2021 Biomass Production Costs for the 2024 Billion Ton Analysis

July, 2024

Adapted from version 3/7/2023

Compiled by Burton English, University of Tennessee

List of Tables

Introduction

The Forest Sustainable and Economic Analysis Model (ForSEAM) is a linear programming model that can be used to estimate forestland production over time, and its capacity to produce not only traditional forest products but also products of woody biomass to meet energy feedstock demand. It minimizes cost subject to a set of demands and forest inventory. Once solved, ForSEAM generates information on the quantity and types of woody biomass that can be available as energy feedstock with respect to certain marginal costs at the 305 Crop Report District (CRD) level of United States (Figure 1).

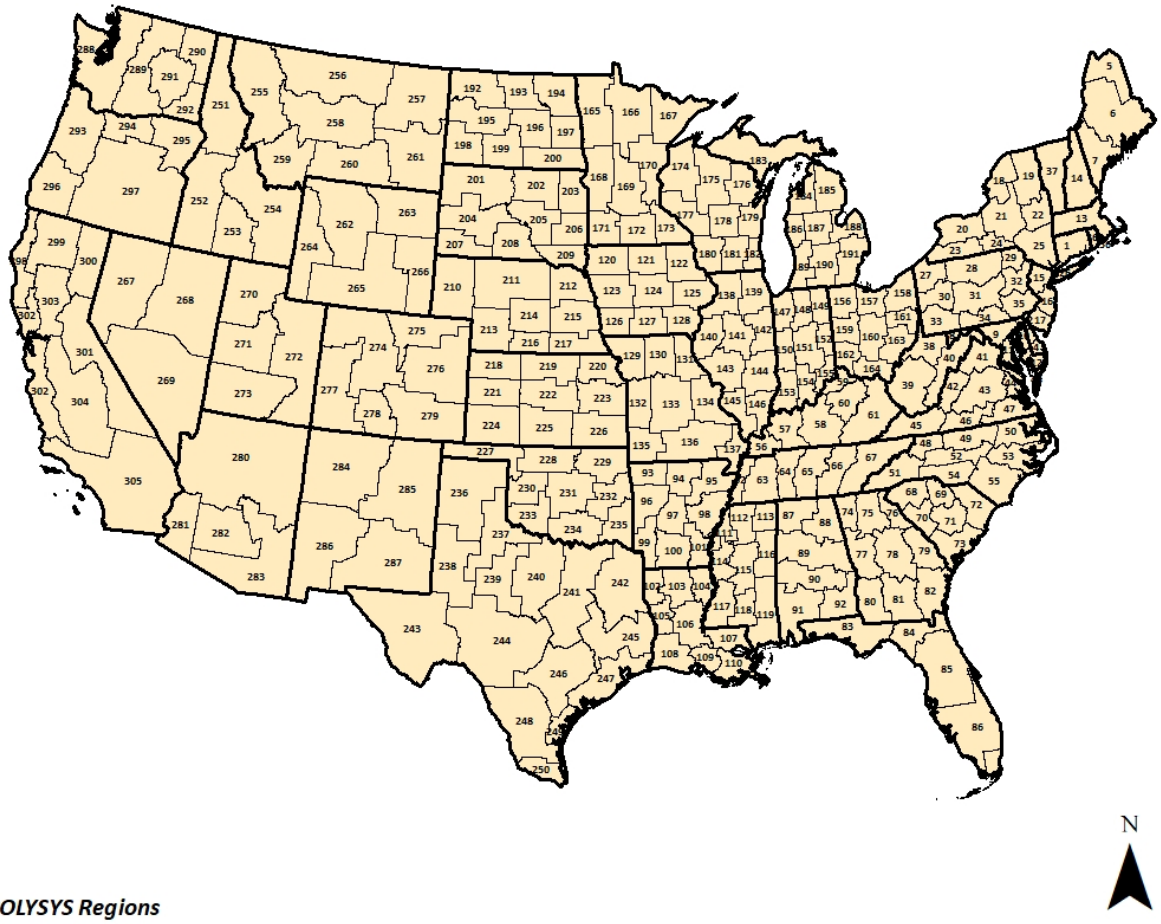

Figure 1. The 305 POLYSYS Regions

Model Description of ForSEAM

ForSEAM is divided into three major sections including supply, demand, and sustainability. The supply component includes general timber production activities for 305 production regions or crop reporting districts (CRD). Each region has a set of production activities defined by the U.S. Forest Service (Stokes, 2014). These production activities include saw timber, pulpwood, and energy feedstock (woody biomass) (He et al., 2014). Two sources of energy feedstock are considered in the model: logging residue generated from sawtimber and pulpwood harvest activities and removal of whole pulpwood and un-merchantable trees. Production costs for traditional forest activities and for biomass in the model include stumpage, harvest, and transporting the material to the forest landing. Whole trees are transported to the forest landing where they are bucked and delimbed. The logs are then assumed to be used for meeting traditional demands and the remaining material is available as energy feedstock. Whole pulpwood and non-merchantable trees are also available as an energy feedstock. The Biomass is assumed to be chipped at the landing and placed in a truck ready to be hauled to a bioenergy facility. Transportation costs are therefore not included in the ForSEAM model as precise location of bioenergy facilities are not known. The Demand component is based on U.S. Forest Service Scenarios with estimates developed by the U.S. Forest Products Module (USFPM). The sustainability component ensures that harvest in each region does not exceed annual growth, that roads have been constructed so that forest tracts considered are located within a mile of these roads, and that current year forest attributes reflect previous year's conventional wood product harvests and woody biomass energy feedstock removals. Dynamic tracking of forest growth is incorporated into the analysis (He et al., 2016).

Objective

This purpose of this publication is to describe how the harvest costs inherent in the

production of logs and biomass feedstock were updated from 2014 dollars to early 2022 dollars. The costs of harvest and skidding material to the landing along with the chipping cost are based on information provided for the 2016 billion Ton report (U.S. Department of Energy, 2016) (Appendix Tables A.1 through A.4). In that report, costs were developed for 17 different forest silvicultural and harvest methods (Table Appendix A.4) with some designed as thinning the current forest and others as clearcutting.

Methodology

Of the 17 systems, six were assigned as thinning to different forest production zones and six reflecting clearcuttings. Of the 17 forest harvest systems (FHS), 12 were assigned to be representative to the 5 different cost production zones (Figure 2). FHS for thinning included

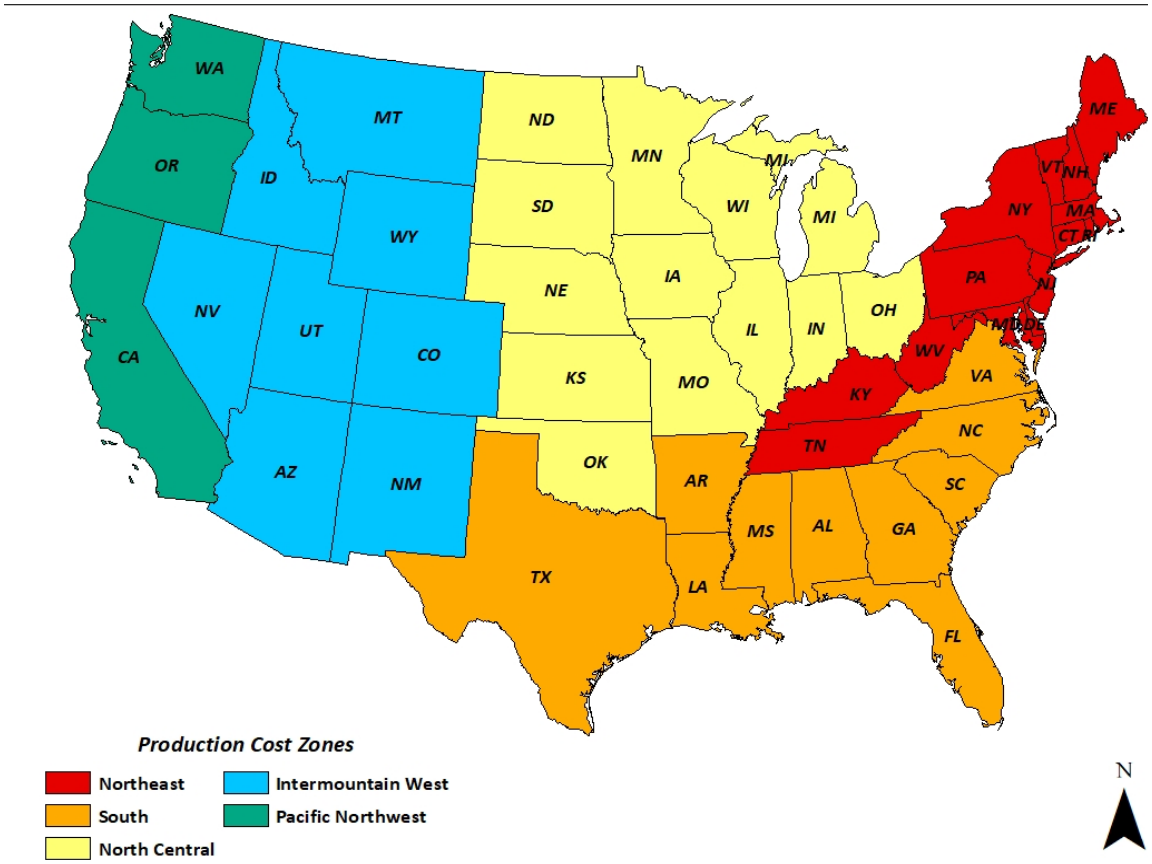

Figure 2. Cost of Harvest Production Zones

systems 1, 3, 5, 6, 10, and 12; for clearcutting the forest harvest systems included 1, 2, 3, 4, 11, and 13. Systems 7, 8, 9, 14 through 17 were not assigned as representative in any production zone. The FHS assignments are displayed in Table 1.

Table 1. Forest Harvest Systems and the regions[a] they represent hardwoods, softwoods, and mixed using silvicultural methods of thinning and clearcut.

FHS	Upland	Bottomland	Natural Pine	Planted Pine	Mixed
			Thinning		
1	NE, NC	NE, NC			
3			NE, IW, PNW	IW, PNW	NE, S, IW, PNW
5	S	S			
6			S, NC	NE, NC, S	NC
10			IW, PNW >40%[b]		
12			NC, IW CTL Opt[c]	NC, IW CTL Opt	
16	BMO[d]	BMO	BMO	BMO	BMO
			Clear Cut		
1	NC				
2	NE				
4	S	NE, NC, S	IW, PNW	IW, PNW	NE, S, IW, PNW
7			NE, NC, S	NE, NC, S	NC
11			IW, PNW >40%		
13			NC, IW CTL Opt		
17	BMO	BMO	BMO	BMO	BMO

[a] Region abbreviations used in the table are as follows: Intermountain west (IW), Northeast (NE), North Central (NC), Pacific Northwest (PNW), and South (S).
[b] >40% indicates the practice is used on timber located in areas where the slope is greater than 40%
[c] CTL Opt indicates this is used if the cut to length option is used.
[d] BMO is a Biomass Only harvesting system.

The ForSEAM model production activities include tree type, slope, and dbh (diameter at breast height). These are shown in Table 2. In addition to traditional forest management practices, a method used when harvest softwood on slopes greater than 40% is modelled. However, if harvest occurs on land with a topography characterized by slopes greater than 40 degrees, a cable system is assumed, and no forest residues are removed. The costs of production

estimates currently used in ForSEAM's production activities are based on Forest Service 2014 estimates on the 17 Forest Harvest Systems (FHS). The FHS consist of two to four subcomponents. Each component of the system has a machinery cost and a labor cost and are used to determine the cost on a bone-dry ton basis. For instance, elements of FHS_1 are defined in Table 3. Each piece of equipment has an estimated per scheduled hour machinery and labor costs. These costs are used in determining the per dry ton of each subcomponent using equation

Table 2. Criteria used to develop forest harvest activities in ForSEAM.

1.

Tree Type	dbh	Slope
Pulpwood:		
Hardwood	5-10"	< 40"
Softwood	5-11"	< 40"
Sawtimber		
Hardwood	> 10"	< 40"
Softwood	> 11"	< 40"
Other		
Hardwood	< 5"	< 40"
Softwood	< 5"	< 40"
Un-merchantable		
Hardwood	?	< 40"
Softwood	?	< 40"

Table 3. Costs of a thinning operation in ForSEAM for Forest Harvest System 1 by subcomponent used in the 2016 Billion Ton Update.

Subcomponent of FHS1	Value of the subcomponents for FHS 1 ($SC_{i,j}^{2014}$)	Proportion of subcomponent $(\frac{SC_{1,j}^{2014}}{TC_1^{2014}})$	Machinery Cost ($C_{1,j,1}^{2014}$)	Labor Cost ($C_{1,j,2}^{2014}$)
	$/bdt		$ / SMH	$ / SMH
IW Hand Felling, Thin	$9.17	21%	3	25
IW Large Cable Skidder, Thin	$13.99	32%	50	20
IW Chainsaw Delimbing	$7.08	16%	0.62	35
IW Medium Loader	$6.79	16%	35	25
Medium Whole Tree Chipper	$6.37	15%	180	35
Total Cost (TC^{2014})	$43.40	100%		

Source: (Stokes, 2014)

$$TC_i^{2021} = \sum_j^n (SC_{i,j}^{2014} + \left(\left(\sum_{k=1}^{2} \left(C_{i,j,k}^{2014} * \frac{PI_k^{2021}}{PI_k^{2014}} \right) \right) * \left(\frac{C_{i,j,k}^{2014}}{\sum_{k=1}^{2} C_{i,j,k}^{2014}} \right) \right) \quad (1)$$

i = (1, 2, 3 ... 17) for the FHS, j = 1, 2, … 4) for the FHS subcomponents, and k = 1,2 for the machinery operation and labor costs.

Where:

TC_i is the cost of FHS i in 2021 dollars;

$C_{i,j,k}^{2014}$ is the 2014 k cost of subcomponent j in FHS i;

$SC_{i,j}^{2014}$ is the 2014 subcomponent j cost of FHS i;

PI_k^{2021} is the production cost index for cost k for January 2021; and

PI_k^{2014} is the production cost index for cost k in January 2014.

The change in cost between 2014 and the end of 2021 are estimates using indices from the Occupational Employment and Wage Statistics for labor cost (Table 4) and the PPI Commodity Data survey's Agricultural Machinery and Equipment, less parts special index data for machine costs.

Table 4. PI_k indices used in upgrading costs from 2014 to 2021.

	Time observed				
Cost Item (k)	Time period	2014	Time period	2021	Factor $(\frac{PI_k^{2022}}{PI_k^{2014}})$
Machinery Cost	Jan-2014	225.9	Jan-22	286.5	1.212
Labor Cost (loggers)	First quarter 2014	117.3	Fourth quarter 2021	150.2	1.280

Sources are from the Bureau of Labor Statistics Data Viewer for PPI Commodity Data for Special indexes-Agriculture machinery and equipment, less parts, not seasonally adjusted and private industry workers.

Results

The HPC costs were estimated for all 17 systems (Table 5). Using the same process, the

chipper costs were estimated independent of other FHS components (Table 6). Allocation of both the HPC and the chipper costs to their Production Cost Zones similar to Appendix Tables A.1-A.3 is shown in Table 7. The January 2022 cost to harvest trees and bring them to the landing is estimated at between $28 and $88 depending on the harvest system typically used. In general, systems used in clearcut operations use larger equipment than the thinning operations and are less expensive per bone dry ton. In addition, a cost of ranges between $7 and $8 per bone dry ton for chipping the residue, unmerchantable material or pulpwood destined for an energy feedstock. Estimated total cost ranges from $35 to $88 per bdt depending on the FHS.

Table 5. Estimated Change in Harvest Production Costs ($/bdt) not including chipping from 2014 thru 2021.

Forest Harvest System	2014$	2021$	Percent Change	Forest Harvest System	2014$	2021$	Percent Change
1	$37.03	$46.38	20.2%	9	$26.94	$33.18	18.8%
2	$34.84	$43.60	20.1%	10	$44.29	$55.82	20.7%
3	$33.32	$41.47	19.7%	11	$30.21	$38.08	20.7%
4	$30.01	$37.31	19.5%	12	$71.65	$88.26	18.8%
5	$34.96	$44.10	19.6%	13	$53.06	$65.12	18.5%
5a	$30.01	$37.31	19.5%	14	$27.88	$34.44	19.1%
6	$31.88	$39.37	19.0%	15	$22.93	$28.25	18.8%
7	$26.94	$33.18	18.8%	16	$27.88	$34.44	19.1%
8	$31.88	$39.37	19.0%	17	$22.93	$28.25	18.8%

Table 6. Estimated Change in Chipping Costs ($/bdt) from 2014 to 2021.

Forest Harvest System	2014$	2021$	Percent Change		2014$	2021$	Percent Change
1	$6.37	$7.79	18.2%	9	$5.89	$7.19	18.1%
2	$5.89	$7.19	18.1%	10	$6.37	$7.79	18.2%
3	$6.37	$7.79	18.2%	11	$5.89	$7.19	18.1%
4	$5.89	$7.19	18.1%	12			
5	$6.37	$7.79	18.1%	13			
5a	$5.89	$7.19	18.1%	14	$6.37	$7.79	18.2%
6	$6.37	$7.79	18.2%	15	$5.89	$7.19	18.1%
7	$5.89	$7.19	18.1%	16	$6.37	$7.79	18.2%
8	$6.37	$7.79	18.2%	17	$5.89	$7.19	18.1%

Table 7. Forest production costs including felling, skidding, delimbing, and chipping into a truck at the landing ($/bdt).

Forest Cost Production Zones	Upland Hardwood		Bottomland Hardwood		Natural Softwood		Plantation Softwood		Mixed	
	Thin	Clearcut	Thin	Clearcut	Thin	Clearcut	Thin	Clearcut	Thin	Clearcut
NE <40%	$54.17	$50.79	$54.17	$44.49	$49.26	$40.37	$47.16	$40.37	$49.26	$44.49
South <40%	$51.29	$44.49	$51.29	$44.49	$47.16	$40.37	$47.16	$40.37	$49.26	$44.49
NC <40%	$54.17	$54.17	$54.17	$44.49	$47.16	$40.37	$47.16	$40.37	$47.16	$40.37
IW <40%					$49.26	$44.49	$49.26	$44.49	$49.26	$44.49
PNW <40%					$49.26	$44.49	$49.26	$44.49	$49.26	$44.49
PNW >40%					$63.61	$45.27				
IW>40%					$63.61	$45.27				
IW CTL option					$88.26	$65.12				
NC CTL option					$88.26	$65.12				
Biomass Only	$42.22	$35.43	$42.22	$35.43	$42.22	$35.43	$42.22	$35.43	$42.22	$35.43

References

Bryce Stokes (2014), Burton_draft_costs, attached spreadsheet to an email resent in February 2023 from Matthew Langholtz .

He, L., B. C. English, D. G. De La Torre Ugarte, and D. G. Hodges. 2014. Woody biomass potential for energy feedstock in United States. Journal of Forest Economics, 20(2), 174-191. doi: http://dx.doi.org/10.1016/j.jfe.2014.04.002.

He, L., B. C. English, R. J. Menard, and D. M. Lambert. 2016. Regional Woody Biomass Supply and Economic Impacts from Harvesting in the Southern US. Energy Economics, 60:151-161. doi:10.1016/j.eneco.2016.09.007

U. S. Bureau of Labor Statistics, BLS Data Viewer for PPI Commodity Data for Special indexes-Agriculture machinery and equipment, less parts, not seasonally adjusted, last accessed at https://beta.bls.gov/dataViewer/view/timeseries/WPUSI021012 on 3/7/2023

U. S. Bureau of Labor Statistics, BLS Data Viewer for Wages and Salaries for Private Industry Workers in Production. https://beta.bls.gov/dataViewer/view/timeseries/CIS2020000510000I on 3/7/2023

U.S. Department of Energy. 2016. 2016 Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy, Volume 1: Economic Availability of Feedstocks. M. H. Langholtz, B. J. Stokes, and L. M. Eaton (Leads), ORNL/TM-2016/160. Oak Ridge National Laboratory, Oak Ridge, TN. 448p. doi: 10.2172/1271651. http://energy.gov/eere/bioenergy/2016-billion-ton-report

Appendix: Information available from the 2016 Billion Ton Update Analysis

Appendix Table A.1. Estimated harvest and chipped material cost at the landing of upland and bottomland hardwood a slope of less than 40 percent for the Northeast, North Central, and Southern Production Cost Zones ($/dry ton).

Forest Cost Production Zones	Upland Hardwood				Bottomland Hardwood			
	Thin		Clearcut		Thin		Clearcut	
Region	Timber	Chipper	Timber	Chipper	Timber	Chipper	Timber	Chipper
NE <40%	37.03	10.07	34.84	9.37	37.03	10.07	30.01	8.89
South <40%	34.96	9.87	30.01	8.89	34.96	9.87	30.01	8.89
NC <40%	37.03	10.07	37.03	10.07	37.03	10.07	30.01	8.89
Biomass Only		34.25		28.82		34.25		28.82

Biomass Only is harvesting everything for biomass, so the "chipper" cost is total cost.

Source: (Stokes, 2014)

Appendix Table A.2. Estimated costs of harvest and chipped material at the landing of planted and natural softwood having a slope of less than 40 and greater than 40 percent for the Northeast, North Central, Southern, Intermountain, and pacific northwest Production Cost Zones developed in April 2014 ($/dry ton).

	Natural Softwood					Plantation Softwood			
Region	Thin Timber	Chipper	Clearcut Timber	Chipper		Thin Timber	Chipper	Clearcut Timber	Chipper
NE <40%	33.32	9.70	30.01	8.89	NE <40%	31.88	9.56	26.94	8.58
South <40%	31.88	9.56	26.94	8.58	South <40%	31.88	9.56	26.94	8.58
NC <40%	31.88	9.56	26.94	8.58	NC <40%	31.88	9.56	26.94	8.58
IW <40%	33.32	9.70	30.01	8.89	IW <40%	33.32	9.70	30.01	8.89
PNW <40%	33.32	9.70	30.01	8.89	PNW <40%	33.32	9.70	30.01	8.89
PNW >40%	44.29	10.80	30.21	5.89	PNW >40%	44.29	10.80	30.21	8.91
IW>40%	44.29	10.80	30.21	5.89	IW>40%	44.29	10.80	30.21	8.91
IW CTL option	71.65		53.06		IW CTL option	71.65		53.06	
NC CTL option	71.65		53.06		NC CTL option	71.65		53.06	
Biomass Only		34.25		28.82	Biomass Only		34.25		28.82

Biomass Only is harvesting everything for biomass, so the "chipper" cost is total cost.

Source: (Stokes, 2014)

Appendix Table A.3. Estimated costs of harvest and chipped material at the landing of mixed hardwood and softwood stands having a slope of less than 40 and greater than 40 percent for the Northeast (NE), North Central (NC), Southern (S), Intermountain (IW), and Pacific Northwest (PNW) ($/bdt).

	Mixed Hardwood and Softwood			
Region	Thin Timber	Chipper	Clearcut Timber	Chipper
NE <40%	33.32	9.70	30.01	8.89
South <40%	33.32	9.70	30.01	8.89
NC <40%	31.88	9.56	26.94	8.58
IW <40%	33.32	9.70	30.01	8.89
PNW <40%	33.32	9.70	30.01	8.89
PNW >40%				
IW>40%				
IW CTL option	71.65		53.06	
NC CTL option	71.65		53.06	
Biomass Only		34.25		28.82

Biomass Only is harvesting everything for biomass, so the "chipper" cost is total cost.

Source: (Stokes, 2014)

Appendix Table A.4. Selected Harvest Systems used in ForSEAM.

System Design Number		Forest Operation	Cost ($/dry ton)	Forest Operation Description
1	T-S-CS-S-NC	Thin	$9.17	IW Hand Felling, Thin
			$13.99	IW Large Cable Skidder, Thin
			$7.08	IW Chainsaw Delimbing
			$6.79	IW Medium Loader
	T-S-CS-S-NC	Thin	$37.03	Total Timber
	B-S-CS-S-C	Thin	$6.37	Medium Whole Tree Chipper
2	T-S-CS-S-NC	CC	$8.56	IW Hand Felling, CC
			$13.99	IW Large Cable Skidder, Thin
			$7.08	IW Chainsaw Delimbing
			$5.20	IW Large Loader
	T-S-CS-S-NC	CC	$34.84	Total Timber
	B-S-CS-S-C	CC	$5.89	Large Whole Tree Chipper
3	T-SFB-GS-S-NC	Thin	$3.84	IW Medium Feller Buncher, Thin
			$15.61	IW Medium Grapple Skidder, Thin
			$7.08	IW Chainsaw Delimbing
			$6.79	IW Medium Loader
	T-SFB-GS-S-NC	Thin	$33.32	Total Timber
	B-SFB-GS-S-C	Thin	$6.37	Medium Whole Tree Chipper
4	T-SFB-GS-S-NC	CC	$4.56	IW Large Feller Buncher, CC
			$13.17	IW Large Grapple Skidder, CC
			$7.08	IW Chainsaw Delimbing
			$5.20	IW Large Loader
	T-SFB-GS-S-NC	CC	$30.01	Total Timber
	B-SFB-GS-S-C	CC	$5.89	Large Whole Tree Chipper
5	T-RTFB-GS-S-NC	Thin	$5.48	IW Medium Feller Buncher, Thin
			$15.61	IW Medium Grapple Skidder, Thin
			$7.08	IW Chainsaw Delimbing
			$6.79	IW Medium Loader
	T-RTFB-GS-S-NC	Thin	$34.96	Total Timber
	B-RTFB-GS-S-NC	Thin	$6.37	Medium Whole Tree Chipper
	T-RTFB-GS-S-NC	CC	$4.56	IW Large Feller Buncher, CC
			$13.17	IW Large Grapple Skidder, CC
			$7.08	IW Chainsaw Delimbing
			$5.20	IW Large Loader
	T-RTFB-GS-S-NC	CC	$30.01	Total Timber

System Design Number		Forest Operation	Cost ($/dry ton)	Forest Operation Description
	B-RTFB-GS-S-NC	CC	$5.89	Large Whole Tree Chipper
6	T-SFB-GS-MD-NC	Thin	$5.48	IW Medium Feller Buncher, Thin
			$15.61	IW Medium Grapple Skidder, Thin
			$4.01	IW Fixed Base Landing Delimber
			$6.79	IW Medium Loader
	T-SFB-GS-MD-NC	Thin	$31.88	Total Timber
	B-SFB-GS-MD-NC	Thin	$6.37	Medium Whole Tree Chipper
7	T-SFB-GS-MD-NC	CC	$4.56	IW Large Feller Buncher, CC
			$13.17	IW Large Grapple Skidder, CC
			$4.01	IW Fixed Base Landing Delimber
			$5.20	IW Large Loader
	T-SFB-GS-MD-NC	CC	$26.94	Total Timber
	B-SFB-GS-MD-NC	CC	$5.89	Large Whole Tree Chipper
8	T-RTFB-GS-MD-NC	Thin	$5.48	IW Medium Feller Buncher, Thin
			$15.61	IW Medium Grapple Skidder, Thin
			$4.01	IW Fixed Base Landing Delimber
			$6.79	IW Medium Loader
	T-RTFB-GS-MD-NC	Thin	$31.88	Total Timber
	B-RTFB-GS-MD-NC	Thin	$6.37	Medium Whole Tree Chipper
9	T-RTFB-GS-MD-NC	CC	$4.56	IW Large Feller Buncher, CC
			$13.17	IW Large Grapple Skidder, CC
			$4.01	IW Fixed Base Landing Delimber
			$5.20	IW Large Loader
	T-RTFB-GS-MD-NC	CC	$26.94	Total Timber
	B-RTFB-GS-MD-NC	CC	$5.89	Large Whole Tree Chipper
10	T-S-CY-S-NC	Thin	$9.17	IW Hand Felling, Thin
			$21.25	IW Medium Skyline, Thin
			$7.08	IW Chainsaw Delimbing
			$6.79	IW Medium Loader
	T-S-CY-S-NC	Thin	$44.29	Total Timber
	B-S-CY-S-C	Thin	$6.37	Medium Whole Tree Chipper
11	T-S-CY-S-NC	CC	$8.56	IW Hand Felling, CC

System Design Number		Forest Operation	Cost ($/dry ton)	Forest Operation Description
			$9.37	IW Large Skyline, CC
			$7.08	IW Chainsaw Delimbing
			$5.20	IW Large Loader
	T-S-CY-S-NC	CC	$30.21	Total Timber
	B-S-CY-S-C	CC	$5.89	Large Whole Tree Chipper
12	T-H-F-NC	Thin	$38.63	IW Small Cut to Length Processor, Thin
			$33.02	IW Medium Forwarder, Thin
	T-H-F-NC	Thin	$71.65	Total Timber
13	T-H-F-NC	CC	$24.68	IW Large Cut to Lenth Processor, CC
			$28.38	IW Large Forwarder, Thin
	T-H-F-NC	CC	$53.06	Total Timber
14	B-SFB-GS-C	Thin	$5.48	IW Medium Feller Buncher, Thin
			$15.61	IW Medium Grapple Skidder, Thin
			$6.79	IW Medium Loader
			$6.37	Medium Whole Tree Chipper
	B-SFB-GS-C	Thin	$34.25	Total Cost
15	B-SFB-GS-C	CC	$4.56	IW Large Feller Buncher, CC
			$13.17	IW Large Grapple Skidder, CC
			$5.20	IW Large Loader
			$5.89	Large Whole Tree Chipper
	B-SFB-GS-C	CC	$28.82	Total Cost
16	B-RTFB-GS-C	Thin	$5.48	IW Medium Feller Buncher, Thin
			$15.61	IW Medium Grapple Skidder, Thin
			$6.79	IW Medium Loader
			$6.37	Medium Whole Tree Chipper
	B-RTFB-GS-C	Thin	$34.25	Total Cost
17	B-RTFB-GS-C	CC	$4.56	IW Large Feller Buncher, CC
			$13.17	IW Large Grapple Skidder, CC
			$5.20	IW Large Loader
			$5.89	Large Whole Tree Chipper
	B-RTFB-GS-C	CC	$28.82	Total Cost
			$9.17	