Assessing the Economic Availability of Woody Biomass

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This document describes how Wood to Energy Outreach Program researchers assessed the economic availability of biomass resources in 28 communities across the thirteen southeastern states. This approach was taken to be able to apply nation-wide forestry data anywhere in the U.S. For instructions of a simplified approach to assessing the availability of biomass using site-specific information, see the Do-It-Yourself Supply Curves in this appendix and at http://www.interfacesouth.org/woodybiomass.

Biomass (i.e., plant material), including urban wood waste, logging residues, and forest thinning, can be used to generate renewable energy, reduce greenhouse gas emissions, improve forest health, and provide economic benefits to rural communities. The feasibility of bioenergy (i.e., energy generated from biomass) projects depends largely on the availability of woody biomass resources. More specifically, it is the economic availability, or total delivered price for a given quantity, rather than just the physical availability, that is relevant to the development of bioenergy projects. A simple way to express the economic availability of a resource is with a supply curve. Here we describe supply curves and how we developed biomass resource supply curves for communities in the thirteen southeastern states.

Supply Curves

A supply curve is a basic economic tool used to express the price of a resource at a given quantity of demand. For example, Figure 1 illustrates a hypothetical woody biomass resource supply curve. Quantity Q_1 can be generated at marginal price P_1 from urban wood waste, which is the cheapest resource. If biomass demand is increased due to higher levels of power generation capacity, more costly woody biomass resources such as logging residues might then be utilized to supply quantity Q_2 at price P_2. A more complex supply curve might include other available resources and would account for transportation cost in ranking the economic availability of these resources of different types at different travel times.

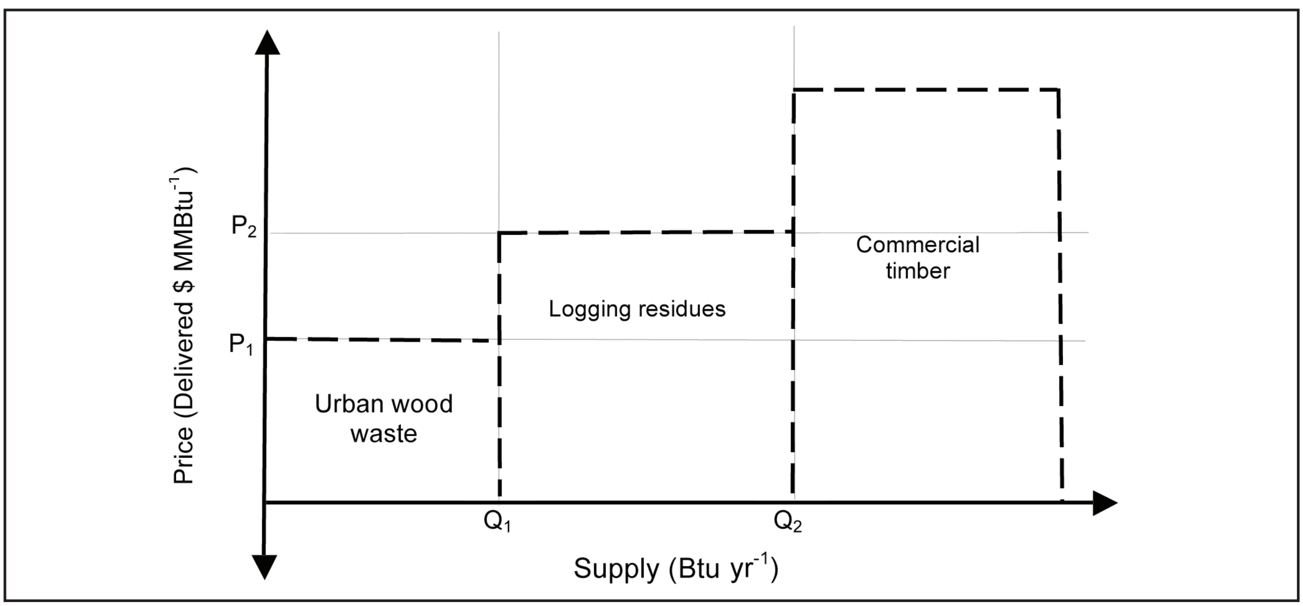

Figure 1. *Hypothetical supply curve illustrates woody biomass resource categories.*

The total cost for biomass depends on how biomass is actually purchased locally. If utilities offer a premium price for biomass resources that are more expensive and/or farther away, the total cost to the utility to meet a specified generation capacity is calculated as the area under the curve, or the sum of price multiplied by quantity for each resource category employed. In Figure 1 under these conditions, the calculation to purchase Q_2 with price discrimination is $(Q_1*P_1)+(Q_2*P_2)$. However, some utilities may not be able or willing to differentiate between different biomass resources that have different costs. If utilities cannot vary the price according to the resource, the total price to acquire a given quantity is the maximum price times the total quantity. In the example below, this calculation to purchase Q_2 is P_2*Q_2, which would result in a higher total cost to the utility.

Constructing biomass supply curves requires information about production costs and the physical availability of resources. Following we describe how we calculate costs, determine the physical availability and geographic distribution of biomass, and create biomass resource supply curves to assess the economic availability of biomass resources.

Cost Calculations

The delivered cost of woody biomass can be defined as a sum of procurement (i.e., the amount paid to buy the wood), harvest, and transportation costs. We use the cost assumptions shown in Table 1, and calculate transportation cost as a function of haul time. More details of our assumptions are shown on page 6 and in a forthcoming USDA Forest Service General Technical Report. Haul times are calculated using ArcGIS Network Analyst extension as described in Box 1 and in ArcUser Magazine, October – December 2006, available at www.esri.com/news/arcuser/index.html. We assume haulers drive the speed limit on the fastest road available to them, calculate total transportation times for the area of interest, and increase haul times (and thus costs) by 25 percent to account for operational delays. Transportation costs could alternatively be calculated by haul distance rather than time, or transportation cost could be assumed uniform for each woody biomass resource within a maximum haul radius. The next step in constructing the woody biomass resource supply curve is to determine what quantity of biomass is available in each woody biomass resource-haul time category for a given community.

We sum procurement, harvest, and transportation costs to calculate the total delivered cost of each woody biomass resource within a given haul time at 15-minute increments as shown in Table 1. By ranking these resource-haul time categories from lowest cost to highest cost, the progression of most to least economically available woody biomass resources is estimated (Table 2). Under these cost assumptions, logging residues requiring a one-way haul up to 45 minutes are cheaper than the nearest pulpwood resources.

Table 1. *Summary of Cost Assumptions for Three Woody Biomass Resources*

	Urban Wood Waste	Logging Residue	Pulpwood
	$/green US ton ($/dry metric ton)		
Procurement cost	-15.00 (-27.56)	1.89 (3.31)	6.89 (14.33)
Harvest and process	18.00 (33.07)	15.12 (26.46)	12.72 (26.46)
Load and unload	1.24 (2.28)	1.18 (2.06)	0.92 (1.91)
One-way haul (per hour)	3.72 (6.83)	3.54 (6.19)	3.12 (5.73)
Example total delivered cost of a one-hour haul[a]	11.68 (21.45)	25.27 (44.21)	26.77 (54.16)

[a]Equals the sum of two times the one-way haul cost and the remaining three cost categories. Assumptions for calculations are found on page 6.

Table 2. *Wood Resources Ranked by Total Delivered Energy Cost*

Resource/Haul time category	Delivered cost ($/dry US ton)	Delivered cost ($/MMBtu)
Urban wood: 0-15 minutes	0.02	$0.65
Urban wood:15-30 minutes	0.11	$0.85
Urban wood: 30-45 minutes	0.16	$1.05
Urban wood: 45-60 minutes	0.17	$1.25
Logging residues: 0-15 minutes	0.09	$2.03
Logging residues: 15-30 minutes	0.50	$2.21
Logging residues: 30-45 minutes	0.97	$2.39
Pulpwood: 0-15 minutes	0.24	$2.56
Logging residues: 45-60 minutes	1.29	$2.57
Pulpwood: 15-30 minutes	1.50	$2.72
Pulpwood: 30-45 minutes	3.03	$2.88
Pulpwood: 45-60 minutes	4.14	$3.04

Physical Availability

In addition to production costs, information about the physical availability of resources is required to construct supply curves. We compiled county-level woody biomass resource information for all counties in the southern U.S. To estimate woody biomass quantities from logging residues and pulpwood, we accessed Timber Product Output (TPO) reports (http://srsfia2.fs.fed.us/php/tpo2/tpo.php) maintained by the Forest Inventory and Analysis (FIA) work unit of the USDA Forest Service, Southern Research Station (SRS). This database provides forest inventory and harvest information, including annual yields of logging residues and pulpwood at the county level. The TPO reports use the latest available FIA Inventory data as a baseline, which is then updated according to more frequent (about every 2-3 years) mill surveys. The 2003 TPO Report for Florida is used here. Logging residues includes TPOs annual non-growing stock removals reduced by 30 percent to exclude stumps and account for unavailable resources.

Because the pulpwood harvest identified in the FIA TPO report is currently used to produce pulp and paper products, not all of this resource is economically available for bioenergy. However, additional biomass is available from forest thinnings (Perlack et al. 2005, Condon and Putz 2007), which are not included in this assessment. Furthermore, southwide softwood and hardwood growth exceeds removals (Adams et al. 2003), indicating that more wood can be sustainably harvested. Recent trends of poor stumpage prices and loss of markets for forest products in the South may have reduced forest management activities (Smidt et al. 2005), which could be mitigated by providing additional timber markets.

We assume 0.111 dry metric tonnes (0.203 green tons) of urban wood waste per capita annually (based on Wiltsee 1998). This per capita estimate includes municipal solid waste wood from yard waste and tree trimming but excludes an additional 0.1 dry metric tonnes (0.2 green tons) per capita annually reported from industrial wood (e.g., cabinet and pallet production) and construction and demolition debris. We multiply this average annual per capita yield by county level 2005 U.S. Census population estimates (www.census.gov/popest/counties/) to estimate total annual county yield of urban wood waste. Assumptions of availability, wood densities, and energy content for all included woody biomass sources are shown in Tables 3 and 4. We then use the method described below to estimate what portion of these county-level resources are within each resource-haul time category for a given delivery point.

Supply Curve Construction

Given information regarding quantities, distribution, and procurement, harvest, processing, and transport costs for each woody biomass resource, supply curves can be constructed. Assuming homogeneous distribution of woody biomass resources within counties (a necessary assumption given the FIA source data), we calculate the amount of woody biomass in each haul time category in each county, and summarize quantities available from each resource-haul time category for the area of interest. We assign total delivered costs for each resource-haul time category, and sort from least to most expensive (Table 2). Supply curves are then plotted where the x-axis is the cumulative total amount of woody biomass with each additional resource-haul time category and the y-axis is total delivered cost. Curves can be plotted as an Excel© scatter plot or by using the Macro Economic Supply Curve Chart Excel© add-in. We express units based on energy content of the biomass, though units could be expressed as mass. The steps in the supply construction are discussed in Box 1 and shown in the work flow diagram in Figure 2.

For more information see the "Community Economic Profiles" section and our other materials at http://www.interfacesouth.org/woodybiomass.

References

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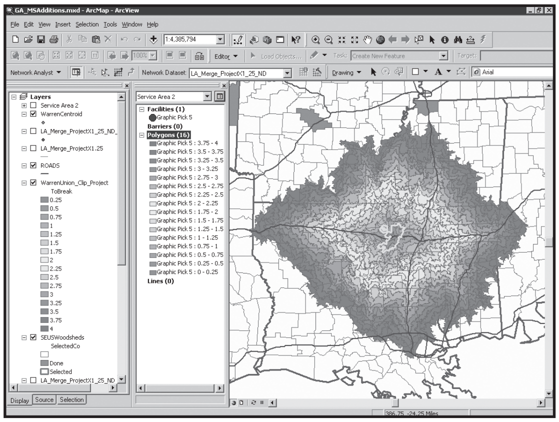
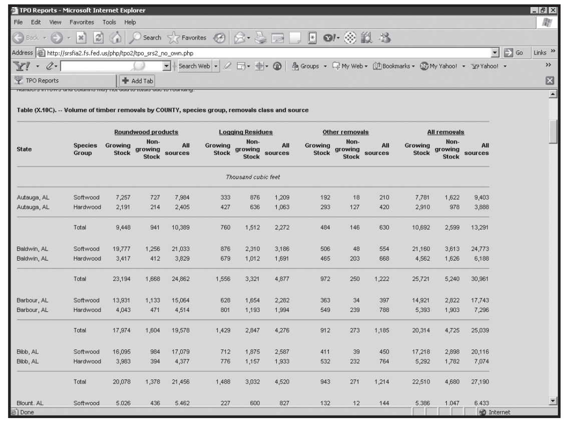
Box 1. *Steps in Supply Curve Construction*

Assessing transportation cost based on haul time rather than distance accounts for road infrastructure in a woodshed. Haul times can be estimated by using GIS to account for speed limits assigned to U.S. Census Topologically Integrated Geographic Encoding and Referencing (TIGER) roads layers. Following is a summary of steps that can be used to assess haul times by generating service areas with ArcGIS© Network Analyst:

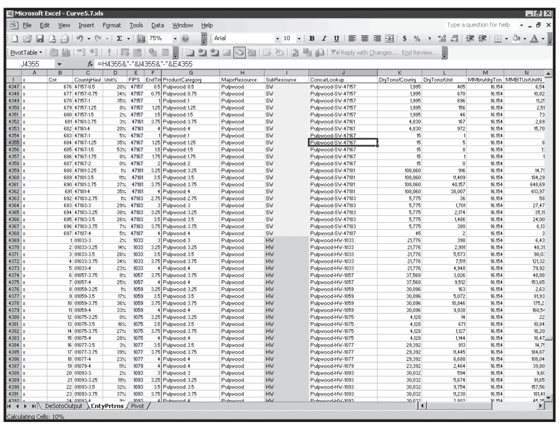
1. Identify delivery point (e.g., county centroid, generation plant).
2. Identify area of interest (AOI) to include the maximum potential extent of the woodshed. A 450 km (280 mile) radius includes more than a 4-hour one-way haul. Identify counties within the AOI.
3. Download U.S. Census TIGER roads shapefiles for the AOI from http://arcdata.esri.com/data/tiger2000/tiger_download.cfm. Merge the roads, define the projection (see Price and Coleman 2003), and re-project the merged roads layer. Keep all layers in the same projection.
4. Assign speed limits to each roads segment according to census feature class codes and calculate travel time (see Price and Price 2003). To account for expected travel delays, we increase calculated travel times by 25 percent.
5. Calculate service areas based on haul time using the ArcGIS Network Analyst Service Area Calculator (see Chandrasekhar 2005). We assess haul times based on 15-minute haul intervals, and assume the "ToBreak" field value for each haul time category. Export service area polygons to a shapefile.
6. Union the service area polygons to the county polygons and clip as necessary. Ensure the unioned shapefile is projected, add a "NewArea" field (float) and calculate areas of each feature.
7. Add a "ConCat" field (text) and concatenate the county name or "FIPS" field with the "ToBreak" field. Summarize the "ConCat" field including the average of the original area and the sum of the "NewArea" field.
8. Import the summarized *.dbf to a spreadsheet software such as Excel©. For each "FIPS-ToBreak" record, divide the "NewArea" by the original area to determine what percentage of each county is in each haul time category.
9. This percentage can be used to estimate what percentage of the woody biomass resource in each county resides in each haul time category. A Microsoft Excel Pivot Table can then be used to summarize the estimated total of each biomass resource in each haul time category.



Haul time categories are calculated from U.S. Census TIGER roads in ArcGIS Network Analyst©.



County level resource data are retrieved from FIA. Urban wood waste estimates are based on county population from the U.S. Census.



The percentage of the area of each county in each haul time category is calculated and exported to Excel©.

County level biomass resource data is multiplied by the proportion of each county in a given haul radius to estimate the proportion of a county's resources in each haul time category.

An Excel© Pivot Table is used to summarize the quantity of each biomass resource in each haul time category, and the costs of each product-haul time category are assigned. Product-haul time categories are sorted from least to most expensive, and supply curves are plotted.

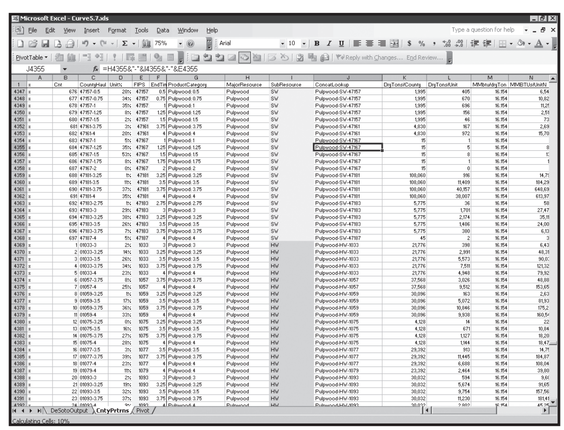


Figure 2. *This work flow diagram illustrates the resources and steps used in woody biomass resource supply curve construction.*

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Table 3. *Operational Assumptions*

Variable/attribute	Logging residues	Urban Wood Waste	Pulpwood
Load and unload time per load (hours)	0.50	0.50	0.50
Load and unload cost per load ($)	$25.00	$25.00	$25.00
Green tons per load	23.0	22.0	28.0
Load and unload cost per green ton ($)	$1.09	$1.14	$0.89
Moisture content (green weight basis)	37%	40%	47%
Ash content	5%	5%	2%
Load and unload cost per dry ton ($)	$1.87	$2.07	$1.73
Haul cost ($/hour/load)a	$75.00	$75.00	$75.00
Haul cost ($/hour/green ton)	$3.26	$3.41	$2.68
Two-way haul cost ($/hour/dry ton)	$11.24	$12.40	$10.40
MMbtu/dry ton	15.58	15.58	16.15
Harvest and process ($/dry ton)	$24.00	$30.00	$24.00
Procurement cost ($/dry ton)	$3.00	$(25.00)	$13.00
Quantity assumed recoverable	90%	60%	100%

Table 4. *Density Assumptions*

	Gram cubic cm-1 (Pounds cubic foot-1):
Hardwoods	0.513 (32)
Softwoods	0.481 (30)

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