liquids remain pumpable and ready for transport. We anticipate the use of a typical railcar steam heating system, which requires active management by personnel. Finally, the stationary holding tanks and mobile transfer tanks would need to be cleaned periodically, which will require specialized equipment, and we don't yet know the implications for disposal in terms of treatment requirements, operating cost or permitting.

2.3. Plant Design Configuration Comparison

The plant design configurations we evaluated have their advantages and disadvantages and carry different levels of implementation risk. We evaluated implementation risk in 4 impact categories - safety and hazards, codes and permitting, reliability and uptime, and performance. Evaluations were based on uncertainty in our current perceived confidence to predict the impact of risks, along with weighted risk impact in each category, based on the following methodology:

U = uncertainty, or current perceived confidence in predicting the impact of each risk
I_n = impact category *n* rating
W_n = weight of each impact category *n*
Total Risk Score = $U \times (W_1 \times I_1 + W_2 \times I_2 + \dots + W_n \times I_n)$

The scoring is shown in Table 25, and the scoring definitions are shown in Table 26.

							Impact Areas				
						Weight >	0.3	0.3	0.2	0.2	
Config.	Feed stock	Reactor	Cap. (ODT/hr)	Elect. Gen.	Bio-liquids Capture	Uncertainty of Prediction	Safety & Hazards	Codes & Permits	Reliability & Uptime	Perf.	Total Risk Score
A	SDTs	Mfg. X 5X	1.5	Yes	No	3	3	3	7	3	11.4
B	mill waste	Mfg. X 5X	1.5	Yes	No	3	1	1	3	3	5.4
C	SDTs	Combind CK 1000	1.1	Yes	No	3	3	3	3	1	7.8
D	SDTs	Combind CK 1000	1.1	No	Yes	7	7	7	7	7	49
E	campus chipping	Mfg. X 5X	1.5	Yes	No	3	1	1	3	3	5.4
F	campus chipping	Combind CK 1000	1.1	Yes	No	3	1	1	1	1	3
G	campus chipping	Mfg. X 5X (Qty 2)	1.5	Yes	No	3	1	1	3	3	5.4
H	SDTs	Mfg. X 5X (Qty. 2)	1.5	Yes	No	3	3	3	7	3	11.4
I	campus chipping	Combind CK 1000	1.1	No	Yes	7	7	7	7	7	49

Table 25: Summary of implementation risk for the facility configurations evaluated.

Level	Uncertainty "U" - the team's ability to predict the impact of risks in each area		
7	...low, based on confidence in high-quality data, information and/or documentation		
3	...moderate, based on confidence in mixed quality data, information and/or documentation		
1	...high, based on confidence in doubtful and/or low-quality data, information and/or documentation		
	Impact "I" - general impact level of risks in each area		
Impact Area	1	3	7
Performance	Minimal or no impact	Minor to moderate impact on performance. Same approach retained, or minor workarounds required	Major to unacceptable impact on performance; workarounds or alternatives require significant redesign or are not yet known
Safety & Hazards	Minimal or no impact	Manageable with no harm to personnel, and minimal system damage and/or disruption	Personnel at harm; major damage system
Codes & Permitting	Minimal or no impact	Minor to moderate impact on detailed engineering and implementation cost; no compromise required for system requirements and capabilities	Major to unacceptable impact on detailed engineering and implementation cost; some compromises needed on system requirements and capabilities
Reliability & Uptime	Minimal or no impact	<48 hours process interruption	>48 hours process interruption

Table 26: Risk scoring guidelines used to rate configuration options.

As reflected with Configurations D and I, we have the highest uncertainty in predicting the impacts of bioliquids capture, and at this time, we believe that implementing this functionality would bring significant risk to the operation, across impact categories. The liquids will likely be classified as combustible, impacting safety and hazards, and codes and permitting. The behavior of the liquids through processing - condensing, separation, storage and handling - is generally understood via literature and advisory anecdotes, but we don't have enough specific data to design the process for high confidence in system performance and reliability. All of these uncertainties and impacts can be addressed by producing a relatively small but meaningful volume of the liquids through multiple trials (e.g. several gallons across 3 trials), and characterizing their properties, processing behavior, and variation.

Another source of high risk impact is the combination of our lower confidence in the reliability of the Mfg. X reactor and the level of complication with pre-processing small diameter logs. We believe this puts the overall system reliability and uptime at significant risk of major interruptions. Major interruptions to the pre-processing system, especially earlier in the week when chip inventory is low, could drive shutdowns of the biochar production line. Major issues with the reactor would likely result in shutdown and cooldown to address them, which takes significant time given the thermal capacity of the system. Pre-processing risk can be mitigated via careful process design, including review by experienced mill engineers and operators, investment in sensing and instrumentation that detects issues and notifies personnel so they can quickly address them, and investment in the right tools to correct the most likely issues (e.g. a jib crane located where crooked stems are most likely to cause problems along their conveyor). Reactor risk can be better characterized and possibly mitigated by visiting a site where they are installed and running on a 24/7 basis, monitoring their operation and interviewing operations personnel.

In general, the configurations that are based on collocated forest products campus chipping are the lowest risk for us, and we recognize that risks with a pre-processing system are simply transferred to another entity in these scenarios. Compartmentalizing risk and associated capital intensity between a campus pre-processor and its campus customers likely helps to make both more attractive to investors. However, the dependency of the customers on the reliability of the pre-processor's operation will almost certainly become a topic of inquiry. Given the decades of history of high-utilization log pre-processing technology implemented by sawmills and chip mills, we expect that a reliable high-utilization pre-processing is achievable via careful design and well-considered investments. We probably couldn't justify the capital intensity of some of those investments as a low-utilization user of such a system.

3. Regulatory & Permitting Assessment

A summary of our permitting assessment is shown in Table 27. We completed a formal Chelan County pre-application meeting in January 2023. We didn’t identify any major permitting challenges in that process. There are a few areas, namely Critical Areas, Fire Safety, and Solid Waste, that should be re-visited based on changes to our site layout and operational plan. Critical Areas and Fire Safety should be revisited with Chelan County officials based on the chosen site layout, which differs from what was presented for the pre-application meeting. Solid Waste permitting should be revisited with WA Dept. of Ecology and the Chelan-Douglas Health Authority if we decide to receive and store wood chips from other mills. We had determined that a solid waste permit was not necessary for receiving and storing logs from forest health treatments.

We expect air quality permitting to be challenging based on past experience obtaining a permit for a small research pyrolysis system in 2020-21. Once all the equipment that generates atmospheric emissions is selected, we would begin an emissions inventory process that relies on existing data for similar processes (e.g. drying wood particles). We would also test stack emissions for especially risky equipment, namely the thermal oxidizer that combusts vapors generated in the pyrolysis reactor, in order to obtain direct emissions data to inform the permitting process.

Application/Topic	Agency	Status	Next Steps
Solid Waste	- Chelan-Douglas Health District - WA Dept of Ecology	Open - Re-visit	Re-visit on the topic of receiving wood chips from mills or other sources.
Critical Areas / Shorelands	- Chelan County DNR - WA Dept of Ecology	Open - Re-visit	Re-visit, as pre-processing will be in a different open area than described in pre-app meeting
Fire Safety	Chelan County Fire Marshal	Open - Re-visit	Re-visit to review pre-processing line further from exposures & biochar production in same area as previously reviewed; review bioliquids capture in more detail if these products are to be pursued
Building / General	Chelan County Community Development	Open - In Progress	Submit modification plans to plans examiner once drafts are developed
Electrical	WA Dept of Labor & Industries	Open - Not Started	Work with EE & controls engineer + electrician on detailed design
Noise	Chelan County Public Works	Open - In Progress	Build SPL table of chosen equipment, analyze impact on nearby properties
Health & Safety	WA Dept of Labor & Industries	Open - In Progress	Develop operational SOPs
Domestic/Potable Water	Chelan-Douglas Health District	Open - In Progress	Property owners to work with CDHD to meet compliance
Septic & Sewage	Chelan-Douglas Health District	Open - In Progress	Property owners to work with CDHD to meet compliance
Air Quality	WA Dept of Ecology	Open - In Progress	Emissions inventory after energy balance is finalized with reactor and emissions control tech manufacturer
Hazardous Waste & Toxics Reduction	WA Dept of Ecology	Closed - Not Needed	Follow handling regs and best practices by ECY if we capture bioliquids as product with offtake contracts
Water Quality	WA Dept of Ecology	Closed - Not Needed	N/A
Building / General	City of Leavenworth	Closed - Not Needed	N/A

Table 27: Status summary of key permits for the C6 Pilot Facility at the Winton mill site.

4. Winton Mill Site Lease Findings

Between September and November of 2023 we worked closely with the agent leasing the Winton mill site to draft a lease Letter of Intent (LOI) for portions of the property. C6 decided to shut down operations prior to finalizing the lease LOI, so there are likely some terms that would have changed during final negotiations. Despite that, we believe the latest version of the lease LOI is indicative of the final terms for the site.

4.1. Footprint

As we iterated through different system designs we considered a few different site footprints. For the lease LOI, we included three spaces:

1) Space V, approximately 2.9 acres of yard to be used for log storage
2) Space W, approximately 1.3 acres of yard to be used for log pre-processing
3) Space E1, approximately 26.3k sq ft of shop to be used for our biochar production line

In addition to these leased spaces, we would have access to logistics lanes and the rail siding onsite for inbound feedstock deliveries, processed materials handling and outbound product deliveries.

4.2. Rent Structure

We structured the rent payments in the lease on a gross rent basis for years 1-5, then on a triple net basis for years 6-20. In the gross rent structure, C6 would pay a set rate per square foot, which would include an estimate to cover the cost of shared expenses insurance, taxes and the BNSF rail siding. In the triple net structure, C6 would pay a lower rate per square foot plus a portion of those shared expenses. Both sides felt like the triple net structure was better because the landlord and C6 shared the risk of shared expense increases. By allocating this risk, the landlord could keep base rent increases lower.

Year	Base Rent Charge	Triple Nets Charge
Year 1-5	$X/sq ft	none
Year 6-20	$X/sq ft ($Y < $X)	% of property insurance, tax, BNSF rail siding

Table 28: Rent structure summary

4.3. Site Conditions & Investments

As a former sawmill, the Winton mill site already has a lot of the infrastructure we need for operations. However there were a number of site conditions and investments (see categories below) that needed to be addressed prior operations.

1) Electricity
2) Water
3) Septic/Drainage
4) Common Bathrooms
5) Fire Suppression
6) Stormwater
7) Site Cleanup

We provided the landlord with a detailed set of requirements for each of these categories but stopped working on the lease LOI before determining who would pay for the cost of these investments.

4.4. Options to Extend

Although we believe the Winton mill is a good site to locate a biochar facility, we wanted to structure the lease to give us flexibility to address risks associated with operations. As such we set the lease with a shorter initial term and three optional extensions.

- Initial Term = 3 years
- Extension Option #1 = 5 years
- Extension Option #2 = 5 years
- Extension Option #3 = 5 years

Together these terms would cover the full life-cycle of the facility:

1) construction (~1 year)
2) operations (15-16 year)
3) salvage (1 year).

4.5. Comparables Cost Analysis

In an attempt to ensure that we would be paying fair market rents (including site improvement), we compared estimated Winton rents to comparable properties available on the market. Our unique site needs (see below) made it more challenging to find good comparable sites. Despite those challenges we were able to find some options and determined that the Winton mill site's rent costs were on the lower end of the range.

Lease				
Location	**Lot Size (ac)**	**Building Size (sqft)**	**Rent Rate (sf/yr)**	**Other**
Chewelah	12	12,000	$4.20	Old building, low ceilings
Elma	0	17,500	$4.80	New building, no yard
Winton	4.2	26,300		
Centralia	1	10,000	$6.00	4 acres adjacent for additional $
Yakima	2	17k sf	$6.96	
Moses Lakes	0	5,000	$7.20	More like a DC than plant
Winlock	10	62,000	$8.76	
Sunnyslope	0	15,500	$10.44	We viewed site, not a good fit
E. Wenatchee	5.26	22k sf	$11.48	new insulated building, flat paved fenced yard

Table 29: Comparable properties used to assess the Winton mill site lease against the market.

Unique site needs:

1) a site that logging trucks can use for delivering feedstock

2) a site with both a large yard that can accommodate log decks and a large shop that accommodate biochar production
3) a location that can accommodate loud, heavy equipment operations
4) a location within a short haul radius of forest health treatments

If a project developer pursues a biochar operation that's configured to rely on collocated wood chip production as part of a forest products campus, we recommend that they first work with Chelan County on the latest vision for the forest products campus, whether biochar production fits within that, and where it would be located. The Winton mill site includes covenants restricting its use as a sawmill and similar operations, which would likely preclude its use for other product manufacturing on a forest products campus.

If a developer pursues a biochar operation at the Winton mill site, we recommend that they follow a similar process of evaluating comparable properties with an awareness that this is a unique site in central WA, requiring qualitative assessment.

5. Conclusions and Remaining Gaps

Based on our general facility requirements, necessary processing functionality and necessary site characteristics and conditions, we found a viable site layout approach at the Winton mill site that should work well for the type of pilot facility we propose, with room to scale to 4-5 times the pilot capacity. Pre-processing for a standalone biochar production facility (which would be required at the Winton mill site) would be best located at the north of the site, adjacent to the log decks previously used for log storage by the sawmill. The chips produced there would then need to be transported to the SE space in the mill building (Space E1), where the biochar pilot production line would be located with plenty of space for pilot optimization and production scaling.

Open permitting items should be addressed for the county pre-application process, as we made changes to the site layout since our initial pre-application meetings. If an operator plans to receive wood chips from outside sources, then they should re-visit the requirement for a solid waste permit. Our approach to operating at the north part of the site should be reviewed to ensure it doesn't incur any new concerns about critical areas and shorelands. And, the pre-processing line update and latest biochar production line concept should be reviewed with the fire marshal. We also recommend characterizing the bioliquids' combustibility rating and reviewing that with the fire marshal if capturing these products is intended.

In our early negotiations with the Winton mill lease agent, we were on track to secure favorable lease terms, including rent structure, options to extend, and rent rates compared to other facilities in the region. However, we did not complete agreements related to site conditions and investment ownership for each of the improvements we listed.

As we assessed plant configurations of various combinations of feedstock, reactors and product outputs, we noted significant implementation risk in bioliquids capture and moderate risks in reactor selection and pre-processing small diameter logs as a standalone operation.

- The bioliquids capture implementation risks should be carefully considered in the context of overall business model performance, ideally with more product characterization data in hand.
- The reactor selection risk should be mitigated via in-person reviews of the systems and discussions with their operators.
- The pre-processing risk is best addressed by locating the biochar production line at a biomass utilization or forest products campus where pre-processing of small-diameter logs is a shared service that can be operated at an optimal utilization rate. **We believe this precludes the Winton mill site given covenants on its use, but could fit with other prospective forest products campus options that Chelan County is pursuing.**

Finally, we should note that the plant design configurations are of moderate development maturity. We considered a wide variety of layout concepts, using actual equipment sizing and considering equipment interfaces. We worked with several equipment manufacturers to integrate and develop these concepts, and walked through the Winton mill site with a plant engineer and a local industrial construction contractor to review our intended operation and required site modifications. We used inputs from literature and advisors to build comprehensive mass and energy balance models to understand how much feedstock we would need considering losses in processing, how much product we would produce, where and how much waste heat we'd produce, how much energy we would consume and how much electricity we might generate. However, more work is to be done to validate the most likely configuration concept(s) before finalizing equipment selection and general layout to initiate detailed engineering. The items that would be most helpful for final concept validation, sizing and system model improvement include:

- Definitive data on seasonal moisture content variation for small diameter trees in the Wenatchee Valley, or whatever region the facility operates in.
- Characterization of the raw pyrolysis vapor generated in producing biochar from the planned feedstocks, including its heating value and stoichiometric air-fuel ratio for complete combustion.
- Characterization of the non-condensable syngas generated (post-condensation), including its heating value and stoichiometric air-fuel ratio for complete combustion.
- Characterization of the bioliquid generated, including its heating value, separation velocity, and combustible fluid classification (ASTM D93 closed-cup flash point).

These items will require additional investments in trials and lab services. A couple of carefully planned trials should yield the necessary product characterizations, and to be of useful scale from directly representative equipment, they'd likely cost ~$30,000 each, including feedstock procurement and shipping. It's typical for these trials to take 6-8 weeks to complete.

Once decisions are made about which feedstock approach and product mix to pursue, final equipment evaluations and decisions, permit pre-application updates, system layout and design updates and system design reviews should take about 3-6 months, depending on which vapor-based products are pursued (none, electricity, liquids capture). These activities would need to be coordinated with the trials mentioned above.

Final system design would be followed by a couple of parallel activities - equipment ordering and fabrication, and detailed engineering for all the civil, mechanical, electrical and control system specifications necessary to guide contractors in site modifications, equipment installation and system commissioning. Equipment lead times are trending toward 9-12 months, and the detailed engineering will take ~4 months. Site modifications can be initiated after detailed engineering, while waiting for equipment to be completed.

Products and Customers

Developing markets and generating sufficient revenues for the multiple products that can be generated from biochar production is required to ensure profitable operations and eventually to scale our proposed solution. Biochar production using slow pyrolysis can yield multiple products: biochar, electricity, bio-oil, wood vinegar. The maturity of the markets for these products varies considerably. Electricity is at one end of the spectrum, with high demand, transparent pricing and clear distribution partners. Wood vinegar and bio-oils are at the other end of the spectrum, and biochar is somewhere in the middle.

Through our biochar customer discovery we identified interest within the agricultural community to explore new solutions like biochar to help reduce costs, boost yields and improve resiliency. However, those benefits need to be demonstrated locally, in Columbia Basin soils and for regional crop rotations, before farmers will make the investment in biochar. Once benefits have been confirmed, federal biochar subsidies will likely help increase adoption but their near-term impact is unknown.

Based on our assessment there are two realistic options for products that can be made from the vapor stream: burn it to generate electricity or condense and separate it to generate bio-oil and wood vinegar. We suggest initially using the vapor stream to generate electricity while the markets for bio-oil and especially wood vinegar develop. Although the revenue upside associated with electricity generation is currently limited, the market is fully developed and would allow the operation to focus on developing its biochar products.

Products and Customers Objectives

1) Summarize the products that the facility could potentially produce.
2) Summarize the potential regional markets and customer segments for biochar. Highlight the market opportunities that make most sense for us to pursue.
3) Summarize the potential returns on investment a biochar customer might realize and how that impacted our pricing assumptions.
4) Summarize our recommendations for developing products from the vapor stream.
5) Define conclusions and highlight gaps.

1. Potential Products for the C6 Pilot Facility

Biochar production of the type we propose can yield multiple co-products along with the biochar (Figure 20), and the process can be designed and operated to produce certain types of co-products while avoiding others.

In general, biomass pyrolysis involves heating biomass to high temperatures (~350°C - 900°C typical) in the absence of oxygen. Without oxygen to support flame combustion, a vapor stream is generated by the thermochemical decomposition of the volatile biomass components - primarily cellulose, hemicellulose and lignin. There are typically two pyrolysis regimes considered for this type of biomass application. “Fast” pyrolysis involves heating very small particles (< 1mm, sawdust) to high temperatures (>700°C) in very short periods of time (seconds), and is oriented toward maximizing extraction of the volatile content from the biomass, resulting in bioliquids or “bio-oils” that can be directly burned for energy or converted to fuels. We propose to use “slow” pyrolysis, in which particles of ~3 - 12mm in cross section are heated to moderate temperatures (~450°C - 550°C) over several minutes. This regime is more oriented toward controlling properties of the biochar itself, which aligns with our long-standing goal of producing “engineered biochar” for specific applications, thus helping to maximize its value and price point to maximize leverage for our mission of wildfire risk reduction.

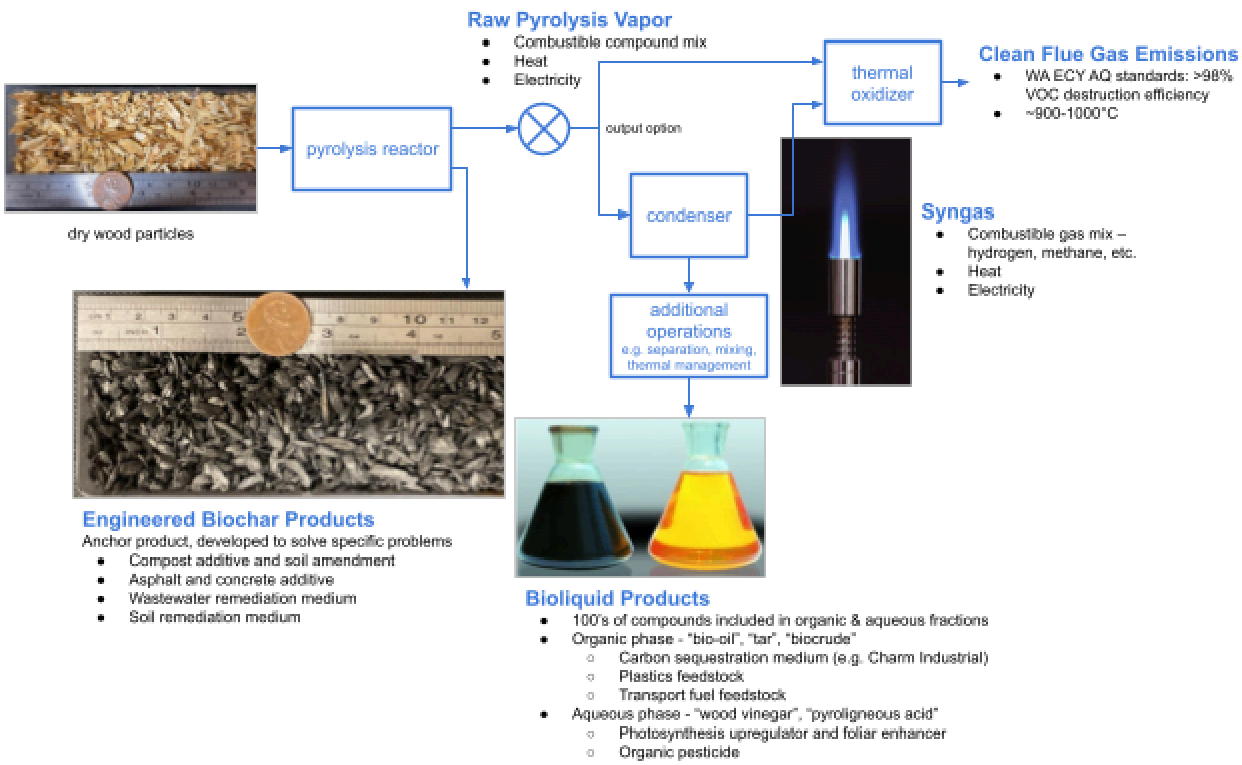


Figure 20: Potential product streams that can be produced with slow pyrolysis systems.

As shown in Figure 21, the relative product yields for slow pyrolysis with the woody feedstock we propose include biochar typically at 20-25% of the output mass, with the balance in the vapor stream, around 75-80%. The vapor stream split between the bioliquids and syngas can be highly variable depending on the feedstock and processing conditions, and we’ve seen indications that it will likely be just under half bioliquid content given our approach. Finally, the bioliquid stream can be split into an organic “bio-oil” phase and an aqueous “wood vinegar” phase. Initial trials and anecdotes from advisors and reactor manufacturers indicate that the organic “bio-oil” phase will be about 20% of the bioliquid stream.

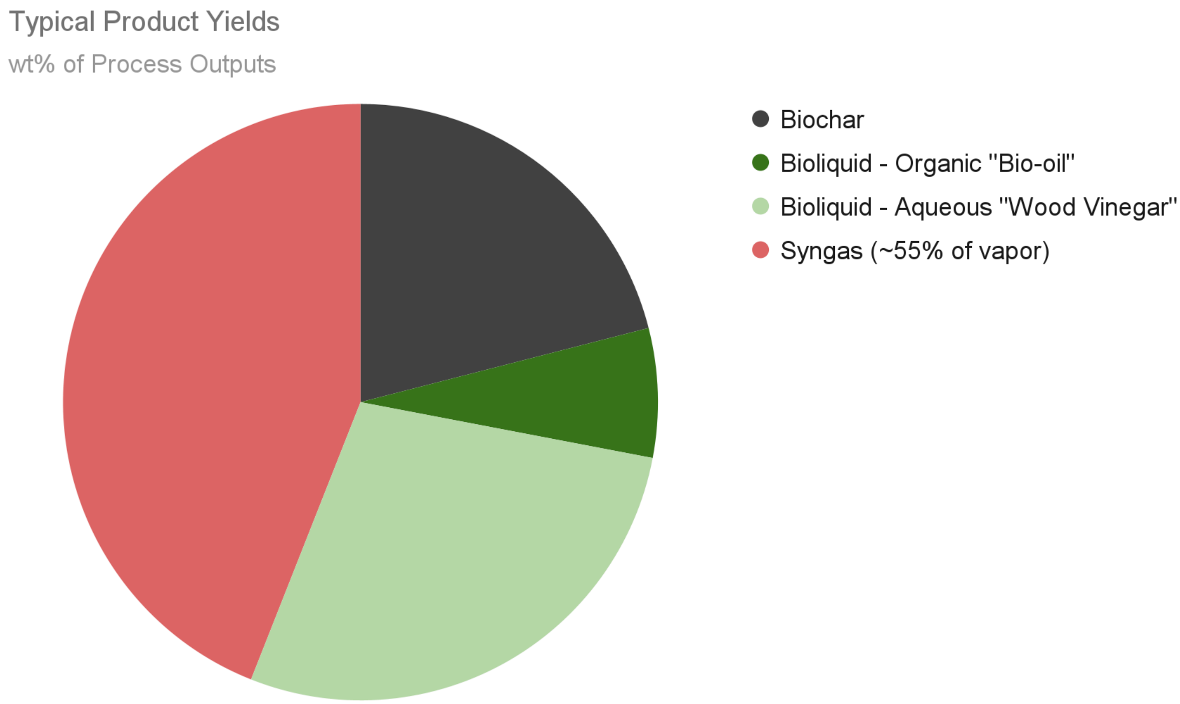


Figure 21: Approximate product yields. The biochar yield of 21% is based on small-scale trials with C6 feedstock by Mfg. X. The liquid fraction yields are based on aggregate trial results from Combind.

The products yielded from this process are dependent on the specific reactor, driving a critical choice for plant design given local market potential. For example, some reactor systems don't offer the option of capturing the bioliquids, because they combust the raw vapor as an integral part of their operation. Others offer integrated bioliquids condensers, but capture only a small portion of the liquids, and otherwise accessing the raw vapor for external condensing is difficult and costly. Others are optimized for capturing bioliquids with superior properties, but the producer must have solid long-term purchase agreements for the bioliquids to justify that investment. Bioliquids that aren't products with offtake agreements are considered dangerous wastes by the WA Department of Ecology, and they set strict limits on how long they can be accumulated and how they must be labeled, handled and stored. Based on a budgetary estimate from a waste disposal service, we know that if we are forced to dispose of these wastes, the costs are prohibitively high (at least ~$1,300 per ton).

The product mix is also dependent on the processing parameters (Figure 22). Three of the key process control parameters are implemented upstream of the reactor - the feedstock composition, the particle size and the feedstock moisture content as it enters the reactor. The feedstock's chemical composition is the source of the products generated and the particle size determines the ease with which volatile compounds are extracted in pyrolysis. The moisture content impacts the water content of the condensable portion of the vapor, which would then impact the composition and processing of liquid products. Our mission drives the feedstock, and we can easily design our pre-processing system to control particle size and moisture content.

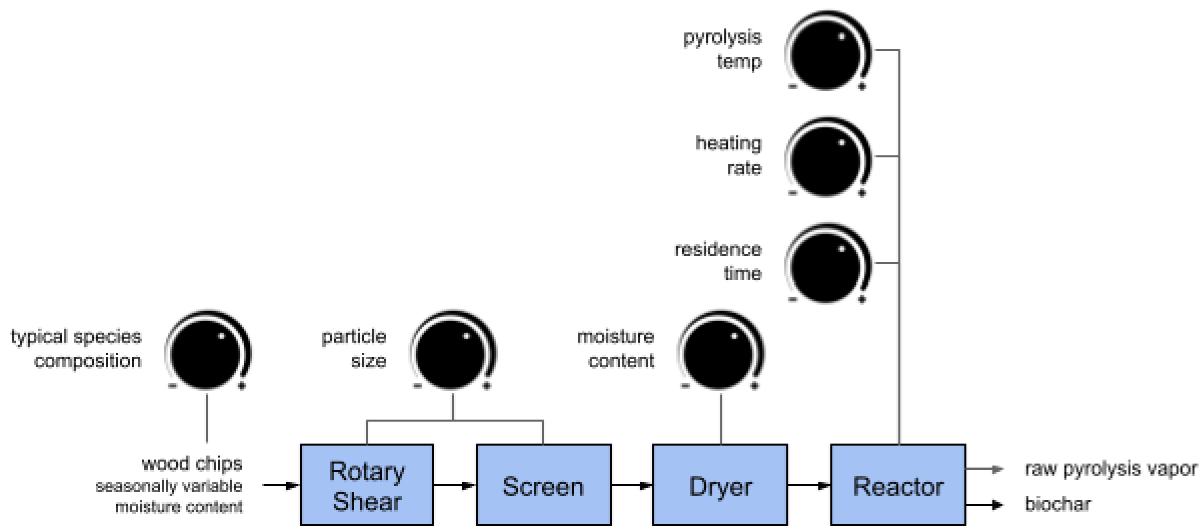


Figure 22: Primary process control parameters available to manage product outputs.

The reactor itself provides control of the pyrolysis temperature, heating rate and the residence time of the feedstock in the pyrolysis chamber. Most reactors offer similar levels of control accuracy. Given that process control at the reactor is similar across options, our approach has been to evaluate candidate reactors by their product output flexibility, in addition to their capacity, cost and reliability.

Finally, the products we'd target from this process should take transport modes and emissions into account. Just as we want local biomass as feedstock in order to minimize transport emissions, we generally prefer that our target markets be as local as possible for the same reason. Biochar can be hauled in conventional trucking formats, so we simply want to minimize truck miles traveled.

The raw pyrolysis vapor could conceivably be transported via pipeline, but the condensable products in the stream would create pipe fouling and clogging challenges in practice, making long-distance pipeline transport infeasible. This means that the raw pyrolysis vapor should be used at the facility, ideally burned to generate heat. Some of the heat is best recycled for feedstock drying, and surplus heat can be converted to electricity. The local context of electricity production is then a critical consideration.

If the liquids are captured in their own stream, the remaining syngas could be more readily transported via pipeline, especially if upgraded into renewable natural gas (RNG). However, that requires a locally-available RNG pipeline network, and requires significant equipment and process investments for upgrading. The more feasible option, especially at a location like the Winton mill where a RNG pipeline is not accessible, is the same as for the raw pyrolysis vapor - burn it for heat, and potentially convert surplus heat to electricity.

The bioliquid products can be hauled in tanks, so we'd also want to minimize truck miles traveled for a regional market. For longer-distance bioliquids transport, we'd consider rail shipping, which has much lower emissions per mile-weight profile.

1.1. Biochar Products

Biochar is a broad class of products of varying quality and application value due to the variation of properties that can be achieved with the variety of feedstocks and processing systems available. Our mission-driven feedstock constrains the possibilities, but they remain extensive in support of our approach of creating engineered biochars for specific applications. Because most biochar properties respond to multiple process control parameters as shown in Table 30, realizing specific property values is theoretically achievable via multiple process formulations. However, the dynamic, complex chemical interactions within the pyrolysis process are difficult to characterize and sensitive to control parameter adjustments, requiring careful empirical testing of process controls to achieve reliable output product characteristics.

	Process Control Parameter Coupling					
Biochar Properties	Feedstock species	Feedstock particle size	Feedstock Moisture content	Pyrolysis temp	Heating rate	Residence time
Acidity, pH	✅	✅		✅		✅
Surface area	✅			✅		✅
Porosity	✅	✅	✅	✅	✅	✅
Carbon content	✅	✅	✅	✅		✅
Ash content	✅	✅		✅		

Table 30: Basic correlations between process control parameters and output biochar properties (source).

We had limited opportunities to produce biochar with our target mission-aligned feedstock, at small trial scales. These trials indicated that our biochar will likely have characteristics similar to those shown in Table 31. Rigorous process development would be needed at system startup to determine robust process parameters to achieve the biochar properties needed for customer applications, as would evaluations of potential feedstock pre-treatments and/or biochar post-treatments for specific applications.

Property	Trial 1	Trial 2	Comments
Inputs & Process			
Feedstock	Douglas fir, debarked	Douglas fir, debarked	
Particle size	~6mm	~4mm	
Input moisture content	22.0%	7.7%	
Pyrolysis temp	550°C	550°C	
Residence time	20m	15m	
Product Outputs			
Biochar yield	~19.2% dry mass	~21% dry mass	dry BC portion of dry feedstock
Organic carbon	91.0% dry mass	87.8% dry mass	
H:C	0.29 IBI Carbon Storage Class 5	0.43 IBI Carbon Storage Class 3	
Total ash	3.4% dry mass	3.3% dry mass	
pH	8.60	6.30	
Liming capacity	5.1% $CaCO_3$-eq IBI Class 1	9.6% $CaCO_3$-eq IBI Class 1	LC is a factor of multiple properties in addition to pH, especially ash composition
Surface area correlation	231 m^2/g_{dry}	207 m^2/g_{dry}	

Table 31: Biochar properties from initial trials with C6's mission-aligned feedstock. Trials were performed with a bench-scale auger reactor by a candidate reactor manufacturer.

One key biochar property is pH, particularly for soil amendment applications. The Trial 1 biochar is slightly basic, and the Trial 2 biochar is slightly acidic, but they are close to neutral, which could alleviate concerns by row crop growers about acidity impact on their soils. Row crop soils in the Columbia Basin tend to be acidic due to decades of intensive agricultural activity. Applying more basic biochar could be beneficial to help raise soil pH, depending on the location and crops (source), but the liming capacity of these trial biochars is considered low by International Biochar Initiative (IBI) standards, and their overall acidity buffering impact would need to be evaluated in trials.

Another biochar property of interest for product applications is its surface area. These trials yielded biochar with low to moderate surface areas. They could be used for soil amendment applications, though their levels of water and nutrient holding capacities aren't optimized to that application, and we don't yet know how much that's limited by the feedstock itself. They could also be used in building material applications where they have appreciable binding surface area for inclusion in a material matrix, and could positively impact the thermal, mechanical and/or electrical properties of the overall material.

Finally, the 100-year soil carbon storage potential of these biochar samples is considered high by IBI standards given the high organic carbon content and the low

H:C ratios. Lower hydrogen content indicates more closed-ring carbon molecules, which are not considered susceptible to long-term chemical degradation in the soil.

All biochar is not created equal, particularly considering any specific application. Our focus has been to maximize our plant's processing flexibility so that we can create a wide range of product formulations in response to a comprehensive set of market needs, even if our feedstock is limited by our mission and local conditions.

1.2. Raw Pyrolysis Vapor & Syngas - Heat and Electricity

In our case, the raw pyrolysis vapor is the secondary product of a pyrolysis process anchored on producing specific biochar formulations, meaning we would not be controlling its composition. This vapor stream contains a condensable portion, which is what the bioliquids would come from if captured, and a noncondensable portion, which is the syngas. As shown in Figure 20, we have multiple choices about what to do with these outputs.

A fundamental driver of our approach to these outputs has been air quality constraints. We must maintain the ability at all times to properly combust this entire vapor stream to produce clean emissions in accordance with WA Dept. of Ecology requirements. Even if we plan to capture liquid products from the vapor stream, the capture and handling equipment could fail and we must be able to respond quickly and responsibly with an appropriately-sized combustion system. The same system must also properly combust the syngas stream if the liquids are captured, which dictates its minimum capacity.

Combusting either the raw vapor stream or the syngas fraction yields significant amounts of heat in the form of flue gas, estimated at ~1.5-3.8 MW, depending on reactor capacity and whether the liquids are condensed out. This hot flue gas (>850°C, likely approaching 1000°C to ensure complete combustion and acceptable emissions) can be used for multiple purposes, and it's in our best interest to recover and use as much of the heat as we can.

The most obvious way to use the heat from the flue gas stream is for drying our feedstock prior to its infeed to the reactor. Because of its very high temperature, its heat would either have to be transferred to an airstream, or the gases would have to be directly mixed with an air stream to achieve appropriate temperature and enthalpy for the drying process.

Depending on the system configuration, we believe we could first use the flue gas heat to generate electricity, then dry our feedstock using the exhaust from that process. Our goal would be to certify as a Public Utility Regulatory Policies Act (PURPA) small power production Qualifying Facility and sell the electricity to Chelan PUD based on their avoided generation and purchasing costs. Given the general capacity and operating model we've targeted for the facility, and depending on the products and equipment chosen, we believe we could reliably generate ~375-575kW on a 24/7 basis for several weeks at a time between short maintenance shutdowns, through most of the year. This would require careful communication with Chelan PUD about shutdown dates relative to high power demand periods, and we believe that is achievable given the biochar production equipment and process. Based on initial discussions with Chelan PUD, we believe we would have good operational alignment in the spring when our drying energy demands are high due to elevated feedstock moisture content and their auxiliary source needs are low due to the high river flows in the hydroelectric system. The proposed plant operating model doesn't allow generation for 1-2 months during that period, and they can't justify purchasing the power.

1.3. Bioliquid Products

In some system configurations, we can capture the condensable bioliquid contents from the raw vapor stream. The prospective products we've identified for it require that it at least be separated into its organic and aqueous fractions.

The organic fraction, which we refer to as bio-oil, is a viscous, tarry liquid that contains a wide array of carbon-rich compounds including sugars, phenols and acids. Speculation abounds regarding its use as a feedstock for transportation fuels, plastics, chemicals and pharmaceuticals (source, source, source, source). The most easily implemented use we've found for it is as a carbon sequestration medium, where it is injected into abandoned oil and gas wells. If captured, it would have to be kept within an appropriate temperature range throughout its handling and transport chain. Below ~70°F, its viscosity rapidly increases, and above ~120°F it polymerizes and forms solidified chunks. In either case, it is no longer pumpable and becomes a major logistical challenge.

	Process Control Parameter Coupling					
Bioliquid Properties	Feedstock species and ash content	Feedstock particle size	Pyrolysis temp	Reactor Type	Condenser Type	Comments
Yield	✅	✅	✅	✅		
Acidity, pH					✅	Due to separation into organic and aqueous fractions
Viscosity					✅	
Heating Value	✅					
Carbon content	✅		✅			
Water content	✅			✅	✅	
Phase separation potential	✅			✅		

Table 32: Matrix of high-level correlations between process control parameters and output bioliquids properties (source).

The aqueous fraction is commonly referred to as “pyroligneous acid” or “wood vinegar.” It contains a variety of compounds, including acids, aldehydes and alcohols. It has demonstrated some agricultural potential as a foliar enhancer, organic pesticide, and/or photosynthesis upregulator, depending on its application concentration and method. However, more research and trials are needed to convince large-scale growers of its value. If captured, it would have to be handled carefully given its acidity.

The bioliquids could also be processed through more extensive refinement to extract basic compounds that could be sold as commodities and/or used as feedstocks for other processes. A University of Idaho undergraduate chemical engineering capstone project team evaluated these possibilities during the 2023-24 academic year. The full report is available on request, and Table 33 shows a summary of the pathways they evaluated and how they perform in terms of payback period.

Process	Minimum Bare Module Cost ($)	Product Flow Rate (kg/yr)	Revenue Low-End Estimate ($/yr)	Projected Payback Period (years)	Comments
Three-stage initial vapor condensing	754,000	N/A	N/A	N/A	This is the basic liquids capture process.
Condense + separate acetic acid product	2,600,000	~83,000	44,000	58.9	
Condense + separate phenol product	2,900,000	~167,000	113,000	25.1	
Condense + separate catechol product	2,250,000	~15,000	479,000	4.7	
Condense + separate vanillin products	763,000	~19,000	231,000	3.3	
Condense + separate levoglucosan product	287,000	~63,000	97,000	2.9	Bare module cost is likely underestimated - lack of availability of cost of industrial-scale HPLC equipment that can achieve purity to match pricing estimates, which may also be overestimated.
Separate total pyroligneous acid fraction	2,400,000	744,000 **gal/yr**	18,900,000	2.3	The pricing used for this product should be validated for wholesale commercial application

Table 33: Bioliquids product capture & refinement pathways evaluated in University of Idaho undergraduate chemical engineering capstone project.

Acetic acid isn’t viable, because only 5% of the separated product stream is acid. The remainder is water, requiring more processing. Phenol and phenolic products make up a larger portion of the liquids, but the capital cost of the equipment is quite high given the revenue potential. The catechol stream is worth some future exploration, given the potential revenues and payback period. Vanillin from biomass lignin sources like ours is considered a natural product and can be used in foods labeled “no artificial ingredients.” While it has been identified as a high-value product that can be extracted from biomass, few industrial-scale operations have been implemented, and local markets could not be identified. Levoglucosan has also been identified as a high-value compound that could be derived from these liquids, and high price points are associated with high purity levels. The equipment needed to achieve those high purity levels at the flow rates we can provide is likely ~5-10X the cost of what’s shown in Table 33. That, combined with the uncertainty of commercial pricing, put this product stream’s feasibility in doubt. It could be worth some future investigation, building off what the U of I team has uncovered.

The most promising liquid product stream is the total aqueous fraction, which we investigated as an agricultural input product.

1.4. Product Energy Balance

We estimated our core biochar production energy balance for a few system configuration scenarios that include different reactor and product mixes (more information on these configurations is included in the Plant section). The input and output energy pathways and system boundary are shown in Figure 23, and the numerical estimated values are shown in Table 34.

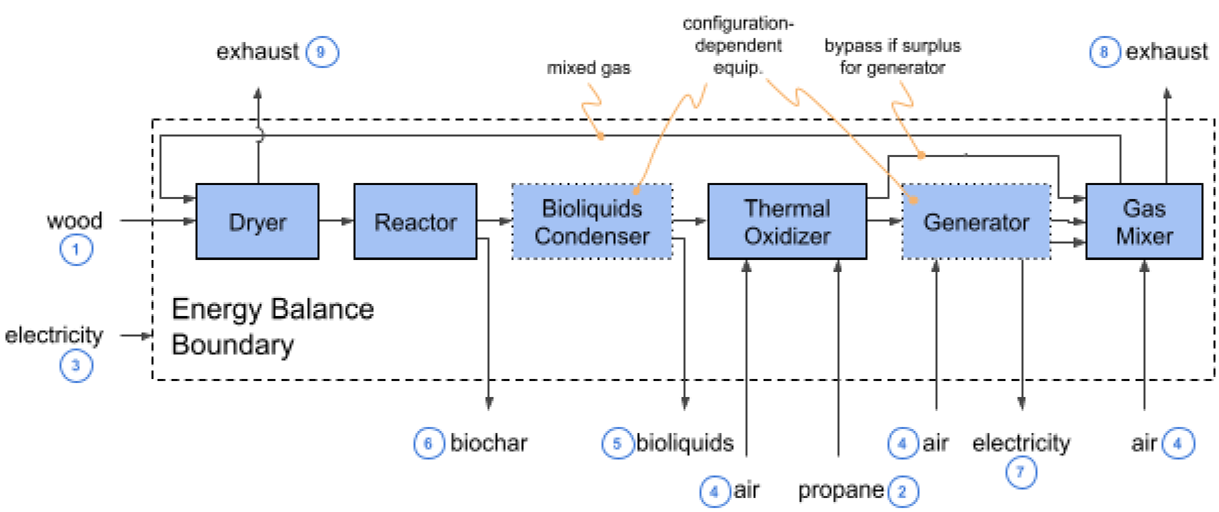


Figure 23: Product energy balance boundary with element tags for reference in Table 34.

Energy Balance Annual Average			Configuration			
Parameter	Tag	Sign	A	C	D	Comments
Reactor	N/A	N/A	Mfg. X 5X	Combind ComKiln 1000	Combind ComKiln 1000	
Reactor infeed capacity (ODT/hr)	N/A	N/A	1.5	1.1	1.1	
Condensing Bioliquids?	N/A	N/A	N	N	Y	
Lower heating value, wood (W)	1	(+)	6,594,373	4,835,873	4,835,873	Based on douglas fir bole LHV (dry basis) per proximate analysis
Lower heating value, propane (W)	2	(+)	219,813	156,250	156,250	Estimated use for the thermal oxidizer to help ensure complete combustion.
Electricity consumed (W)	3	(+)	169,744	288,973	291,210	This is what's consumed inside the system boundary shown in Figure 23.
Air energy content (W)	4	(+)	371,952	323,544	202,588	Enthalpy of combustion and mixing air, based on ambient temp and humidity ratio
Lower heating value, bioliquids (W)	5	(-)	0	0	2,489,565	Rough estimate based on literature - likely source of error, needs trial validation
Lower heating value, biochar (W)	6	(-)	1,984,659	1,386,111	1,386,111	Rough estimate based on literature - likely source of error, needs trial validation
Electricity generated (W)	7	(-)	506,667	332,500	0	Based on 247 Solar Heat2Power generator
Gas mixer exhaust (W)	8	(-)	3,860,896	3,077,023	90,764	Enthalpy of gases not sent to the dryer
Dryer exhaust (W)	9	(-)	1,064,701	1,107,900	1,107,900	
Balance (W)		N/A	-61,042	-298,894	411,581	These imbalances, particularly for Configs. C and D should be addressed with better manufacturer data and validation of biochar and bioliquids energy contents

Table 34: Estimated product energy balances for a representative selection of system configurations.

Many of the parameters used to calculate these balances are estimated due to the lack of published data on material characteristics and system operations, particularly at industrial scale. For example, the heat content of the flue gas generated in the thermal oxidizer is sensitive to the heating value of the incoming pyrolysis gases, and its mass flow rate is very sensitive to the air-fuel ratio of those gases. These sensitivities have impacts on generation and drying performance. We have estimated both values based on literature, but the potential contributions to error in the overall energy balance is appreciable.

Given the scale of the input energy, we believe the magnitudes and levels of uncertainty in the balances can be addressed with final equipment selection and detailed design to provide sufficient flexibility for process optimization in launch operations. These product mixes are viable given our feedstock and proposed process.

2. Regional Markets & Prospective Customer Segments

2.1. Our Process for Finding Biochar Customers

Despite a growing amount of academic and private research related to the benefits of biochar across multiple commercial applications, as of early 2024 there isn't a defined market for biochar in Washington State. Because there isn't an obvious market to pursue, we used the following process to help determine which markets and customers to pursue.

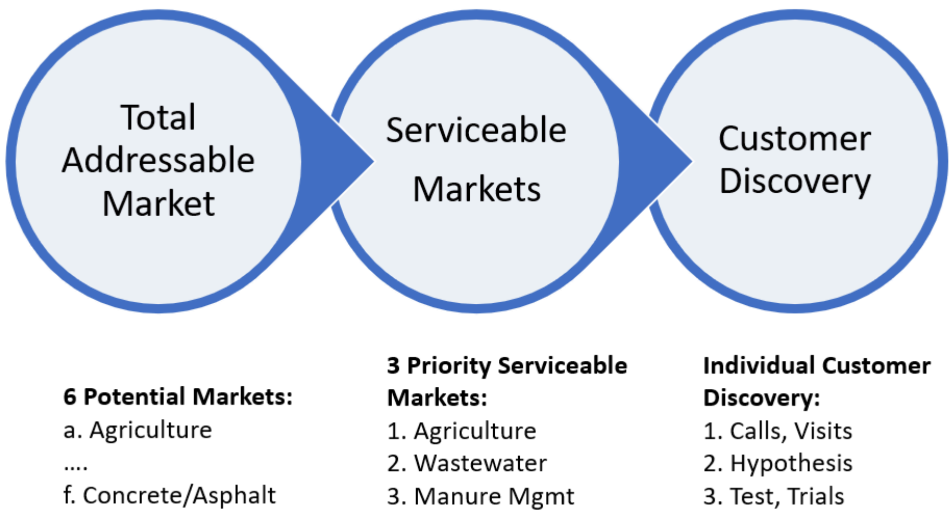


Figure 24: Process we followed to prioritize markets and build a biochar product roadmap.

In our Total Addressable Market (TAM) assessment, we started with a wide lens, and evaluated a number of different options for using biochar from agriculture to wastewater. After narrowing down these options to three priority serviceable markets, we initiated a customer discovery process by reaching out to potential customers in those markets. During our customer discovery we tried to leverage product development best practices, especially the scientific method (observation, hypothesis, test) to decide which specific markets to target with the goal of eventually building a product roadmap to support. We were fortunate enough to connect with a number of potential customers (observation) and developed hypotheses on how biochar could help solve some of their problems. Unfortunately, we didn't have the resources to produce biochar or run trials, so our hypotheses remain untested.

2.2. TAM Assessment

Because of both the climate benefits and potential application value of biochar, there is a growing amount of research to identify and develop markets for biochar. From that research a number of potential markets have already been identified (source). We evaluated a subset of those by removing markets that either had regulatory challenges (e.g. using biochar as a feed for livestock) or no local presence (e.g. 3D printing). Below is our assessment, which led us to focus on 3 markets: a) using biochar as a soil amendment with local agricultural producers, b) using biochar as an additive in wastewater treatment facilities, and c) using biochar to improve existing manure management practices.

Markets	Proximity	Volume	Value	Readiness	Incentives	Overall	
Agriculture (soil amendment)	5	5	2	3	3	**3.6**	**Priority 1 Markets**
Waste Water (filtration)	4	3	5	3	0	**3.0**	
Manure Mgmt (filtration)	5	5	3	1	0	**2.8**	
Remediation (soil)	2	3	3	4	0	**2.4**	
Concrete/Asphalt	4	4	3	1	0	**2.4**	
Packaging Material	1	5	2	3	0	**2.2**	

Table 35: Our initial assessment of potential markets for biochar.

2.3. Identifying Agricultural Sub-Markets

Since the Washington State agriculture market is diverse (apples to zucchini) we further broke down the market into submarkets to help us focus. We used crop-level data from the USDA's NASS (National Agricultural Statistics Service) database to help us select submarkets. Our initial focus crops included corn/potato/wheat rotations, wine grapes and cannabis. We prioritized based on the following factors:

1) Proximity (to Chelan Co) [6]
2) Volumes (acres)
3) Value ($/acre)
4) Assumed Readiness
5) Shorter Feedback Loops [7]

[6] Finished biochar isn't a dense product (~350 lb/cu yd). To reduce shipping costs and emissions (a factor in carbon offsets calculations), we prioritized local markets. California-based biochar producers charge $250/ton to ship biochar to WA State.

[7] We felt it was important to focus on crops with shorter growing cycles (e.g. corn/potato/ wheat) so we could more quickly prove the benefits of biochar to customers.

2.4. Customer Discovery Findings

After completing our initial customer discovery, we felt strongly that partnering with a commercial compost producer to target the farmers in nearby Grant county (~35 miles from Wenatchee) who commonly grew a corn/potato/wheat rotation was a good path forward. Although we deprioritized vineyards and cannabis, biochar has already developed some traction in those markets and we would plan to continue monitoring them.

Based on the customer discovery we completed for anaerobic digestion (AD), we think this market has high potential, especially as it relates to using biochar as an additive in wastewater treatment plant (WWTP) AD's. In order to confirm the potential, we would need to do additional customer discovery with the municipal wastewater treatment plant operators.

We did not do customer discovery with either dairies or feedlot operators to understand if biochar could address manure management challenges. But based on the existing research related to the topic, we think this is a significant potential market.

Market	Biochar could address valuable problems	No major blockers identified	Priority Serviceable Market
Potato / Corn / Wheat	✅	✅	✅
Vineyards	🟨	🟨	❌
Cannabis	🟨	❌	❌
Dairy AD's	✅	❌	❌
WWTP AD's	✅	tbd	tbd
Manure Mgmt	tbd	tbd	tbd

✅ = confirmed
🟨 = partial confirmation, needs additional analysis
❌ = denied
tbd = analysis not completed

Table 36: Assessment of potential biochar markets based on our customer discovery process.

2.5. Corn/Potato/Wheat Rotations Discovery (Priority Serviceable Market)

We selected these three crops because they are a common rotation set in neighboring counties in the Columbia Basin. While doing our customer discovery we were introduced to a commercial manure compost producer based in Grant County. We developed a close relationship with this compost producer, which eventually led them to signing a biochar purchase MOU with C6. Most of our customer discovery for these crops came via discussion with our compost partner since they had an established customer base and a deep understanding of their customers' needs. As a result, our problem statements are written from their perspective.

Problem Statements
#1 Higher NPK: Compost managers, whose compost is viewed by many growers as a substitute for conventional fertilizers, are looking to maximize the amount of nutrients in their compost - specifically nitrogen, phosphorus, and potassium (NPK). Higher nutrient content compost reduces growers costs and increases their yields.
#2 More Microbes: Compost managers, especially those that make compost for sophisticated agricultural producers, want to increase the microbial levels of their compost, and as a result, the soil it's applied to. Soils with higher microbial populations tend to be more productive and resilient to diseases.
#3 Faster Finishing: Compost managers are looking to reduce the cost of producing compost by eliminating the number of times they need to turn their windrows and reducing the time it takes for their compost to be considered "finished" (per WA State Dept. of Ecology).
#4 Higher CEC: Compost managers, especially those with well-informed agricultural customers, want to produce compost that has high cation exchange capacity (CEC). Soils with higher CEC hold more positively charged nutrients, including potassium, calcium, magnesium, and ammonium, which reduces growers' costs and increases their yields.
#5 Higher Water Holding Capacity: Compost managers, especially those that make compost for sophisticated agricultural producers, want to increase the water holding capacity of their compost, and as a result, the soil it's applied to. Soils with higher water holding reduce growers cost (rights, pumping) and, depending on the crop, tend to be more productive.
Potential Blockers
During our initial discovery, we didn't identify any high impact potential blockers.

Table 37: Problem statements for compost producers with corn/potato/wheat growing customers.

In addition to the number of ways that biochar could help their customers, we were excited to learn that a number of the compost producer's end customers were interested in doing biochar trials.

There are a couple of potentially important tailwinds for adding biochar to compost. In June of 2022, the Washington State Legislature passed the Organics Management Law through House Bill 1799. The goal of the law is to reduce methane emissions by diverting organic materials from municipal landfills where they would decompose and create gas. The legislation could help biochar in compost adoptions for multiple reasons.

1) HB 1799 will considerably increase the volume of composting, which will make improving operational efficiency and reducing compost finishing times

critical, so that facilities can handle higher volumes. Biochar has been shown to reduce compost finishing times by 20%.

2) As more compost is produced, the price of undifferentiated compost will likely drop. To charge premium prices, producers will need to ensure their product delivers more benefits: higher nutrient value, higher microbial populations, higher CEC, and higher water holding capacity. Biochar has been shown to help deliver all those benefits.
3) Compost production inevitably results in volatile organic compound (VOC) emissions. The level of VOC emissions from composting depends on a number of variables but at higher levels they can be a public health risk and a public nuisance (rotten egg smell). Based on our discussions with compost producers, they didn't have problems complying with WA Dept. of Ecology VOC regulations. However, there is some concern within the industry that the WA Dept. of Ecology could adopt stricter VOC emission regulations in the future, which would impact existing operations. Biochar has been shown to reduce VOC emissions in compost.[8]

2.6. Anaerobic Digesters (Additional Customer Discovery Required)

Over the past decade, researchers have conducted trials using biochar as an additive to anaerobic digestion systems and identified multiple potential benefits to system performance.

Anaerobic digestion (AD) is a process through which bacteria break down organic matter—such as animal manure, wastewater biosolids, and food wastes—in the absence of oxygen. Anaerobic digestion for biogas production takes place in a sealed vessel called a reactor, which is designed and constructed in various shapes and sizes specific to the site and feedstock conditions. These reactors contain complex microbial communities that break down (or digest) the waste and produce biogas and digestate (the solid and liquid material end-products of the AD process), which is then discharged from the digester. In Washington State, anaerobic digestion is most commonly used at wastewater treatment plants, and to a lesser extent for manure management at dairies.

Although we didn't complete our customer discovery for the AD market, we were fortunate to meet with 3 dairies and 1 wastewater treatment plant that operate AD's. Through those discussions we identified a few problem statements that biochar could likely address. For dairies, we also discovered a couple potential blockers to adoption. Based on our limited discussions with wastewater treatment plant

[8] In 2019 Washington State University (WSU) has started publishing results of research on co-composting (*Co-Compost Study WSU, WA Dept. of Ecology*). Based on their research, adding biochar to unfinished compost at the beginning of the composting process reduces emissions of volatile organic compounds (VOC's) and potentially GHG's.

operators, we believe the market potential could be large[9] and there might be a strong fit for biochar.

Problem Statements
#1 More Methane: AD operators, especially those looking to maximize returns, face challenges increasing the amount of in-system methane production.
#2 System Instability: AD operators, especially those looking to maximize returns, face challenges with system instability as a result of rapid accumulation of volatile fatty acids, which can lead to low pH level and inhibit the activity of methanogenic microbes.
Potential Blockers
#1 Slow Growth Market (dairies only): As of mid-2023, only 6 AD's were in operation on dairies in Washington. Additionally, no new AD's had come online for more than a decade. That might change in the future as Washington State has committed considerable funding in the most recent budget to increase the adoption of dairy-based AD's.
#2 Capacity Constraints (dairies only): Some of the dairy-based AD operators we talked to informed us if they improved the performance of their system and produced more methane, they wouldn't be able to generate additional revenue because of downstream capacity limits. One dairy converts methane to electricity using a generator which is currently running at maximum capacity. Another dairy informed us that the local distribution lines he fed his electricity into couldn't accept a higher load.

Table 38: Problem statements and potential blockers for anaerobic digester operators.

We are very appreciative to all the anaerobic digester operators that shared their thoughts with us - especially Daryl Williams (Qualco Energy/Werkhoven Dairy), Eric Powell and Craig Frear (Regenis/Vander Haak Dairy), Steve Worley (City of Pasco).

2.7. Manure Management (Additional Customer Discovery Required)

Similar to anaerobic digestion, researchers have conducted trials over the past decade using biochar to tackle some of the challenges associated with manure management. Unfortunately, outside of reviewing academic research, we didn't connect with any potential customers. However, based on our initial research and the size of the market, we think this is a potentially valuable market to explore.

---

[9] As of 2021 there were 33 wastewater treatment plants (WWTP) operating anaerobic digesters (AD). In many cases, a single WWTP will operate multiple AD's. The City of Wenatchee is in the process of bringing a 4th AD online at their Worthen Street plant.

2.8. Vineyards Customer Discovery (Deprioritized Market)

Biochar has gained some adoption by vineyards in California, so we were initially bullish about this crop. We were fortunate to meet with 7 Washington-based vineyards. Through those discussions we identified a few problem statements that biochar could likely address. However we also identified a number of potential blockers to biochar adoption (see below) and ultimately decided to explore other crops.

Problem Statements
#1 Less compact soils: Vineyard managers, especially those whose acreage is silty and prone to compaction, struggle to ensure their vines get access to enough water and that their soils get enough air to support healthy microbial communities and root development.
#2 Higher water & nutrient retention: Vineyard managers, especially those whose acreage is sandy and well drained, struggle to ensure their vines get enough water & nitrogen and that their soils develop healthy fungal growth.
#3 More consistent soil chemistry: Vineyard managers, especially those whose acreage is sandy, spend a lot of time & money and struggle to ensure their acreage has the right “soil chemistry” on a consistent basis (e.g. pre- vs. post-harvest).
Potential Blockers
#1 Stressing Vines: Multiple vineyards informed us their vines produced “better” grapes when the vines were “stressed and starved”. They were therefore concerned about enhancing their soils.
#2 Existing Soils, Wine Taste Profile: Multiple vineyards expressed concerns about altering their soils even if those alterations ultimately led to “better” grapes (as measured by BRIX) because they considered their existing soils critical to the taste profile of their wines.
#3 Long, Expensive Trials: Through our conversations, we determined that vineyard trials would be difficult because of the high opportunity cost of a failed trial and the long feedback loops. As far as the feedback loops, newly planted vines typically take at least 3 years before they produce grapes for harvest. Therefore a multi-year trial could take 5-7 years.[10]

Table 39: Problem statements and potential blockers for vineyard operators.

We are very appreciative to all the vineyards that shared their thoughts with us - especially Paul Beveridge (Wilridge Winery), Mickey Dunne (Badger Mountain Organic Winery), Matthew & Patrick Rawn (Two Mountain Winery), Marcus Miller (Airfield Estates Winery) and James Mantone (Syncline Winery).

[10] Pacific Biochar publishes the annual result of a vineyard trial they started in 2016 (source).

2.9. Cannabis Customer Discovery (Deprioritized Market)

Biochar has gained some adoption by cannabis producers - so despite some internal concerns about potential negative stakeholder perceptions of selling biochar into the market, we reached out to cannabis producers. Unfortunately, we struggled to get much response. We did meet with one producer from Okanogan County and identified a few problem statements that biochar could likely address, and a couple potential blockers to cannabis adoption. We ultimately decided to explore other crops.

Problem Statements
#1 Higher water & nutrient retention: Cannabis growers, especially those growing a premium product, face challenges ensuring their plants get enough water & nitrogen.
#2 Longer lasting soils: Cannabis growers, especially those growing plants indoors, can deplete their soils in a single growing season, requiring them to replace all their soils.
Potential Blockers
#1 Fragmented Market: Although many cannabis grow operations replace their soils on an annual basis, the market is fragmented and the volume of biochar we could sell to an individual grower is relatively small.
#2 High Customer Turnover: Although cannabis growers are progressive and willing to try new inputs that drive higher quality products and/or higher yields, profit margins for cannabis growers are thin due to a constant influx of growers. This has led to high insolvency rates amongst growers.

Table 40: Problem statements and potential blockers for cannabis growers.

3. Serviceable Market Analysis: Potato/Corn/Wheat via Co-Compost

As discussed in section 2, our initial customer discovery indicated that biochar is a good fit for use as a soil amendment for potato, corn, and wheat rotations when mixed with compost - what we refer to as “co-compost”. Because we determined there was a strong fit, we explored this agricultural sub-market in more depth. We worked through the following Go-To-Market topics:

1) co-compost distribution
2) subsidies, pricing and customer ROI’s
3) volume estimates

3.1. Co-Compost Distribution Summary

Working with our former compost partner, we tentatively agreed on the distribution model outlined below. This approach leveraged the assets our former compost partner already had and simplified distribution for both sides.

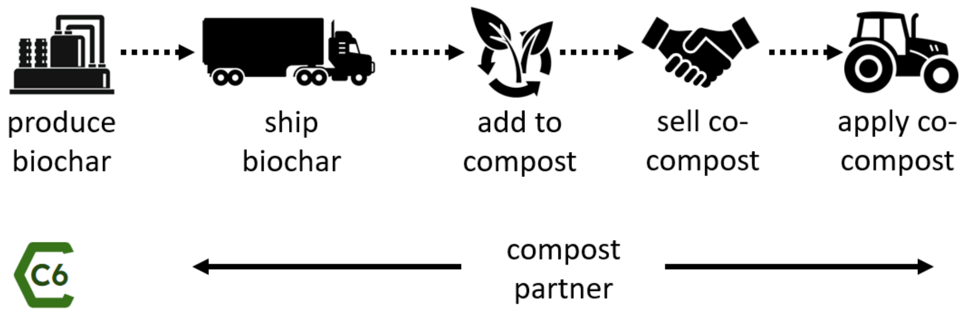


Figure 25: Potential biochar product distribution when partnering with a compost producer.

This model would allow us to focus on producing high quality biochar while allowing our partner to focus on compost production and addressing customer needs. Understanding that biochar is new to the Washington market, we planned to provide support to ensure the benefits of biochar were clear to the end customer during and after the sales cycle. We planned to coordinate trials with both end customers and local research institutions (WSU, OSU, USDA, etc). We would summarize trial results, new research and lab results into easily consumable product marketing material that our compost partner could use on customer calls.

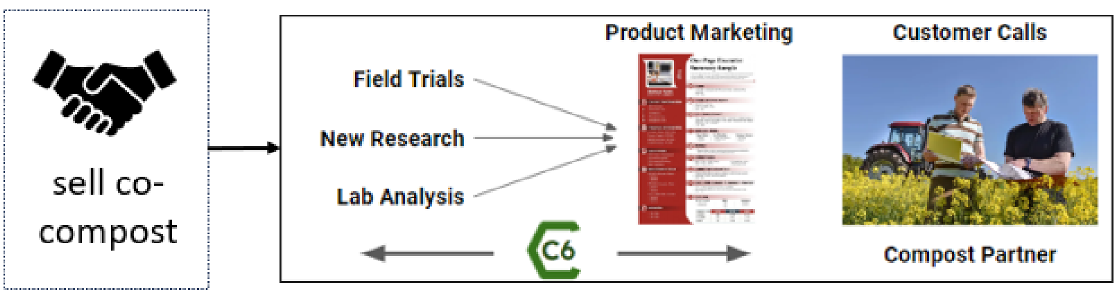


Figure 26: Potential biochar product marketing collaboration when selling biochar with a compost producer.

3.2. USDA Subsidies

Through NRCS practice 336, the USDA is trying to increase the adoption of biochar as a soil amendment by offering farmers generous subsidies for biochar applications. A NRCS practice is a structured program used to protect or reduce the degradation of soil, water, air, plant, animal, or energy resources. NRCS practice 336 offers subsidies on biochar and biochar blended into compost (aka “co-compost”). The aim of this program, “using carbon-based amendments to increase soil carbon and improve the physical, chemical, and biological properties of the soil” is an attempt to reverse the impacts of conventional farming practices on soil carbon levels (source). According to the Center for Climate & Energy Solutions, “U.S. agricultural soils to date have lost an average of 30 to 50 percent of their original organic carbon content" - which makes US soils less productive (source).

Specific NRCS program subsidies vary by state, but based on the FY2024 Washington State NRCS payment schedule, a 20/80 biochar/compost mix (by volume) would be subsidized at $476 per unit (unit = 4 cu yds). At these levels, NRCS 336 would subsidize the full cost of an application at our assumed $650/ton of biochar and would also give our facility some flexibility to price our biochar higher, though this would require more analysis to balance the obvious advantages with potential challenges.

Code	Practice	Component	Units	Unit Cost
334	Controlled Traffic Farming	Controlled Traffic	Ac	$55.87
334	Controlled Traffic Farming	HU-Controlled Traffic	Ac	$67.05
336	Soil Carbon Amendment	100% Biochar	Ac	$769.52
336	Soil Carbon Amendment	HU-100% Biochar	Ac	$923.43
336	Soil Carbon Amendment	20% Biochar-80% Compost	Ac	$476.67
336	Soil Carbon Amendment	HU-20% Biochar-80% Compost	Ac	$572.00
336	Soil Carbon Amendment	40% Biochar-60% Compost	Ac	$554.72
336	Soil Carbon Amendment	HU-40% Biochar-60% Compost	Ac	$665.67
336	Soil Carbon Amendment	60% Biochar-40% Compost	Ac	$632.78
336	Soil Carbon Amendment	HU-60% Biochar-40% Compost	Ac	$759.34
336	Soil Carbon Amendment	80% Biochar-20% Compost	Ac	$710.84
336	Soil Carbon Amendment	HU-80% Biochar-20% Compost	Ac	$853.01
336	Soil Carbon Amendment	Compost - Off Site	Ac	$206.28
336	Soil Carbon Amendment	HU-Compost - Off Site	Ac	$247.53
336	Soil Carbon Amendment	Compost - On Site	Ac	$88.70
336	Soil Carbon Amendment	HU-Compost - On Site	Ac	$106.44
336	Soil Carbon Amendment	Compost - Small Areas	kSqFt	$44.97
336	Soil Carbon Amendment	HU-Compost - Small Areas	kSqFt	$53.96
336	Soil Carbon Amendment	Compost + Biochar - Small Areas	kSqFt	$53.17
336	Soil Carbon Amendment	HU-Compost + Biochar - Small Areas	kSqFt	$63.81
336	Soil Carbon Amendment	Other Carbon Amendment	Ac	$709.48
336	Soil Carbon Amendment	HU-Other Carbon Amendment	Ac	$851.38

Table 41: Washington State's NRCS Payment Schedule for practice 336 (pg. 33, source)

Despite the generous subsidies, the impact of NRCS 336 on biochar prices and growers' willingness to adopt biochar is unknown. Unfortunately, funding for individual NRCS programs is based on the discretion of the Washington State Conservation District, and at this point they haven't fully funded the program. The administrative requirements a farmer has to complete to receive subsidies can also reduce adoption.

It's our opinion that in the long term, NRCS practice 336 will likely be very valuable but in the near term we assume adoption will be low and priced our biochar accordingly.

3.3. Customer ROI

Since there isn't an established biochar market in Washington to use as a guide, we considered a few factors when setting our assumed biochar price of $650/ton. First, we thought about pricing in the context of the considerations outlined in the image below - especially our unit cost and the resulting end customer ROI. Second, we looked at biochar prices in California and Oregon.

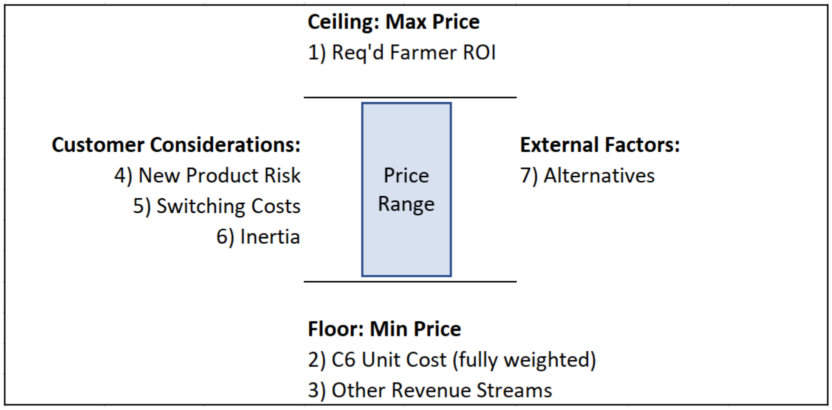


Figure 27: Pricing framework used to estimate biochar pricing.

To better understand what price points result in positive returns, we estimated incremental cash a farmer with a corn, potato, and wheat rotation (common in the Quincy area) could realize by making a multi-year investment in 20/80 co-compost (20% biochar, 80% compost).

We ran a few scenarios using different biochar + co-compost price points, and yield increases. On a mass basis, biochar is a small input into co-compost as the below 20/80 example shows. Therefore, if C6 sells biochar to a compost producer for $650/ton, the price the farmer will pay for the resulting co-compost will be much lower. For our analysis, we estimated that $650/ton biochar would result in co-compost priced at ~$93/ton (delivered and applied).

	volume	mass
biochar	20%	6%
compost	80%	94%

Table 42: Biochar and compost volume and mass in 20/80 co-compost.

Below is a summary of our base case, which includes biochar being sold at $650/ton and yield increases of 10%. In the estimate a farmer would make a 6 year, $527k investment in biochar, by applying 10 tons of co-compost (20/80) to a 130 acre pivot. Co-compost would be applied for the initial five years (Yr 0-4) and again in Yr 9. The breakeven period in this example is Yr4 due to the multi-year investment the farmer makes in their soil. The farmer would realize roughly $1M in incremental revenue due to higher yields, which nets a $472k return or a 36% IRR.

Incremental Cash Flow ($ k's)		Yr 0	1	2	3	4	5	6	7	8	9	10
Crop Rotation												
Biochar Cost	($527)	($82)	($84)	($86)	($87)	($89)	$0	$0	$0	$0	($98)	$0
Revenues	$999	$0	$156	$16	$84	$165	$16	$90	$175	$16	$95	$186
Cash Flow	$472	($82)	$72	($70)	($3)	$76	$16	$90	$175	$16	($3)	$186
IRR	36%											

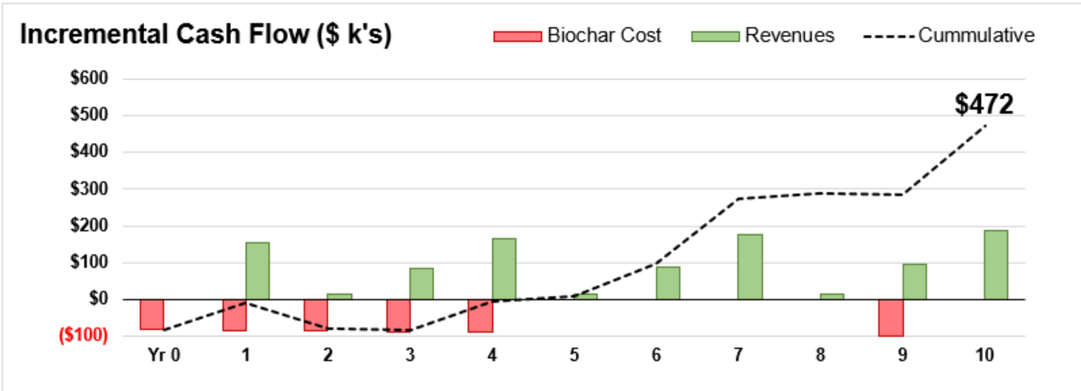


Table 43: Base case corn, potato, wheat ROI estimate at $650/ton.

Below is a summary of farmer ROI's using the same assumptions as the base case above but for different biochar prices and crop yield increases. Biochar sold by C6 at $250/ton likely results in co-compost sold to a farmer at $57/ton (delivered and applied), $650/ton biochar is $93/ton co-compost and $1,050/ton biochar is $130/ton co-compost.

		Biochar Price ($/ton) as an Input Into Co-Compost								
		$ 250	$ 350	$ 450	$ 550	$ 650	$ 750	$ 850	$ 950	$1,050
	0.0%	-100%	-100%	-100%	-100%	-100%	-100%	-100%	-100%	-100%
	2.5%	5%	-7%	-16%	-24%	-100%	-100%	-100%	-100%	-100%
	5.0%	54%	26%	13%	4%	-2%	-7%	-12%	-16%	-20%
Yield	7.5%	139%	70%	41%	26%	16%	10%	4%	0%	-4%
Increase	10.0%	247%	138%	82%	53%	36%	26%	18%	13%	8%
	12.5%	358%	218%	137%	90%	62%	45%	34%	26%	20%
	15.0%	470%	300%	201%	137%	96%	70%	53%	41%	32%
	17.5%	581%	384%	266%	189%	137%	100%	76%	59%	47%
	20.0%	693%	467%	333%	244%	181%	136%	104%	81%	64%

Table 44: sensitivity table for 20/80 co-compost, using different biochar prices and yield increases.

The model relies on a number of assumptions, including assumed yield increases. In recent years there has been a major increase in research related to using biochar as a soil amendment[11]. Unfortunately we weren't able to find research that ran trials for

[11] Agronomic biochar research is a rapidly evolving field of research moving from less than 100 publications in 2010 to more than 15,000 by the end of 2020.

that specific crop rotation in soils similar to the Columbia Basin. We instead used a study published by researchers in Europe that aggregated the results of multiple studies focused on biochar's impact as a soil amendment (source). By aggregating multiple studies, the study was able to estimate average results for metrics such as root biomass, nitrogen uptake and microbial populations in addition to yield increases. Based on the study, yields increased on average by between 10% and 12%. Based on a 95% confidence interval, the yield increase could dip down to +5%.

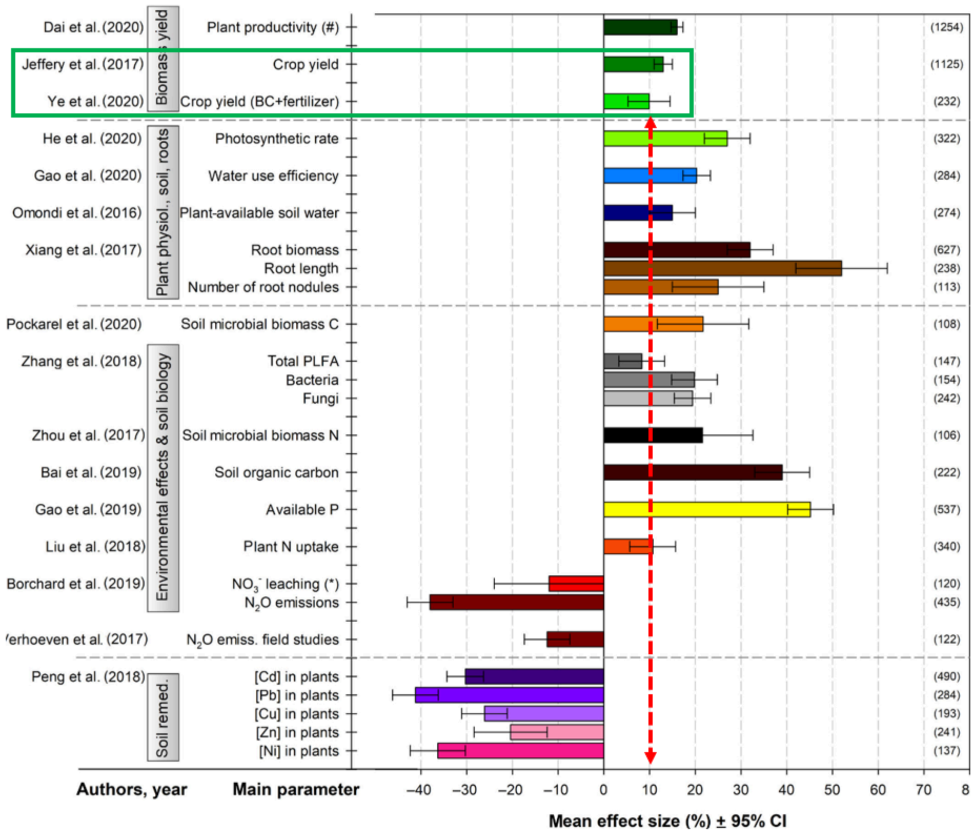


Figure 28: Selected parameters with highest agronomic relevance from the "Biochar in agriculture – A systematic review of 26 global meta-analyses" study (source).

In addition to looking at customer returns, we also looked at pricing of California and Oregon biochar producers. Since not all biochar has the same bulk density or product attributes, comparing prices across different producers isn't ideal. That said, based on list prices from the largest, most established producers on the West Coast, Pacific Biochar (CA) and Oregon Biochar Solutions (OR), biochar delivered to the Columbia Basin costs somewhere between $400 and $600/ton. This is well within the range we'd consider.

3.4. Volume Projections

Assuming our biochar solved problems for customers and was priced appropriately, the amount of biochar we'd be able to sell to our compost partner depends on a few variables. The most important is the concentration of biochar in the co-compost (for example 20% biochar / 80% compost). For our initial projections, we assumed the final co-compost would be between 7-20% biochar by volume. That range was chosen after considering 3 factors:

Biochar Concentration Factors
#1 Keeping Co-Compost Prices Lower: When you factor in all the costs (direct, logistics, mixing), adding biochar to compost can dramatically increase the cost of the finished product. For example, a 7% mix of biochar by volume would add ~$13/ton to the finished co-compost, a 40% increase over the existing retail price. A 20% mix of biochar would add ~$39/ton, or 130% to the existing retail price.
#2 Aligning with Existing Research: The impact of different biochar concentrations on yield increases in existing research varies dramatically based on different variables. However, there seems to be some consensus that concentrations need to be above 5% and that higher concentrations (above ~40%) can have adverse impacts.
#3 Align with NRCS practice 336: Although we didn't assume that 336 would be highly adopted initially, we thought it was important to consider a concentration that complied with the practice's minimum biochar concentration of 20% biochar/80% compost.

Table 45: Factors influencing the biochar application rate chosen for co-compost.

In the future, after we run trials with customers, our compost partner would presumably create different blends of co-compost, some with higher levels of biochar and some with lower levels of biochar, tailored for different applications.

At a 7% concentration, we would produce just enough biochar (3,000 tons) to mix with our former compost partner's existing compost production (150,000 tons). At a 20% concentration, our 3,000 tons of biochar would be mixed with 50,000 tons of compost, which is about ⅓ of our former compost partner's output. Based on these assumed concentrations, we could likely sell all our pilot output to a single customer.

	Tons		
Volume Mix	**Biochar**	**Compost**	**Total**
7/93 Mix	3,000	164,110	167,110
20/80 Mix	3,000	49,412	52,412

Table 46: Co-compost compositions for two mix ratios.

4. Other Products

Slow pyrolysis yields multiple products: syngas (44% of mass), aqueous bioliquids (28%), biochar (21%) and organic bioliquids (7%). In most of the plant configurations we analyzed, biochar is the principal product from a revenue perspective - especially when you factor in biochar-linked carbon offsets. However, biochar and biochar-linked carbon offsets revenues aren't enough (especially at the pilot scale) for the project to deliver positive returns.Therefore, creating value and generating revenues from the other three products is important.

Based on our discovery, there are 2 primary options to unlock revenues from the other products. Option 1 is to convert them into electricity. Option 2 is to condense and separate the liquids in the vapor stream.

4.1. Electricity

Using the byproducts of pyrolysis to produce electricity is a low-risk approach that, unburdened of any other operational costs, does generate positive returns. However, as we'll cover in more detail in the Plant Configuration section, unless there are major technological improvements or additional clean energy incentives, the upside associated with electricity generation seems to be limited, especially in a region like central WA with high levels of hydro power. In summary, there is a path to achieve positive return with electricity generation, but due to the limited revenue potential it requires increased operational scale (2X the pilot) and seamless execution across the rest of the business.

We evaluated possible electricity offtake agreements with both Chelan County PUD and Puget Sound Energy (PSE). Although their offtake agreements had slightly different structures, the resulting revenues were very similar, roughly $4.4m from 61.7k MW-hr generated over the assumed 15-year life of the plant (pilot scale).

Both PSE and Chelan County PUD would pay a standard fixed rate for electricity generated by C6, what we're calling "electricity generation revenue" below. Electricity generated for PSE would also generate renewable energy credits which could be increased by a clean standard fuel multiplier. Alternatively Chelan County PUD would pay C6 what is referred to as a "Resource Adequacy Rate" which is a function of how much electricity generation capacity C6 has available for deployment. At pilot scale, C6 would run three 190kW generators, therefore have a resource capacity of 570kW.

Though our discussions with both utilities did not progress to contracting, we didn't identify any blockers to this revenue stream.

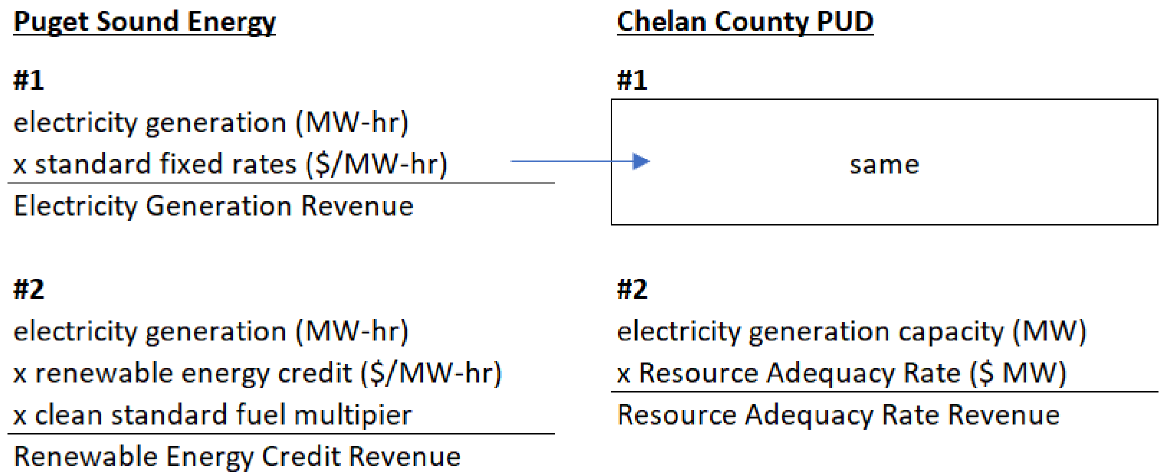


Figure 29: electricity related revenue streams available to C6 from Puget Sound Energy (PSE) and Chelan County PUD.

4.2. Bioliquids

The alternative approach to leveraging the byproducts of slow pyrolysis involves condensing and separating the liquids in the vapor stream to produce bio-oils and wood vinegar. As we'll cover below, this approach is much higher risk but potentially has a much higher upside. Generally speaking, we only explored opportunities where we could sell our bioliquids to offtake customers, because converting bioliquids into commercial products would require material investments in R&D and CAPEX for refinement equipment.

4.2.1. Bio-Oils

If the vapor stream is condensed and separated, bio-oils will make up roughly 7% of total output, or ~600 tons per year. There is research being done to use the bio-oils from pyrolysis as a clean energy precursor but those efforts are in the early stages. We instead focused on selling our bio-oils to a carbon sequestration company (referred to here as Carbon Co. A for confidentiality sensitivity).

Over the course of a few months, we had a number of conversations with Carbon Co. A. Although we did not sign an offtake contract with them, we did explore the opportunity enough to allow us to understand the likely project revenues, cost and CAPEX associated with the partnership. Carbon Co. A would pay us $150/ton for our bio-oils. As long as our bio-oils met their requirements, which they did based on our initial lab analyses, Carbon Co. A was willing to purchase all of our bio-oil volumes. To realize this revenue, we would need to temporarily store bio-oils onsite and eventually load them into rail tank cars. Once the bio-oils are loaded into the rail tank cars, we would realize the revenues and Carbon Co. A would assume control of the product.

The investment in storage, transport and transfer equipment to handle the bio-oils onsite until we shipped them is roughly $270k. Based on our initial conversations with Carbon Co A's logistics provider, if the pilot was located at the Winton mill, we'd likely be able to use the rail siding to fill rail tank cars, which would reduce costs and complexity. Otherwise, we would need to use a 3rd-party logistics company to transport the bio-oils to a nearby rail siding. For our financial projections we took the more conservative approach, assuming we wouldn't be able to use the Winton rail siding.

In summary, selling the bio-oils to Carbon Co A. would generate a very modest return. We estimate annual revenues of $100k and income of $70k per year. Based on those cash flows, the completely unburdened cumulative cash flows over 15 years is $765k with an IRR of 22%. On the other hand, if not handled correctly, bio-oils can become a major liability - so the partnership provides a safe offtake until higher value uses can be developed. Additionally, Carbon Co A's mission is closely aligned with ours.

4.2.2. Wood Vinegar

If the vapor stream is condensed and separated, the aqueous "wood vinegar" fraction will make up roughly 32% of total output, or ~2,800k tons per year. It typically consists of aliphatic, aromatic, and naphthenic hydrocarbons and other oxygenated compounds such as alcohols, aldehydes, ketones, furans, acids, phenols and ethers. Wood vinegar exhibits antioxidant and scavenger properties and agricultural academic studies have tested its efficacy as an antimicrobial agent, insecticide, and promoter of seed germination and plant growth. Based on our limited discovery, there seems to be a lot of potential for wood vinegar usage in agriculture. However at this point, the research and commercial adoption is less developed than biochar, so will likely take more time to gain traction.

Corigin (source) is one commercial producer of wood vinegar targeting agricultural applications in California. They produce and distribute a wood vinegar product called Coriphol (source), but they don't post list prices for it on their website. Based on their customer case studies, it appears they sell Coriphol at roughly $5,000/ton.

Although we didn't reach out to Corigin to see if they would be interested in buying our wood vinegar, finding offtake customers for wood vinegar would be the recommended path forward. We'll cover this in more in the financial section, but we did estimate how a wood vinegar offtake agreement might impact our financials. Since we didn't conduct extensive customer discovery for wood vinegar, our estimates carry significant risk and it is therefore important to consider a range of outcomes.

5. Conclusions and Remaining Gaps

Biochar production of the type we propose yields multiple outputs. Biochar (typically 20-25% of output mass) doesn't require additional refinement to convert it into products. However, the other outputs, derived from the vapor stream (bioliquids and syngas, 75-80% of output mass), do require additional processing and refinement to convert them into products. We explored the market for biochar and the 3 products that could be created from vapor stream: a) electricity, b) bio-oils and c) wood vinegar. The biochar production process can be designed and operated to produce certain types of co-products, but this flexibility is dependent on the reactor and post processing equipment chosen.

Despite a growing amount of biochar research, as of early 2024 there isn't a defined market for biochar in Washington State. Without an obvious market to target, we did customer discovery on multiple potential markets for biochar including: a) field crops commonly grown in rotation in the Quincy area (corn, potato, wheat), b) vineyards, c) cannabis, d) anaerobic digesters and e) manure management. Based on this discovery, we strongly believe that additional investment in targeted plot-scale and field-scale trials are needed to validate and demonstrate that biochar can deliver results for specific crop and soil type combinations. The selection and design of trials is critical, and they should be done with both local research institutions (WSU, USDA) and farmers in the region. The results of these trials will help determine what types of biochar to produce and which reactor to select.

We also recommend partnering with a compost producer to sell co-compost to farmers growing higher value crop rotations (e.g. corn, potatoes, and wheat), as it simplifies customer outreach and product distribution. Based on customer ROI estimates, pricing biochar at $650/ton will allow customers to earn a positive return on their investment in biochar and aligns with California and Oregon biochar producers' prices.

As far as the co-products that could be made from the vapor stream, we suggest initially using it to generate electricity. Although electricity rates in Central Washington are low due to the abundance of hydroelectric power, the alternative of producing bio-oil & wood vinegar is too risky at this point. The financial upside associated with electricity generation is currently limited. Based on our discussions with two regional utilities, we recommend further effort to determine if either a corporate offtake partner or clean energy program might provide more revenue.

Otherwise, we recommend closely following developments related to commercial adoption of the bioliquid products. We explored an offtake agreement with one carbon sequestration company, but additional discovery could identify other higher-value uses for the bio-oils. We reviewed how one producer, Corigin, is selling their wood vinegar product. Determining whether Corigin and/or any other new retailers of wood vinegar would be interested in an offtake agreement is an important next step.

Carbon Markets

Despite their recent growth, the carbon markets are still fairly nascent, fragmented and can be difficult to navigate. Biochar offsets are widely considered one of the highest quality offset types, are in high demand and sell at a premium price. The pilot biochar facility we propose would generate a material volume of offsets, which we project to account for ~20% of total revenue.

In an attempt to accelerate the pace of new project development, large corporate buyers of offsets have been known to "pre-purchase" offsets. A pre-purchase agreement, where the end-customer pays for the offsets before the facility is operational, can be an important source of capital for construction. Once a project is well defined, it will likely take at least 12 months to unlock capital via the carbon markets as the project must get certified, and in the case of "pre-purchase" agreement, go through additional due diligence.

The carbon markets would be critical to the C6 pilot facility for both plant capital and ongoing revenues, but they will require time and resources to unlock.

Carbon Markets Objectives

1) Understand how the carbon markets work and how they can support the project.
2) Establish a preliminary assessment of the net carbon sequestration potential of our biochar to validate participation in carbon markets.
3) Determine whom we want to partner with in two areas:
    a) biochar standard,
    b) go-to-market partner

Carbon markets, trading systems in which carbon credits are bought and sold, can be an important source of capital to launch a new carbon sequestration project like the C6 Pilot Facility. Carbon markets can also be an important source of ongoing revenue to ensure projects are profitable and remain operational.

1. Carbon Markets

At a high level, there are two types of carbon markets, compliance and voluntary.
The compliance market aims to establish a carbon price by laws or regulations which control the supply of allowances that are then distributed by national, regional, and global regimes. This can be accomplished through either a carbon tax or a cap-and-trade scheme, shifting economic incentives by making it more expensive to pollute. For example, the State of Washington recently launched its compliance market with the introduction of the Climate Commitment Act.

The voluntary markets are incentive-based markets that allow individuals and companies to purchase voluntary carbon offsets to compensate for residual or unavoidable carbon emissions on a voluntary basis. Individuals and companies typically attempt to directly avoid, reduce and substitute harmful greenhouse gases they produce before buying voluntary carbon offsets.

However, the demand for voluntary carbon offsets has been strong as companies are struggling to reduce their emissions due to a lack of current emissions avoidance technology and/or costs. For example, Microsoft's Corporate Sustainability Program buys voluntary carbon offsets in an attempt to offset all its carbon emissions (Scope 1, 2, 3) going back to the launch of the company in 1986.

1.1. Focus on Voluntary Markets

Although the compliance carbon markets, especially the Washington Climate Commitment Act[12], represent major future opportunities, C6 has focused on selling carbon offsets in the voluntary carbon markets for two reasons.

1) Higher Pricing:
   - Voluntary Markets: Biochar offsets are commonly sold for between $100-200/offset (mt of CO2e)
   - Compliance Markets: Biochar offsets aren't regularly sold in compliance markets, likely because compliance market buyers typically only buy offsets if they are cheaper than compliance market allowances. In the case of the Washington Climate Commitment Act, allowances in the initial rounds of the program sold for ~$50/mt of CO2e.

2) Market Access
   - Voluntary Markets: Once a biochar project is certified by a biochar standard[13], the producers can market their offsets to any buyers.
   - Compliance Markets: Compliance markets often restrict what types of offset can be bought by participants. For example, the Washington Climate Commitment Act allows regulated emitters to buy four types of offsets, but it doesn't allow biochar offsets.

1.2. Biochar Carbon Offsets, Strong Demand, Premium Price

There are a number of different categories of carbon offsets available in the carbon markets ranging from improved forest management (IFM) to industrial process emissions reductions. Biomass with carbon removal and storage (BiCRS) is one type of offset that has gained a lot of traction recently because of its potential to remove large amounts of carbon dioxide. According to the U.S. nonprofit Rocky Mountain Institute (RMI), BiCRS has the potential to remove 5.5 gigatons of CO2 (GtCO2) globally per year - roughly ⅔ of what the World Resources Institute estimates need

---

[12] It's worth mentioning there is currently some momentum to either repeal or revise the Washington Climate Commitment Act (Initiative 2117) which adds more risks to participating in that market.

[13] Biochar standards (also referred to as protocols, methodologies) are covered in more detail in a subsequent section but in summary they set forth a methodology for quantifying emissions reduction from a proposed offset project, as well as requirements to demonstrate additionality, permanence, and certainty.

to be removed by 2050. Currently Biochar is the most mature BiCRS related technology available on the market. Because of this potential to remove so much carbon dioxide and their high quality, biochar offsets sell at a premium compared to other categories.

Reasons the carbon market values biochar offsets so highly:

1) Scale Potential: Biochar has the potential to sequester carbon at a huge scale.
2) Permanence: Carbon in biochar is resistant to decomposition (recalcitrant). It is common for 85% of the carbon in biochar to remain 100 years after it's produced.
3) Durable: Once biochar is used in an approved application, for example as a soil amendment, its carbon is at very low risk of returning to the atmosphere. Unfortunately forest-related carbon offsets are an example of lower durability offsets, due to the risks that wildfire, disease or other natural disasters pose.
4) Measurable/Verifiable: When biochar is produced in a facility such as the pilot C6 was pursuing, the inputs used to calculate how much carbon has been sequestered is relatively easy to measure and verify.
5) Co-Benefits: In addition to high quality carbon sequestration, the biochar produced in C6's pilot facility would have a number of other co-benefits including:
    a) wildfire risk reduction
    b) reduced emissions from slash piles
    c) improved soil health which reduces need for fertilizer and increases soil's water holding capacity
    d) rural economic development

The carbon markets in general and biochar prices specifically are very difficult to predict. Biochar offset prices could go either way as there are both tailwinds (growing awareness) and headwinds (increasing supply). There are a couple of attributes that differentiate the offsets that would be produced by the proposed C6 pilot facility: a) the impact on wildfire risk reduction and b) the project's proximity to Seattle. Both these could reduce price volatility in the future.

1.3. Source of Plant Capital & Ongoing Revenues

Due to the premium price of biochar carbon offsets, offset revenue can be critical to a biochar operation's financial performance. For the C6 Pilot Facility, carbon offset revenues are projected to be ~$800k per year, or 20% of the total. These revenues are important for two reasons.

1) Unlocking Capital for Facility Construction: If a project developer like C6 can find a buyer for their carbon offset prior to construction, in some cases they can negotiate contracts that will unlock capital to build the facility. That could take the form of the buyer pre-paying the project developer for offsets they will be owed in

the future. Or that could take the form of a binding purchase agreement that would allow the project developer to access other funding: investor equity or debt.

2) Cash to Support Ongoing Operations: Based on C6's current financial projection, the C6 Pilot Facility isn't profitable without carbon offset revenues. In the future, that might change as commercial applications for other co-products created during pyrolysis become more established.

2. Preliminary LCA

A biochar facility must show that its operations are holistically carbon-negative in order to participate in the carbon markets. The standard approach to determine the carbon balance is a Life Cycle Assessment (LCA). We began the process of developing a preliminary LCA in mid-2022, working with CORRIM and their partners at the University of Washington School of Environmental and Forest Sciences. In order to match standards for the system boundary of a biochar production system, we modeled a system that included all the process steps from "waste" forest biomass recovery, to the application of the biochar in the soil (Figure 30). Furthermore, in order to align with the most stringent standard (puro.earth), we included the carbon footprints of the equipment in our provisional plant design.

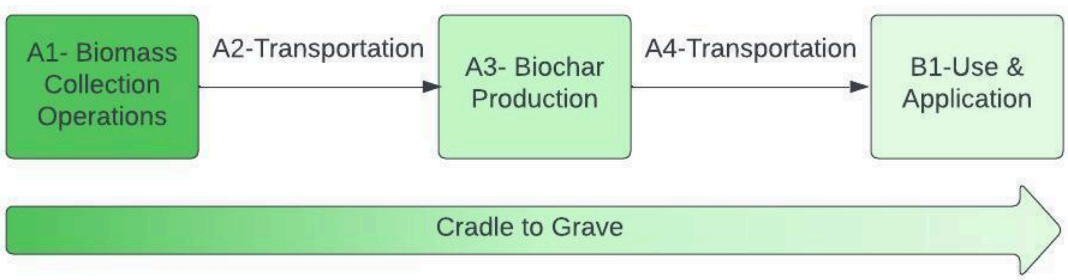


Figure 30: Elements within the system boundary of our preliminary LCA.

We initially modeled the system to include:

- an average biomass haul distance of 25 miles one-way based on the topographies of the Methow and Wenatchee Valleys.
- a plant production capacity of 1.0 dry short tons of wood per hour input to the pyrolysis reactor, which is close to the capacity we would later target for the pilot facility.
- most of the log pre-processing, biochar production and materials handling functionality we would later include in our pilot designs.
- a bulk application, where the biochar is integrated into manure compost, with an eventual mixed biochar + compost field application on multi-crop pivot circles via an existing broadcasting process. This application was developed with input from a prospective customer in the compost industry.

We subsequently revised the analysis in 2023 to include:

- biochar properties based on a small-scale pyrolysis trial with our target feedstock profile

- scaling results based on a new target production capacity - we assumed that we could achieve about the same carbon emissions to biochar carbon content ratio with a slightly larger operation

We found that our operation is projected to be carbon negative. Some key results are summarized in Table 47. Through this process, we will emit the equivalent of about 6% of the carbon contained in the logs we receive, or about 15% of the carbon contained in the biochar itself. We expect to sequester the equivalent of 2.90 tons of CO_2 per dry ton of biochar. Furthermore, based on the soil permanence algorithm included in the puro.earth standard, which is largely based on soil temps where the biochar is applied, we predict that about 86% of the carbon in the biochar will still be present in the soil in 100 years. Research published since our preliminary LCA suggests that biochar carbon is even more durable in the soil than previously understood.

Parameter	**Value**	**Unit**
Average haul distance, one-way	25	miles
Plant capacity, reactor infeed	1.0	dry tons per hour
Organic carbon content of biochar	91.0%	%, dry weight
Carbon dioxide stored per mt of biochar	2.90	mt CO_2 / mt dry biochar
Feedstock supply-chain emissions	0.06	mt CO_2-eq/dry mt input feedstock
Biochar supply-chain emissions	0.15	mt CO_2-eq/mt dry biochar
Annual average soil temperature at site of biochar use	15	°C
Permanence factor $F_p^{TH,Ts}$ (carbon remaining in soil in 100 yrs)	86.4%	%

Table 47: Summary of preliminary LCA results.

These results reinforce that we are well-positioned with our target mission-aligned feedstock, general process design and product applications to sell biochar-based carbon offsets.

If we began to capture and sell physical co-products (e.g. pyroligneous acid as an agricultural product), they would bear their own share of carbon emissions in the analysis, releasing that burden from the biochar and improving its sequestration potential.

While we would potentially see some degradation of carbon sequestration potential when running another LCA for a fully engineered and funded process, we are pleased with the starting position this preliminary LCA put us in.

3. Standards and Carbon Market Partner Assessment

3.1. Carbon Market Ecosystem Summary

In order for a carbon sequestration project operator like C6 to sell carbon offsets, they must select a few partners. The number of partnerships a project developer establishes depends on a) the complexity of the project and b) how much carbon market related work the project developer will handle in house. The following infographic summarizes the complex ecosystem associated with carbon dioxide removal offsets - which are one type of offset.

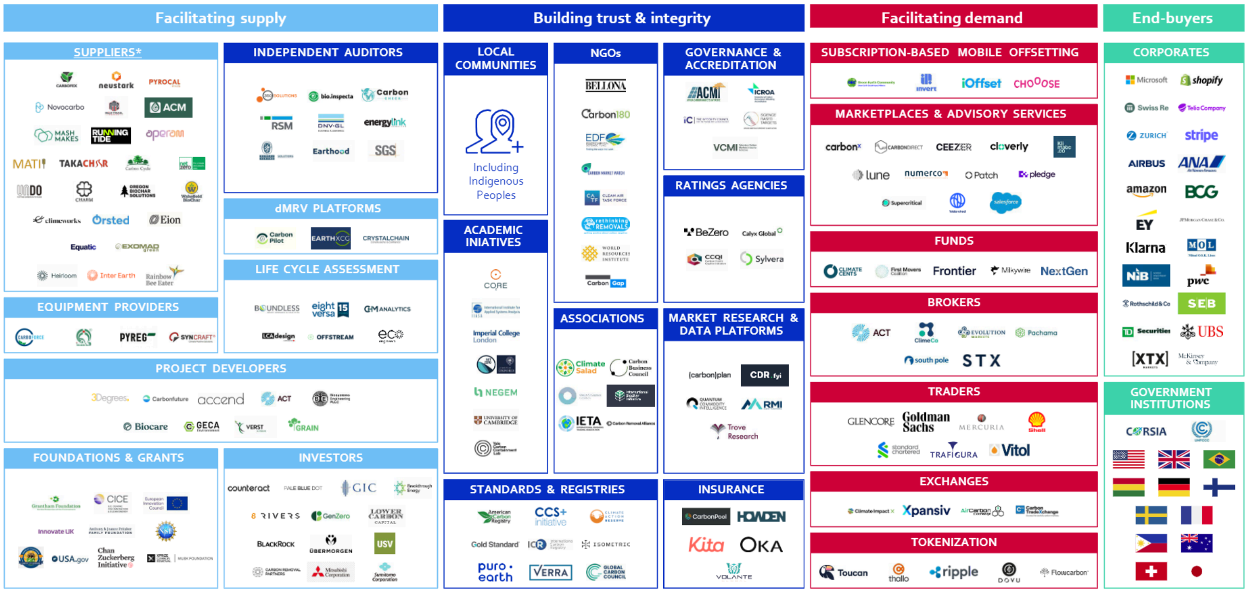


Figure 31: the carbon dioxide removal *(CDR) partner ecosystem.*

For the C6 Pilot Facility, we determined we would need to select a minimum of two partners to cover the following areas:

1) Biochar Standard

   Carbon offset standards refer to a set of requirements that we must adhere to in order to claim that they reduce carbon emissions. Standards include guidelines that will determine how many offsets a project will generate, what's commonly referred to as "issued credits" and the process for selling or "retiring" credits.

   CLIMATE ACTION RESERVE

   Climate Action Reserve has developed a biochar standard

2) GTM Partners: Project Development

   GTM Partners can offer a number of services. C6 focused on 3 areas: a) support to get our project certified by a standard and subsequently ensure our project remained in compliance post-launch and b) support marketing C6's offsets to buyers and facilitating transactions.

   3Degrees.

3Degrees is a project developer that supports biochar projects

3) GTM Partner: Measure/Reporting/Verification Platforms (MRV)

   After a carbon offset project has completed its initial certification, it must follow a standard's rules & guidelines to ensure it remains in compliance. Those rules & guidelines typically require the project to perform a suite of operational measures and submit regular reporting so that offsets issued are verifiable.

   Carbonfuture

   Carbonfuture offers a MRV platform that is widely used for biochar projects

4) Offset Buyers

   Offset buyers are typically large corporations that are looking to meet a carbon emissions target by purchasing carbon offsets on the voluntary market. For a number of reasons, it is helpful if a project operator like C6 has one or two supportive offset buyers committed to their project.

   Microsoft

   Microsoft has been an important offset buyer for multiple biochar projects.

3.2. Biochar Standards

As previously mentioned, carbon market "standards" are the set of requirements that project operators must adhere to in order to claim that they reduce carbon emissions and can therefore sell carbon offsets. As of early 2024 there are three approved biochar related carbon standards in the market. A fourth biochar standard, the Climate Action Reserve Biochar Protocol, will likely be approved in the near future.

1) Puro
2) Verra
3) The European Biochar Certificate (EBC)

C6 did a two-step evaluation of these three standards to understand how they are different and to determine which might be the best fit for our project. First, we screened each standard using three screens (below) which led us to focus on Puro and The European Biochar Certificate (EBC). Second, we scored Puro and EBC using 6 criteria (below) where both standards scored similarly.

Screens (Y,N)					
Screen	**Description**		**Puro**	**EBC**	**Verra**
Established	Biochar projects "live" using standard		✓	✓	
Rigorous	ICROA Certified		✓	✓	✓
Eligibility	C6 project meets eligibility		✓	✓	tbd (1)
Criteria (1,3,9)			**Score: 1,3,9 (worst to best)**		
Criteria	**Description**	**Weight: 1,3,9 (least, most)**	**Puro**	**EBC**	**Verra**
Financials	High profit potential (low cost, high revenues)	3	9	9	
Financials	Favorable cashflows	3	9	9	
Standard	Clear, actionable MRV requirements	3	9	9	
Standard	Good partner (high engagement, MRV partners, etc)	1	3	9	
Standard	Allow operational flexibility (temps, feedstock, etc)	3	3	3	
Standard	Stable standard, unlikely to change adversely	3	9	9	
		Total	**120**	**126**	

Table 48: Biochar standards assessment matrix.

There were important differences between the standards but in summary we believe that both the Puro and EBC standards would be a strong fit for our project.

3.3. Go-To-Market Partner (Project Developers, Measure/Reporting/Verification Platforms)

As the “CDR partner ecosystem” map (Figure 31) illustrates, there are many companies providing different types of services in the carbon market ecosystem. Based on our analysis, we determined that we would at a minimum need support in three areas:

1) getting our project certified with a standard,
2) marketing our carbon offsets to offset buyers,
3) providing tools to comply with a standard’s ongoing MRV requirements.

In 2023, C6 had a number of discussions with go-to-market (GTM) partners to better understand their offerings and determine which biochar standards they support (most GTM partners support one or two standards). At the time, we assumed that we’d launch our project, so in some cases we signed NDA’s with these GTM partners. Due to the restrictions in the NDA’s, we’ll focus our discussion on how we evaluated the different GTM partners but will not disclose which GTM partner scored or how they fared in our evaluation.

1) Standards
   As previously mentioned, most GTM partners typically support one or in some cases two standards. If a GTM partner didn’t support Puro or EBC, we eliminated them from consideration.

2) Project Certification Services & Cost

Most GTM partners provide a base level of services to help a project get certified. For example, most GTM partners will work directly with a biochar standard to ensure submitted applications are certified.

However some GTM partners provide additional services. For example, some will draft the Project Design Document (PDD), a required document for certification, on behalf of the project operator. In addition to offering different services, GTM partners have different ways of charging project operators like C6 for these services. Some GTM partners recoup this cost through high commissions on offsets, while others require multi-year exclusivity to a project.

C6 scored partners based on the services they provided and our estimate of the costs they charge.

3) Pre-Selling
Some biochar projects have sold their carbon offsets prior to construction and used this capital to help fund construction. Since we believe this could be an important source of capital for our project, we worked closely with the various GTM partners to understand the pre-selling programs they offered. Based on those discussions, we learned that although GTM partners are involved in pre-selling, they act more as gatekeepers than facilitators. In the best case, a GTM partner will allow pre-selling but they won't necessarily help a project operator like C6 find a buyer who would pre-pay for offsets. Since we still believe that pre-selling is an important source of construction capital, we eliminated a GTM partner that didn't offer it.

4) Marketplace/Offset Buyer Networks
One of the biggest services that GTM partners offer is selling offsets to buyers - typically large corporations with carbon emission targets. We scored each GTM partner based on our estimate of their buyer portfolio.

5) MRV Platform
Once a biochar project is live, it must comply with a standard's MRV requirements which typically requires lots of data collection and reporting. GTM partners either build or offer external MRV platforms to support these tasks. We scored each GTM partner on what we believed was the strength of their MRV platform.

6) Account Management Support
Biochar project operators like C6 would need ongoing support from their GTM partner as it relates to things like project recertification, offset sales and the MRV platform, so a GTM partner's account management support is important. Since this is a difficult criteria to assess, we attempted to estimate

each GTM partner's account management support based on our interactions during the sales cycle.

At the end of our evaluation, there was one GTM partner that clearly scored better than the rest and would have been the partner we would have selected.

4. Conclusions and Remaining Gaps

In summary, the carbon markets for biochar offsets are very strong. Biochar offsets are widely considered one of the lowest risk, highest quality offsets on the market. As a result, biochar offset prices are much higher than other offset types, commonly sold at between $100-200/offset. Based on feedback from experts in the field, the market for biochar offsets using feedstock sourced from forest health treatments would be even more coveted because of the additional wildfire risk reduction impact. As such we believe carbon markets represent an important source of ongoing revenue (modeled at 20% of total) and even potentially a source of capital to fund construction of the plant.

Through our carbon market discovery, we have a much better understanding of how the ecosystem works and who we'd partner with. Based on that discovery, we are confident that our project would be certified and be able to generate a material number of offsets.

At the same time there are some challenges for C6 to unlock that potential. First, there are a lot of organizations like C6 looking to launch new biochar facilities, which makes it difficult to secure time and support from key partners in the carbon market (especially GTM partners). Related to that, GTM partners are prioritizing their efforts on organizations that have secured a majority of their capital and are looking to "top off" their funding with carbon offset capital. Finally, once a biochar producer has decided how it's going to move forward in the carbon markets and defined their operations enough to complete certification, there are long timelines related to certification and pre-selling. It can take 12+ months for the project to be certified. For a new project, it's common for due diligence associated with a pre-sell agreement to take 9-12 months. These long timelines don't necessarily preclude using offset funding for construction but they do mean new biochar producers like C6 would have to have a substantial amount of seed funding in place.

The other gap relates to our preliminary LCA, which will need to be updated to reflect potential changes associated with our feedstock strategy, plant design and launch customers. At this point, we don't anticipate major changes to the carbon sequestration potential per ton of biochar, but it's important to determine the impacts of the final system design. We expect this analysis would take approximately 2-3 months to complete.

Recommended Configurations

In order to unlock capital and achieve our mission at scale, we believe it is important to design a plant that will generate positive returns.

- In the near-term, as the market for bio-products develops, positive returns could take the form of a profitable, self-sustaining business model that a) requires less upfront capital and b) wouldn't need additional capital post-launch.
- In the longer-term, once markets for bio-products are more established, those positive returns would take the form of a positive project IRR that would attract private capital.

Because financial returns for various business models and plant configurations are so dynamic - resulting in different CAPEX, revenues, OPEX and risk - we evaluated 9 plant configuration combinations, which we introduced in the Plant section (Figure 32). Through this process, we gained valuable insights that informed the next iteration of the plant configuration we evaluated. We identified some "show stoppers," viable options and, most importantly, risks that we've not been able to mitigate at this point.

Recommended Configurations Objectives

1) Share 3 key learnings we gained from evaluating multiple plant configurations.
2) Explain how we evaluated each plant configuration and recommend 3 viable options to pursue.

1. 9 Plant Configurations

The plant configurations we considered in our analyses were described in depth in the Plant section, and are summarized in Figure 32.

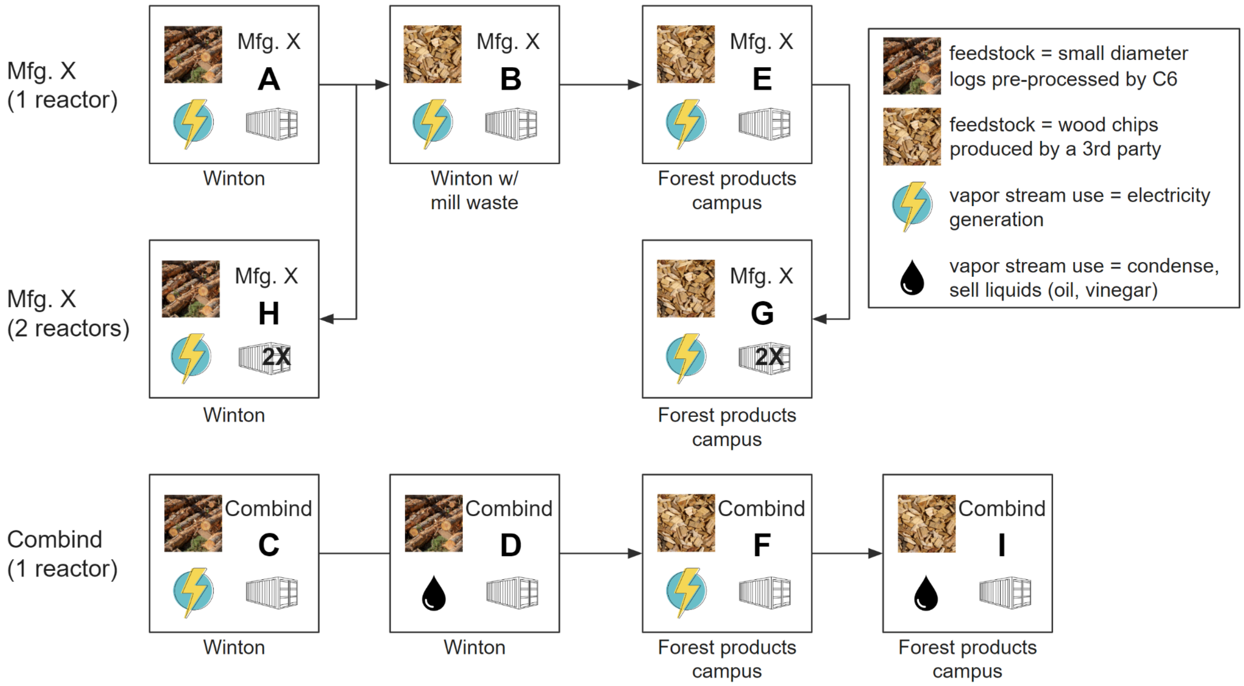


Figure 32: Plant configurations included in our detailed economic analyses.

1.1. Three Key Learnings

1.1.1. Key Learning #1: Pre-possessing Small Diameter Logs

Pre-processing small diameter logs into chips onsite is very capital intensive and drives incremental OPEX. At the pilot scale, when you amortize the pre-processing CAPEX across the life of the facility, the fully-burdened costs are too high to operate profitability.

Takeaway: The facility needs to be sited at a location where it can buy chips from another provider, either on a forest products campus or co-located near a mill or similar forest products producer.

1.1.2. Key Learning #2: Co-Product Outputs

If you assume the whole vapor stream (roughly 75-80% of total output), or its syngas content (roughly 44% of total output) are waste products and don't burden them with any of the plant's costs, then using them to generate electricity nets a marginally positive IRR. At the pilot scale, the lower risk returns from electricity generation could lead to profitable operations but not a positive IRR. In a region with low electricity rates, the upside associated with electricity generation is limited and could make it difficult to attract capital needed to scale operations. Alternatively, condensing the liquid in the vapor stream and separating it into its "bio-oil" and "wood vinegar" fractions, is a higher risk and potentially higher return approach.

Takeaway: Although electricity generation nets a positive IRR, the upside is limited and longer-term the facility needs to find higher value uses for the vapor stream.

1.1.3. Key Learning #3: Pilot Scale

In an effort to reduce required capital and give the operations an opportunity to mitigate risks, we suggest initially operating the facility with a single reactor (aka "pilot scale") before increasing the scale with an additional reactor(s). This approach has many advantages, but based on our financial projections, netting a positive IRR at initial pilot scale is unlikely due to underutilization of labor, fixed costs and CAPEX.

Takeaway: Initially operating the facility at pilot scale is the best path forward but the pilot should be designed with the assumption that a second reactor will be brought online.

1.2. Key Learning #1: Pre-possessing Small Diameter Logs

Figure 33 indicates a site layout for Winton that includes pre-processing small diameter logs onsite. In this configuration, logging trucks deliver small diameter logs to Space V where they are loaded onto log decks - similar to a saw mill. The logs are then brought to the pre-processing line at Space W where they are (from left to right in detailed diagram) fed onto a live deck, singulated, cut to length, debarked, chipped and loaded into a chip trailer. Full trailers are then moved to Space E1, where the chips are converted into biochar.

Although this approach ensures the facility uses mission-aligned feedstock and has fewer dependencies, pre-processing small diameter logs into chips onsite is very capital intensive and drives incremental OPEX. At the pilot scale, when you amortize the pre-processing capital across the life of the facility, the fully burdened costs are too high to operate profitability.

Pre-processing related CAPEX is estimated at $4.5M, roughly $4.0M more than an alternative approach of directly sourced chips. Below is a breakdown of pre-processing related CAPEX.

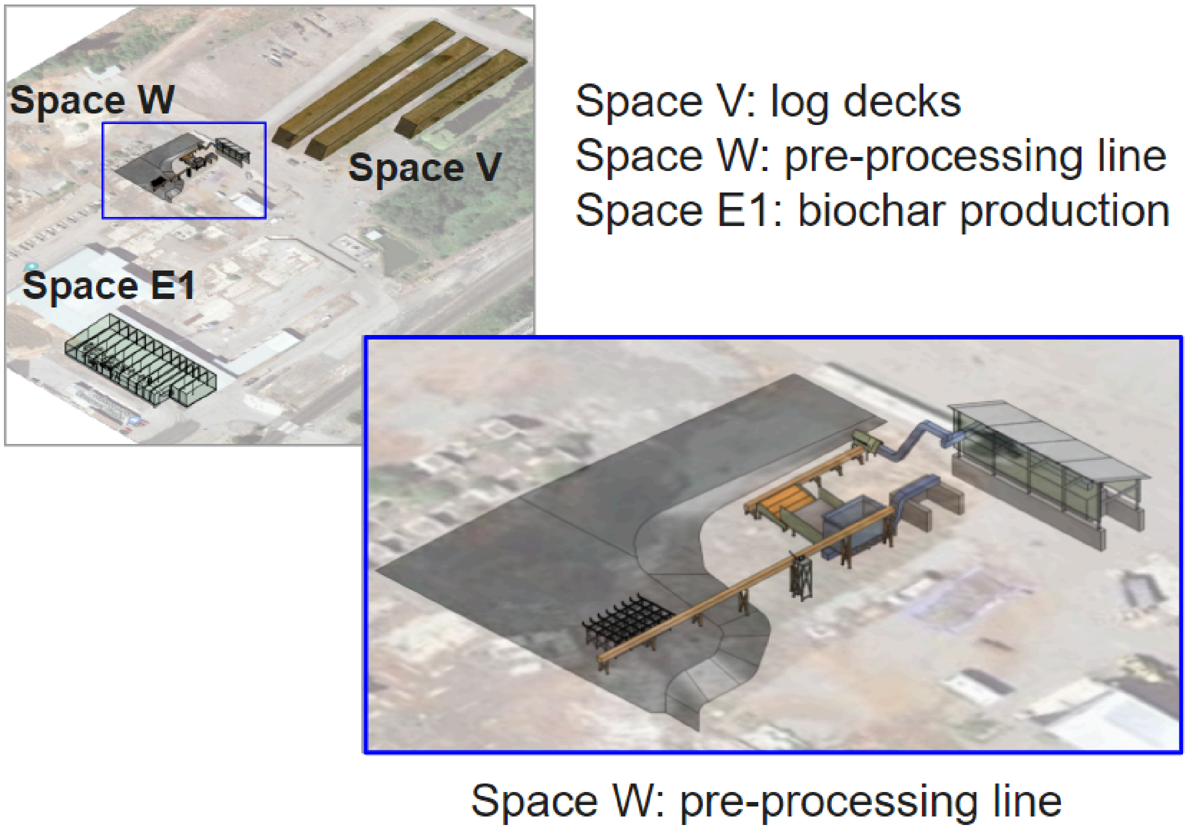


Figure 33: Primary potential elements of Winton pilot biochar facility.

Pre-Processing Equipment	Cost
Debarker	$ 880,000
Log Unloader	$ 540,000
Live Deck >> Debarker Conveyor	$ 486,000
Chip Trailer*	$ 360,000
Control Hardware	$ 325,000
Stem Feeder + Stop-N-Load	$ 246,750
Live deck	$ 184,800
Chipper	$ 177,450
Chipper Infeed Conveyor	$ 168,000
All Other	$ 1,168,705
Total	**$ 4,536,705**

* Staffing schedule assumes pre-processing chips on weekdays, so several chip trailers are required to ensure sufficient chips for weekend production.

Table 49: Pre-processing equipment cost breakdown.

Onsite pre-processing also drives incremental OPEX costs across 4 categories[14,15].

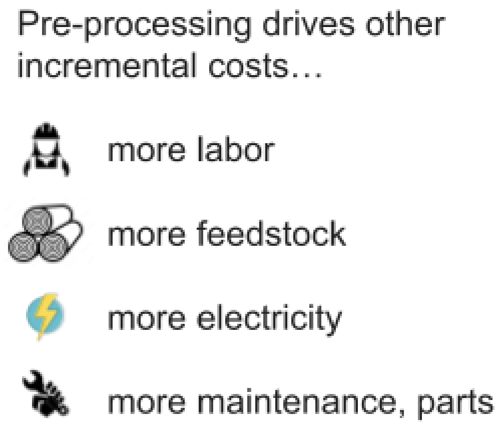


Figure 34: OPEX impacts of onsite pre-processing.

When you calculate the direct costs of onsite pre-processing on a per ton of biochar basis (at pilot scale), pre-processing costs $646 per ton of biochar. This pre-processing cost is almost equal to our assumed selling price of biochar, $650/ton of biochar. Although the pilot has other revenue streams, that doesn't leave much room for profitable operations at the pilot scale.

Cost Categories	Cost $ / Ton of Biochar
CAPEX (1)	$139
Labor	$55
Feedstock	$431
Other Variable	$6
Fixed costs	$16
Total Cost	$646
excl Feedstock	$215

* CAPEX related to pre-processing small diameter logs into wood chips and integrating wood chips into the biochar product line (Space E1).

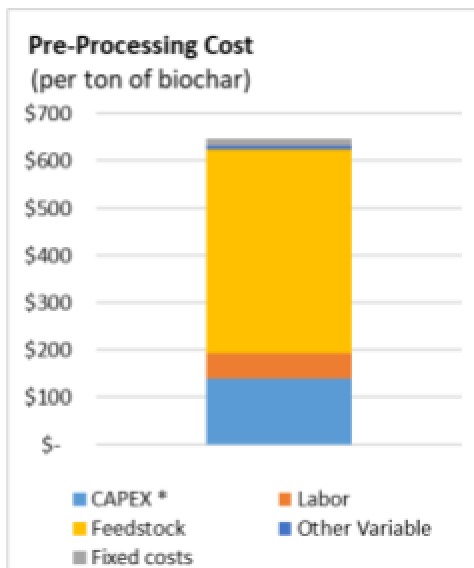


Figure 35: Pre-processing cost breakdown, evaluated per ton of biochar produced.

[14] 1 additional team member is required to support feedstock deliveries, and chipping operations.
[15] Roughly ~11% of the biomass from small diameter logs pre-processed onsite in essence becomes "waste" - mainly the bark which is removed, and some sawdust from cutting logs to length.

If you assume the pilot is successful and a second reactor is added, then the economics of onsite pre-processing improve considerably as you increase utilization of the equipment and labor. However, this approach carries a lot of risks and could be especially challenging if the pilot doesn't scale.

Because of the high capital requirements, the impact on OPEX and profitability, we evaluated a plant configuration where we would buy pre-processed chips from Hampton Lumber's Darrington mill. Although the Hampton Mill Waste configuration did result in lower CAPEX and reductions in labor, electricity and parts/maintenance costs, it never generated profits due to the a) the high cost of hauling chips from Darrington ($70/ton) and b) the high moisture content of westside feedstock, which drives higher drying loads and limits our ability to realize revenue from waste heat products.

After eliminating the approaches of onsite pre-processing and buying westside mill waste, we evaluated 4 plant configurations that assumed the facility was sited on an eastside forest products campus. In these scenarios, we assumed that the campus owner would own and operate all equipment needed to pre-process logs and C6 would buy wood chips from the campus operator at market prices similar to what Hampton charges for undelivered chips, $30/ton. We'll cover forest products campus plant configurations in more detail later but locating the pilot on such a campus dramatically reduces the cost of chips and aligns with profitable operations.

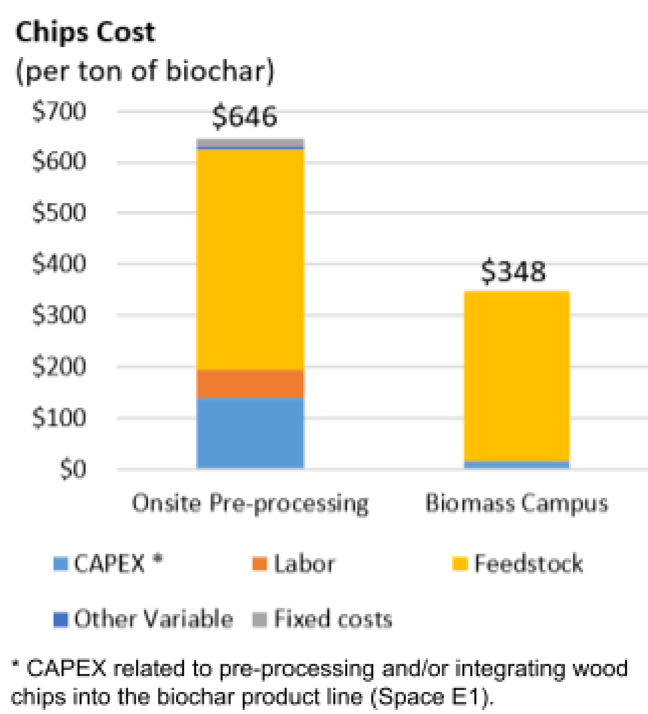


Figure 36: Wood chip cost comparison between C6 log pre-processing and a campus co-located chip supplier.

Based on our analysis of plant configurations with both onsite pre-processing and buying chips as part of a forest products campus, we believe the pilot facility needs to be sited on a campus or co-located near a mill or similar forest products producer.

1.3. Key Learning #2: Co-Products Outputs

As stated in the Products section, we expect slow pyrolysis of our feedstock to result in ~20-25% biochar and ~75-80% raw pyrolysis vapor. About 55% of that vapor, or 44% of the total output, would be a noncondensable syngas.

If you assume the raw vapor stream or syngas are waste products and don't burden them with any of the plant's costs (feedstock, labor, rest of plant CAPEX), then the $1.7M investment in electricity generation equipment breaks even in year 7 and nets a positive IRR over the 15-year life of the plant.

15 Year Returns ($ M's)
Mfg. X with 3 generators

Investment	($1.7)
OPEX	($0.03)
Revenues	$4.3
Net Cashflow	$2.6
IRR	14%

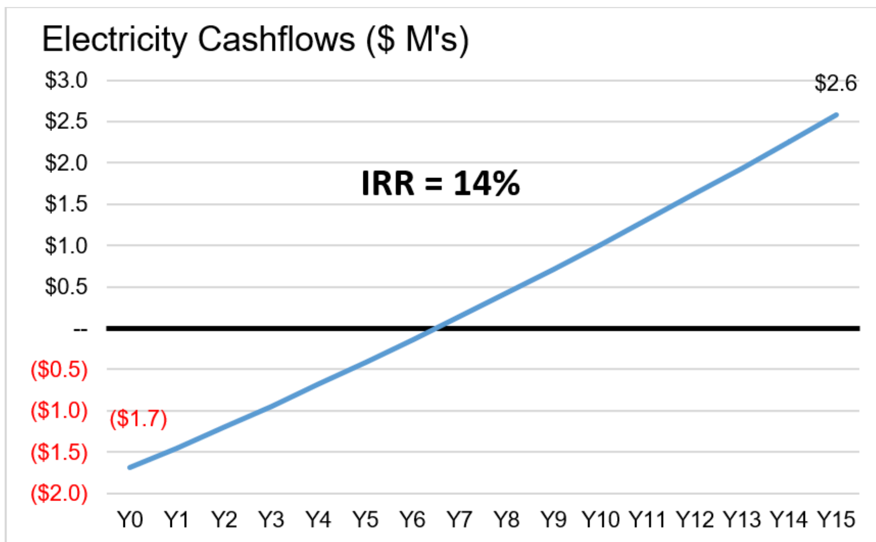


Figure 37: Electricity generation financial returns.

Unfortunately, the relatively modest unburdened returns from electricity generation aren't enough to make up for the losses in the rest of the pilot.

15 Year Pilot Returns ($ M's)
Mfg. X with 3 generators

	CAPEX + OPEX	Revenue	Net
rest of pilot	$ 41.2	$ 36.3	$ (4.9)
electricity	$ 1.7	$ 4.3	$ 2.6
total pilot	$ 42.9	$ 40.6	$ (2.3)

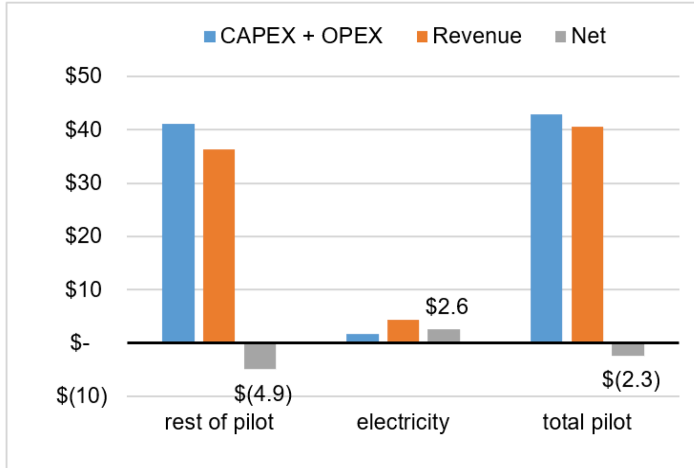


Figure 38: Illustration of electricity generations contribution to total pilot financial returns.

In summary, unburdened electricity generation nets a positive return. However, based on the financial returns for the rest of the plant, it's difficult to achieve a positive IRR when 79% of output (on a mass basis) yields 11% of revenues. Therefore it is critical to develop higher value uses of the vapor stream to ensure positive returns.

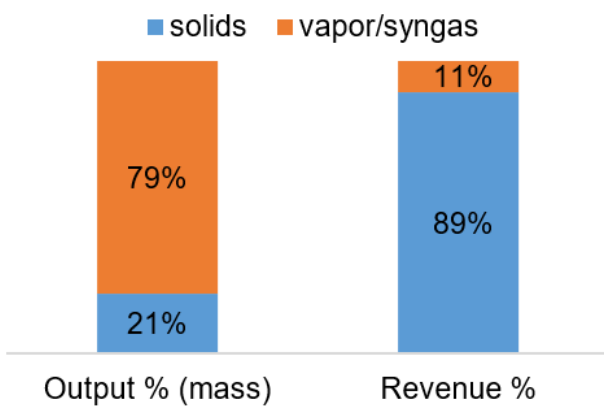


Figure 39: Illustration of discrepancy between mass output % and revenue % with electricity generation.

Capturing the bioliquid from the vapor stream and separating it into its 2 primary "bio-oil" and "wood vinegar" fractions, is a higher risk and potentially higher return approach. Due to differences in liquids capture technology offered by the reactor manufacturers, the Combind reactor allows for condensing essentially all the liquids in the vapor stream, but Mfg. X's reactor does not. We evaluated 2 bioliquids capture configurations based on the Combind reactor.

Both the bio-oil and the wood vinegar have emerging commercial applications that will likely mature considerably in the coming years, but are nascent at this time. In the near-term, we believe we can establish an offtake agreement for the bio-oils to a well funded, carbon-sequestration focused company - albeit on a lower risk, lower return basis. Based on initial research there seems to be more potential upside for the wood vinegar as an organic pesticide, herbicide and foliar enhancer.

We'll cover the potential financial returns associated with condensing the liquids in more detail in the financial projections section but unlocking value for the vapor stream is critical for generating positive financial returns in a low-cost electricity region like central Washington.

1.4. Key Learning #3: Pilot Scale

In an effort to reduce required capital and give the operations an opportunity to mitigate risks, we suggest initially operating the facility with a single reactor (aka "pilot scale") before increasing the scale with an additional reactor(s). This approach has many advantages but based on our financial projections it is unlikely to net a positive IRR at pilot scale due to a lack of leverage on labor, fixed costs and CAPEX.

The following comparison of a scaled versus a pilot plant highlights the financial advantages of adding a second reactor. In these projections we assume the plant is located at a forest products campus, generates electricity and uses a 5X pyrolysis reactor from Mfg. X. In the scaled plant, we assume a second reactor is bought in year 3 and operational in year 4.

15 Year Financial Projections

Returns	Scaled	Pilot	Var		
Project IRR	8.6%	0.0%	8.6%		1

Capital	Scaled	Pilot	Var	Var %	
Phase 1	$10.0	$9.9	$0.1		
Phase 2	$5.5	$0.0	$5.5		
Total Capital	$15.5	$9.9	$5.6	57%	2

Income Statement	Scaled	Pilot	Var	Var %	
Biochar	$45.2	$24.1	$21.1	88%	
Electricity	$7.8	$4.3	$3.6	83%	
Carbon Offset	$22.3	$12.2	$10.2	83%	
Revenue	$75.4	$40.6	$34.8	86%	3
Labor	$12.0	$12.0	$0.0	0%	
Feedstock	$21.7	$11.8	$9.9	84%	
Other Variable	$0.8	$0.5	$0.2	44%	4
Variable Costs	$34.5	$24.4	$10.1	41%	
Fixed costs	$9.6	$8.6	$1.0	12%	
Total Costs	$44.1	$33.0	$11.1	34%	
Net Income	$29.7	$6.2	$23.6	382%	5

Metrics	Scaled	Pilot	Var	Var %	
Labor	16%	30%	(14%)	(46%)	
Feedstock	29%	29%	(0%)	(1%)	6
Other Variable	1%	1%	(0%)	(23%)	
Fixed	13%	21%	(8%)	(40%)	
OPEX (% of Revenue)	**59%**	**81%**	**(23%)**	**(28%)**	

Table 50: Comparison of long-term returns between single-reactor and multi-reactor scenarios.

Some key highlights of the scaled plant are:

1) The additional returns driven by the addition of a 2nd reactor net a positive project IRR of 8.6%
2) The additional reactor and electricity generation equipment do require $5.6M in additional capital but this is only a 57% increase as some of the pilot plant's CAPEX can be leveraged for the additional reactor.
3) By adding a second reactor in year 4, revenues increase by 86%.
4) The addition of a second reactor allows operations to leverage some of its costs - specifically labor, other variable costs and fixed costs. It is worth noting

that due to the level of automation designed into the plant operations, we project that no additional labor would be needed to operate a second reactor. Other variable costs and fixed costs would increase but only marginally.

5) Due to the increased revenues and cost leverage, the additional reactor drives a nearly 4X increase in net income.
6) Looking at OPEX as a % of revenue highlights the leverage achieved by adding a second reactor. With a second reactor, labor costs decline from 30% to 16%, fixed costs decline from 21% to 13%, and total costs decline from 81% to 59%.

We still believe that launching the facility at pilot scale is important to mitigate key risks but as the financial projections illustrate, scaling the plant is critical to achieve financial returns that will attract the capital needed to accomplish our mission.

2. Recommended Plant Configurations

As discussed in the previous sections, we learned a lot about the financial returns of several different plant configurations. We also assessed how closely each plant configuration aligned to our mission and how well it mitigates key risks.

For mission alignment, we evaluated the configurations against each element of our organizational vision statement:

- Healthy, fire-resilient forests
- Reduced smoke from wildfires and slash burning
- Long-term carbon sequestration
- Healthy, productive soils
- Family wage jobs and clean, sustainable rural economic development
- Creating economic value from forest biomass previously considered waste

For high-level risk assessment, we evaluated the configurations against the top 6 high-level risks we've identified for this venture, all of which impact revenue potential, profitability and long-term returns. They include:

- If sufficient feedstock is not available, then the facility will not be able to run at full utilization.
- If $40/ton is not sufficient to drive feedstock deliveries to the plant, then our feedstock costs will increase.
- If our plant doesn't perform at the uptime and utilization rate we anticipate, then our revenues will decrease and costs will likely increase to address issues.
- If we cannot hire sufficient high-quality staff to operate the facility, then our utilization will decrease.
- If we cannot sell biochar for at least $650/ton, then we won't realize the necessary revenues.
- If we cannot earn sufficient revenues from the vapor stream, then the economic resilience of the business will decrease if other costs or revenue assumptions are

significantly impacted (e.g., increased feedstock costs and labor rates, decreased biochar and carbon offset revenues).

2.1. Plant Configurations Assessment

Based on our assessment of the 9 plant configurations against the criteria outlined above, we recommend focusing on three configurations: E, G, and I.

	Config A	Config B	Config C	Config D	Config E	Config F	Config G	Config H	Config I
Feedstock	Small Diameter Logs	Mill Waste	Small Diameter Logs	Small Diameter Logs	Wood Chips	Wood Chips	Wood Chips	Small Diameter Logs	Wood Chips
Reactor Manfuncturer	Mfg. X	Mfg. X	Combind	Combind	Mfg. X	Combind	Mfg. X	Mfg. X	Combind
Reactor Count	1	1	1	1	1	1	2	2	1
Vapor Stream Use	Electricity	Electricity	Electricity	Liquid	Electricity	Electricity	Electricity	Electricity	Liquid
1.Mission Alignment	🟢 6/6	🟠 4/6	🟢 6/6	🟢 6/6	🟢 6/6	🟢 6/6	🟢 6/6	🟢 6/6	🟢 6/6
2.Risks Mitigated	🟠 1/6	🟢 3/6	🟠 1/6	🔴 0/6	🟢 3/6	🟢 3/6	🟢 3/6	🟠 1/6	🟠 2/6
3.Financial Projections	🔴 0/3	🟠 1/3	🔴 0/3	🟢 2/3	🟢 2/3	🟠 1/3	🟢 2/3	🟠 1/3	🟢 3/3
Overall					🟢		🟢		🟢

Feedstock Definitions:
Small Diameter Logs = onsite pre-processing of small diameter logs
Mill Waste = buying wood chips from Hampton Lumber's Darrington mill
Wood Chips = buying wood chips as a tenant of a forest products campus

Table 51: Comparison of evaluated plant configurations.

2.2. Recommended Plant Configurations E, G and I

We'll cover these three recommended plant configurations in more detail below but Configuration E and G are the same except that E has 1 reactor and G has 2 reactors. So Configuration E can be thought of as the Pilot and Configuration G can be thought of as the partially or fully scaled plant.

Mfg. X doesn't support condensing the vapor stream into a liquid fraction, so electricity generation is the only viable usage of the vapor stream. The Combind reactor supports both electricity generation and condensing the liquid in the vapor fraction.

Parameter	Config. E	Config. G	Config. I
Location	Forest Products Campus	Forest Products Campus	Forest Products Campus
Feedstock	Wood Chips	Wood Chips	Wood Chips
Vapor Stream Use	Generate Electricity	Generate Electricity	Condense Liquid
Reactor Manufacturer	Mfg. X	Mfg. X	Combind
Reactor Count	1 (yr 1-15)	1 (yr 1- 3),2 (yr 4- 15)	1 (yr 1-15)

Table 52: Summary of Configurations E, G and I.

2.3. Mission Alignment

Based on our assessment, all three of the recommended plant configurations aligned with our mission. A key assumption in this assessment is that the forest products campus would source feedstock from forest health treatments. If the pilot was co-located with a mill then our assessments of 1) healthy, fire-resilient forests and 6) creating economic value from forest biomass might change depending on the mill's feedstock strategy.

		Config E	Config G	Config I
	Feedstock	Wood Chips	Wood Chips	Wood Chips
	Reactor Manfucturer	Mfg. X	Mfg. X	Combind
	Reactor Count	1	2	1
	Vapor Stream Use	Electricity	Electricity	Liquid
	1.Mission Alignment			
1	Healthy, fire-resilient forests	●	●	●
2	Reduced smoke from wildfires and slash burning	●	●	●
3	Long-term carbon sequestration	●	●	●
4	Healthy, productive soils	●	●	●
5	Family wage jobs, rural economic development	●	●	●
6	Creating economic value from waste forest biomass	●	●	●
		● 6/6	● 6/6	● 6/6

Table 53: Mission alignment assessment of configurations.

2.4. Risk Mitigation

For our assessment, we assumed risks 1 and 2, the risk of being able to source enough feedstock at costs that support profitable operations, would be reduced by the fact that we were located on a forest products campus. This is due to the assumption that such a campus would have strong local government and private sector support and would leverage enough biomass to get more support from forest landowners and logging operators - especially compared to a standalone operation at Winton.

Based on our assessment, none of the three of the recommended plant configurations mitigated risks 3, 4, 5. Risks 3 and 4 are difficult to mitigate through a given plant configuration, and more generally pre-operations. Risk 5 could be partially mitigated by doing extensive customer discovery and trials pre-operations. However it's difficult to get strong customer engagement and to run accurate trials before initiating operations. By capturing the liquids instead of generating electricity, Configuration I is the most risky of the 3 configurations.

		Config E	Config G	Config I
	Feedstock	Wood Chips	Wood Chips	Wood Chips
	Reactor Manfucturer	Mfg. X	Mfg. X	Combind
	Reactor Count	1	2	1
	Vapor Stream Use	Electricity	Electricity	Liquid
	2.Risks Mitigated			
1	Enough local feedstock (USFS, wildfires, etc)?	🟢	🟢	🟢
2	$40/ton enough to get loggers to deliver feedstock?	🟢	🟢	🟢
3	Will our plant produce large volumes, high quality?	🔴	🔴	🔴
4	Will we hire a high quality crew to run the plant?	🔴	🔴	🔴
5	Will we be able to sell biochar for ~$650/ ton?	🔴	🔴	🔴
6	Will we earn revenues from the liquid faction?	🟢	🟢	🔴
		🟢 3/6	🟢 3/6	🟡 2/6

Table 54: Risk mitigation assessment of configurations.

2.5. Financial Returns

We'll cover financial performance in more detail in a subsequent section. For our assessment, we considered a plant configuration to have a low capital requirement if the CAPEX was less than $10.5M for 1 reactor. It is worth noting CAPEX for Configuration G is $15M but that is for 2 reactors, and the incremental CAPEX for the second reactor is $5M which would be done 3 years after launch.

Configuration G is profitable and self-sustaining but the project 15 year profits of $6.2M are less than the initial investment of $9.9M so it doesn't have a positive IRR.

		Config E	Config G	Config I
	Feedstock	Wood Chips	Wood Chips	Wood Chips
	Reactor Manfucturer	Mfg. X	Mfg. X	Combind
	Reactor Count	1	2	1
	Vapor Stream Use	Electricity	Electricity	Liquid
	3.Financial Projections			
1	Low capital requirement	🟢	🟢	🟢
2	Profitable, self-sustaining operations	🟢	🟢	🟢
3	Positive IRR	🔴	🟢	🟢
		🟢 2/3	🟢 3/3	🟢 3/3

Table 55: Financial returns assessment of configurations.

3. Conclusions and Remaining Gaps

In summary, there are multiple variables to consider when configuring a biochar plant. For our analysis we considered four important variables:

1) how will we acquire wood chips for biochar production,
2) which pyrolysis reactor to use for biochar production,
3) how many reactors to include in the plant,
4) how to create value from the vapor stream.

Since these variables have multiple impacts, it was important to model each plant configuration so that we could understand how each aligned with our mission, mitigated risks, and the resulting financial returns.

Based on our analysis of nine plant configurations, we identified 3 key learnings.

1) Due to the high costs of pre-processing small diameter logs into wood chips, the facility is best sited at a location where it can buy chips from another provider, either on a forest products campus or co-located near a mill or similar forest products producer.
2) Using surplus heat from the raw pyrolysis vapor (~75-80 wt%) streams to generate electricity delivers a low risk, marginally positive return. However those returns are limited and aren't likely enough to generate the positive IRR needed to attract capital to accomplish our mission at a larger scale. The facility needs to find higher value uses for the vapor stream.
3) Initially operating the facility at pilot scale is the best path forward to manage launch risk, but the pilot is unlikely to generate the positive IRR needed to attract capital to accomplish our mission at a larger scale. The pilot should be designed with the assumption that at least one additional reactor will be brought online.

Based on our assessment, all nine plant configurations we analyzed aligned with our mission but some did a better job mitigating risks. More specifically, plants sited at a forest products campus could reduce two feedstock related risks associated with sourcing enough feedstock at costs that support profitable operations. This is based on our assumption that such a campus would have strong local government and private sector commitment, and would drive enough demand for biomass to incentivize forest landowners and logging operators to accelerate forest health treatments.

A number of plant configuration related gaps remain. First, although Chelan County is working toward making their vision of a forest products campus a reality, at this point we had to make some assumptions about how it might work once launched. For our analysis, we assumed the campus operator would take the lead on sourcing biomass, pre-processing and selling wood chips to campus tenants for $30/ton. In reality that might not be how the campus operates.

Another critical plant configuration related gap relates to commercial applications of wood vinegar. Based on published research and studies from one commercial producer (Corigin), wood vinegar has considerable potential when used as an organic pesticide and herbicide, as well as a foliar enhancer to increase plant yields. It is difficult to know if wood vinegar will establish itself as an agricultural product but the upside on the plant's financial returns are material given the current price of Corigin's wood vinegar product (~$4,800/ton) and based on the fact that nearly one-third of our plant's output could be wood vinegar. This unknown impacts which reactor we would select, as the Combind reactor allows us to condense liquids but the Mfg. X reactor essentially doesn't. It also impacts whether we'd generate electricity or condense the liquids.

Project Financial Projections

In order to unlock capital and achieve our mission at scale, we believe it is important to design a plant that will generate positive financial returns. In order to understand those returns we projected financial results for all 9 plant configurations. And after selecting three configurations to focus on, we did additional analysis to understand the opportunities and tradeoffs associated with each.

Financial Projections Objectives

1) Introduce the facility's financial statements and terminology.
2) Review and compare the "base case" financial projections of the 3 recommended plant configurations.
3) Clearly communicate the key assumptions used in our financial projections and highlight the assumptions with the biggest risks.
4) Summarize the potential upside and downside risk associated with the 3 recommended plant configurations based on various sensitivity analyses.
5) Review the sources of capital that we explored for plant funding.

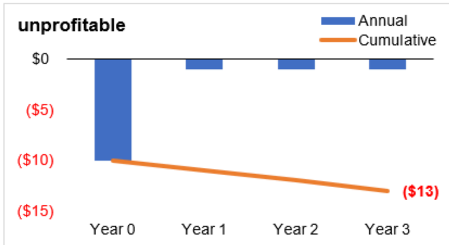
1. Financial Statements and Terminology

1.1. Financial Statements

Our financial projections include all 3 standard financial statements: income statement, balance sheet & statement of cash flows. For the remainder of this section we'll focus primarily on the income statement & statement of cash flows because they are most helpful as far as understanding the financial returns of the various plant configurations. As far as the balance sheet, we don't refer to it because our asset & liability assumptions are simplified: a) we assumed all plant equipment are fully depreciated at the end of the 15 year plant, b) we assumed the plant was leased, not property value, c) we didn't assume any debt, so there is no repayment schedule to track.

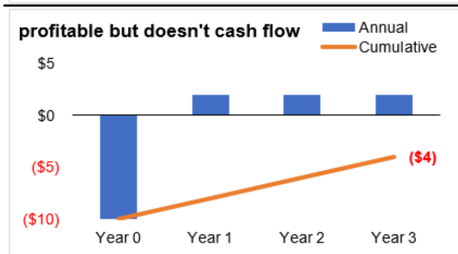
1.2. Project Cash Flow Categories

Based on the project's cash flows, we'll refer to project returns in one of 4 categories: 1) unprofitable, 2) profitable but doesn't cash flow, 3) positive cash flow, and 4) exceeds hurdle rate. The only difference between 3) positive cash flow and 4) exceeds hurdle rate would be a minimum return the project sponsor requires. In the below examples, the hurdle is an IRR higher than 20% but that would vary based on the project, project sponsor.



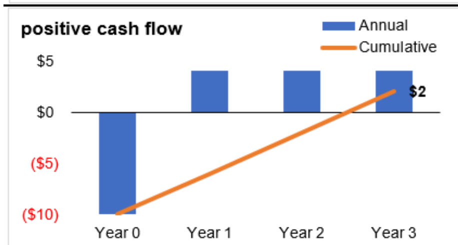
	Year 0	Year 1	Year 2	Year 3
Annual Cash Flow	($10)	($1)	($1)	($1)
Cumulative Cash Flow				($13)

IRR Actual	--
IRR Hurdle	20%



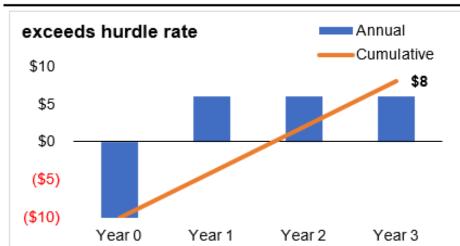
	Year 0	Year 1	Year 2	Year 3
Annual Cash Flow	($10)	$2	$2	$2
Cumulative Cash Flow				($4)

IRR Actual	-22%
IRR Hurdle	20%



	Year 0	Year 1	Year 2	Year 3
Annual Cash Flow	($10)	$4	$4	$4
Cumulative Cash Flow				$2

IRR Actual	10%
IRR Hurdle	20%



	Year 0	Year 1	Year 2	Year 3
Annual Cash Flow	($10)	$6	$6	$6
Cumulative Cash Flow				$8

IRR Actual	36%
IRR Hurdle	20%

Figure 40: projects categorization based on financial returns

2. Base Case Financial Projections for 3 Recommended Configurations

2.1. Recommended Plant Configurations

We recommend considering three plant configurations E, G, and I based on our assessment of their a) alignment with our mission, b) risk mitigation and c) financial performance. Lower risk, electricity generating plant configurations E and G are the same, except configuration G includes a second reactor added in year 4. Plant configuration I, which captures bioliquids instead of generating electricity, is a higher risk approach.

Parameter	Config. E	Config. G	Config. I
Location	Forest Products Campus	Forest Products Campus	Forest Products Campus
Feedstock	Wood Chips	Wood Chips	Wood Chips
Vapor Stream Use	Generate Electricity	Generate Electricity	Condense Liquid
Reactor Manufacturer	Mfg. X	Mfg. X	Combind
Reactor Count	1 (yr 1-15)	1 (yr 1- 3),2 (yr 4- 15)	1 (yr 1-15)
Biochar Output	2,400 tons/yr	4,800 tons/yr	1,675 tons/yr
Fuel Acres Removed[16]	1,000/yr	2,000/yr	725/yr

Table 56: Summary of Configurations E, G and I.

2.2. Plant Configurations Cash Flows

The financial projections of all three configurations will be covered in more detail but below is a summary of each. All three configurations share 2 common assumptions that impact cash flows (labeled 1 and 2 on chart in Figure 41).

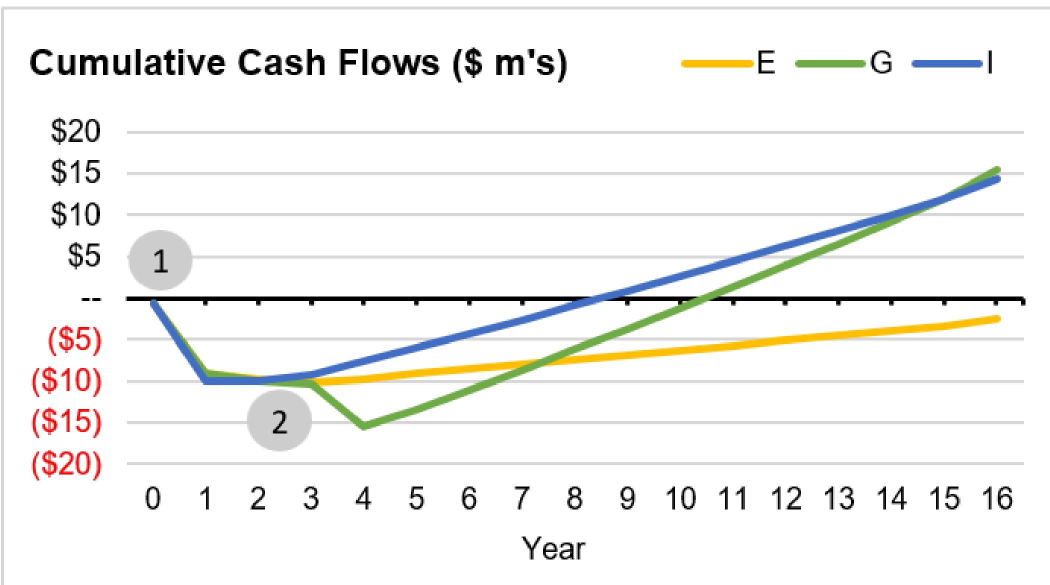


Figure 41: Summary of Configurations E, G and I financial projections.

1) In year 0 (year prior to construction) and year 1 (year of construction), all three configurations have $1.3M in CAPEX related to additional planning, engineering and construction management.
   a) $340k for additional product development and system engineering,

[16] Fuel Acres Removed = acres of forest health treatment's biomass that would be removed for feedstock. Assumes 20 tons/acre.

b) $510k for electrical and system controls engineering,
c) $430k for an engineer and project manager to oversee construction.

2) In year 2 (1st year of operations) and year 3 (2nd year of operations), all three scenarios have either negative or marginally positive net income. The two main drivers are:
   a) in the first year of operations, the facility will operate at reduced capacity as the crew commissions the plant, and develops standard operating procedures,
   b) we plan to provide large qualities of biochar to customers for trials at no charge.

Operating Year	Operating Capacity	Free Biochar for Trials
1	75%	66%
2	100%	33%
3	100%	5%

Table 57: Operating capacity and trial biochar allocation over the first 3 years of operation.

2.2.1. Plant Configuration E - Overall Summary

Capital ($ m's)	Phase 1	Phase 2	Total
Construction	$1.6		$1.6
Plant Equipment	$6.9		$6.9
Total CAPEX	**$8.6**		**$8.6**
Launch Ops Losses	$1.3		$1.3
Total Capital	**$9.9**		**$9.9**
Revenues			$40.6
OPEX & Taxes			$34.4
Net Income			$6.2
Cummulative Cash Flows			($2.4)
IRR			**0.0%**

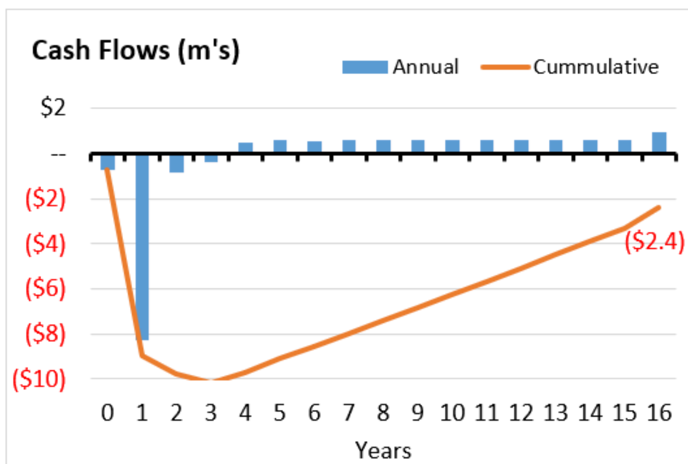


Figure 42: Configuration E financial summary.

Configuration E is a single reactor (Mfg. X) plant that generates 2,400 tons of biochar per year. It is profitable but doesn't cash flow.

Configuration E requires $9.9M in capital - $8.6M for CAPEX and $1.3M to cover operating losses during the launch. Over its 15-year life, Configuration E will generate $40.6M of revenues and $34.4M of OPEX and taxes, resulting in a $6.2M in Net Income but will have ($2.4M) in cumulative cash flow.

After initial operating losses the plant will be a profitable, self-sustaining operation. However the low biochar production levels (2,400 tons per year) result in low utilization of labor and fixed costs, and a narrow profit margin (~15%). As a result this configuration isn't projected to recoup its initial investment.

Since Configuration E can be viewed as the first phase of a larger plant, for example Configuration G, it wouldn't ideally operate as a single reactor scale for 15 years. However, if it does remain a single reactor plant, it is encouraging to know it's projected to be self-sufficient and require no additional capital.

2.2.2. Plant Configuration E - Launch Capital Summary

Capital ($ m's)	Phase 1	Phase 2	Total
Planning	$0.3		$0.3
3rd Party Engineer	$0.5		$0.5
Construction Mgmt	$0.4		$0.4
Site Dev	$0.4		$0.4
Reactor	$2.1		$2.1
Other Equip	$4.9		$4.9
Total CAPEX	**$8.6**		**$8.6**
Ops Loss	$1.3		$1.3
Total Capital	**$9.9**		**$9.9**

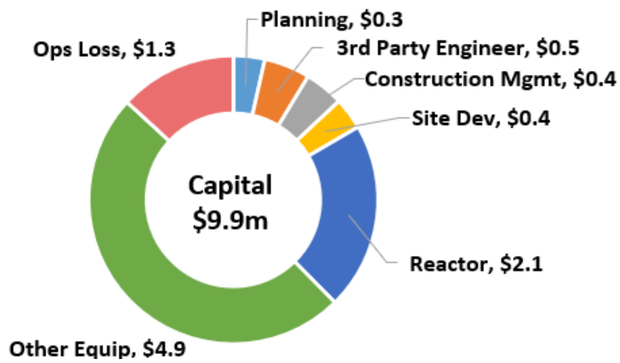
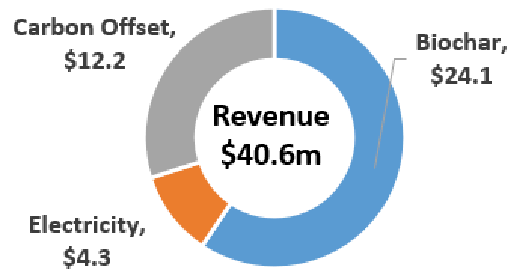


Figure 43: Configuration E launch capital summary.

Plant equipment costs $7.0M, including $2.1M for the reactor and $4.9M for all other equipment. There are a number of pieces of equipment in the "Other Equip" category, but the more expensive items include: a) $1.5M electricity generation equipment, b) $750k for a pre-dryer, and c) $600k for a comminution and screening module. In addition to the $8.6M in CAPEX, $1.3M in capital is required to cover operating losses incurred during the year 1 and 2 of operations.

2.2.3. Plant Configuration E - Revenue, Cost Summary

Revenues ($ m's)	Total	% Total
Biochar	$24.1	59%
Bio-oils		
Wood Vinegar		
Electricity	$4.3	11%
Carbon Offset	$12.2	30%
Total	**$40.6**	**100%**



Costs ($ m's)	Total	% Rev
Labor	$12.0	30%
Feedstock	$11.8	29%
Other Variable	$0.5	1%
Fixed costs	$8.6	21%
Total costs	**$33.0**	**81%**
Taxes	$1.4	4%
Net Income	**$6.2**	**15%**

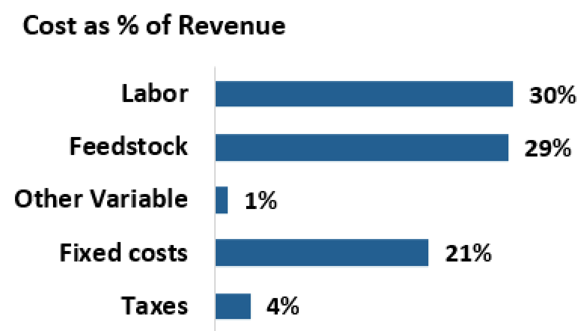


Figure 44: Configuration E revenue and cost summary.

In plant configuration E, the 3 revenue streams generate $40.6M in revenue over the 15-year life of the plant. Biochar, priced at $650/ton, is the largest revenue stream, generating $24.1M or 59% of total. Carbon offsets, priced at $150/metric ton, is the second, generating $12.2M, or 30%. Electricity generation, priced at $50/MW-hr, accounts for $4.3M or 11%.

Costs (including taxes) are $34.4M or 85% of revenue. Plant labor and feedstock are the biggest expense categories, each at roughly 30% of revenue. Fixed costs include rent (based on Winton lease negotiations), a general manager to run the plant, and repairs and maintenance.

2.2.4. Plant Configuration G - Overall Summary

Capital ($ m's)	Phase 1	Phase 2	Total
Construction	$1.7		$1.7
Plant Equipment	$6.9	$5.5	$12.5
Total CAPEX	**$8.7**	**$5.5**	**$14.2**
Launch Ops Losses	$1.3		$1.3
Total Capital	**$10.0**	**$5.5**	**$15.5**
Revenues			$75.4
OPEX & Taxes			$45.7
Net Income			**$29.7**
Cummulative Cash Flows			$15.5
IRR			**8.6%**

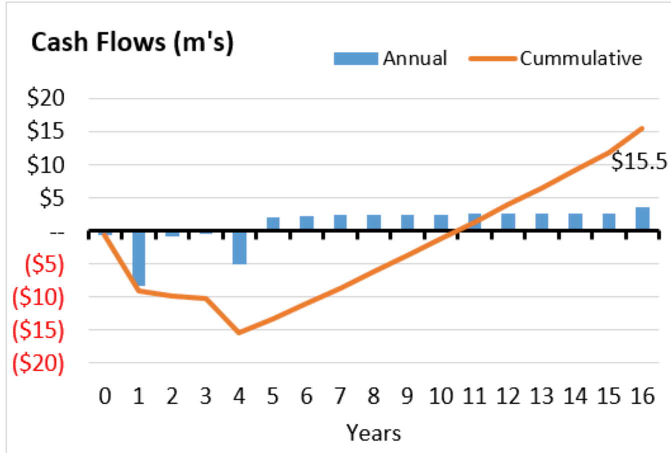


Figure 45: Configuration G financial summary.

Configuration G is a two reactor (Mfg. X) plant. It will generate 4,800 tons of biochar per year starting in operating year 4. It is projected to generate positive cash flows and its positive returns (IRR 8.6%) could potentially exceed a project sponsor's hurdle rate.

Configuration G requires $15.5M in capital over 2 phases. The configuration's initial single reactor phase, requires $10M in capital and is very similar to Configuration E. The configuration's second phase, which doubles its capacity by adding a second reactor, requires an additional $5.5M in capital in year 4.

Due to its increased capacity, Configuration G will generate $75.5M of revenues and $45.7M of OPEX and taxes, resulting in a $29.7M in Net Income, which results in $15.5M in cumulative cash flows.

The increased biochar production (4,800 tons per year) can be achieved with the same sized crew, so there is much higher utilization of labor and fixed costs, and healthier profit margin of 39%. As a result, this configuration is projected to recoup its initial investment and net a positive IRR.

2.2.5. Plant Configuration G - Launch Capital Summary

Capital ($ m's)	Phase 1	Phase 2	Total
Planning	$0.3		$0.3
3rd Party Engineer	$0.5		$0.5
Construction Mgmt	$0.4		$0.4
Site Dev	$0.5		$0.5
Reactor	$2.1	$2.1	$4.2
Other Equip	$4.9	$3.5	$8.3
Total CAPEX	**$8.7**	**$5.5**	**$14.2**
Ops Loss	$1.3		$1.3
Total Capital	**$10.0**	**$5.5**	**$15.5**

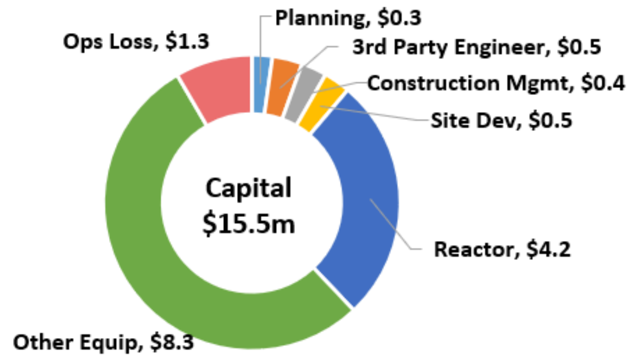
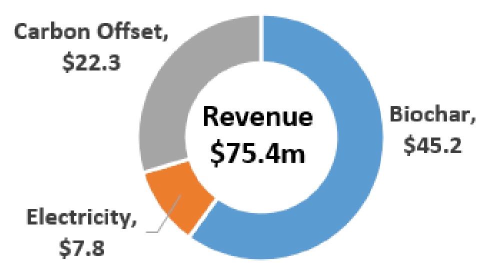


Figure 46: Configuration G launch capital summary.

Phase 1 plant equipment costs $7.0M, including $2.1M for the reactor and $4.9M for all other equipment. In Phase 2, the plant's capacity is doubled by adding a second reactor. The additional reactor costs $2.1M. Additional investments need to be made to the plant to support the increased capacity including an additional dryer ($750k), surge bins, conveyance, and second set of electricity generators ($1.7M). Similar to Configuration E, $1.3M in capital is required to cover operating losses incurred during the year 1 and 2 of operations.

2.2.6. Plant Configuration G - Revenue, Cost Summary

Revenues ($ m's)	Total	% Total
Biochar	$45.2	60%
Bio-oils		
Wood Vinegar		
Electricity	$7.8	10%
Carbon Offset	$22.3	30%
Total	**$75.4**	**100%**



Costs ($ m's)	Total	% Rev
Labor	$12.0	16%
Feedstock	$21.7	29%
Other Variable	$0.8	1%
Fixed costs	$9.6	13%
Total costs	**$44.1**	**59%**
Taxes	$1.5	2%
Net Income	**$29.7**	**39%**

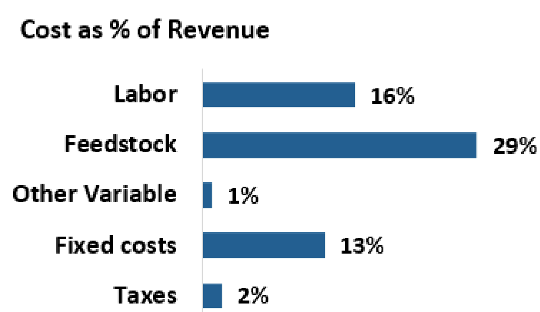


Figure 47: Configuration G revenue and cost summary.

In plant configuration G, the 3 revenue streams generate $75.4M in revenue over the 15-year life of the plant which is an 86% increase over configuration E. The splits between the revenue streams remains the same as configuration E.

Costs (including taxes) are $45.7M, or 61% of revenue. Feedstock costs increase in line with production growth but labor is unchanged (vs. configuration E) and fixed cost increases by only $1.0M (vs. configuration E). The higher labor utilization and increased fixed cost leverage dramatically reduces costs measured as a % of revenue and increases the profit margin to 39%. As we show later, the improved profit margin also provides a buffer in case biochar prices fall in the future.

2.2.7. Plant Configuration I - Overall Summary

Capital ($ m's)	Phase 1	Phase 2	Total
Construction	$1.7		$1.7
Plant Equipment	$7.8		$7.8
Total CAPEX	**$9.5**		**$9.5**
Launch Ops Losses	$0.5		$0.5
Total Capital	**$10.0**		**$10.0**
Revenues			$55.5
OPEX & Taxes			$31.7
Net Income			**$23.9**
Cummulative Cash Flows			$14.4
IRR			**11.2%**

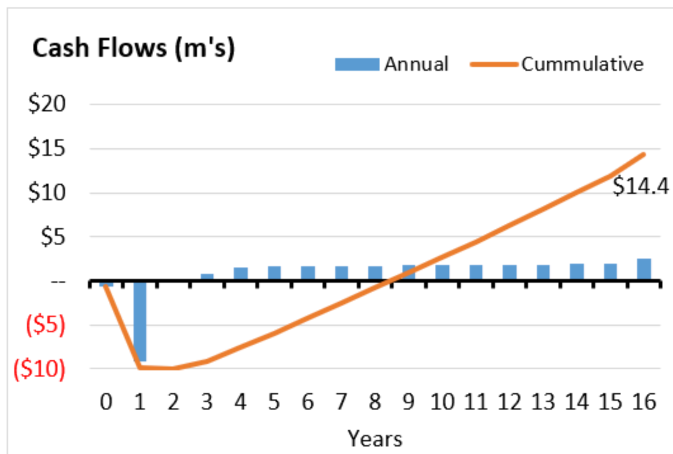


Figure 48: Configuration I financial summary.

Configuration I is a single reactor (Combind) plant. The Combind reactor has a lower capacity than the Mfg. X reactor, and can produce 1,675 tons of biochar per year. However, the Combind reactor supports can capture liquids from the vapor stream, and we estimate it can produce 2,800 tons of wood vinegar and 595 tons of bio-oil per year. We'll cover the risks associated with wood vinegar in more detail in a later section, but configuration I is higher-risk compared to configuration E & G (electricity generation) due to its dependence on wood vinegar revenues. Configuration I is projected to generate positive cash flows and its positive returns (IRR 11.2%) could potentially exceed a project sponsor's hurdle rate.

Configuration I requires $10M in capital - $9.5M for CAPEX and $0.5M to cover operating losses during the launch. Over its 15-year life, Configuration I will generate $55.5M of revenues and $31.7M of OPEX and taxes, resulting in $23.9M in Net Income and $14.4M in cumulative cash flow.

Although configuration I is a relatively low-capacity single-reactor configuration with low labor utilization and fixed cost leverage, the addition of wood vinegar revenues materially improves its margin.

2.2.8. Plant Configuration I - Launch Capital Summary

Capital ($ m's)	Phase 1	Phase 2	Total
Planning	$0.3		$0.3
3rd Party Engineer	$0.5		$0.5
Construction Mgmt	$0.4		$0.4
Site Dev	$0.5		$0.5
Reactor	$4.2		$4.2
Other Equip	$3.5		$3.5
Total CAPEX	**$9.5**		**$9.5**
Ops Loss	$0.5		$0.5
Total Capital	**$10.0**		**$10.0**

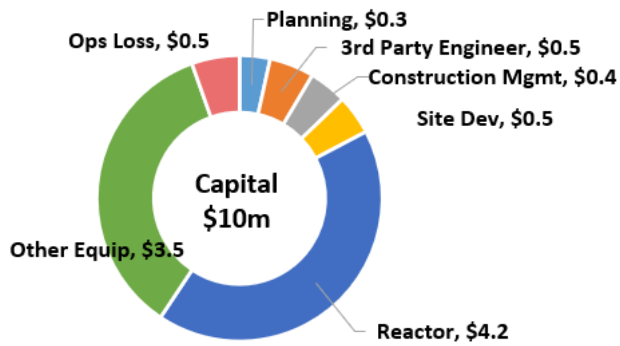
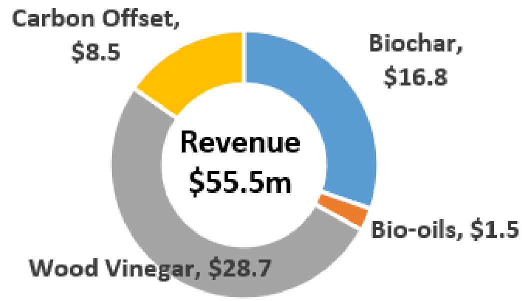


Figure 49: Configuration I launch capital summary.

Configuration I plant equipment costs $7.7M, $4.2m for the reactor and $3.5m for all other equipment. The $7.7M is $800k more than the cost of the single reactor configuration E (Mfg. X). Configuration I, which condenses liquids from the vapor stream, requires very different ancillary equipment compared to configuration G which generates electricity from the vapor stream. Configuration I includes equipment to separate, cool, pump, and store the liquids as well as a thermal oxidizer to ensure compliance with state air quality regulations. In the end, the cost of the equipment needed to condense the liquids is almost the same as the cost of the equipment needed to generate electricity - so the cost difference is a function of the Combind reactor costing $800k more than Mfg. X.

2.2.9. Plant Configuration I - Revenue, Cost Summary

Revenues ($ m's)	Total	% Total
Biochar	$16.8	30%
Bio-oils	$1.5	3%
Wood Vinegar	$28.7	52%
Electricity		
Carbon Offset	$8.5	15%
Total	**$55.5**	**100%**



Costs ($ m's)	Total	% Rev
Labor	$12.0	22%
Feedstock	$8.7	16%
Other Variable	$1.5	3%
Fixed costs	$7.7	14%
Total costs	**$29.9**	**54%**
Taxes	$1.7	3%
Net Income	**$23.9**	**43%**

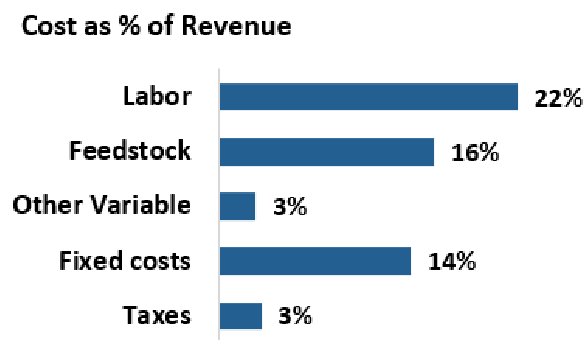


Figure 50: Configuration I revenue and cost summary.

In plant configuration I, the 4 revenue streams generate $55.4M in revenue over the 15-year life of the plant. Wood vinegar revenues are projected to be the largest at $28.7M, followed by biochar at $16.8M, carbon offsets at $8.5M and bio-oils at $1.5M.

Wood vinegar revenue is the main driver of financial returns in configuration I. The $28.7M in revenue is based on selling 2,800 tons per year at $600/ton (increasing 2% per year). At those volumes and prices, the revenue impact is similar to adding a second reactor. We'll cover the risks associated with wood vinegar in more detail below.

Configuration I includes $1.5M in revenue associated with bio-oils. Unlike wood vinegar, we believe this is a lower risk revenue stream as we've been in discussions with a carbon sequestration company that leverages pyrolysis bio-oil as a feedstock. There might be upside associated with bio-oil revenue if it could be refined into a clean fuel but we've not assumed that in our projections.

Costs (including taxes) are $31.7M or 37% of revenue. Again due to the additional wood vinegar, costs as a % of revenue are similar to a 2-reactor configuration with electricity generation. The improved profit margins provide a buffer in case feedstock costs are higher or biochar prices are lower than projected.

2.3. Major Assumptions

Each plant configuration's financial projections are based on a large number of assumptions. The below list is a subset of those that are highly impactful. Three higher-risk assumptions have been highlighted in red. We will quantify the risk of those assumptions in the following section.

Timing Assumptions			
#	**Variable**	**Value**	**Comment**
1	Pre-Construction (yrs)	1	additional product development, engineering
2	Construction (yrs)	1	
3	Plant Operations (yrs)	15	
Production Assumptions			
#	**Variable**	**Value**	**Comment**
1	Biochar Yield	~20%	
2	Liquid Yield	~40%	Liquids composed of wood vinegar + bio-oils
3	Syngas Yield	~40%	
4	Production Runs (days)	28	Operate plant 24 hrs/day for 28 days straight
5	Regular Maint. (days)	2	2 days of maintenance after 28 day run
6	Special Maint. (day/qtr)	2	2 additional days of maintenance per quarter
Revenue Assumptions			
#	**Variable**	**Value**	**Comment**
1	Biochar Price ($/ton)	$650	Based on CA, OR biochar supplier pricing
2	Trial Biochar (% total bc)	5%	5% of biochar given to customers for trials[17]
3	Offset Price ($/mt)	$150	Based on existing biochar offset pricing
4	Offset Commissions (%)	8%	% of price paid to offset marketplace partner
5	Offset Reserve (%)	10%	% offset volume withheld as reserve (not sold)
6	Electricity ($/mwh)	$50	Based on guidance from Chelan Co PUD
7	Electricity Resource Adequacy ($/kw month)	$5	Revenue for having electricity generation capacity available from CC PUD
8	Bio-oil Price ($/ton)	$150	Based on term sheet from prospective offtake customer
9	Wood Vinegar ($/ton)	$600	Based on existing CA supplier pricing [18]
10	Annual Price Increase	2%	Assume all prices increase 2% annually

[17] At launch, we plan to provide large qualities of biochar to customers for trials at no charge. Starting in year 3 of operations we plan to commit 5% of total biochar production to trials and R&D.

[18] The use of wood vinegar as an organic herbicide and foliar enhancer is new. There are a number of suppliers selling wood vinegar online and at least one large producer targeting commercial agricultural producers (Corigin).

OPEX (Feedstock) Assumptions			
#	Variable	Value	Comment
1	Feedstock Cost ($/ton)	$35	Based on undelivered wood chip price (mill)
2	Annual Cost Increase	2%	
OPEX (Staffing) Assumptions			
#	**Variable**	**Value**	**Comment**
1	Plant Manager ($/hr)	$30	
2	Weekday Crew ($/hr)	$25	
3	Weekend Crew ($/hr)	$20	
4	General Manager ($k's/yr)	$120	
5	Benefits Factor (% of $/hr)	50%	Crew, GM costs increased 50% for benefits
6	Annual Wage Increase	3%	
OPEX (other) Assumptions			
#	**Variable**	**Value**	**Comment**
1	Leased Building (sq ft)	26,600	
2	Avg Rent ($/sq ft)	$8.40	Avg rent over 15 year lease
3	Liquid Shipping Cost ($/mile)	$5.48	Includes mileage fee, tank wash
4	Liquid Shipping Cost (miles)	200	Assume shipped from Wenatchee to Spokane
5	Reactor Maint: Mfg. X ($/yr)	$67k	
6	Reactor Maint:Combind($/yr)	$15k	
7	Other Maintenance ($/yr)	$10k	
8	Annual Cost Increase	2%	Generally increase other costs 2%
Tax Assumptions			
#	**Variable**	**Value**	**Comment**
1	Fed Payroll Tax (% payroll)	8.3%	Social Security, Medicare, Unemployment Ins.
2	Fed Income Tax (% income)	0%	As a 501(c)(3) we are exempt[19]
3	WA Payroll Tax (% payroll)	5.3%	Worker Comp, Unemployment Ins.
4	WA B&O Tax (% rev)	0.484%	
5	Chelan Co Hazmat (% rev)	0.7%	Only applies to liquids

Table 58: Major assumptions included in financial projections.

[19] As a 501(c)(3) C6 would be exempt from federal income taxes. The impact of that exemption varies depending on the plant configuration which impacts EBITDA and Depreciation. For configuration G, a higher profit configuration, the exemption would be $200k and $250k per year.

3. Sensitivity Analyses

3.1. Biochar Price

In our base case we assume a biochar price of $650/ton, increasing 2% per year. This assumption was based on the current market environment and factored in pricing from existing, established biochar producers (mainly Pacific Biochar, and Oregon Biochar Solutions) and estimated customer ROI's. Looking forward there are both risks that could push biochar prices down and opportunities that could lead to higher prices.

Risks	Opportunities
1. Low customer awareness 2. High opportunity cost of field scale trials and generally farmer's hesitation to trial new solutions 3. Potential new local biochar producers 4. Barriers to market entry, especially from traditional nutrient suppliers that view biochar as a threat	1. Increasing body of academic & commercial data validating biochar's ability to increase yields, and reduce costs 2. Increased interest in regenerative agricultural solutions - including soil carbon 3. Increased federal support for biochar, including NRCS 336 and potentially the Biochar Research Act

Table 59: Risks and opportunities involved in biochar pricing.

Since it's difficult to predict which dynamics will have the most impact on biochar pricing, we ran sensitivities for a wide variety of prices - both higher and lower than the assumed $650/ton.

Biochar Price per Ton

cumulative cash flows (m's)

	Configurations		
Price	E	G	I
$150	($20.8)	($19.1)	$1.5
$250	($17.1)	($12.1)	$4.1
$350	($13.5)	($5.2)	$6.7
$450	($9.8)	$1.7	$9.2
$550	($6.1)	$8.6	$11.8
$650	($2.4)	$15.5	$14.4
$750	$1.3	$22.4	$16.9
$850	$5.0	$29.3	$19.5
$950	$8.6	$36.2	$22.1
$1,050	$12.3	$43.1	$24.7

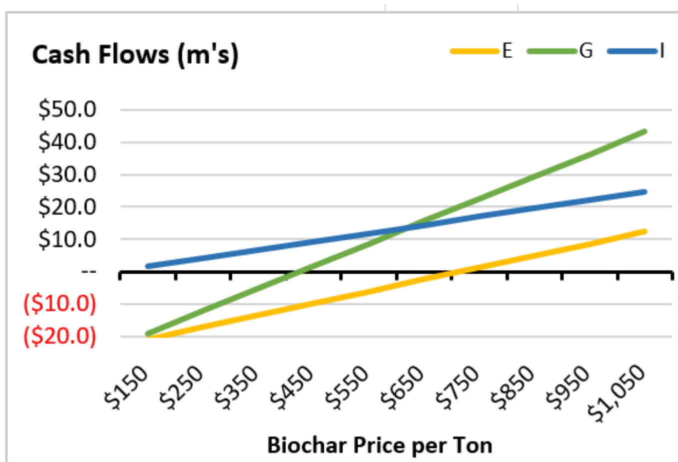


Figure 51: Cumulative cash flow sensitivities to biochar pricing.

As the table shows, cash flows are sensitive to changes in biochar prices. A couple of observations:

- The Configuration E base case projects profitable operations but negative cumulative cash flows of ($2.4M). At a biochar price of $400/ton or less, Configuration E isn't profitable and would need ongoing support to operate.
- Configuration G is more resilient to biochar price drops due to the OPEX leveraged resulting from the addition of a second reactor.
- Configuration I is able to generate positive cash flows even at low biochar prices due to its projected wood vinegar revenue.

3.2. Wood Vinegar Price

Of the 3 recommended configurations, only configuration I includes condensing liquids and selling wood vinegar. In our base case we assume a wood vinegar price of $600/ton, increasing 2% per year. Wood vinegar commercial applications are less mature than biochar, so this assumption carries more risk.

The $600/ton assumption factored in pricing from Corigin (Corigin website), the only established seller of wood vinegar for commercial agricultural applications that we could identify, and estimated customer ROI's based on Corgin case studies and academic research. Corigin doesn't post list prices for Coriphol on their website. However, based on their customer case studies, it appears they sell Coriphol at roughly $5,000/ton.

For our financial projections we assumed we would sell our raw wood vinegar to a company like Corigin as an input to their product. Since selling a commercial wood vinegar agricultural product requires additional refinement, and sales and marketing - this approach would reduce the complexity of our operations and required capital.

The $600/ton price is somewhat arbitrary, but it is high enough to support our revenue needs and low enough that the wood vinegar retail product manufacturer (for example Corigin) could cover transportation, refinement, sales and marketing cost and still realize healthy return for the risk they are taking selling a new product.

Wood Vinegar Price per Ton
cumulative cash flows (m's)

	Configurations		
Price	E	G	I
$0	--	--	($14.0)
$200	--	--	($4.5)
$400	--	--	$4.9
$600	--	--	$14.4
$800	--	--	$23.8
$1,000	--	--	$33.3
$1,200	--	--	$42.7
$1,400	--	--	$52.1
$1,600	--	--	$61.6
$1,800	--	--	$71.0
$2,000	--	--	$80.5

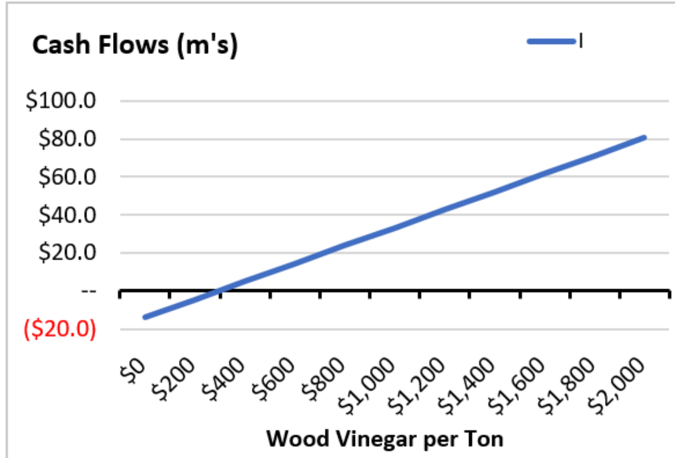


Figure 52: Cumulative cash flow sensitivity to wood vinegar price

As the table shows, cash flows for configuration I are sensitive to changes in wood vinegar prices. Project cash flows become negative at a wood vinegar price of $300/ton.

3.3. Feedstock Cost

In all 3 of the recommended configurations, we assume the plant would be sited on a forest products campus, with the ability to buy wood chips at $35/ton. We arrived at the $35/ton price based on our discussions we had with the residuals team at a local mill. The actual cost of wood chips a forest products campus tenant would pay likely depends on a number of factors such as haul radius, if the chips came from small diameter logs which are more expensive to transport and process than commercial saw logs, and the market price of wood chips.

Feedstock Cost per Ton
cumulative cash flows (m's)

	Configurations		
Price	E	G	I
$15	$4.3	$27.9	$19.3
$20	$2.7	$24.8	$18.1
$25	$1.0	$21.7	$16.8
$30	($0.7)	$18.6	$15.6
$35	($2.4)	$15.5	$14.4
$40	($4.1)	$12.4	$13.1
$45	($5.8)	$9.3	$11.9
$50	($7.5)	$6.2	$10.7
$55	($9.2)	$3.1	$9.4
$60	($10.9)	($0.0)	$8.2

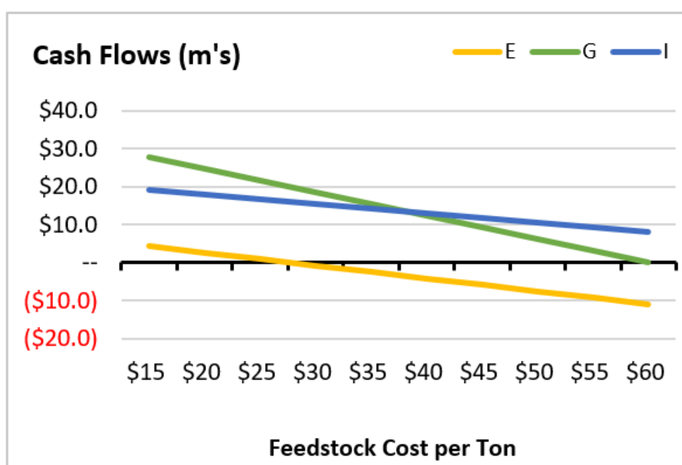


Figure 53: Feedstock cost sensitivity on cumulative cash flows.

As the table shows, cash flows are sensitive to changes in wood chips costs. A couple of observations:

- If the cost of wood chips is below $30/ton, then single reactor Configuration E could actually generate positive cash flows.
- Configuration G can remain cash flow positive with wood chip costs as high as $60/ton.
- Configuration I is able to generate positive cash flows even at very high wood chip costs due to its projected wood vinegar revenue.

4. Sources of Capital

Over the past two years we've explored a number of potential sources of capital. During that process, we've raised roughly $2.8M of which we plan to release $2.0M back to funders. Below is a summary of the sources we explored and our assessment of their fit for funding a biochar facility based only on our experience.

Source	**Description**	**Fit for Pilot Facility**	**Fit for Subsequent Facilities**
Public Funding	direct appropriations from federal, state and local governments	🟢	🟡
Grants	federal and state grants, such as USFS or WA Dept of Commerce	🟢	🟡
Foundations	national and local environmental, forest health focused foundations	🟡	🟢
Individual Donors	high net worth individuals	🟡	🔴
Project Finance	debt secured with projected cash flows, not balance sheet assets	🔴	🟢
Traditional Debt	debt secured with balance sheet assets	🔴	🟡
Equity [20]	Investors taking an ownership stake	🔴	🔴

Table 60: Summary of potential funding sources.

4.1. Public Funding

Pilot Fit =🟢, Subsequent Facility Fit = 🟡

Direct appropriations from federal, state and local governments whose constituents directly benefit from our mission has been our most successful source of funding. Direct appropriations can be a critical source of funding to help prove the concept and create momentum for this new solution but likely won't be an option for subsequent facilities.

[20] As a non-profit, C6 could not issue equity shares.

Over the past 2+ years, the State of Washington has awarded C6 funding in 2 different appropriations: a) $155k to support our initial POC (2021 biennial budget) and b) $1.4M to purchase equipment for the pilot facility (in the 2023 biennial budget). In October of 2022, Chelan County awarded C6 $312k to complete this feasibility study related to establishing a biochar plant in Chelan County.

We want to thank Rep. Steele, Rep. Goehner, former Commissioner Bugert, Commissioner Overbay, Commissioner Gering, and Commissioner Smith for their commitment to addressing wildfires and their support with these appropriations. We also want to thank John Willett for his support with the 2021 appropriation that got C6 off the ground.

4.2. Grants

Pilot Fit =🟢, Subsequent Facilities Fit = 🟡

Federal and state grants with aligned objectives such as wildfire risk reduction, circular economy, or regenerative agriculture have also been a successful source of funding. Grant funding has challenges (outlined below) but it can also be a critical source of funding to help prove the concept and create momentum. Grant funding for subsequent facilities might be a possibility if there is strong alignment, but will become more difficult as the model gains traction.

C6 received funding from a USFS Wood Innovations Grant and an Icicle Fund Community Grant. We were also recently contacted about a possible award for a WA Dept. of Commerce Grant. Those grants were used for feasibility planning but there are larger grants that could be used for funding the pilot. For example, we submitted a $5.4M application for the USFS Community Wildfire Defense Grant.

The main challenges with grant funding are:

a) Large grants have long timelines. Grant reviews often take 6 months to evaluate and select awards. Once an award is announced, it can take 6-12 before contracts are complete and funds are available.

b) Large grants typically work on a reimbursement basis which will be difficult if we plan to use it for plant equipment & construction.

c) Many grants prohibit using funds for either equipment purchases or site development activities.

4.3. Foundations

Pilot Fit =🟡, Subsequent Facilities Fit = 🟢

There are many foundations that focus on forest health, so we believe foundations could be a valuable source of funding long-term. However, we weren't able to build much traction based on our limited conversations with several foundations.

4.4. Project Finance

Pilot Fit =🔴, Subsequent Facilities Fit = 🟢

Project finance is a common funding strategy for long-term infrastructure and industrial projects, and is very common for renewable energy projects. With project finance, a project developer raises debt based upon the projected cash flows of their project rather than based on their balance sheet. Usually, a project financing structure also involves equity investors. Debt is typically structured as non-recourse loans, which are secured by the project assets, including the revenue-producing contracts and paid entirely from project cash flow.

In the future project finance could be an extremely valuable source of capital but in the near term there are challenges to leveraging it.

a) Project finance deals typically require the project to be constructed by an EPC contractor that is willing to contractually guarantee the plant performs to a certain level at commissioning. At this point, we don't believe there are any such EPC contractors.

b) Project finance deals typically require the project to be operated and maintained by an O&M contract operator that is willing to contractually guarantee the plant performs to a certain level. Similar to above, we aren't aware of any such O&M contractors.

c) Project finance requires the project developer to have rock-solid revenue offtake agreements to cover debt service. Those could be an option for electricity generation and carbon offset revenue, but it isn't an option for our larger project revenue streams, biochar or wood vinegar.

4.5. Traditional Commercial Debt

Pilot Fit =🔴, Subsequent Facilities Fit = 🟡

We did not discuss our project with any traditional lenders, but were consistently told by funding experts that our project would not be a good fit.

4.6. Equity

As a non-profit, we weren't able to offer equity stakes in the organization, so we didn't pursue this source of funding.

5. Conclusions and Remaining Gaps

Accurately forecasting the financial performance of the proposed biochar facility requires a thorough understanding of the business including supply, plant design, operations, customers, carbon markets. Fortunately over the past three years, we've learned a lot about the business, which has decreased the risk associated with certain assumptions. At the same time, we still have some major gaps that increase the uncertainty of the forecast.

Although awareness and usage of biochar is growing, currently there isn't an established market for it in Washington State which makes sales forecasting difficult. Through our initial customer discovery, we made some progress identifying potential customers and understanding what problems biochar might solve for them. Unfortunately those product development efforts didn't progress far enough for us to have confidence that we could deliver Customer X N tons of biochar and charge price Y. Instead our sales volume projections assume we'll be able to create a market for our biochar based on the benefits it's proven it can deliver in both academic research and early commercial applications. From that, we assume we will be able to sell 95% of our annual output. And our pricing assumptions are primarily based on existing biochar supplier prices.

Plant configurations with wood vinegar sales have much more upside than those with electricity generation. In these configurations, wood vinegar is the biggest output by mass and based on the promising results of the initial academic and commercial trials it could be sold at a premium. Unfortunately, our understanding of the wood vinegar market is less developed than biochar and this product development gap would need to be closed before pursuing a plant design that relies on material wood vinegar revenues.

Another big knowledge gap relates to the idea of locating the plant at a forest products campus. We believe that co-locating with other wood products producers to help with feedstock supply and create high equipment utilization is important. However we don't know the specifics of how a forest products campus might work, which impacts forecast assumptions, whether we invest in pre-processing equipment, how much we pay for feedstock and rent.

Another gap which should be closed relates to confirming labor availability. More specifically, can the plant operator hire employees with the right skills and at the assumed wages. We've had a few conversations with officials that know the Wenatchee employment market and they indicated an operator would be able to hire a quality team at the proposed wages. To eliminate the risk, it would be good to meet with a placement agency or other local employment experts.

In summary, additional investment needs to be made in specific areas, especially product development and understanding if siting the plant on a forest products campus is an option, in order to reduce the risk of the financial projection.

Conclusions

Over the past few years, we assessed the feasibility of launching a biochar-based manufacturing facility in central Washington to create economic demand for the small-diameter trees central to our region's high and increasing regional extreme wildfire risk. We initially focused on the Methow Valley, and faced significant site challenges. With strong support from Chelan County, including introduction to a strong candidate site, we pivoted to developing a facility at the Winton mill site in the upper Wenatchee Valley. We determined that feedstock for a plant is plentiful and a plant is technically and financially feasible under certain circumstances, but that the biochar market in Washington requires further development.

The Winton mill site sits at the intersection of the 2 top-priority USFS firesheds for wildfire risk reduction, making it a prime mission-aligned location. Assuming USFS projects proceed as planned, we project that sufficient biomass from forest health treatments within a 50-mile haul radius can be made available to supply a pilot biochar facility (~23,000 green tons woody biomass & ~2,500 tons of biochar per year) for at least the 15-year projected facility lifetime. The area could likely also support significant scaling into the future as the USFS adjusts its project administration to make more biomass available.

As a former sawmill, the Winton mill site is conceptually a good fit for the type of operation we propose, particularly if it is a standalone operation that receives logs and pre-processes them for biochar production. It has most of the infrastructure necessary, and can be modified to meet our needs where there are gaps.

The equipment and technology for biochar production are mostly mature and readily available, and system design is largely an integration exercise. System layout and equipment selection decisions are dependent on the site conditions, the targeted feedstock format and the products to be made from the biomass. While we have considered biochar to be our 'anchor' product, several others are possible, including heat, electricity, and bioliquids of various forms.

Unfortunately, the biochar market in Washington is nascent and requires further development to ensure sales volumes that support meaningful production levels relative to our mission. Biochar shows promise as a valuable soil amendment for a variety of crops, but it hasn't been sufficiently demonstrated in the region to convince growers of its value. The value must be quantified via trials to build customer demand.

Even less mature than the biochar market is the bioliquids market. The aqueous "wood vinegar" fraction of the bioliquid could be captured as an agricultural product, with the potential to be a foliar enhancer, organic pesticide or photosynthesis upregulator. However, the trials and research on these uses are far from sufficient to convince regional growers of the value, driving the need for investment in market development.

A better-known revenue source for the vapor stream is electricity generation. We project that it generates positive returns, but its relatively low revenues based on our region's abundant hydropower don't make up for losses in the remainder of the plant. It should be revisited when deciding the system capacity and reactor, based on the latest revenue potential.

Biochar carbon offsets sold through the voluntary market have gained considerable traction in the past 3 years. For a variety of reasons biochar offsets are widely considered among the highest quality, are purchased by well-informed corporate buyers like Microsoft, Spotify, and sell for a premium compared to other types of offsets. Realizing these revenues does impact system design and how the end biochar can be used but we don't anticipate those requirements to be major blockers and offsets could generate 15-30% of total revenues.

Revenue Stream	Customer Adoption Risk	Price Point Risk	Revenue (% of total)	Comments
biochar	🔴high	🟡moderate	P1: 60% P2: 30%	Price decreases as supply increases; NRCS subsidy adoption slow
electricity	🟢low	🟢low	P1: 10% P2: -	Well-developed market
bioliquids - "wood vinegar"	🟢low	🟡moderate	P1: - P2: 50%	Nascent market, high prices could drop with increased supply; pricing vs. value not yet quantified
bioliquids - "bio-oils" for sequestration	🔴high	🔴high	P1: - P2: 5%	Single buyer with high application risk that could impact pricing in unanticipated ways
carbon offsets	🟢low	🟡moderate	P1: 30% P2: 15%	Currently relatively high prices for biochar offsets, expected to remain a well-regarded option; subject to market volatility
P1 (Plant 1) - plant configuration with electricity generation but no liquids capture				
P2 (Plant 2) - plant configuration with liquid capture but no electricity generation				

Table 61: Summary of potential revenue streams and their risk levels.

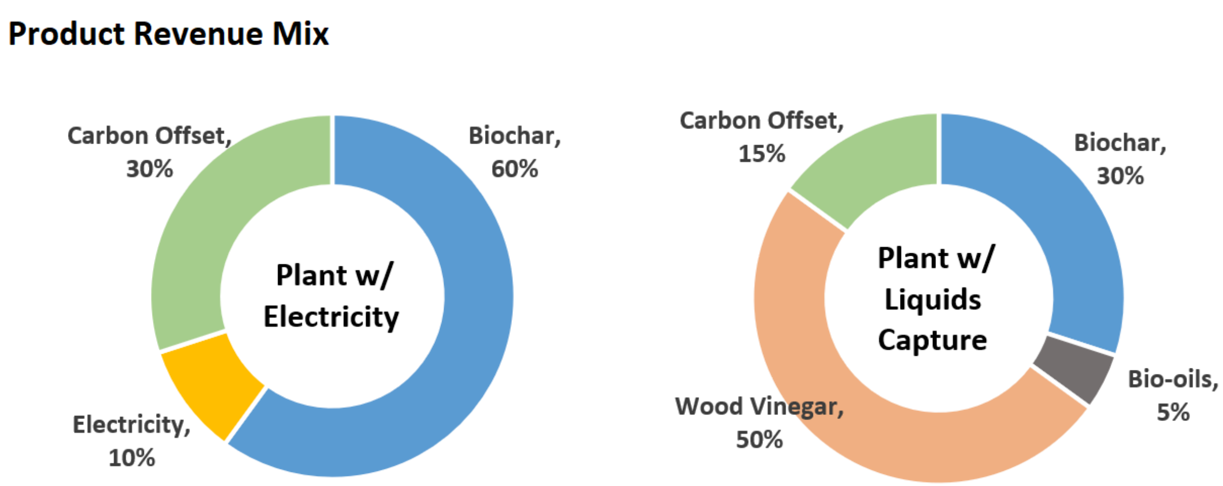


Figure 54: Product revenue mixes for 2 co-product scenarios.

1. Key Takeaways

As we evaluated several plant configurations to identify feasible mixes of feedstock sources, equipment, and products, we identified 3 key takeaways:

1) Pre-processing small diameter logs into chips onsite is very capital intensive and drives incremental operating costs. At the pilot scale, the fully-burdened costs are too high to operate profitability. We believe it's best to site the facility at a location where it can buy chips from another provider, either on a forest products campus or co-located near a mill or similar forest products producer.
2) Positive financial returns are dependent on finding high-value uses for the vapor stream. If one assumes the whole vapor stream or its syngas content are waste products and don't burden them with any of the plant's costs, then using them to generate electricity nets a marginally positive IRR. At the pilot scale, the lower risk returns from electricity generation could lead to profitable operations but not a positive IRR. In a region with low electricity rates, the upside associated with electricity generation is limited and could make it difficult to attract capital needed to scale operations. Alternatively, capturing the bioliquid from the vapor stream and separating it into its "bio-oil" and "wood vinegar" fractions, is more capital intensive and higher risk, with a significantly higher potential return.
3) In an effort to reduce required capital and give the operations an opportunity to mitigate risks, we suggest initially operating the facility with a single reactor (aka "pilot scale") before increasing the scale with an additional reactor(s). This approach has its advantages, but based on our financial projections, netting a positive IRR at pilot scale is unlikely due to underutilization of labor, fixed costs and CAPEX. We believe initially operating the facility at pilot scale is the best path forward but the pilot should be designed with the assumption that a second reactor will be brought online.

As we've attempted to balance the risk of this venture with our desire to make a meaningful impact on wildfire risk reduction, we've been biased toward a pilot reactor infeed capacity of at least 1 ODT/hr (about 16,000 green tons of biomass per year, and about 1,600 dry tons of biochar per year, resulting from ~1,000 acres of forest health treatments). This is a scale at which the equipment, operations, and required personnel skills reflect high-volume systems and would allow us to meaningfully mitigate risk toward future facility scaling. However, we were not able to adequately mature the markets for biochar and its potential co-products to justify investments in a pilot system of this scale.

2. Recommended Next Steps

The biggest risk with this venture and therefore the most important next step is to develop a market for biochar. Based on our experience, it is difficult to engage meaningfully with prospective customers unless a project is able to provide biochar for trials. With that in mind, we recommend that project developers pursue biochar production in the region at a large enough scale that supports customer discovery and trials. We recommend considering 2 avenues:

- Launch a small-scale R&D system to produce biochar for trials. In this case, the developer would have to raise more capital and source feedstock (a mill or other existing processor is recommended). They would likely have more control over the processing parameters and would get more direct hands-on learning to inform pilot system design and product development. We believe a meaningful scale to balance a representative process and production rate would be about 0.11 ODT/hr (100 kg/hr) feedstock infeed, resulting in about 42 tons of biochar annually[21]. A key consideration of this approach is timing - the trials will be determined by growing season, and this approach will likely require more than a year to raise the necessary capital, design the system, wait for equipment, install and commission the system, and perform processing experiments - all before producing the first biochar needed for the trials.

- Work with an existing biochar producer in the region that uses the same types of feedstock. There aren't many biochar producers in the region yet, but as an example, Restoration Fuels in John Day, OR produces biochar from mill waste derived from conifer wood processing. The project developer should evaluate potential product limitations of the existing producer's process, but this approach would significantly reduce required capital and implementation risk. If the project developer has the funding to directly buy biochar, they could pursue an agreement to buy trial volumes of multiple biochar formulations. If funding is short or it seems like both parties could benefit from the trial results, they could pursue a more flexible shared product development partnership with the producer.

We believe it's best to pursue small plot-scale trials initially, across several biochar formulations and crops, in order to determine which combinations hold most promise for larger-scale field trials. For example, Washington State University's extension service has a small experimental farm in Pasco focused on experiments for typical eastern WA rotated row crops - potatoes, corn, onions, etc. They can help design a set of trial protocols to test different biochar formulations across multiple crops on substantially-sized plots in a single season. The results can be used to determine what biochar formulations and crops to target for larger-scale field trials. One of our prospective compost customers noted that they have customers willing to experiment with new inputs on quarter or half pivot circles for potato-based crop rotations. Assuming positive outcomes, carefully designed protocols that track crop quality, yield and soil health on fields of this scale would result in outputs that convince growers to pursue NRCS subsidies and begin their own biochar adoption.

[21] Assuming a co-composting model with 2.5 wt% biochar at a compost application rate of 10 tons/acre, this would be enough biochar to serve ~5 quarter-pivot circle trials, 6,800 100-square meter plots, or a mix thereof. Testing higher application rates for direct soil amendments would greatly reduce the number of plots that can be tested, but should remain reasonable.

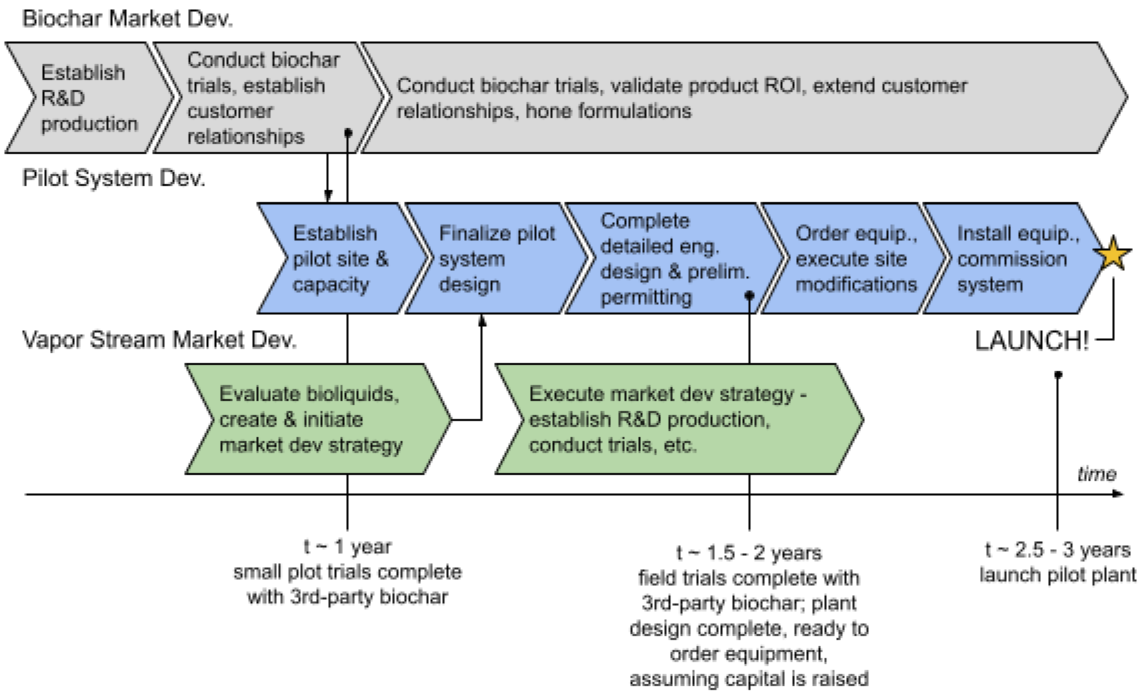


Figure 55: Next steps and rough anticipated alignment between activities. Trial timing based on seasonal alignment and willingness of a few growers to participate could significantly impact the overall timeline.

Relevant bioliquids markets should be assessed once biochar demand is established, and before the pilot reactor is selected and system design is completed. The R&D production system could generate enough bioliquids to support initial trials if the right equipment is added. The size and cost of the pilot bioliquids capture and handling system would need to be evaluated alongside the required market development activities to determine the right balance between investment magnitude and risk reduction value.

Once momentum is established with prospective biochar customers, the pilot production capacity and site can be determined. The capacity to achieve a self-sustaining operation with positive returns would largely be determined by full labor utilization, and also by the feedstock approach and electricity generation. Phasing the operation by starting with a single reactor at launch and adding a second one later is a way to balance launch risk with long-term financial performance.

The site is dependent on the feedstock approach that is selected. While the Winton mill site is generally a good fit for a biochar production facility, property covenants prevent it from being a forest products campus that includes sawmill or woodworking operations, and pre-processing small-diameter logs as a standalone operation is cost-prohibitive. Receiving wood chips, from a sawmill (unlikely, given the regional scarcity of mills) or a co-located chip mill in a forest products campus that can fully utilize the equipment, greatly reduces the upfront capital intensity. It also reduces the feedstock procurement costs for the biochar producer.

Once these elements are determined, the system design can be finalized. The reactor and peripheral equipment can be chosen based on a final round of manufacturer evaluations. The system mass and energy balances would be updated accordingly, as would the financial model. The system layout would be updated to balance the site conditions and processing requirements, and the permit pre-application process would be initiated once again. Once these items are reviewed and approved, detailed engineering can be initiated to prepare for equipment ordering, site preparation, equipment installation, system commissioning and launch.

We're hopeful that other developers can take on these challenges. Grant funding could be available to support market development, and Chelan County is evaluating the prospects for a forest products campus in the region. After three years of development, we still believe that biochar and some of its liquid co-products have the potential to be high-value forest products with multiple benefits:

1. drive economic demand for small diameter trees and meaningfully decrease wildfire risk
2. help reduce the smoke from wildfires and prescribed burns to improve air quality in local communities
3. help make our regional agricultural soils healthier and more productive
4. sequester carbon for the long-term to help address climate change
5. help create stable family-wage jobs