WOOD to ENERGY

Background

Do-It-Yourself Supply Curves

Matthew Langholtz, Douglas R. Carter, & Richard Schroeder

his document describes how you can assess the economic availability of biomass resources in your community. This approach requires information about quantities and costs of locally available biomass, which might be in addition to or instead of resources identified in the University of Florida/USDA Forest Service Wood to Energy Outreach Program. For details about how we assessed the economic availability of biomass resources in 28 communities across the thirteen southeastern states, visit http://www.interfacesouth.org/woodybiomass.

Biomass can be used to generate renewable energy, providing various benefits. The feasibility of bioenergy (i.e., energy generated from biomass) projects depends largely on the economic availability, or total delivered price for a given quantity, of biomass resources. A simple way to express the economic availability of a resource is with a supply curve. Here we describe how you can construct supply curves for biomass resources in your area.

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. A small amount of biomass (Quantity Q_1) is available at low cost (Price P_1) in the form of urban wood waste. More biomass can be acquired in the form of logging residues, though at a higher price (P_2), and even more biomass can be purchased in the form of commercial timber, though it would be the most expensive. Thus a supply curve shows the price of biomass at certain levels of demand. If enough biomass (the X-axis) can be delivered sustainably at a low enough price (the Y-axis) then enough feedstock is available to supply a bioenergy project. A more complete supply curve might include other available resources and account for transportation cost in ranking the economic availability of these resources of different types at different travel times.

The total cost for biomass depends on how biomass is actually purchased locally. If utilities or other biomass buyers offer a premium price for biomass resources that are more expensive 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 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, the calculation to purchase Q_2 is P_2*Q_2, which would result in a higher total cost to the utility.

Following we describe how you can construct biomass supply curves. These instructions use Microsoft® Excel 2003, though the basic approach could be applied by other means. The process includes the following steps:

1. Survey quantities and costs of locally available biomass resources.

2. Convert quantities and costs to consistent units.

3. Rank resources from cheapest to most expensive.

4. Create the supply curve.

These steps are described below.

1. Survey quantities and costs of locally available biomass resources.

The first step is to gather information about what biomass resources are available and how much of each resource is available at what price. The price should be expressed as the total delivered cost to the facility, including purchase, harvest, process, and transportation costs. Compiling this information is likely to be the most time consuming step in this process. The information gathered is also likely to be subject to some uncertainty, as quantities and prices of biomass fluctuate with agricultural and forestry practices and market conditions. A good approach is to identify a range of possible values for each resource to later construct "worst case," "most likely," and "best case" scenarios.

A good starting point for learning about the types of resources that might be available is "A Geographic Perspective on the Current Biomass Resource Availability in the United States," available at http://www.nrel.gov/docs/fy06osti/39181.pdf. Quantities of logging residues available at the county level are reported by USDA Forest Service Southern Research Station at http://srsfia2.fs.fed.us/php/tpo2/tpo.php. Local county extension offices, universities, or consultants may offer other sources of information.

Potential biomass suppliers, such as foresters, farmers, loggers, landowners, and mill owners, may also provide information. At some latter phase in the development of a bioenergy project, biomass buyers and sellers will have to negotiate an agreement regarding how much biomass would be sold and at what price. Therefore, exact price information is likely to be sensitive and might require formal letters of interest or bids. While costs of harvest, process, and transportation may be revealed, the exact profit margin demanded by potential sellers is again uncertain, and a range of potential values for each resource can be used to construct a range of scenarios. The level of detail required is also dictated by the phase of development of the biomass project. An initial feasibility assessment may only require general estimates, while a more advanced stage would require more precise information. See *Assessing the Economic Availability of Woody Biomass* in this appendix and on our Web site, http://www.interfacesouth.org/woodybiomass, for more information about compiling quantity and cost information.

2. Convert quantities and costs to consistent units.

Initial information is likely to be reported in dollars per green ton, or other units, such as dollars per cubic yard or dollars per truckload. Furthermore, different types of biomass have different moisture contents and energy contents. To be able to compare "apples to apples" and put different resources in the same supply curve, the information needs to be converted to consistent units, probably dollars per dry ton and eventually dollars per million British thermal unit (Btu), or million Btu (MMBtu). As a hypothetical example, let's say that after research and surveys of local businesses, the following local biomass supplies are identified, with available quantities and total prices per green ton, delivered and processed as required by proposed power generation technology.

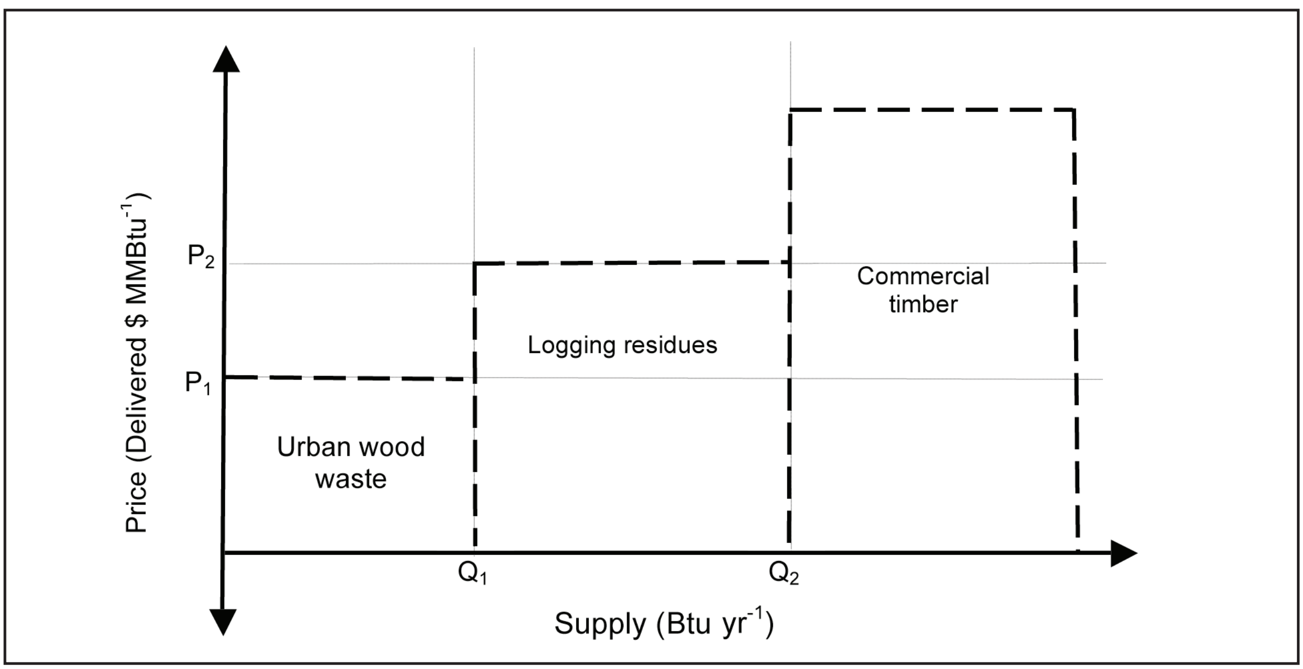


Figure 1. *Hypothetical supply curve illustrates woody biomass resource categories.*

	Supplier	Category	Quantity (green tons/year)	Price ($/green ton delivered)
2	County waste wood	Urban wood	5,000	$10.00
3	Bob's Peanuts	Peanut hulls	3,000	$15.00
4	Mike's Sawmill	Sawmilll waste	52,000	$15.00
5	John's Tree Trimming	Urban wood	4,500	$15.00
6	Jane's Land Clearing	Urban wood	36,500	$20.00
7	Marie's Forestry	Foresty thinnings	140,000	$25.00
8	Forest Service Data	Logging residues	60,000	$25.00
9	Barbra's Pulpwood	Pulpwood	250,000	$30.00

In this example, County Power Line Clearing provides the cheapest biomass on a green ton basis. However, these resources contain different quantities of water, which reduces the energy content. Therefore, we need to convert the prices and quantities to equivalent units on a dry weight basis. Some research or sampling can identify typical moisture contents of each of these resources, which are added in column E (moisture content on a green weight basis is typically ranges from 20 percent for air-dried biomass to 50 percent for fresh green biomass). These moisture contents can then be used to convert the price in dollars per green ton to the price in dollars per dry ton by dividing by one minus the moisture content, as shown in column F, shown here.

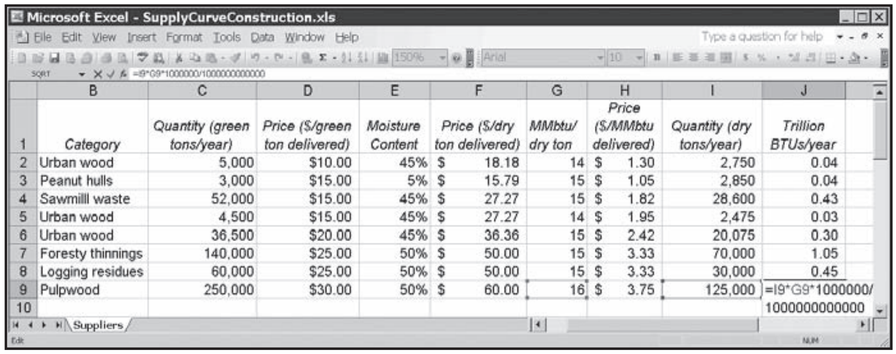
	Category	Quantity (green tons/year)	Price ($/green ton delivered)	Moisture Content	Price ($/dry ton delivered)
2	Urban wood	5,000	$10.00	45%	$ 18.18
3	Peanut hulls	3,000	$15.00	5%	$ 15.79
4	Sawmilll waste	52,000	$15.00	45%	$ 27.27
5	Urban wood	4,500	$15.00	45%	$ 27.27
6	Urban wood	36,500	$20.00	45%	$ 36.36
7	Foresty thinnings	140,000	$25.00	50%	$ 50.00
8	Logging residues	60,000	$25.00	50%	$ 50.00
9	Pulpwood	250,000	$30.00	50%	=D9/(1-E9)

When expressed as a price on a dry ton basis, the peanut hulls are cheaper than the urban wood waste, because they contain much less water. Expressing costs on a dry ton basis doesn't necessarily mean that the resources will be dried, it's just a way to express prices excluding the water, so the different options can be compared in equivalent units. We can make a supply curve showing costs on a dry ton basis, which may make the most sense for biomass producers, or we may also want to make a supply curve showing costs on an energy basis, which may be clearer for people involved from an energy perspective. To that end, we need to find out the Btu content of the biomass. All species of wood and most biomass resources have similar Btu contents on a dry weight basis, about 8,000 Btu per dry pound, or 16 MMBtu per dry ton. This value decreases as the proportion of ash or soil in the biomass increases. Results from lab testing indicate Btu content per dry ton shown below in column G. Dividing the price per dry ton by the MMBtu per dry ton gives the price per MMBtu, show in column H.

	Category	Quantity (green tons/year)	Price ($/green ton delivered)	Moisture Content	Price ($/dry ton delivered)	MMbtu/ dry ton	Price ($/MMbtu delivered)
2	Urban wood	5,000	$10.00	45%	$ 18.18	14	$ 1.30
3	Peanut hulls	3,000	$15.00	5%	$ 15.79	15	$ 1.05
4	Sawmilll waste	52,000	$15.00	45%	$ 27.27	15	$ 1.82
5	Urban wood	4,500	$15.00	45%	$ 27.27	14	$ 1.95
6	Urban wood	36,500	$20.00	45%	$ 36.36	15	$ 2.42
7	Foresty thinnings	140,000	$25.00	50%	$ 50.00	15	$ 3.33
8	Logging residues	60,000	$25.00	50%	$ 50.00	15	$ 3.33
9	Pulpwood	250,000	$30.00	50%	$ 60.00	16	=F9/G9

Depending on local conditions, it may be necessary to account for the additional cost that it would take to reduce the moisture content of biomass. Though the above step excludes moisture from the price of the biomass, it doesn't actually account for the energy and cost that may be required to reduce the moisture in the biomass. In many cases, the additional cost of energy loss due to moisture is accounted for in the bioenergy facility's efficiency or heat rate. Whether or not the additional cost of removing moisture from the biomass should be included in the total cost depends on the power-generating technology and biomass-purchasing agreement.

Now that values for the Y-axis are calculated, we can calculate values for the X-axis. By multiplying the available green tons per year in column C by one minus the moisture content, we can calculate the available dry tons per year in column I. We will then convert these available dry tons per resource to available Btu per resource. When assessing power generation, energy values may be expressed in trillions of Btu, because it takes about 2 to 4 trillion Btu to generate about 20 to 40 megawatts (MW), and locally available biomass resource are likely to be in the range of 5 to 20 trillion Btu per year. By multiplying available dry tons per year in column I by MMBtu per dry ton in column G, we calculate the available MMBtu per year. This can be multiplied by one million to convert to Btu, and divided by one trillion to be converted to trillion Btu.



	Category	Quantity (green tons/year)	Price ($/green ton delivered)	Moisture Content	Price ($/dry ton delivered)	MMBtu/ dry ton	Price ($/MMbtu delivered)	Quantity (dry tons/year)	Trillion BTUs/year
2	Urban wood	5,000	$10.00	45%	$ 18.18	14	$ 1.30	2,750	0.04
3	Peanut hulls	3,000	$15.00	5%	$ 15.79	15	$ 1.05	2,850	0.04
4	Sawmilll waste	52,000	$15.00	45%	$ 27.27	15	$ 1.82	28,600	0.43
5	Urban wood	4,500	$15.00	45%	$ 27.27	14	$ 1.95	2,475	0.03
6	Urban wood	36,500	$20.00	45%	$ 36.36	15	$ 2.42	20,075	0.30
7	Foresty thinnings	140,000	$25.00	50%	$ 50.00	15	$ 3.33	70,000	1.05
8	Logging residues	60,000	$25.00	50%	$ 50.00	15	$ 3.33	30,000	0.45
9	Pulpwood	250,000	$30.00	50%	$ 60.00	16	$ 3.75	125,000	=I9*G9*1000000/1000000000000

Now we have all the values required to create the supply curves, shown either in dry ton units or expressed on an energy basis. Because the objective is to use the cheapest resources possible, the next step is to sort the resources from cheapest to most expensive.

3. Rank resources from cheapest to most expensive.

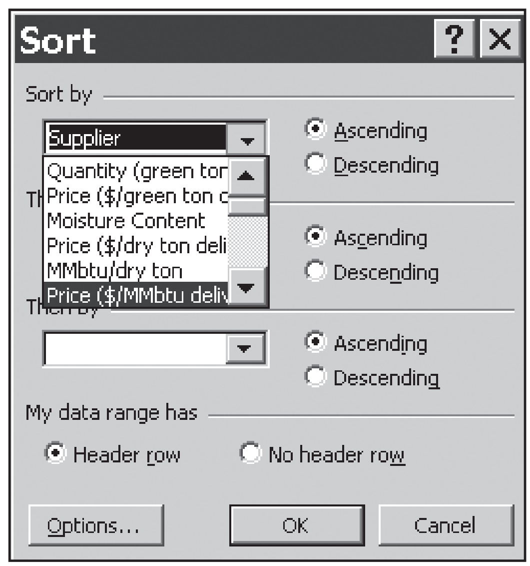
This step can be done manually or can be automated by using the following process:

1. Select all the data in the table

2. select "Sort…" under the "Data" menu

3. select the "Header row" radial button

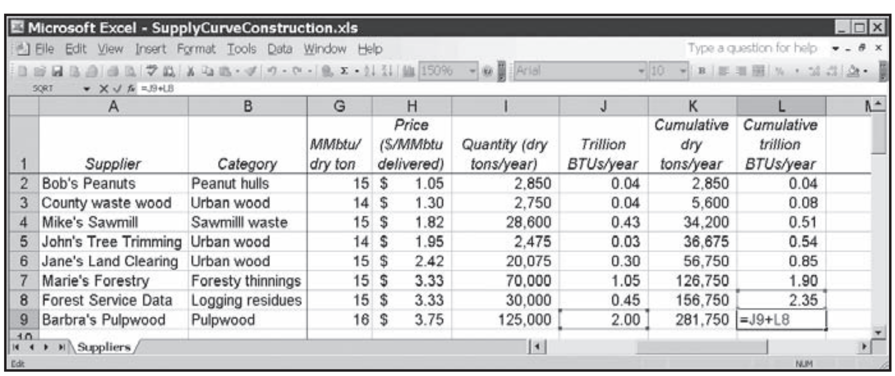
4. select "Price ($/MMBtu delivered)" under the "Sort by" drop down menu.



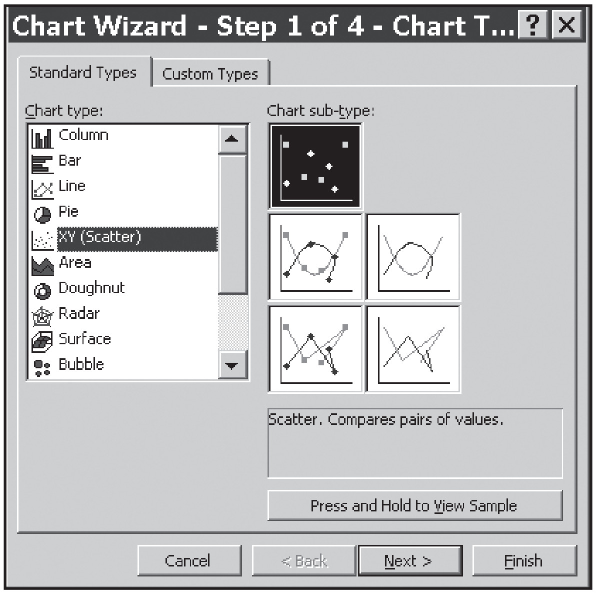
Now the data are ranked from cheapest to most expensive in consistent units. In most cases this ranking will be the same on both a price per dry ton basis and price per Btu basis. If not, you'll have to re-sort the information depending on which units you want to show in the supply curve. Now we can go on the final step and create the supply curve.

4. Create the supply curve.

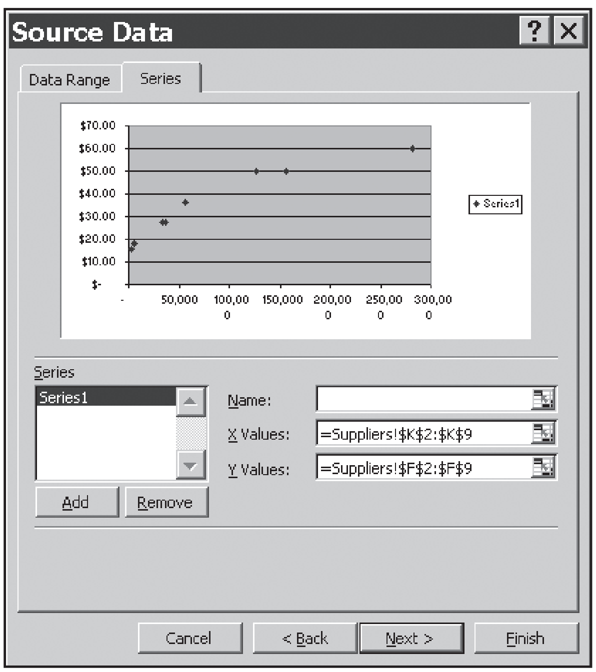
For the Y-axis, available quantities need to be expressed as a cumulative sum. So we add a column showing the cumulative sum of the resources as dry tons (column K) and the cumulative sum of the resources as trillion Btu (column L).



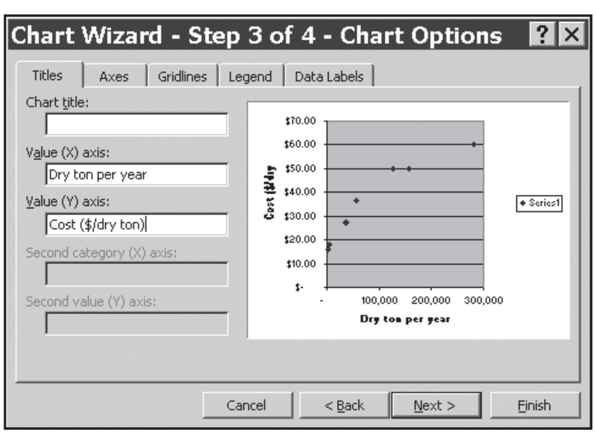
	Supplier	Category	MMbtu/ dry ton	Price ($/MMbtu delivered)	Quantity (dry tons/year)	Trillion BTUs/year	Cumulative dry tons/year	Cumulative trillion BTUs/year
2	Bob's Peanuts	Peanut hulls	15	$ 1.05	2,850	0.04	2,850	0.04
3	County waste wood	Urban wood	14	$ 1.30	2,750	0.04	5,600	0.08
4	Mike's Sawmill	Sawmilll waste	15	$ 1.82	28,600	0.43	34,200	0.51
5	John's Tree Trimming	Urban wood	14	$ 1.95	2,475	0.03	36,675	0.54
6	Jane's Land Clearing	Urban wood	15	$ 2.42	20,075	0.30	56,750	0.85
7	Marie's Forestry	Foresty thinnings	15	$ 3.33	70,000	1.05	126,750	1.90
8	Forest Service Data	Logging residues	15	$ 3.33	30,000	0.45	156,750	2.35
9	Barbra's Pulpwood	Pulpwood	16	$ 3.75	125,000	2.00	281,750	=J9+L8



We then click on the Excel Chart Wizard Icon and select the "XY (Scatter)" chart type and click next.

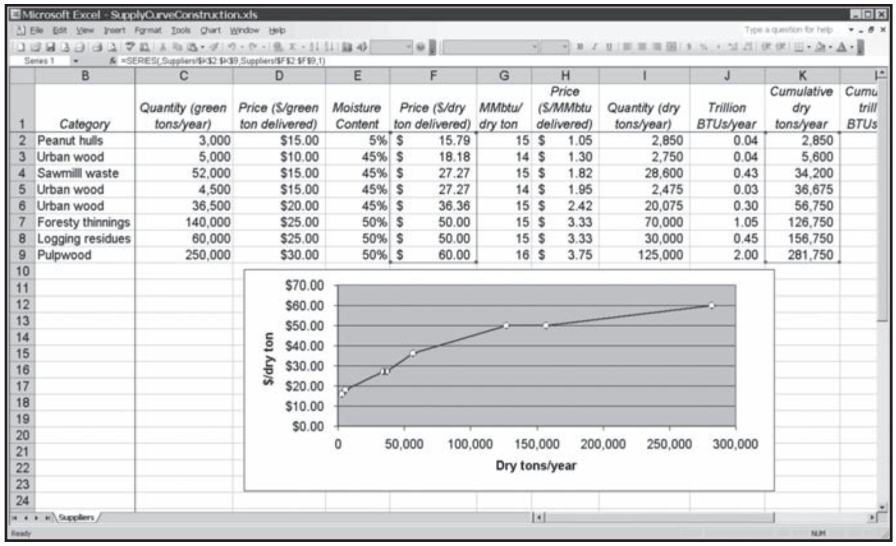


To create a supply curve showing units on a per ton basis, we can select the X-axis as column K, cumulative supply, and the Y-axis as column F, price per dry ton and click next.



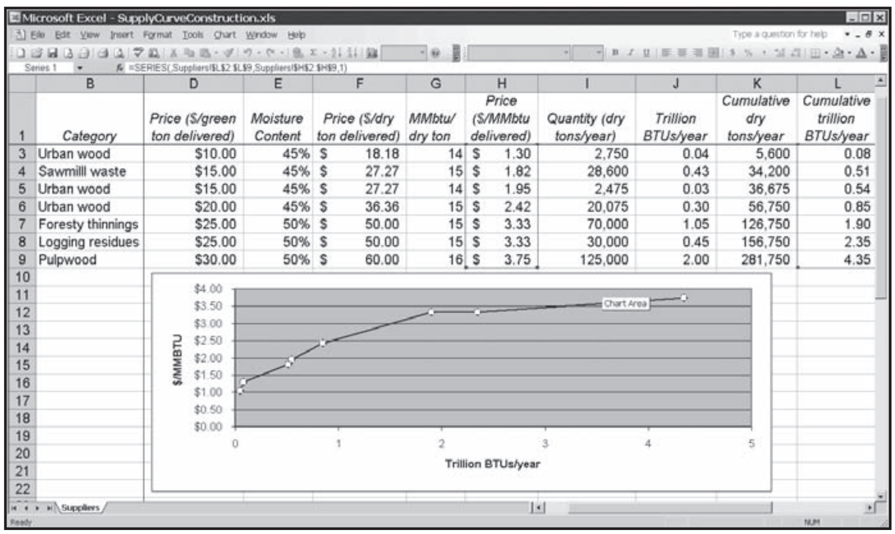
We then add the titles for the X- and Y-axis and set any chart options.

Finally, the supply curve is constructed.



Category	Quantity (green tons/year)	Price ($/green ton delivered)	Moisture Content	Price ($/dry ton delivered)	MMbtu/ dry ton	Price ($/MMbtu delivered)	Quantity (dry tons/year)	Trillion BTUs/year	Cumulative dry tons/year
Peanut hulls	3,000	$15.00	5%	$ 15.79	15	$ 1.05	2,850	0.04	2,850
Urban wood	5,000	$10.00	45%	$ 18.18	14	$ 1.30	2,750	0.04	5,600
Sawmilll waste	52,000	$15.00	45%	$ 27.27	15	$ 1.82	28,600	0.43	34,200
Urban wood	4,500	$15.00	45%	$ 27.27	14	$ 1.95	2,475	0.03	36,675
Urban wood	36,500	$20.00	45%	$ 36.36	15	$ 2.42	20,075	0.30	56,750
Foresty thinnings	140,000	$25.00	50%	$ 50.00	15	$ 3.33	70,000	1.05	126,750
Logging residues	60,000	$25.00	50%	$ 50.00	15	$ 3.33	30,000	0.45	156,750
Pulpwood	250,000	$30.00	50%	$ 60.00	16	$ 3.75	125,000	2.00	281,750

The supply curves illustrate that up to about 37,000 dry tons per year are available at a price of up to $27.27 per dry ton, delivered, up to almost 57,000 dry tons per year are available at a price of up to $36.36, etc. By selecting column L for the X-axis and column H for the Y-axis, the supply curve can be presented in units of energy.



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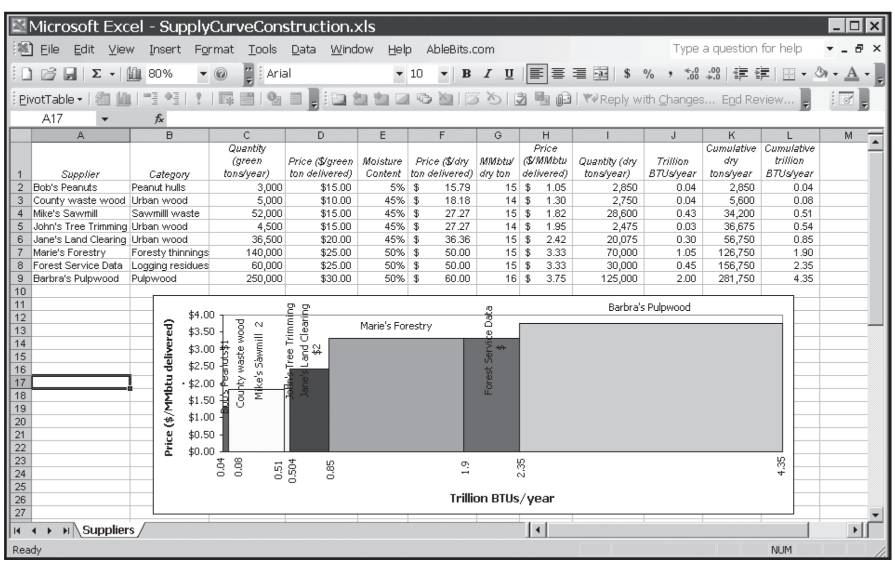
Foresty thinnings	$25.00	50%	$ 50.00	15	$ 3.33	70,000	1.05	126,750	1.90
Logging residues	$25.00	50%	$ 50.00	15	$ 3.33	30,000	0.45	156,750	2.35
Pulpwood	$30.00	50%	$ 60.00	16	$ 3.75	125,000	2.00	281,750	4.35

Alternatively, supply curves can be shown as a bar graph, and resources can be individually labeled. The following supply curve was made using the Macroeconomic Supply Curve Excel add-in, available at www.mrexcel.com.



Supplier	Category	Quantity (green tons/year)	Price ($/green ton delivered)	Moisture Content	Price ($/dry ton delivered)	MMbtu/ dry ton	Price ($/MMbtu delivered)	Quantity (dry tons/year)	Trillion BTUs/year	Cumulative dry tons/year	Cumulative trillion BTUs/year
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Barbra's Pulpwood	Pulpwood	250,000	$30.00	50%	$ 60.00	16	$ 3.75	125,000	2.00	281,750	4.35

The steps above describe the basic concepts for how supply curves can be constructed and how they can be used to illustrate the economic availability of biomass resources. While making supply curves is a fairly straight forward process, gathering the needed information can be more difficult. Care should be taken to identify uncertainty about both quantities and prices, and present a range of possible scenarios.

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