Recommendations to support pricing forest biomass for long-term feedstock agreements through a decision support system

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Overview

The Forest Resource and Renewable Energy Decision Support System (FRREDSS) is a web-based forest biomass-to-energy plant siting application that was developed by UC Davis under a project funded by the California Energy Commission (CEC). FRREDSS allows users to quickly assess preliminary forest feedstock availability as well as evaluate the economic feasibility and basic life cycle emission estimates of potential wood-based bioenergy facilities in California. FRREDSS is intended to assist in identifying potential sources of feedstock for project development. Additionally, the spatial analysis model of FRREDSS also has the capability to assess proximity of feedstock to infrastructure, e.g., access to landings and road networks, along with estimated delivered costs of feedstock at the facility and overall levelized cost of energy (LCOE). Users can access FRREDSS 1.0 through this link.

In 2023, the Watershed Research and Training Center (WRTC) partnered with UC Davis on the use of the FRREDSS to stress test its effectiveness as a tool to determine long-term feedstock contract prices in a spatial environment. Sensitivity analyses were conducted by summarizing the 20-year profit and loss (P&L) statement across silvicultural and harvest types, expansion factors, and inflation rates across six (6) site locations within Nevada, Placer, and El Dorado Counties. Results found that an effective price mechanism may need to exist outside of the FRREDSS environment while applying the best features of the FRREDSS model. However, the recommendations in this document are intended to further the goals of a long-term feedstock price mechanism within the FRREDDSS environment as a way to provide a foundation for discussion. The development of a stand along price mechanism will need to consider many of these recommendations and their correlating function within the FRREDSS model. More information on this process can be found in the FRREDSS Price Mechanism Final Report.

If any or some of the recommendations outlined in this report is adopted, further sensitivity analyses will be conducted to assess model efficacy. It is recommended that the model be stress tested in more complicated landscapes like Plumas or Shasta County in its next iteration.

These recommendations are categorized into primary and secondary needs which is further categorized by **research** and **model modifications**. Many recommendations in one section inform the recommendations in another section and there are opportunities for synergy. Recommendations are organized in order of priority.

1 Primary Recommendations

1.1 Research

Additional research is needed to improve the price forecasting. Both topics can be combined in the same research proposal.

(1) **Escalation factor.** Inflation rates were found to be the most influential factor impacting prices over time. At a rate of 2.1%, average prices changed by $69 per BDT. When compared to a zero inflation rate scenario, prices over a 20 year period only changed $7 per BDT showing the importance of a constant escalation factor. Identifying the correct escalation factor will be the most important factor in determining a regular price increase. Due to the heavy influence diesel prices play on the supply chain, one suggestion is to tie

escalation rates to the fluctuations in diesel listed on commodity markets (Solomon, 2017; Mason, 2023). This approach is referred to as index based pricing.

(2) **Analysis on scattered harvest sites from site location. T**he sensitivity analysis only looked at feedstock procurement within the immediate radius around each site location. However, the FRREDSS tool has the ability to identify different harvest locations than the immediate facility. Further research should incorporate this into another set of sensitivity analyses in order to have a more realistic picture of transportation distances and costs. Distance is discussed further in the following section.

Action: Continue research and sensitivity analyses regarding these two topics. Integrate findings with next iteration of model development and report accuracy with existing market prices.

Labor hours and budget estimate: varies depending on consultant

Supplemental data:

- US Environmental Information Administration – CA Diesel prices
- Biomass Supply Chain Risk Standards. "1.2.7 Accuracy/Suitability of price indices" page 7.

Considerations: The FRREDSS model operates on an annual price forecast. Due to the daily and weekly price fluctuations of diesel, attention will need to be given on how frequent new model runs will be needed to generate accurate prices.

1.2 Model modifications

1.2.1 Updating the vegetation layer

Current: FRREDSS 1.0 currently uses 2016 F3 data which integrates Forest Inventory and Analysis (FIA) plots, Forest Vegetation Simulator (FVS), and Field and Satellite for Ecosystem Mapping (FastEmap) as their vegetation base layer just for the Sierra Nevada mountain range. There is a need to update this layer to current vegetation conditions including the removal of forest treatment polygons and wildfire scars. The UC Davis team is working to modify FRREDSS to accept the post-processed vegetation layer from the Schatz Energy Research Center's California Biomass Residue Emissions Characterization (CBREC) tool. The CBREC vegetation layer will use 2016 TreeMap data in combination with the Forest Vegetation Simulator to grow stands to 2030. The Schatz Energy Center will also remove forest treatment polygons and wildfire scars to the present day. Post-treatment biomass volumes will be calculated based on a limited set of silvicultural prescriptions in FVS. Both the CBREC vegetation layer and FRREDSS tool rely on FVS to compute biomass residue estimates from forest treatments, although while FRREDSS looks at predetermined harvest intensities by silvicultural treatment, CBREC only processes harvest intensity based on thin from below and thin from above options. Discussions indicate that there is little concern with the current FRREDSS model pivoting away from silvicultural selection and towards simple harvest intensities as generated under the C-BREC vegetation processing.

Action: Modify FRREDSS to accept C-BREC post-processed vegetation layers

Work required: This work is currently being completed by the UC Davis team with funding from the Office of Planning and Research (OPR).

Programming Complexity Score: Complexity 5. involves considerable data processing, integration with external datasets, and changes to the data model, GIS expertise.

Labor hours and budget estimate: Funding has already been allocated to complete this task and should be completed by the end of 2024.

Supplemental Data:

- 2016 USFS TreeMap ; TreeMap Attributes
- UC Davis Github dataprep for F3 veg
- UC Davis GitHub Forest Reduction Cost Simulator

Considerations: If the 2023 TreeMap vegetation developed for CBREC is used before CBREC's FVS modeling, then FRREDSS can function on its existing model structure.

1.2.2 Improve operation feasibility layer occurring along terrain and distance from roads

Current: The Fuel Reduction Cost Simulator (FRCS) is the base which the FRREDSS model is built on. FRREDSS pulls data from the attribute table of a specific 30x30 meter pixel and copies it into FRCS' input requirements with variables such as skidding distance to road and slope percent. As such, it is assumed that the FRREDSS model does already include slope constraints to determine the feasibility of the user-selected harvest system. However, the distance away from roads should be incorporated as a stronger constraint than what the current model assumes. If the model does not incorporate slope into its considerations for biomass equipment to be feasible, then it should use a 35-40% slope cut off as recommended by North et al.

Action: Build or modify existing operational feasibility to be within a 1,000 ft maximum distance from the road. For cable logging, accessible harvests decrease to 500ft from roads.

Work Required: North et al's layers can be acquired for the Sierra Nevada south of Placer County. This work will need to be replicated above Placer County in the Sierra Nevada. Tukman Geospatial has completed a similar feasibility analysis for the 7-county region of the North Coast, including Sonoma, Mendocino, Humboldt, Trinity, Del Norte, and Siskiyou.

Programming Complexity Score: Complexity 2 or 3. Sounds relatively simple but would need to investigate FRCS inputs & formulae.

Labor hours and budget estimate:

- Tukman Geosptial estimates $5,000 to $7,500
- UC Davis estimate

Supplemental Data:

- Tukman Geospatial Mechanical Feasibility Analysis

- North et al "Constraints on Mechanized Treatment Significantly Limit Mechanical Fuels Reduction Extent in the Sierra Nevada"

Considerations: none

1.2.3 Basic feedstock competition analysis

Current: In regions with more developed biomass supply chains like Shasta County, feedstock competition influences pricing. FRREDSS 1.0 currently only projects forest biomass demand needs for a single biopower facility but oftentimes here are multiple facilities competing for the same resource within a given region. However, biomass pricing under competition is a sophisticated exercise and may not be a realistic feature to incorporate.

Action: The FRREDSS can incorporate the UCANR sawmill and biomass dataset which contains existing, proposed, and active development facilities throughout the state and their reported feedstock demand. A simple wood basket around each existing facility can be created to ease processing burden. This will help the user better understand what other sites are competing for and how that might affect biomass supply and price. Determine if pricing under competition is feasible within an optimized environment such as FRREDSS.

Work Required: Program script to calculate percent overlap of existing facilities within the supply area of interest. Results will be in percent of the feedstock under competition. Determine best way to approximate price changes under competition.

Programming Complexity Score: Complexity 3. Analysis of overlapping areas and competition metrics involves moderate data processing and coding.

Labor hours and budget estimate:

- UC Davis estimate

Supplemental Data:

- UCANR sawmill and biomass facility database
- Research required for price changes under competition in CA

Considerations: In order to simplify this effort, a percent overlap with the proposed facility wood basket could be summarized in an output table. The spatial layer of the existing facilities could be a linear radius or an isochrone. A spatial layer to toggle could also be added to the user interface to let users know the extent of existing wood baskets in advance.

1.2.4 Subsidies

Current: There is a clear need to better understand how subsidies play out over a 20-year period and its utility in a model such as this. Feedback we repeatedly received was regarding the model's inability to account for subsidies, especially when tied to feedstock procurement.

Action: Devise a method within the FRREDSS environmental to account for subsidies both upstream (i.e. Land management grants from CALFIRE) or downstream (e.g. Power purchase agreements, carbon credits, etc.).

Work required: Significant attention needs to be directed here if the model were to function accurately.

Programming Complexity Score: Complexity 2.

Labor hours and budget estimate:

- UC Davis estimate

Supplemental Data: To be determined.

Considerations: The simplest way to account for subsidies may be to subtract them from outputs post-processing in the excel sheet. If the recommendations from 2.2.2 were to be adopted, a new entry could be created to account for forest implementation subsidies or subsidies for end-users. This could discount the harvest costs or the transportation costs to deliver biomass and expand the wood basket proportional to the subsidy received. However, due to the inherent nature of subsidy availability over time, it becomes problematic to forecast prices based on subsidies 10 to 20 years in the future.

1.2.5 Improving user-friendliness

Labor hours and budget estimate to complete all tasks below:

- UC Davis estimate

1.2.5.1 Inputs

Option to input fully loaded costs for operators

Current: The Fuel Reduction Cost Simulator relies on a variety of inputs to determine the move-in, harvest, and transportation costs. However, contractors already have fully loaded rates that they use when bidding for projects. Similar to how the transportation section of the DSS can be gamed to apply a fully loaded contractor rate of $150 per hour, timber operators should have the option to use a fully-loaded rate as well.

Action: Add an option for timber operators to apply their own fully loaded rates

Programming Complexity Score: Complexity 2. Basic user input changes but requires validation and integration into cost calculations.

Considerations: None

Option to return to model inputs after running the model outputs

Current: The FRREDSS must be reset to its default assumptions after every model run. This creates a small burden for the user to continually input the same assumptions for different model runs. While the sensitivity analysis completed under the OPR project only had <10 items to customize each model run, the FRREDSS offers a total of 42 variables to customize.

Action: Allowing the option for certain model runs to be saved, or having a model run history may prove to be beneficial for usability.

Programming complexity score: Complexity 2. Primarily user interface will need to be changed to store and retrieve user inputs, but also involves some backend state management.

Considerations: None

1.2.5.2 Outputs

Calculate travel distance to feedstock for each year

Current: The FRREDSS model is built to assume that feedstock closest to the facility would be more favorable and is consumed first. As the size of the facility increases so will the feedstock demand. Distance is not calculated within the outputs of FRREDSS but can be easily derived using the $150 hourly hauling rate for contractors and transportation costs found with the model.

Action: Apply a new row into the output spreadsheet that calculates distance (miles) as a function of the hourly contractor rate and the time calculated with the transportation network module of the FRREDSS.

Programming complexity score: Complexity 2. Straightforward addition to the output, assuming transportation costs and times are already calculated.

Considerations: None

Note financial excel formulas in a separate introduction sheet

Current: The DSS generates a 20-year P&L statement based on the input assumptions in the user interface. However, the output Excel table only contains a text version of financial calculations. While a financial professional may understand how each line item is calculated, providing an easily accessible location to view the financial formulas used in the output table may allow the output table more usability.

Action: Have financial excel formulas available for the user to replicate in the model as a separate introduction sheet, a separate link containing the formulas online, or embedded within the excel spreadsheet.

Programming complexity score: Complexity 1. straightforward, mainly requires documentation and possibly some UI enhancements.

Considerations: None

2 Secondary Recommendations

These recommendations were identified as being important to improve accuracy but may represent more work than required to get FRREDSS to the next step.

2.1 Model Modifications

2.1.1 Approximate local and region workforce capacity for treatments

Current: The current FRREDSS does not incorporate contractor and workforce capacity as a limitation to feedstock procurement. This is one of the most significant barriers to expanding biomass markets. Providing a site assessment tool without accounting for workforce capacity to bring the material to market would be incomplete. While this information may have been immensely challenging to compile at the time of model development, there are new data tracking systems which crosswalk all the available public resources on treatment occurrence in California. This can be used to account for a baseline on workforce capacity to procure feedstock.

Action: Consider the Wildfire and Forest Resilience Task Force's treatment tracking data dashboard as an approximate estimate on the capacity any one region can complete. Additionally, incorporate average harvest intensity per year per county as a baseline capacity for industry. Lumber estimates can be found on the Timber Harvest Statistics by County data managed by the Department of Tax and Fee Administration (CDTFA). Additionally, data on biomass piles has been completed by CLERE Inc and SIG, which can further validate practically available biomass can be cross-referenced with workforce availability. If biomass is being generated, then it is likely that there is some work force in the region. Application of this data in the model can present itself in different ways. A soft threshold may be the most useful where potential workforce constraints do not result in a "fail" output but rather a warning to communicate to the user. For example, a notification can alert the user if a site location exceeds the workforce capacity within a given region.

Work Required: Program script to summarize workforce activity statistics per unit (e.g. MBF per County, Acres per County) from the Treatment Tracking Dashboard and timber tax data. Potential validation and crosswalk with biomass pile data.

Programming Complexity Score: Complexity 3. This would involve data aggregation and further data analysis but may be streamlined with access to good data sources. The methodology for estimating future workforce capacity will need to be considered.

Supplemental Data:

- Timber Tax Data – https://www.cdtfa.ca.gov/taxes-and-fees/timber-yield-tax/harvest-value-and-statistics.htm
- Treatment Tracking Dashboard – https://wildfiretaskforce.org/treatment-dashboard/
- Bureau of Labor Statistics

Considerations: If accepting this recommendation, the model's ability to satisfy feedstock demand requirements may be drastically diminished without applying a large number to the expansion factor variable (eg. What happens if there is no workforce in the area?). This may require the expansion factor to be eliminated or otherwise require a fundamental rethinking of the model as it is designed currently.

2.1.2 Adding more end-use products

Current: The model only performs techno-economic assessments (TEA) for woody biomass conversion systems (combustion, combined heat and power, and gasification). Systems like gasification covers a large swath of large conversion system options being explored by biofuel developers. However, there may be interest in expanding the FRREDSS to include additional market opportunities beyond biomass for energy or fuel production. Additionally, there may be interest in exploring smaller scale mobile equipment options.

This may require a significant amount of work as end-users uninterested in the use of hog fuel as a feedstock will want a better understanding of the **quality and type** of species being removed. See recommendation 2.1.3 for more information on feedstock sources.

Action: Add additional TEA module (e.g., hydrogen, biofuels, RNG, biochar) to the FRREDSS model. Add features on feedstock quality and type.

Work required: Potentially significant research and programming to incorporate additional TEA options and feedstock quality required for new technologies.

Programming Complexity Score: 3-4.

Supplemental Data: Literature Review

Considerations: This may require incorporating agricultural and sawmill residues as a viable feedstock source. Additionally, mobile equipment may be a complicated network analysis to forecast.

2.1.3 Consider adding additional feedstock sources beyond in-woods biomass

Current: The model only incorporates in-woods biomass material. However, facilities can mix their feedstock sources based on market conditions or for desired conversion efficiencies. Agricultural, urban, or other organic waste sources should be considered in order to have a more accurate understanding on facility site feasibility.

Action: Incorporate agricultural feedstocks as well as potential organic waste that can be made available through SB 1383 for biomass conversion.

Work Required: Significant effort to develop a model which optimizes feedstock availability and price across different feedstock sources.

Programming Complexity Score: Complexity 5. Significant model alterations are required to include different types of agro-wastes as well as their logistic considerations that is unique to each specific feedstock.

Supplemental Data: Various

Considerations: More user selection criteria to identify the percent procurement from each feedstock source could improve accuracy. Additionally, this change may increase the computing time and processing power required to generate real-time cost estimates.

2.1.4 Long-term risk to vegetation

Current: Vegetation is expected to be forecasted out to 2030. FRREDSS model will need to further grow this data to 2040. However, vegetation is currently grown forward without risk of disturbance. In order to improve accuracy, vegetation can be subject to risk modeling.

Action: Develop a stochastic model on future vegetation risk to fire

Work Required: Significant time developing fire risk model moving into the future.

Programming Complexity Score: Complexity 5.

Supplemental Data: Cabiyo (2022). "Innovative wood use can enable carbon-beneficial forest management in California". https://www.pnas.org/doi/pdf/10.1073/pnas.2019073118

Considerations: Review Cabiyo's (2022) stochastic fire modeling methods. Consider monte carlo simulations

2.1.5 Use "energy revenue required" as a constraint

Current: The price gap that exists between the biomass seller's price and purchase price can either be solved by reducing operation costs (e.g., cut, skid, load, chip and haul), or increasing product revenue. The FRREDSS currently has no constraint on the amount of revenue required to operate the facility. Therefore, it suggests that additional revenue beyond what the existing electricity market offers is required to operate the facility. However, constraining the revenue will flip the FRREDSS to identify the amount of biomass (as well as distance from the facility and time before forest biomass demand for a user specified biopower faciility outstrips supply) the biopower facility can operate before the economic feasibility becomes insoluble. For example, the FRREDSS calculates an average of $15 million per year in energy revenues for a proposed 5MW biopower bioenergy facility located in Grass Valley. Given the general max allowance of $199.97 per MWh generated under a BioMAT power purchase agreement (PPA)[1], this site location suggests that biopower facility owners would need over an additional $8 million from energy revenues if the full 5 MW were accepted on the grid and the facility were to pay for the full costs to deliver biomass.

Action: Updates would eliminate the expansion factor constraint and instead the constraint would be on the level of revenue of the biopower facility to what we know BioMAT or BioRAM generally offer, and allow the model to calculate the breakeven distance for feedstock procurement. This might be an easier way to incorporate subsidies into the profit and loss (P&L) statement, which has been named as the biggest missing variable in this model. Without this change, it is unclear how to incorporate the presence of subsidies as the model is currently built.

Work required: Potentially significant. Capping the energy revenue generated will result in a "fail" output where not enough biomass would be available within an economically viable distance to satisfy demand under current market prices. Without the ability to incorporate cheaper feedstocks like sawmill or agricultural residues, facilities may have a difficult time forecasting prices within the financial bounds of operability over a 20-year period.

Programming Complexity Score: Complexity 3-4.

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[1] $199.97 per MWh over 8,760 hours with 80% efficiency equals ~$7 million from energy revenues for a 5 MW plant. Note that facilities do not interconnect the full nameplate capacity onto the grid. A more realistic estimate would have the PPA interconnect 3 MW for a 5 MW facility, which would be ~$4.2 million per year in revenues.

Supplemental Data: Incorporate BioMAT rates into the financial analysis. Consider acquiring proprietary information from BioRAM facilities on their power service rates.

Considerations: This recommendation aims to calculate the breakeven distance for the facility given its constraint on known energy price agreements. However, the current model's open-ended price forecasting is in-itself a useful data point. By constraining the model so that it may "fail" to satisfy facility feedstock demand, the user may not be able to see the factors which caused the facility to fail. In its current iteration, users can use the 20 year P&L output table as a basis for further discussions on business management, state policy reform, or market intervention. Both approaches to the DSS (with a revenue constraint and without a revenue constraint) may reveal the same result, albeit in different ways.

2.1.6 Consider areas designated as protected activity centers (PAC)

Current: The vegetation layer does eliminate some areas like wilderness areas from operational viability, however the FRREDSS did not remove areas that are designated protected activity centers (PAC). For a more accurate assessment on feedstock viability, PACs could be considered.

Action: Apply appropriate constraints PACs from feedstock availability estimates. The primary species for consideration are the spotted owl and goshawk and constraints may vary by location (WUI, Non-WUI) and allowable activities specified at a forest level or within unique NEPA analysis.

Work Required: Incorporate PAC polygons into vegetation layer with mapping software

Programming Complexity Score: Complexity 3. Moderate coding but currently the current forest biomass database has no concept of excluded areas. This would likely need to add this as new cluster-level datapoint similar to how fire hazard zones are currently entered in the model.

Supplemental Data: This type of data may exist on a public server, but a more comprehensive assessment will require requesting this data from private entities. Currently, constraint data is available for the Sierra Nevada Region

- see North et al "Constraints on Mechanized Treatment Significantly Limit Mechanical Fuels Reduction Extent in the Sierra Nevada"

Considerations: None

2.1.7 Options for more than one forest treatment type and harvest system combination

Current: The FRREDSS assumes that the facility will satisfy its feedstock demand for a 20-year period using only a single forest treatment type and harvest system. However, facilities must rely on a diversity of feedstock sources coming from a variety of forest treatment types across time and space.

Action: To be determined.

Programming Complexity Score:

Considerations: It is not clear how the FRREDSS would be able to model three unique forest treatment and harvest system combinations within a 20-year period without the user performing their own sensitivity analysis and subsequent composite average. This may be a requirement for users to get a more accurate understanding of the various aspects which impact feedstock procurement. This could be enhanced however with the recommendation in 3.1.3.

2.1.8 Consider road-based isochrones rather than linear radius wood baskets

Current: The FRREDSS model currently uses a transportation model known as the Open Source Routing Machine (OSRM), for estimating the transportation cost between a harvest unit and a biopower facility by adding up estimated labor, fuel, truck ownership costs, and other costs of traveling from the landing site to the biopower facility. The expansion factor is one of the determining factors which impacts the distance at which the model can procure feedstock. When examining the spatial output of a specific model run, it appears the expansion factor is based on a linear radius wood basket. However, more accurate estimates would rely on the time distance-traveling on different quality of roads (paved, gravel, dirt, seasonal, etc.). This would produce a more irregular shape based on equal travel time around a central point known as isochrones.

Action: Modify the expansion factor to be based on isochrone wood baskets rather than the linear radius. Or, the model may replace the expansion factor with a time distance or miles distance radius from the facility center.

Work Required: build model for time-based haul distances based on road surface with a mapping software.

Programming Complexity Score: Complexity 4. Requires sophisticated and time consuming OSRM tracking & additional computation resources.

Supplemental Data: no additional datasets will be required.

Considerations: This change may increase the computing time and processing power required to generate real-time cost estimates. The model would need to generate a unique isochrone for each unique location defined by the user.

2.1.9 Salvage harvests should be limited to within the last 5 years of a wildfire's end date

Current: There appears to be no constraint on the ability to perform salvage harvests.

Action: Incorporate the time sensitivity for salvage harvests into the model. While salvaging before the second or third year is best, salvage harvests rarely happen after year five on a stand level due to safety and viability.

Work Required: Programming

Programming Complexity Score: Complexity 3. Fire history is not currently used in ths model would need to be acquired, incorporated, and determined how to use with projected 30-year analysis.

Supplemental Data: Incorporate the end date of the wildfire event and the max time allowed for harvest feasibility.

Considerations: Typically, sawlog material can be utilized for 2 and possibly 3 (for largest diameter trees) years post wildfire. The material can be safely felled, skidded, and chipped for potentially 5 years, but would need onsite analysis by LTO/TMO to determine feasibility/safety. Biomass facilities also prefer less deteriorated material to improve conversion efficiencies. This will require periodic updates to the vegetation layer to remain current.