# Executive Summary

The study reports the contributions of forest-based biomass as a byproduct of sustainable forest operations to economic development within economic, technological, and ecological constraints. Three major goals were accomplished with the study. First, an estimate was produced of the volume of forest biomass, stratified by landownership categories, forest ecosystem types, species and location (whether it was removed or retained on site). Producing stratified biomass data led to the development of a spatially explicit biomass database. Second, the study assesses biomass availability based on various cost and price considerations, market prices and calculating residual value to the landowner. Third, public to access the biomass database is provided through the internet via a web-based calculator tool. The research team studied the process of biomass production beginning with a forest harvest operation. The team calculated the volume of biomass at all stages of processing and inferred the contribution it makes to market uses and ecological function when it was retained on site. The study also produced an estimate of pre-existing woody material based on references and studies in existing literature.

The report also studied alternative scenarios regarding fuels treatment and forest health in National Forests in eastern Washington. The scenarios reflected a future that increased the number of acres treated for fuels reduction and forest health reasons, and calculated the volume of biomass produced as a result of these treatments.

Figure E.1 shows the allocation of material from a forest harvest operation into merchantable stem volume and biomass starting from left to right. Biomass on a parcel began as the volume of slash that was produced as a byproduct of a forest operation. Biomass was everything generated as part of the timber harvest process including tops, live/dead branches, and foliage, and included breakage and defect associated with stem volume. This biomass was classified as ***post-timber harvest biomass***. Post-timber harvest biomass was then allocated to either potential market or non-market uses. The biomass that was brought to the landing and roadside was calculated and recorded in the biomass database as ***harvested biomass***. The volume that was left scattered in the woods as a product of having been broken off or tops and limbs cut when commercial logs were yarded to the landing was noted as ***residual harvested biomass***. Biomass that reached the landing and roadside was filtered by operability constraints for each ownership and forest type, and became either ***potential market biomass*** or ***residual potential market biomass***. The potential market biomass represented the amount that could be potentially loaded onto a truck. The residual potential market biomass was the portion that did not get loaded due to operability constraints (equipment cannot be brought in) or other factors such as landowner preferences (the landowner does not want to sell their biomass). The potential market biomass was the volume that was subject to market valuation and was furthered filtered by economic parameters. ***Market biomass*** was the portion of the potential market biomass that actually was loaded on a truck. Some market residual was produced when costs considerations were included. This residual was noted as ***residual market biomass***. The accounting was complete when the volume of biomass reaching the market was recorded.

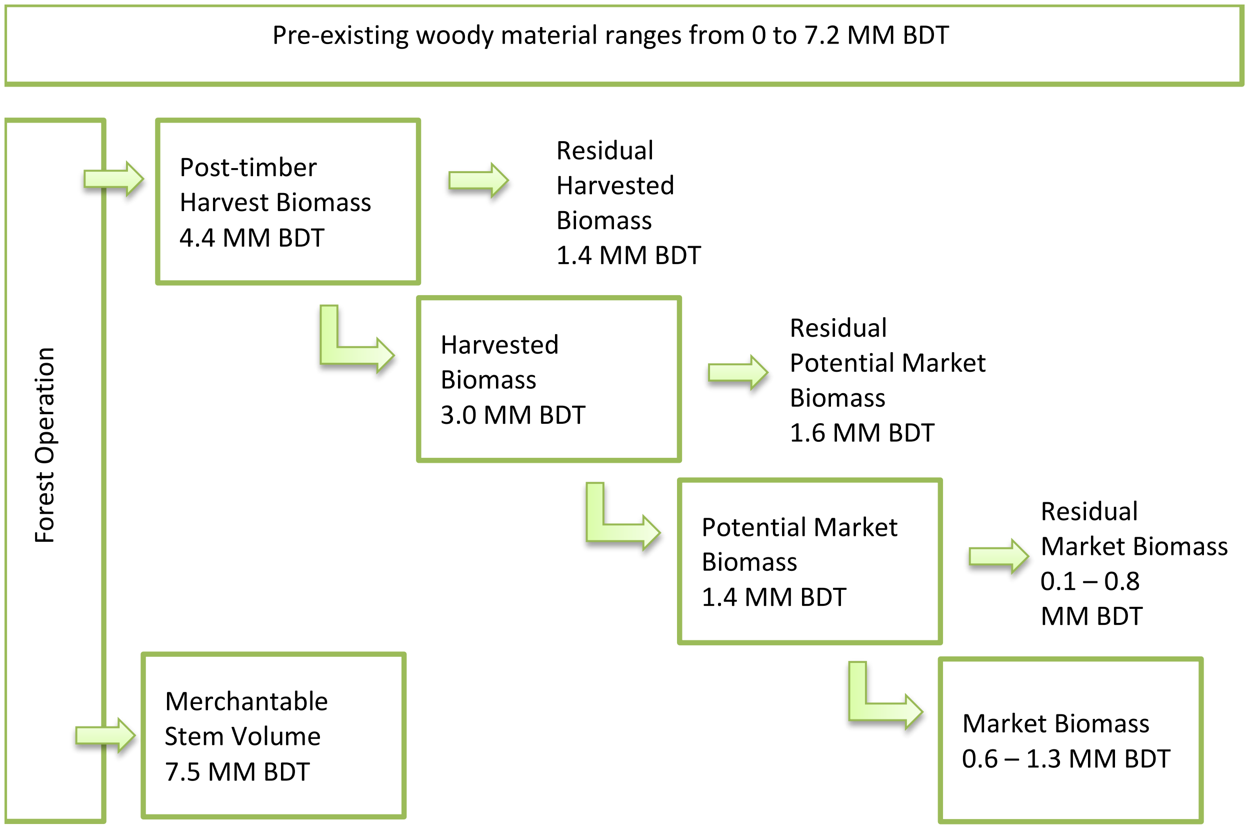


Figure E1. The progression of biomass from forest slash (upper rectangle) to market (lower rectangle). The numbers in boxes represent statewide volume calculated for 2010.

Of nearly 4.4 million bone dry tons (MM BDT) produced by forest operations in 2010, 3 MM BDT were harvested (brought to a landing), and 1.4 MM BDT were retained on site as a byproduct of a forest operation (tops and breakage). The majority of the 1.4 MM BDT of residual harvested biomass was assumed to be left scattered throughout the harvest unit. Of the 3 MM BDT of harvested biomass in 2010, 1.4 MM BDT were potentially marketable. The volume of unmarketable harvested biomass left in piles and at landings was calculated to be 1.6 MM BDT. Of the 1.4 MM BDT of potential market biomass, around 0.6 MM BDT were sold to facilities under 2010 costs and market prices. The amount left in piles at landings due to low market prices amounted to 0.8 MM BDT.

Today's market conditions for biomass, primarily due to low economic activity, restrict the volume of potential market biomass that can reach biomass end users. Under more favorable prices than those observed in 2010, e.g., $100 per BDT (up from $30-65 per BDT in 2010), market biomass could have expanded to 1.3 MM BDT, leaving about 0.1 MM BDT at the roadside.

In addition to the biomass that resulted from a forest operation and that can be marketed, we evaluated woody material that existed prior to the operation. Pre-existing woody material is usually not available as market biomass. Pre-existing woody material was determined by consulting the decayed wood advisor (DecAID, US Forest Service). The range of pre-existing woody material on site ranged from 0 to 7.2 MM BDT when the 80% tolerance limit from DecAID was used (see figure E1). Using the study's mid-range harvest scenario, the 80% tolerance limit of pre-existing woody material estimates provided by DecAID, and the study's technical and economic filters that were used to allocate biomass across its different categories, the study team estimated a minimum of 8.6 MM BDT (in 2010) and a maximum of 11 MM BDT (in 2015) of biomass that were left on harvested sites statewide (figure E2). The variability in this total pictured in figure E2 was a mirrored reflection of the mid-range harvest projection used in the study. The mid-range harvest projection was the middle level of three harvest scenarios analyzed in the study. The minimum tonnage reflected low levels of harvested activity, while the maximum tonnage corresponds to the year of highest harvest activity.

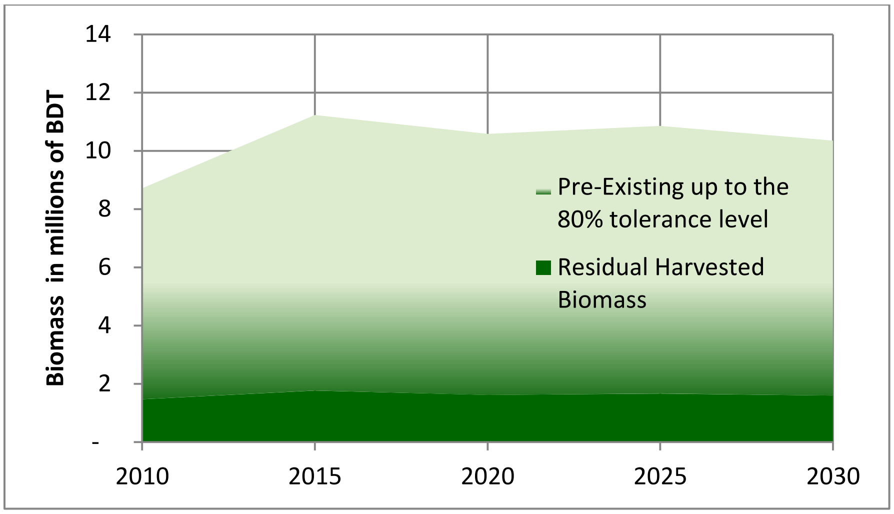


Figure E2. The range of material left scattered in a unit.

More importantly, the source of greatest variability in figure E2 was associated with the pre-existing volume of woody material. The study's calculations show that retained woody biomass immediately following a timber harvest will always add to pre-existing levels. Additional biomass produced as a result of a forest operation in piles and at roadside added 2.4 MM BDT for 2010. This value is the sum of residual biomass associated with potential market biomass and market biomass described in figure E1.

Three harvest configurations were developed to assess how the volume of market biomass produced might change under alternative future views of economic activity. A conservative outlook included lowering harvest levels to 2.1 billion board feet (BBF) in 2015. This outlook took the view that the economic conditions observed in 2010 further deteriorated to 2015, reaching a stable level in 2015. A midrange harvest outlook raised 2015 harvest levels to 3 BBF annual in an expected response to an economic recovery, then fluctuated around a narrow band as economic conditions might fluctuate. The aggressive harvest outlook created harvest levels that were much more responsive in the short term, reaching 3.7 BBF in 2015, then falling back slightly to fluctuate around 3.5 BBF (Figure E3). Future levels of harvest are likely to be within the range embodied by these upper and lower outlooks.

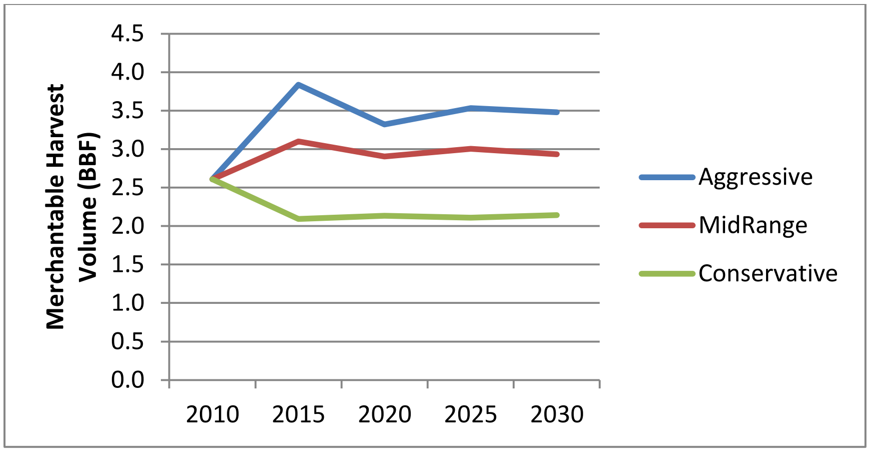


Figure E3. Three harvest configurations used in the assessment

Figure E4 presents the statewide production of potential market biomass volume by management class for the mid-range timber harvest outlook depicted in figure E3. The majority of the potential market biomass was produced by private landowners. The production of potential market biomass was proportional to the timber harvest level.

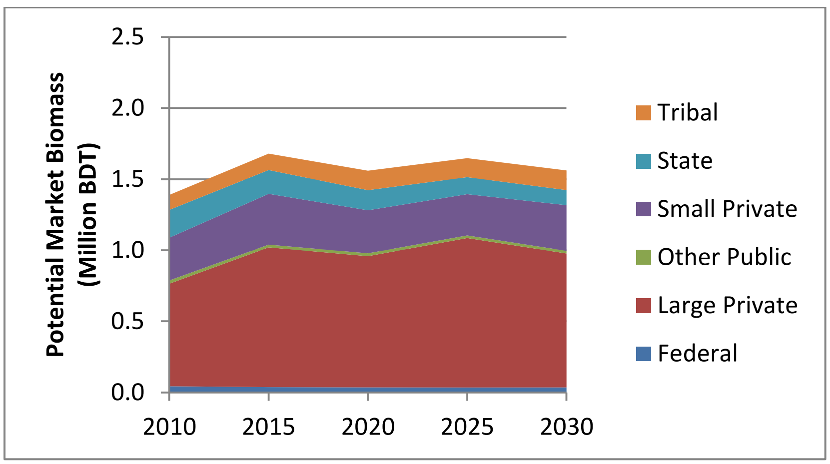


Figure E4. Potential market biomass under a midrange harvest outlook

Aggregate supply was defined using a cost model, the residual value to the landowner, competition from nearby facilities that determined where residuals were sent and market prices. The range of production costs for processing and loading biomass was from $16 to $35 per BDT. The range of hourly rates for transporting processed biomass was from $70 to $115 per hour. Finally, moving equipment to the site ranged from $700 to $1100 per operation. Figure E5 reproduces the market supply functions under the three harvest outlook scenarios depicted in figure E3 for 2015, the period when differences in the harvest volume were greatest. Two points are evident from figure E5. First, existing costs and the availability of potential market biomass suggested that biomass sold to facilities could expand with a small increase in market price per ton, e.g., less than $10 per BDT increase. This is indicated in the figure by the flatness of the curve over a large portion of volume. Second, higher harvest levels increased biomass availability by the same proportional increase in harvest volume. This is indicated in the figure by the shifts in the supply curves from the conservative harvest level (left curve) to the aggressive harvest level (right curve). Changes in the assumptions on cost levels (not shown in Figure E5) also affected biomass supply. The changes led to shifts upwards of the curves as assumptions on production cost associated with processing biomass, and hauling it to facilities increased these costs.

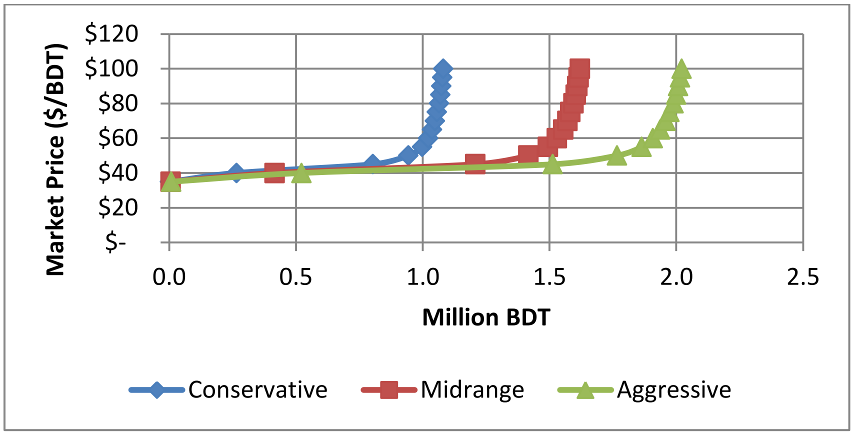


Figure E5. Aggregate biomass supply in 2015 associated with varying levels of timber harvest volume estimated at medium production costs

The research team created a database from their calculations (http://wabiomass.cfr.washington.edu/). Metrics produced from data contained in the study database on BDT per thousand board feet (MBF) and BDT per acre were cross-checked with field interviews and secondary sources (table E1). Per acre measures of biomass retained on site were found to be consistent with these field studies and interviews. The values contained in the study's database appear to be within values needed for ecological functions.

Table E1. Biomass retained on site as a byproduct of a forest operation in BDT per acre. Average vales were weighted by acres.

| | Federal | Large Private | Other Public | Small Private | State | Tribal | AVERAGE |
|---|---|---|---|---|---|---|---|
| **EAST** | 19.18 | 22.66 | 19.69 | 22.12 | 23.98 | 23.43 | 21.95 |
| **DF** | 16.81 | 17.21 | 20.76 | 22.03 | 23.22 | 21.67 | 20.09 |
| **PP** | 20.02 | 18.12 | 15.57 | 16.36 | 21.45 | 20.70 | 18.68 |
| **RA** | | 14.94 | - | 13.81 | 11.66 | 3.49 | 11.86 |
| **TFMC** | 21.00 | 28.22 | 18.87 | 25.43 | 27.62 | 28.75 | 25.27 |
| **WH** | 18.08 | 39.90 | 48.60 | 32.16 | 33.23 | 31.92 | 30.97 |
| **WEST** | 21.94 | 32.92 | 30.66 | 31.55 | 36.68 | 28.35 | 32.14 |
| **DF** | 21.76 | 34.40 | 28.02 | 32.72 | 41.36 | 9.09 | 32.89 |
| **PP** | 11.45 | 12.17 | 8.03 | 12.90 | 16.11 | 15.78 | 13.85 |
| **RA** | 15.87 | 32.37 | 34.15 | 33.14 | 32.32 | 19.51 | 31.09 |
| **TFMC** | 20.11 | 34.53 | 27.36 | 26.54 | 34.38 | 31.61 | 30.13 |
| **WH** | 29.24 | 42.47 | 36.71 | 38.35 | 47.99 | 45.58 | 41.10 |

Source: Biomass database. DF, Douglas fir; PP, Ponderosa pine; RA, Red Alder/Hardwoods; TFMC, True fir/Mixed conifers; WH, Western hemlock; OP, other pine.

An assessment of forest health treatments on Forest Service lands in eastern Washington was completed. An aggressive harvest outlook using heavy thinning options was simulated on eastside Forest Service lands and their production to biomass supply noted. Figure E6 illustrates the shift in market supply associated with this aggressive treatment scenario under 3 costs assumptions. Additional biomass ranged 102,000 BDT to 152,000 BDT at a $100 market price level.  Prices of $45 per BDT suggested biomass availability from 7,300 to 93,000 BDT depending on costs.

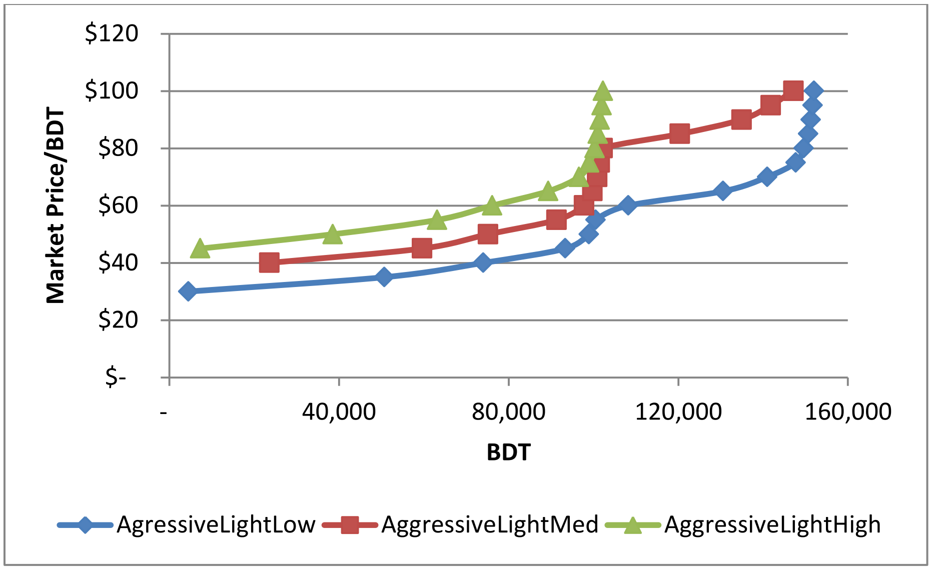


Figure E6. The shift in aggregate supply when forest health treatments in eastern Washington are implemented on Forest Service lands In 2015

The statewide market biomass supply that can be sustained was also calculated.  The sustainable level of biomass was a function the biomass market price.  The study team estimated that from 439,000 to 558,000 BDT of biomass were delivered to facilities in 2010.  Figure E7 combines the market supply under the medium cost level for 2010 with the estimated range in demand.  With market prices slightly higher than current values, the amount of market biomass supplied could double at current timber harvest levels.  Potential market biomass was available to meet a doubling of demand.  Currently market conditions constrained this material to be retained on site in piles or along roadside.  At levels greater than 1 million BDT of market biomass, competition among facilities over the limited amount supplied was evident.  At some facilities, there appears to be competitive factors that restrict supplies locally, bidding prices higher.  The 2010 market could have sustained the production of 1.3 MM BDT at a price of $100 per BDT.

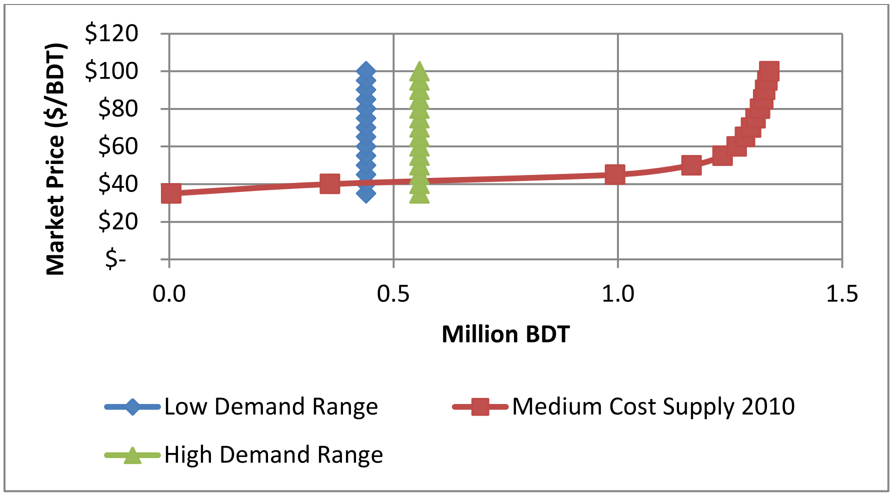


Figure E7. Market supply and demand In 2010

In general, most forest landowners and land managers indicated that the byproduct of their harvest or treatment operations was piled and burned, remained dispersed throughout the unit, or was hauled back and scattered throughout the unit, if biomass recovery was not a viable option. This response was supported by our database calculations. Our calculations revealed that only 14% of the post-timber harvest biomass was marketed (see figure E1). From interviews, the study team summarized that much of the post-timber harvest material was unanimously characterized as unsuited for current market conditions or material not meeting contract removal specifications. This response reflects merchandizing specifications for local and regional markets, species composition, and access to pulp log or niche product markets (e.g., fuel pellets). Material unsuited for markets typically consists of breakage during harvesting, defect culled during log manufacturing, stumps, undersize stems or top diameter, limbs, twigs and needles or leaves. Stumps are typically not included as recoverable biomass, with some exceptions occurring during road right-of-way construction requiring stump removal. However, including soil or rock material embedded within the roots can contaminate the biomass and increase ash content to unacceptable levels.

While the study did not attempt to sort the type of biomass into categories, such a system may yield significant improvements in recovery metrics. Value-added improvements may be as simple as slight modifications to timber harvest operation protocols, stacking and piling that creates opportunities to extract the higher-valued material or other changes in practices to concentrate the most valued material at roadside. In addition, there is likely to be some production efficiency gains in both harvest configuration and operability if market prices were to increase.