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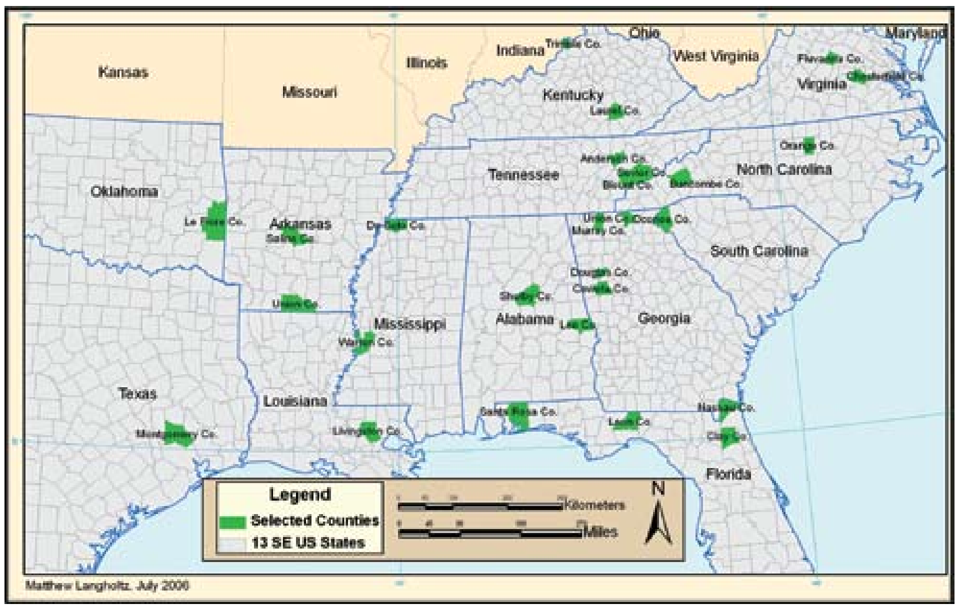
Measuring the Economics of Biofuel Availability

ArcGIS Network Analyst extension provides more comprehensive assessment

By Matthew Langholtz, Douglas R. Carter, Matt Marsik, and Richard Schroeder

***Editor's note:** Evaluating the economic feasibility of biomass resources (i.e., plant material) as an energy source requires comprehensively addressing transportation costs by integrating that cost information based on the type of biomass material, the distance it must be transported, and the available transportation infrastructure. GIS is well suited to this type of analysis.*

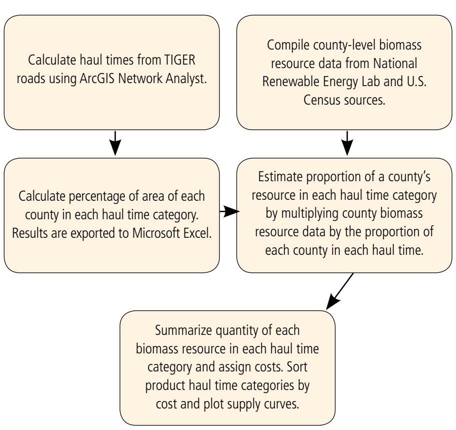


In the southern United States, 27 counties with high potential for energy generation from woody biomass were identified based on cost and haul time calculations.

Biomass resources in the southern United States, such as urban wood waste, forest residues, forest thinnings, and others, 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.

Most assessments of biomass availability to date estimate the total amount of biomass within a given straight-line radius and assume average production costs for the area. A more comprehensive economic assessment of biomass resources takes into account that costs vary with biomass type, distance, and transportation infrastructure. When transportation costs are taken into account, more costly resources in close proximity may be economically competitive with cheaper resources farther away, and vice versa.



Workflow diagram illustrating resources and steps used in woody biomass resource supply curve construction

The Wood to Energy program of the University of Florida School of Forest Resources and Conservation, the United States Department of Agriculture Forest Service's Southern Center for Wildland-Urban Interface Research and Information, and the Southern States Energy Board helps communities evaluate the feasibility of using woody biomass for energy production. The project has identified 27 counties in the southeast portion of the United States that have high potential for energy generation from woody biomass. The ArcGIS Network Analyst extension was used in assessing the economic availability of woody biomass resources to these communities.

Components for Calculating Economic Availability

Assessing the economic availability of biomass requires information about production costs and the physical availability of biomass resources in the area of interest. The methods used are composed of the following three components: calculation of transportation costs and haul times, determination of physical availability and geographic distribution of biomass, and creation of biomass resource supply curves.

The delivered cost of woody biomass can be defined as the sum of procurement (i.e., the amount paid to gain ownership of a biomass resource), harvest, and transportation costs. This requires assembling procurement and harvest cost assumptions for different types of biomass resources and calculating transportation cost as a function of haul time.

GIS is an efficient and useful tool for evaluating woodshed procurement areas and transportation costs (e.g., Young et al. 1991, Brewington et al. 2001, Chalmers et al. 2003). Assessing transportation cost based on haul time rather than distance accounts for site-specific road infrastructure and geographical constraints within a woodshed.

Calculating Haul Time

Determining the proportion of each county within a given haul time category was the first step. Haul times were calculated to account for road infrastructure. Using the Field Calculator in ArcMap, speed limits were assigned to road features in U.S. Census TIGER shapefiles and road lengths were divided by speed limits to estimate travel time. The Service Area function in the ArcGIS Network Analyst extension was used to calculate service areas based on travel time and the proportion of each county. Each haul time category was based on a 15-minute interval. The procedure for calculating haul times by generating service areas with ArcGIS Network Analyst can be used for specific locations of biomass drop-off such as bioenergy generation facilities.

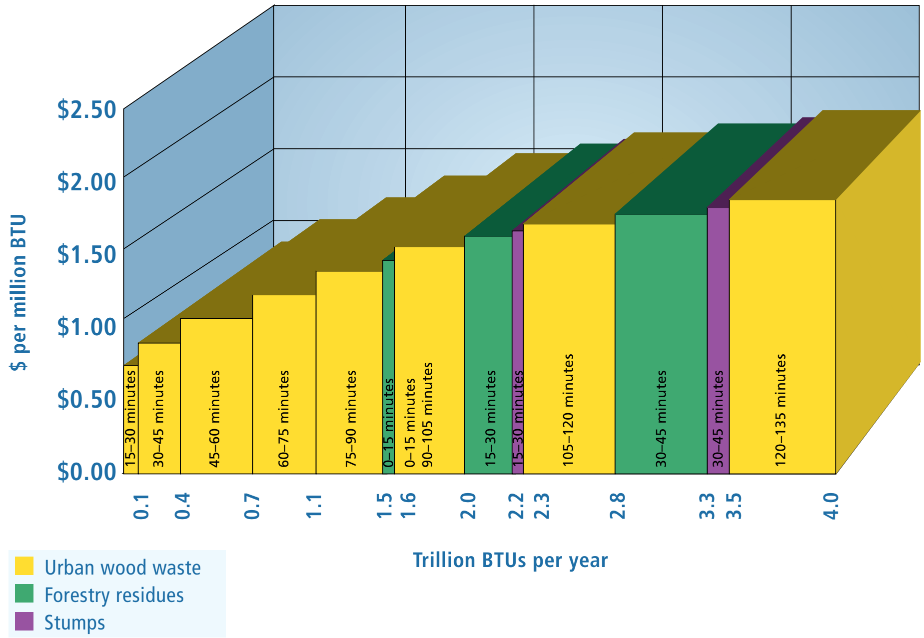
For the 27 counties in the study, the delivery point was calculated using the Centroid function of Xtools Pro 3.2, a third-party extension to ArcGIS from Data East, an ESRI business partner and international distributor. The area of interest (AOI) was defined as counties within the maximum potential extent of the woodshed defined as a 450-kilometer (or 280-mile) radius to include greater than a four-hour one-way haul. U.S. Census TIGER road shapefiles were downloaded from arcdata.esri.com/data/tiger2000/tiger_download.cfm for the counties in each AOI. Using ArcToolbox, the TIGER county roads shapefiles were merged and projected into the appropriate State Plane coordinate system for each AOI. (For a tutorial on this procedure, see “Taming TIGER Data: Create Emergency Management Maps Using Census 2000 Data” by Mike Price and Ronny Coleman in the January–March 2003 issue of *ArcUser.*)

The Field Calculator was used to assign speed limits to road features based on the attribute census feature class codes in U.S. Census TIGER shapefiles, and road lengths were divided by speed limits to estimate travel time. (For more information on using census class codes, see “Coverage Assessment Using Census 2000 TIGER Roads” by Mike Price and Jennifer Price in the July–September 2000 issue of *ArcUser.*)

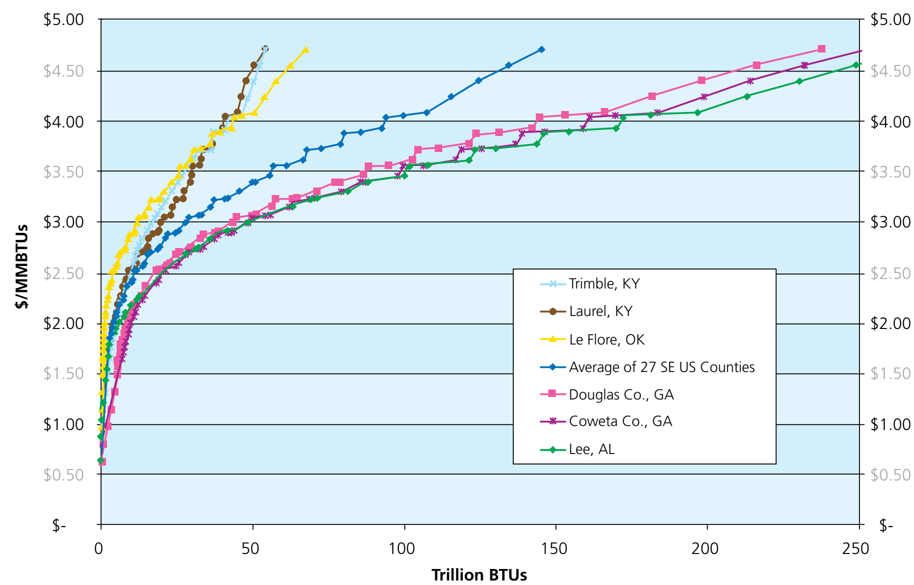
Haul time was increased by 25 percent to account for operational delays. Service areas are calculated based on haul time in 15-minute intervals using the ArcGIS Network Analyst Service Area Calculator. The resulting service area polygons are exported as shapefiles.

Service area polygons were combined with county polygons using the Union function and clipped to the area of interest. A new floating point field called NewArea was added. The new area for each feature in the service area-county union was calculated. A text field called ConCat was added, and county identifier field (FIPS) was concatenated with the service area haul time field (ToBreak) to create the FIPS-ToBreak field.

A table summary was performed based on the ConCat field to include the original area average and the sum of the NewArea field. The summarized table was imported to Microsoft Excel so the percentage of each county in each haul time category could be calculated by dividing the NewArea field by the original area for each FIPS-ToBreak record. This area percentage was used to estimate the percentage of each biomass resource type by each haul time category in each



Prices, quantities, and resource haul category composition of the first four trillion BTUs, based on the average of all 27 counties



Example of low, high, and average woody biomass supply curves of selected counties. Biomass sources include urban wood waste, forestry residues, stumps, and pulpwood within a four-hour haul radius.

county. An Excel pivot table was used to calculate the estimated total of each biomass resource in each haul time category.

The procurement, harvest, and transportation costs were summed to calculate the total delivered cost of each woody biomass resource within a given haul time category. Ranking these resource haul time categories from lowest cost to highest cost yielded the estimated progression of most to least economically available woody biomass resources. Under these cost assumptions, urban wood waste requiring a one-way haul up to 90 minutes is cheaper than other woody biomass resources with shorter haul times.

Supply Curve Construction Using Excel

With the information on quantities, distribution, procurement, harvest, processing, and transport costs for each woody biomass resource, supply curves can be constructed. A supply curve is a basic economic tool used to express the price of a resource at a given quantity of demand. Supply curves can be plotted in Microsoft Excel as a scatterplot or by using the Macro Economic Supply Curve Chart Excel add-in. Supply curves were plotted so that the x-axis was the cumulative total amount of woody biomass with each additional resource-haul time category and the y-axis was the total delivered cost. Units were expressed based on energy content of the biomass; however, these could have been expressed as units of mass.

Project Results

Typical demand was estimated in the range of 2 to 4 trillion British thermal units (BTUs) to produce approximately 20 to 40 megawatts (MW) of electricity (or enough electricity to power between 8,000 and 16,000 households in the southern United States). For the 27-county average cost curve, quantities in this range cost \$1.57 to \$1.91 per gigajoule (GJ-1) or \$1.66 to \$2.01 per thousand thousand BTUs (MMBTU-1) which is competitive with current coal energy costs. Under the average curve, demand up to 4 trillion BTUs can be met with urban wood residues within a 135-minute haul, and forestry residues and stumps within a 45-minute haul, with no need to harvest additional trees.

Conclusion

These supply curves illustrate the local economic availability of woody biomass resources and prices that might be paid as a function of demand. Further results and a sensitivity analysis are included in a pending U.S. Forest Service general technical report. Project conclusions include the following points:

- The approach outlined in this article using ArcGIS Network Analyst to calculate biomass haul service areas uses readily available data layers that can be retrieved from the Internet. The analysis can be replicated for potential bioenergy locations anywhere in the United States.
- Service areas calculated with ArcGIS Network Analyst enhance the speed and accuracy with which biomass supply curves are generated.
- Up to 4 trillion BTUs (i.e., 40 MW or energy to power 16,000 homes annually) of woody biomass are typically available at less than \$1.91 per GJ-1 (\$2.01 per MMBTU-1) in communities in the southern United States.
- The U.S. Forest Service Forest Inventory and Analysis Program is currently developing a national biomass dataset as a raster derived from MODIS (Moderate Resolution Imaging Spectroradiometer) satellite imagery, which could enhance the accuracy of biomass supply curves. When available, the approach presented here could be extended as a raster analysis procedure and improvements in precision and accuracy could be assessed. For more information, contact Matthew Langholtz with the School of Forest Resources and Conservation at the University of Florida at mateo@ufl.edu.

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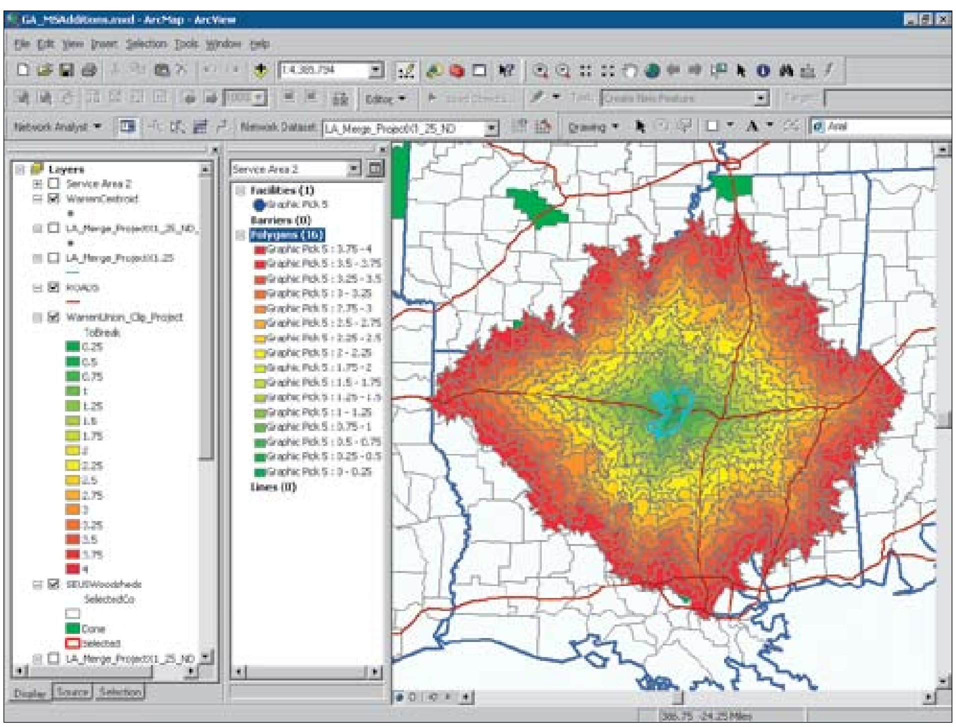

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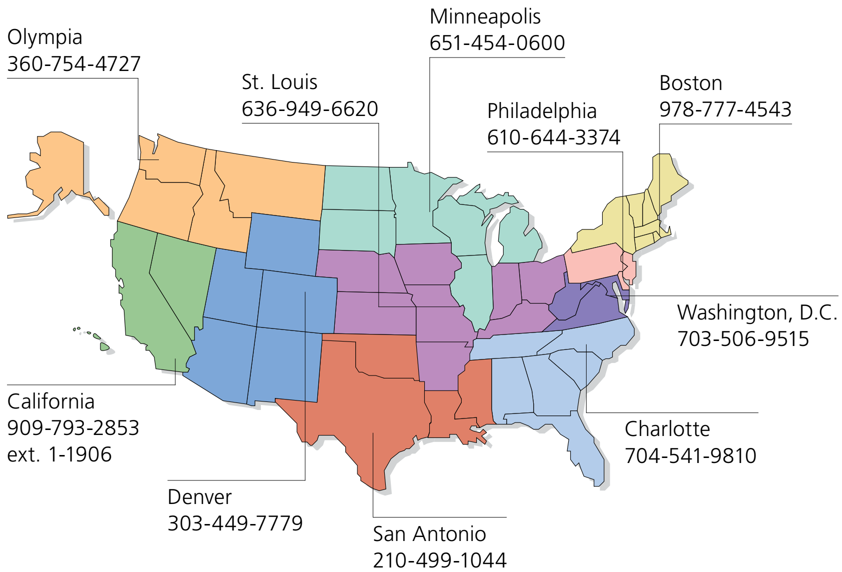

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