Forest-based biomass supply curves for the U.S.

Kenneth Skog[1] Jamie Barbour[2], Marilyn Buford[3], Dennis Dykstra[2], Patti Lebow[1], Pat Miles[4], Bob Perlack[5], Bryce Stokes[6]

Abstract. Nationwide county level supply curves have been estimated for forest-based biomass in order to help evaluate their potential contributions to producing bioenergy and biofuels. These estimates build on the estimates of potential supply in the USDA/ DOE Billion ton biomass supply study. Forest biomass sources include logging residue, thinnings, other removals, unused mill residue, urban wood waste and conventional sourced wood (pulpwood size material). To make the estimates it is assumed that lower cost forest biomass will be supplied by in integrated harvesting operations which also remove sawlogs and pulpwood. It is assumed that such removals can be estimated at the county level in two ways. First as a portion of recent estimates of logging residues and second by simulated thinning operations that use tops, branches and small trees for biomass. Supply from thinning dense forest stands is assumed to occur over 30 years as in the original Billion Ton Supply Study. Harvest and stumpage costs are estimated for each of these methods. Final supply estimates for each county assume supply that is half way between the two estimates. Preliminary forest and agricultural biomass supply estimates have been used to indicate that for about $44 per oven dry ton (odt) at roadside or farm gate forest and agricultural feedstocks could produce 20 billion gallons of advanced biofuels as called for under the 2007 Energy Independence and Security Act. Forests could provide about 40 million odt of biomass per year at about $44 per odt to produce 4 billion gallons and agricultural feedstocks could provide about 200 million odt and produce 20 billion gallons of biofuel.

Introduction

In 2005 researchers from USDA and USDOE prepared estimates of potential biomass supply for bioenergy and bioproducts from forest and agricultural sources (Perlack et al. 2005). That report suggested a potential supply of 1.3 billion dry tons of biomass per year. of the estimates reported here build on the methods in that report and estimate biomass supply amounts and roadside costs (supply curves) for each county in the U.S.

This paper provides estimates of potential biomass supply for bioenergy and biofuels for the U.S. from selected forest based sources. In this paper we use the term "biomass" to mean material that may be used for bioenergy or biofuels production, and, excludes – with one exception – wood sources that are currently used to make wood products. For some biomass sources we have estimates of county level supply curves and for other sources we currently have only preliminary national supply estimates and detailed county estimates will follow. The sources include 1) logging residue, 2) thinnings from timberland and other forest land, 3) wood from "other forest removals" such as land clearing and forest cultural operations, 4) wood and bark residue from

[1] USDA Forest Service, Forest Products Laboratory, Madison, WI
[2] USDA Forest Service, Pacific Northwest Research Station, Portland, OR
[3] USDA Forest Service, Research Staff, Washington, DC
[4] USDA Forest Service, Northern Research Station, St. Paul, MN
[5] USDOE Oak Ridge National Laboratory, Oak Ridge, TN
[6] USDOE, Washington, DC; Formerly USDA Forest Service, Research Staff, Washington, DC

primary wood products mills, 5) urban wood waste, and 6) conventionally sourced wood such pulpwood sized roundwood. These sources include kinds and amounts of wood that are not currently used for products such as logging residue and biomass from thinnings, and some sources that are already used extensively for products including mill residue and conventionally sourced wood (pulpwood).

We do not include estimates of pulp liquor from pulp and paper mill which is already used for production of heat and power nor do we include estimates of supply from short rotation woody crops that are being developed separately in conjunction with estimates for other agricultural sources. We also do not include, in these initial estimates, potential amounts of wood from "other forest" land. There is a large area of Pinyon-Juniper forest in the West that could provide biomass but is currently much more expensive to obtain than biomass from timberland – a current estimate is over $60 per oven dry ton (odt) at roadside (WGA XXXX).

Methods

Estimates of forest biomass supply were developed for several sources by first identifying sustainability principles to guide their use. Specific guidelines are noted for each source discussed. In general terms sustainability means today's management actions will not degrade the ecological functioning of a natural system (Helms 1998). In the context of biomass removal from forests, the question of sustainability requires consideration of a wide range of issues, including: nutrient cycling and soil productivity, maintenance of biodiversity, water quality, and wildlife habitat. These factors, and resulting constraints on forest operations to address these concerns, are generally very site-specific. Soil productivity in certain soil types, for example, may be more sensitive to micro-nutrient levels and thus require retention of some level of woody residue. Wildlife habitat requirements may stipulate retention of snags or maintenance of coarse woody debris. Again, ecological factors including wildlife and endangered species need careful site specific evaluations in determining biomass availability.

Sustainability is addressed in this analysis through several assumptions. The potential forest biomass supply that is modeled here is a secondary output of other management objectives. We consider biomass that would be available from forest health treatments, fire hazard reduction work, or treatment of activity fuels after logging where questions of sustainability are addressed in the larger management plan. The assessment also assumes ecological considerations and practical limitations would reduce the amount of biomass available for removal and utilization. The process we used models silvicultural treatments and estimates total available biomass. The total available biomass is then further reduced to reflect material left on site to meet ecological constraints or is otherwise impractical to remove. The reduced amount is the net biomass available for removal.

In this paper we provide detailed methods and county level supply curves for biomass from 1) thinnings and logging residue, 2) other forest removals, and 3) wood and bark from mill residue. For urban wood waste and conventionally sourced wood we show national supply estimates.

For the first three sources of the six noted above, county level forest biomass supply curves are estimated for 1) non-federal forest land alone and 2) all forest land. The estimates are for forest biomass supply in the near term – for the next 5-10 years and presume a recovery of harvest in the forest sector to levels of production in 2006-2007.

Integrated harvesting operations – Thinnings and/ or logging residue from timberland

It is assumed a major source of lower cost biomass will be wood and bark taken from harvest sites where sawlogs and pulpwood are also taken in integrated harvesting operations. This removes fuels which would otherwise contribute to fire hazard. We assume integrated harvesting would take the form of removing whole trees to roadside where tops and branches are removed and chipped for biomass for fuel. Integrated operations would also remove small trees (less than 5 inches) to roadside where they could be chipped.

We use two methods to estimate the possible biomass amounts and roadside costs from these integrated operations. After making separate estimates by the two methods we combine them in a single estimate as noted later. Roadside costs include cost to harvest and move wood to roadside, cost of chipping at roadside, and cost for stumpage (cost per ton for biomass in standing trees).

Logging residue based estimates - The first way we estimate biomass supply by county is to take a fraction of estimated logging residue left from recent harvesting operations as estimated in the USDA Forest Service Timber product output database for 2007 (USDA FS 2008). It is assumed that 65% and 50% of logging residue can be moved to roadside from private and public forest land, respectively. These are the same removal fractions assumed in the Billion Ton Supply report (Perlack et al. 2005). It is assumed that most of logging residue is moved to roadside as part of whole trees and the only additional costs will be for chipping at roadside (varies by region, about $13/ odt) and the cost for stumpage. Chipping costs were determined by the FRCS model (Fight et al. 2006) as modified and expanded to cover the U.S. North and South as well as the West.[7] FRCS is used to estimate the costs of providing biomass at roadside using any of three alternative harvesting systems—ground-based, whole-tree harvesting with mechanized felling; ground-based, whole-tree harvesting with manual felling; or cable yarding of whole trees that have been manually felled.

The stumpage cost is assumed to be zero for logging residue biomass from federal land and range from $4/ odt to 90% of pulpwood stumpage price for private land. The stumpage price for logging residue from private land is assumed to increase from $4/odt when the first ton of logging residue is used up to 90% of pulpwood stumpage price (Table 1) when 100% of available logging residue used. Where the 100% level of available logging residue is estimated to be 65% and 50% of total logging residue generated as noted above.

Thinning simulation based estimates - The second way we estimate biomass supply by county for integrated operations is to simulate uneven-aged thinning operations on all timberland in the U.S. – as represented by Forest Service forest inventory (FIA) plots on timberland (Smith et al. 2004) – where stand density index is greater than 30% of maximum stand density index for the given forest type (Shepperd 2007). This simulates thinnings to reduce fire hazard and to improve forest health. Uneven aged thinnings are simulated and estimates are made of the amounts of biomass, poletimber and sawtimber that are removed. For the West, biomass removals include 1) all wood from trees 1 to 7 inches dbh and 2) tops and branches of trees greater than 7 inches dbh. For the North and South, biomass removals include 1) all wood from trees 1 to 5 inches dbh and 2) tops and branches of trees greater than 5 inches dbh.

[7] The FRCS model has been updated and modified to make harvest cost estimates for the North and South by Dennis Dykstra, USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

It is assumed that all of the small-tree biomass can be extracted to roadside, but that only 80 percent of the volume in tops and branches of larger tress will make it to roadside due to breakage.

It is assumed that the only costs for tops and braches will be for chipping at roadside and the cost for stumpage. It is assumed that the cost to remove small trees will be the total cost for harvesting and hauling them to roadside as estimated by the FRCS model (which includes a cost for chipping) plus a cost for stumpage[8]. It is assumed that the simulated amounts of biomass supply will be harvested over a 30 year period. This is the same period assumed for thinnings estimates provided in the Billion Ton Biomass Supply report (Perlack et al. 2005).

Stumpage cost is assumed to be zero for biomass from federal land and $4/ odt to 90% of pulpwood stumpage price for private land. The stumpage price for private land is assumed to increase linearly from $4/odt for the first ton of biomass produced, to 90% of pulpwood stumpage price (Table 1) when the simulated removal of sawlogs plus pulpwood for a state reaches the year 2006 level of total sawlog plus pulpwood harvest. This state level restriction is to assure that the estimated biomass supply from integrated operations can be supported by the recent (year 2006) level of sawlog and pulpwood harvest in each state.

Table 1. Pulpwood stumpage prices by region, 2007

Hardwoods			
	Delivered price	Stumpage price	Stumpage price
	$/gt		$/odt
North	32.0	7.7	15.4
South	28.8	6.7	13.3
West			
Softwoods			
	Delivered price	Stumpage price	Stumpage price
	$/gt		$/odt
North	33.6	10.4	20.7
South	29.0	7.8	15.7
West	40.3	13.8	27.6

Sources: (RISI 2008) (FRCS model – Fight et al. 2006 as modified by Dykstra)

<u>Combining the Logging residue and thinning based estimates</u> - It is assumed that as demand for biomass for bioenergy and biofuels increases, there will be a shift <u>from</u> integrated harvesting operations of a type and location that produce amounts similar to our logging residue estimates, <u>toward</u> integrated operations of the type and location represented by our thinning estimates. For our near term estimates we assume supply (for each county) will be represented by one half of the logging residue supply estimate and one half of the thinning supply estimate.

[8] The Biomass Treatment Evaluator (BTE) – a SAS program written by Patti Lebow – was used to prepare county level supply curves by 1) estimating biomass and industrial roundwood removals from thinning treatments on FIA plots on timberland, 2) assigning stumpage costs, and 3) assigning harvest and chipping costs using the FRCS model.

Wood from "other forest removals" such as land clearing and cultural operations

Amounts of other forest removals, by county, are obtained from the TPO database for 2007 (USDA FS 2008). It is assumed that 50% is available for use (Perlack et al. 2005). It is assumed that 34% of the amount available costs $20/ odt at roadside and the remainder costs $30/ odt at roadside.

Wood and bark residue from primary wood products mills

Amounts of wood and bark residue, by county, are obtained from the TPO database for 2007 (USDA FS 2008). For our initial supply estimates it is assumed that only unused mill residue is available. It is assumed the cost for unused residues is up to $10/ odt at mills.

Urban wood waste

The amount of available urban wood waste is estimated to be about 28 million odt per year out of about 62 million tons generated per year (McKeever 2004). These estimates for 2002 are assumed to approximate the current level available. But it is assumed that only 10% of the amount available can be collected at a realistic cost. Cost at collection points is assumed to be $20 per odt.

Conventionally sourced wood – e.g pulpwood

Conventional products – pulpwood - could be used for bioenergy and biofuels if priced competitively with other end-use markets. An initial estimate of a minimum amount that could be supplied is the amount by which annual pulpwood harvest has declined over the last decade or so – about 15 million odt. If pulpwood stumpage prices are at least $13-$27 per odt as shown in Table 1 and roadside chipping costs are $13 then even without covering any harvest costs the cost for pulpwood at roadside would be $26- $40 per odt. So it is plausible the relatively little pulpwood would be supplied for roadside costs less than $35-$50 per odt. As an initial estimate assume pulpwood supply will begin about $40 per odt at roadside and increase from there.

Results and Discussion

The forest based biomass supply curves prepared using the methods above were used in combination with estimates of agricultural biomass supply curves to determine the mix and cost of forest and agricultural biomass supply that would be needed to meet cellulosic biofuels production targets under the 2007 Energy Independence and Security Act (EISA) (BRDi 2008). These targets call for production of 21 billion gallons of advanced biofuels (including cellulosic biofuels) by 2022. One scenario developed for that report indicated a 20 billion gallon target for advanced biofuels could be met by using 40 million oven dry tons (odt) of forest based biomass – at about $44 per odt at roadside - to make 4 billion gallons of biofuels, and about 200 million odt of agricultural biomass – at the same $44 per odt at farmgate – to make 16 billion gallons of biofuels. For that study forest based biomass supply excluded biomass from federal land to meet restrictions in EISA. For the components of this forest based supply at $44 per odt see column in Table 2 for forest supply excluding federal land. Table 2 shows 41.6 million odt may be supplied at $44 per odt.

For this analysis we have not provided detailed methods to estimate how much wood biomass supply may come from pulpwood size material at $44. We have conjectured less than 5 million odt. However the amount of pulpwood supplied could be larger if landowners price the costs for biomass (tops, branches, small trees) at nearer the roadside costs for pulpwood.

If forest supply could include biomass from federal forest then it is estimated that wood biomass supply would be at least 4.5 million odt more. The actual amount that would be taken from federal forest would likely be more than 4.5 million odt. The total federal amount would be determined by how much federal supply is cheaper than private or state supply at $44 per odt.

For several components of forest bases supply, Table 2 indicates how much supply may be increased – within sustainability constraints – if prices were to increase. For integrated supply estimated by the forest thinning method we estimate supply could increase to 45.4 million odt per year if roadside prices were at least $100 per odt. This thinning supply is still constrained to not provide more than the 2006 level of pulpwood and sawlog harvest. For urban wood waste we conjecture that supply at the source may increase from 10% of production (28 million odt) to 50% of production – 14 million odt. For conventionally sourced wood – pulpwood – we estimated that pulpwood supply would at least increase by an amount – 15 million odt - that would return production to its peak level in 1998.

It is important to note that the forest based biomass supply estimated here is in addition to amounts already supplied for residential wood burning and for electric power production. It is also important to note that – given the assumptions and methods used in this paper - if wood biomass demand were to reach 40 million odt for biofuels production and demand for wood biomass for electric power production were to increase then these additional demands would increase use of pulpwood sized wood for bioenergy and biofuels.

The amounts of biomass supply estimated here at $44 per odt are notably less than the maximum potential levels identified in the Billion Ton Supply (BTS) Study. We estimate 35.7 million odt available from integrated harvesting – compared to 81 million odt in BTS. We estimate 6.2 million odt from other removals – compared to 9 million odt in BTS. We estimate no supply from other forest land at $44 per odt – compared to 11 million odt in BTS. We estimate 1.3 million odt from mill residue – compared to 8 million odt in BTS. We estimate 2.8 million odt from urban wood waste – compared to 28 million odt in BTS.

Supply of forest based biomass from the sources and amounts indicated in table 2 – both the amounts provided at $44 per odt and the extended amounts would not notably alter the degree to which annual forest growth exceeds removals in the U.S. This is partly because of the common way forest growth and removals are measured. The common measurement is annual growth of growing stock - the growth in main stem of trees above 5 inches in diameter. Removals of growing stock – removals from the stock of standing trees - in 2006 were about 233 million odt tons (15.5 billion cf). The removals include amounts left on harvest sites as logging residue. Net growth was 401 million odt (26.7 billion cf) (Smith et al. 2009). The amounts of supply noted in table 2 would not increase removals of growing stock with the exception of conventionally sourced wood. This is because they come from non growing stock parts of trees or from growing stock parts of trees that would previously have been left on harvest sites and would already be counted as part of the of growing stock removals.

References

Biomass Research and Development Iniative (BRDi). 2008. Increasing Feedstock Production for Biofuels: Economic Drivers, Environmental Implications, and the Role of Research. Washington, DC. http://www.brdisolutions.com/default.aspx

Fight, R.D.; Hartsough, B.R.; Noordijk, P. 2006. Users Guide for FRCS: Fuel Reduction Cost Simulator Software. USDA Forest Service, Pacific Northwest Research Station, Portland, OR. Gen. Tech. Rep. PNW-GTR-668. 23 pp.

Helms, J.A., ed. 1998. The Dictionary of Forestry. Society of American Foresters, Bethesda, MD. 210 p.

McKeever, D. 2004. Inventories of Woody Residues and Solid Wood Waste in the United States, 2002. Ninth International Conference, Inorganic-Bonded Composite Materials. Vancouver, British Columbia. October 10-13.

Perlack, R.D.; Wright, L.L.; Turhollow, A.F; Graham, R.L.; Stokes, B.J., Erbach, D.C. 2005. Biomass as feedstock for a bioenergy and bioproducts industry: The Technical feasibility of a billion-ton annual supply. DOE/GO-102995-2135 or ORNL/TM-2005/66. Oak Ridge National Laboratory, Oak Ridge, TN. 60 pp.

RISI. 2008. International Wood Fiber Report. San Francisco, CA.

Shepperd, W.D. 2007. SDI-Flex: a new technique of allocating growing stock for developing treatment prescriptions in uneven-aged forest stands, IN Restoring Fire-Adapted Ecosystems: Proceedings of the 2005National Silviculture Workshop, Robert F. Powers (ed.). Gen. Tech. Rep.PSW-GTR-203, USDA, Forest Service, Pacific Southwest Research Station, Albany, CA. http://www.fs.fed.us/psw/publications/documents/psw_gtr203/psw_gtr203_001afm_toc.pdf

Smith, W. B.; Miles, P.D.; Vissage, J.S. and S.A. Pugh. 2004. "Forest Resources of the United States, 2002." Gen.Tech. Rpt. NC-241, U.S. Department of Agriculture, Forest Service, North Central Research Station, St. Paul, MN. http://www.treesearch.fs.fed.us/pubs/11987

Smith, W.B.; Miles, P. D.; Perry, C.H.; Pugh, S.A.. 2009. Forest Resources of the United States, 2007. Gen. Tech. Rep. WO-78. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington Office. http://www.fia.fs.fed.us/program-features/rpa/ Accessed May 17, 2009

USDA Forest Service. 2008. Forest inventory and analysis timber product output (TPO) database retrieval system. See http://ncrs2.fs.fed.us/4801/timberproducts/index.htm

Western Governors Association. 2008. Strategic assessment of bioenergy development in the West – Biomass Resource assessment and supply analysis for the WGA Region. Western Governors Association, Denver, CO. 38 p. http://www.westgov.org/wga/initiatives/transfuels/Task%201.pdf

Table 2 - Estimated forest based biomass supply for the United States with conventional harvest at 2006 levels

	All Forest land		Forest excluding federal land		Increase when federal forest is included	
Source	Estimated supply at $44 per odt at roadside	Extended supply	Estimated supply at $44 per odt at roadside	Extended supply	Estimated supply at $45 per odt at roadside	Extended supply
	Million od tons		Million od tons		Million od tons	
Integrated harvesting						
-Logging residue method x 0.5	22.0	22.0	20.0	20.0	2.0	2.0
-Thinning simulation method x 0.5	13.7	25.3	11.2	22.3	2.5	3.1
Total Integrated harvesting	35.7	45.4	31.3	42.3	4.5	3.1
Other removal residues	6.2	6.2	6.2	6.2	0.0	0.0
Primary mill residues (unused)	1.3	1.3	1.3	1.3	0.0	0.0
Urban wood residue	2.8	14.0	2.8	14.0	0.0	0.0
Conventionally sourced wood	<5.0	15.0	<5.0	15.0	0.0	0.0
Total	46.0 – 51.0	81.9	41.6 – 46.6	78.8	4.5	3.1

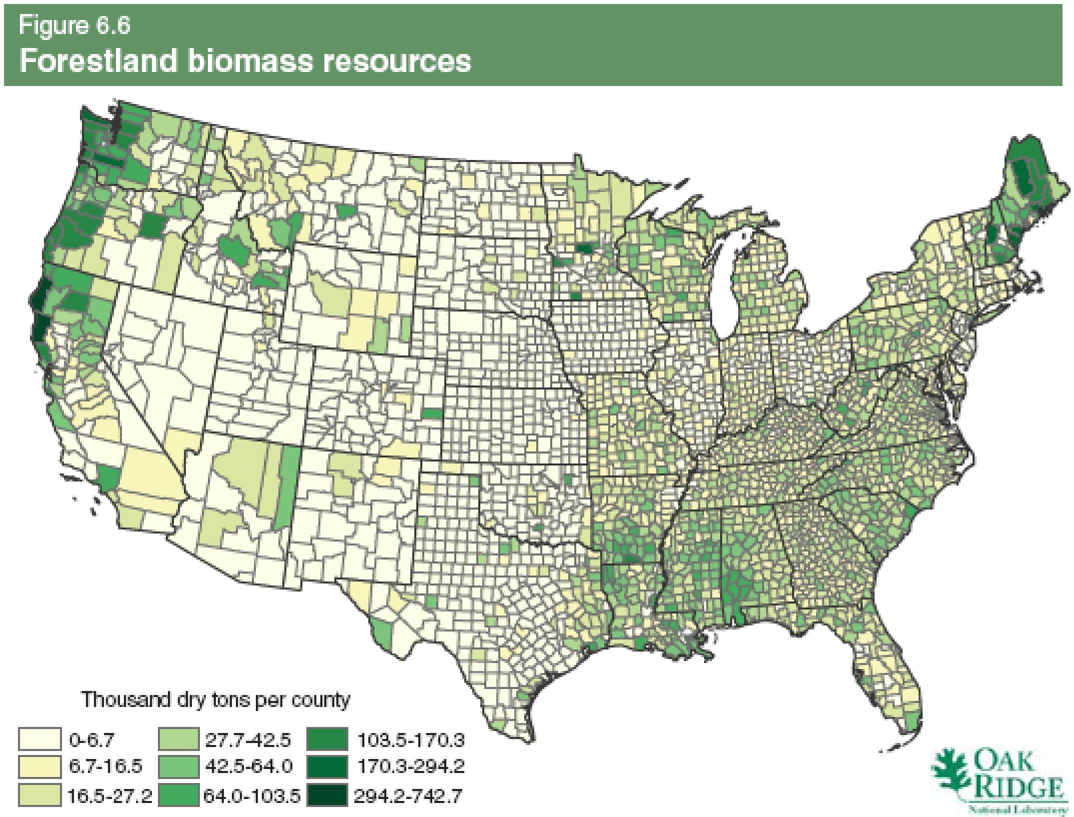
Figure 6.6
Forestland biomass resources
Thousand dry tons per county
0-6.7
6.7-16.5
16.5-27.2
27.7-42.5
42.5-64.0
64.0-103.5
103.5-170.3
170.3-294.2
294.2-742.7
OAK RIDGE

Figure 1