**Bioenergy with Carbon Capture and Storage (BECCS) in the Western United States  
Portfolio Description – First Draft  
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This project explores the potential for restorative forest management practices and the deployment of bioenergy with carbon capture and storage (BECCS) in Western United States – California, Idaho, Nevada, Oregon, and Washington – through the use of an R-Shiny web application interface and visualization tool. The goal of this project is to allow for the iteration and exploration of key biomass and geologic resources in the region that could support BECCS systems, and to make initial estimates of the total potential volume of woody biomass in the region, as measured by bone dry tons (BDT) and tons of CO2e, based on a query-based analysis of Forest Inventory and Analysis (FIA) data. These data are then used in estimates of the potential net emissions benefits from the removal and utilization of this biomass from a life cycle perspective, comparing BECCS to different utilization or removal opportunities, to scope the economic feasibility and generate climactic, environmental, and economic benefits. By using an R-Shiny platform, the web application (<https://nickdahl.shinyapps.io/WoodyBiomassApp/>) generates a friendly user interface for the customization and iteration of various scenarios, each of which returns a host of plots and tables describing, in turn, the available resources that meet the criteria. Those criteria are as follows:

* **Region**: California, Oregon, Washington, Idaho, Nevada
* **Total Available Amount and Unit**: Amount sum or by acre; bone-dry tons or CO2e tons
* **Potential carbon pool by size/type**: Only <5 inch diameter wood, only <9 inch diameter wood, only <12 inch diameter wood, <12 inch diameter wood and tops of additional trees to capacity
* **Method of Biomass Restoration:** Treatment to 60/80/100% of the full stocking amount
* **Fire Risk Field:** Burn probability percentile (state), burn probability percentile (nation), wildfire hazard potential (state), wildfire hazard potential (nation) specified by percentile
* **Deadwood additionally considered in removal:** Include/ignore salvageable dead wood
* **Distance from road:** 100 ft or less, 300 ft or less, 500 ft or less, ½ mile or less, 1 mile or less, 3 miles or less, 5 miles or less

**Description of Methods**

Data are read in through a custom query to the FIA’s Evalidator tool, depending on the selection provided from the above options. Values are recorded on a county-level, within those states that are included in the full analysis. Depending on selection for the potential carbon pool, accessible wood types are limited to the diameter and size specifications of interest. For example, if the user selects “<12 inch diameter wood and tops of additional trees to capacity,” the web application will filter the data to only include biomass that is either in trees <12 inches, or is in the tops of trees that are larger.

Primarily, the total amount available is driven by the method of biomass restoration, which most dramatically impacts the carbon pools from which restoration efforts can draw. The FIA provides a prescriptive level of biomass which it considers to be a “full” level of stocking values to individual trees, and forest type, stand size, and stocking class in all Forest Inventory and Analysis plots nationwide. These are assigned using species specific functions of diameter developed from normal yield tables and stocking charts. For the purposes of restoration treatment, the web application allows for the thinning of eligible plots to specific percentages of this full stocking amount, set at 60%, 80%, and 100%. In all scenarios, biomass which is considered overstocked is eligible removal, and in the more progressive strategies, we allow for thinning to levels that are consistent with similar restoration projects run regionally. Wood is drawn from carbon pools, starting at the smallest diameter and ascending to the largest allowed diameter until capacity is reached or the method of restoration is fulfilled. In the instance where the user has selected to allow for tops to be removed, they are considered from trees that exceed the diameter limit.

With region, size, and methodology sorted, further restrictions or additions are added to the model. Analysis can be limited to counties that meet comparative fire percentile criteria, either on a state or national level. The first compares relative rates of burn probability, either ranked as a national or statewide percentile, while the second compares wildfire hazard potential. The user may, for example, select only counties in California and Oregon which are in the top 20th percentile nationally for wildfire risk. The distance from road can also be added as a limiting factor, to several discrete distances. Selecting for 500 ft or less restricts the acres considered to those where the straight-line distance to the nearest improved road (a road of any width that is maintained as evidenced by pavement, gravel, grading, ditching, and/or other improvements) is within the given range. The user may also elect to include salvageable dead wood, which is restricted to only dead wood in the Decay Class 1.

The visualizations provided illustrate the above queried data to communicate a couple key facets depending on the user input. The first visualization provides a map showing available biomass on a county-level in millions of short dry tons, as well as the sum totals across states in a bar plot. Error bars are provided in scope with the uncertainty attached to the underlying calculations on generalized FIA data and counties with missing data are grayed out and removed from consideration. White counties represent regions that do not meet the criteria, or where there is no available biomass that fit within the customized restrictions.

The second set of illustrations provides a summary view of the short dry tons of biomass by distance from road and fire percentile. Reading the first plot from left to right, the user gets a view for each state of the cumulative amount of biomass within each distance from the road. Reading the second plot from right to left, the user gets a similar narrative showing the cumulative total of biomass available at each consecutively decreasing percentile. The amount considered across these two variables is first filtered by all other inputs, including size, restoration strategy, and dead wood inclusion.

The third set of illustrations exhibits the make-up of the total for each state of the resulting candidate biomass. The top-left plot gives amounts by wood size, as well as the inclusion of salvageable dead wood from Decay Class 1. The top-right plot gives the dry tons of biomass by ownership group.

* **Ownership groups:** Bureau of Land Management, County and Municipal Ownership, Department of Defense, Fish and Wildlife Service, National Forest Grassland, National Forest System, National Park Service, Other Federal, Other Local Government, Private, State

The bottom-left plot shows biomass depending on the slope of the land, binned by discrete 20% widths. Finally, the bottom-right plot shows the elevation of usable land, binned by 1000 ft widths. From this collection of plots, the user can get a sense not only of the type of wood that the scenario retains, but also the ownership, make-up, and geographic context in which the candidate biomass is location. The final element of the output is a table which shows each county’s respective biomass total and fire percentile. There are intermediate sums for totals within states, and a cumulative sum (identical to the sum provided in the first bar graph) at the bottom.

**Purpose of Project**

Bioenergy can have climate benefits, especially when coupled with carbon capture and storage (BECCS) systems. The extent of the climate benefits depends on several factors, including the source of the biomass (how and where it is grown, harvested, transported); how it is processed for energy applications; and on how residual emissions are captured, treated, stored and/or sequestered. The extent to which forests can and should be used for bioenergy is not without its controversy, especially in western states where there is a history of debate over timber and logging practices, as well as controversy over how best to address the increasing number and severity of wildfires in the region. Indeed, it is difficult to generalize about the climate benefits and costs of BECCS compared to other renewable energy systems writ large given the wide variability in all of these factors. Answers are largely regional and often highly specific to the natural resources, infrastructure, technical, ecological, and socio-economic systems in question.

**Conclusions**

The following are conclusions drawn from the methodology and results for four model scenarios of biomass availability based on the FIA datasets. These are each built on different assumptions about biomass use and accessibility, presenting a range of conservative to liberal predictions.

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| **Scenario of Simulation** | **Additional Exclusions Applied** | **Total Available Biomass & Carbon** |
| Scenario 1 (Conservative) | <9-in diameter wood (no tops)  Distance from Road: <1,000 ft | Bone dry tons: 265 million  CO2 equivalent: 487 million |
| Scenario 2 | <12-in diameter and tops  Distance from Road: <1,000 ft | Bone dry tons: 424 million  CO2 equivalent: 778 million |
| Scenario 3 | <9-in diameter wood (no tops)  Distance from Road: All | Bone dry tons: 642 million  CO2 equivalent: 1.18 billion |
| Scenario 4 (Liberal) | <12-in diameter and tops  Distance from Road: All | Bone dry tons: 1.01 billion  CO2 equivalent: 1.96 billion |

Estimates suggest that there is between 265 million and 1.01 billion bone dry tons of woody biomass available to support the development of a BECCS industry. This is equivalent to 487 million to 1.96 billion tons of carbon dioxide. This available biomass comes from regions that met a wildfire hazard potential cut-off of the top 35% at risk nationally. These represent a substantial portion of the 47.2 billion tons of carbon tracked by the FIA across forested counties in the United States. Out of the 5.7 billion tons of carbon stored in woody biomass in Washington and Oregon and the 2.6 billion tons in California, 4.0 billion tons are located in overstocked locations, and up to 1.96 billion of those tons can be extracted and used in a BECCS project.

There are limitations about the degree to which these conclusions are valid. FIA county levels data only provides estimates based on a select number of monitored plots to extrapolate wider estimations, which can only be used to draw high level generalizations. The project thus adjusts available biomass by proportional calculations rather than specific audits of the details of particular acreage. It also relies on relatively course measures of forest health as delineated by the USFS FIA program, which are widely used but not universally accepted. Wildfire hazard data describes current and historic conditions, which may not best represent conditions for forest health and wildfire risk, and population dynamics, flood/draught patterns, and active management schemata may alter the growth and wellbeing of forests. Finally, other potential undocumented factors such as unwilling ownership groups (Fish and Wildlife Service, Department of Defense, small landowners), additional protections, and geographic inaccessibility may interrupt access to lands. All of these solutions may be solved through access and use to higher granularity data, which may become a reality as the quality, scope, and intensity of forestry studies improves in the next decade. The FIA has re-committed to tracking these key features, and with annual updates to publicly available data, the project will improve as it incorporates more sophisticated snapshots of the health and wellbeing of forested lands within the United States.