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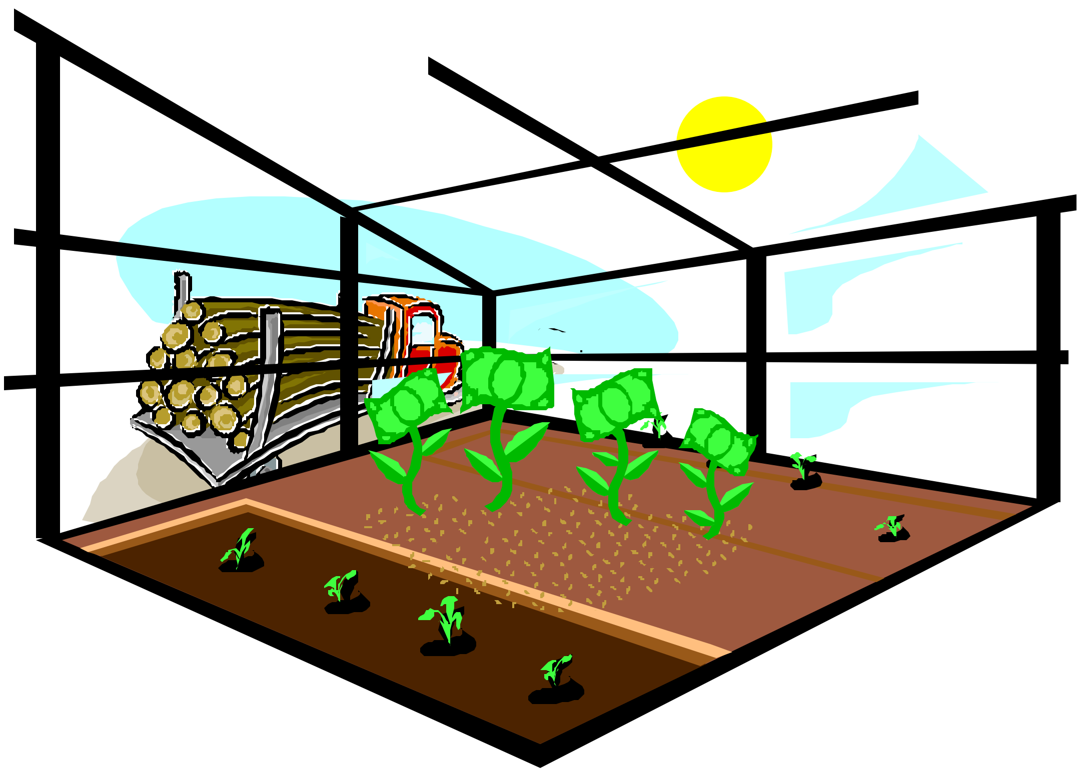
Economic Viability of Using Hardwood Residue Chips as a Heating Source for Nursery Greenhouse Operations in Tennessee



by

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Executive Summary

This study examines the economic feasibility of heating greenhouses with hardwood residue chips. The following are examined; potential costs of heating a 2,000 square foot greenhouse, the potential savings per BTU from using wood as an energy source, estimated costs of installing a wood burning heating furnace, and whether investing in mill residues as an energy source is financially viable. The study also examines the types of wood residues produced in Tennessee and where these wood residues may be located compared with major nursery/greenhouse production areas. Delivered wood prices were obtained from a 2000 survey of wood residue prices and the Wood Transportation and Resource Analysis System (WTRANS) Program. The results from this study suggest that wood heating can be a viable economic alternative to other sources. A consideration in heating with wood fuel is also whether the source would be available year round. In addition, wood fuel systems require more daily labor to keep the system fed with fuel than with other types of fuel systems. A worksheet to assist greenhouse producers in making the decision regarding whether to convert some or their entire greenhouse heating to a wood source is provided in the Appendix.

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Economic Viability of Using Hardwood Residue Chips as a Heating Source for Nursery Greenhouse Operations in Tennessee

Introduction

Tennessee is a major producer of hardwood products in the United States. Sustainable development of the forests in Tennessee may be enhanced by finding new markets to add value to byproducts of hardwood production, such as mill residues. One potential market is for energy generation. Wood residue combustion systems can provide alternative sources for heat, a major expense of greenhouse operations. The purpose of this study is to examine the economic feasibility of heating greenhouses with hardwood residue chips. This report presents the results of a study that examined the potential costs of heating a 2,000 square foot greenhouse, estimated the potential savings per BTU from using wood as an energy source, estimated costs of installing a wood burning heating furnace, and evaluated whether investing in mill residues as an energy source was financially viable. The study also examined the types of wood residues produced in Tennessee and where these wood residues may be located compared with major nursery/greenhouse production areas.

Background

Greenhouse Production in Tennessee

Tennessee is a major producer of horticultural products. A portion of these horticultural products is produced under cover in greenhouse operations. According to the 1998 USDA Census of Horticultural Specialties, 340 operations had a total area of 11,306,000 square feet under cover in the state. This represented an average area under cover per operation of 33,253 square feet. The most commonly used greenhouse covering material was plastic film. As shown in Table 1, products include annual bedding/garden plants, herbaceous perennial plants, potted flowering plants, foliage plants, cut flowers, and nursery plants. For the state, Warren County has the largest value of horticultural products sales for both under cover and acres in the open operations (1997 Census of Agriculture).

Table 1. Tennessee Horticultural Operations by Type, Area under Cover, and Number

Operation Type	Area (1,000 square feet)	Number of Operations	Average 1,000 Square Feet per Operation
Annual bedding/garden plants	4,316	163	26.48
Herbaceous perennial plants	863	87	9.92
Potted flowering plants	2,429	78	31.14
Foliage Plants	709	66	10.74
Cut Flowers	155	7	22.14
Nursery Plants	2,580	81	31.85

Source: 1998 Census of Horticultural Specialties.

Heating costs can represent a major cost in a greenhouse operation. The cost of heating a greenhouse depends on the size of the greenhouse, both outside and required inside temperatures, the type of utilized heating system, the fuel used, and the fuel price. In 1998, estimated energy costs for all horticultural operations in Tennessee were $10,650,000 across a total of 603 operations ($17,662 per year per operation) (1998 Census of Horticultural Specialties). This constitutes about 8 percent of the major expenses for this type of production operation (plants, seeds, etc., commercial fertilizer, other chemicals, energy, and hired labor). It is likely energy costs will constitute a higher share of costs for the more greenhouse intensive operations than for greenhouse operations that are less intensive. Alternative sources of energy to generate heat include electricity, gas, liquid propane, and fuel oil. Wood residues also represent a potential source of energy to be used in heating greenhouses.

Wood Residues in Tennessee

Tennessee is a major producer of hardwood lumber and wood products. Wood residues generated by sawmills and other primary wood users have been estimated at over 140 million cubic feet, with the majority being derived from hardwood residues (Stratton and Wright). These estimates do not include residues generated by secondary wood products manufacturers, such as furniture manufacturers.

According to a 1997 survey of primary (green mill) wood-using plants, about 56% of residues were used for industrial fuel, 20% was used for fiber products, 15% was used for miscellaneous purposes, and 9% was not used (Stratton and Wright). The amount not used is somewhat higher than the national average of 2% (McKeever). The largest proportion of residues is coarse (for example, chips) (43%), followed by bark (32%), and sawdust (25%). Less than 1% of primary mill residues are shavings. About 45% of the coarse mill residues were used for manufacturing fiber products. However, most of the bark and sawdust residues were used for industrial fuel. In total, about 78 million cubic feet of residues were used for fuel. The largest producing counties for hardwood residues that are used for some purpose are Shelby, Macon, Hardeman, Putnam and Henry (Table 2). The counties with the largest amount of unused green mill hardwood residues are Hancock, McMinn, Greene, Henderson, and Lauderdale (Table 3). Warren County, where a large portion of the nursery/greenhouse production in the state occurs, has very little unused tons of bark residues, but uses 11,848 tons of bark. Warren County also has little unused tons of coarse residues, but uses 31,182 tons.

Table 2. Counties with Green Hardwood Residues Currently Being Used

	Used Hardwood (green tons)				
County	Sawdust	Shavings	Coarse	Bark	Total
Shelby	97,599	236	166,954	63,436	328,224
Macon	58,937	0	97,212	35,040	191,189
Hardeman	36,936	0	76,084	26,426	139,446
Putnam	37,618	0	64,068	24,343	126,028
Henry	29,610	0	68,085	25,870	123,566
White	33,829	0	57,985	22,058	113,873
Hardin	17,444	0	30,185	65,059	112,688
Wayne	27,281	0	52,660	18,491	98,432
Houston	28,522	1,797	49,008	18,621	97,949
Montgomery	29,000	0	49,613	18,851	97,464

Table 3. Counties with Green Hardwood Residues Currently Not Being Used

	Not Used Hardwood (green tons)				
	Sawdust	Shavings	Coarse	Bark	Total
Hancock	31,644	0	41,242	18,153	91,039
McMinn	4,219	0	46,450	17,649	68,318
Greene	12,086	0	16,418	6,239	34,743
Henderson	13,506	0	7,442	2,828	23,776
Lauderdale	8,494	0	8,123	4,885	21,502
Macon	5,834	0	9,980	3,792	19,606
Smith	3,529	0	11,172	3,654	18,355
Houston	3,634	0	8,828	3,354	15,816
Fentress	11,467	0	1,271	195	12,933
Washington	5,636	0	3,654	2,906	12,196

As noted above, bark and sawdust are often used for industrial fuel. While residues can be burned as an alternative source of fuel, greater fuel efficiency occurs for dry rather than green residues due to the moisture content. Currently, adequate data on residues from secondary wood products producers (that might constitute a good source of dry residues) is unavailable. However, large concentrations of employment in furniture and fixtures manufacturing are in Hamblen, Rhea, Shelby, Bradley, Sumner, McMinn, Claiborne, Cocke, Greene, and Monroe Counties. Manufacturing plants located in these counties could serve as sources of secondary wood residues (Census of Manufacturers).

The counties with the largest market value of production of nursery/greenhouse products (Census of Agriculture) compared with estimates of green mill hardwood residues produced (Stratton and Wright), and number of furniture and fixtures manufacturers (Census of Manufactures) are shown in Table 4. The map in Figure 1 displays the amount of green hardwood residues by county. The counties with greater than $4 million in nursery/greenhouse sales are denoted by a star symbol. As can be seen from Table 4 and Figure 1, counties with nursery/greenhouse firms and proximity to hardwood residues include Warren, Shelby, Franklin, Sumner, Blount, Grundy, and Coffee. In addition, Davidson, DeKalb, and Knox Counties have green hardwood residues in surrounding counties.

Table 4. Largest Nursery/Greenhouse Producing Counties and Potential Hardwood Residue Resources

County	Market Value of Nursery/Greenhouse Products ($1,000)	Number of Furniture and Fixtures Manufacturers	Green Hardwood Residues, All Types (Tons)
Warren	67,026	1	67,057
DeKalb	17,913	1	0
Shelby	8,596	37	328,373
Knox	7,395	15	0
Davidson	7,163	24	0
Franklin	6,400	1	51,934
Sumner	6,194	10	6,321
Blount	5,555	4	19,197
Grundy	4,446	0	50,847
Coffee	4,441	1	9,755

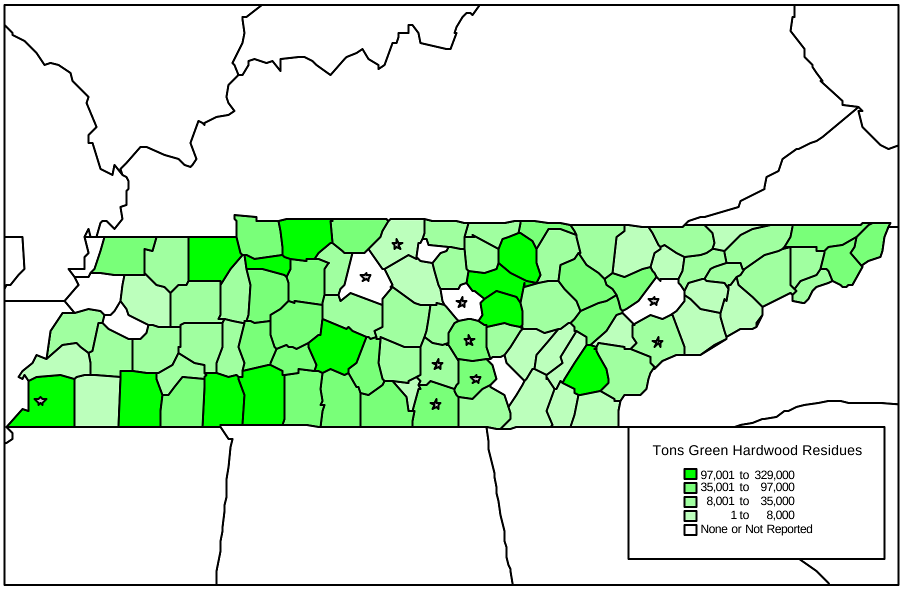

Figure 1. Tons of Green Hardwood Residues and Nursery/Greenhouse Counties. The counties with at least $4 million in nursery/greenhouse sales are denoted with a (*) symbol.

Methodology

Estimated Heating Requirements for a Greenhouse

In evaluating the costs of various energy sources to heat the greenhouse, the heating requirements, based in part on heat loss, of the greenhouse must be calculated. To calculate energy costs to heat a greenhouse, the BTU's[1], conversion of energy into BTU's, the prices of the energy sources, and estimates of the total hours of heating required, either on a monthly or annual basis, are required.

To calculate the BTU's of heat required, the total surface area exposed and total volume of the greenhouse, high and low temperatures, and the heat conductive properties of the greenhouse construction materials are needed. The two components of heat loss are heat conduction loss and air exchange filtration heat loss (Texas A&M University, Department of Horticultural Sciences). The methods to calculate these two heat loss components are as follows:

Heat Conduction Loss

Heat conduction loss occurs when heat is lost to the outside environment. It is influenced by exposed surface area of the greenhouse, inside and outside temperatures, and the heat loss value for the covering material. Heat conduction loss is calculated as:

(1) Heat Conduction Loss Factor = TSA x T x HLV

where:

TSA = Total Surface Area Exposed on the Greenhouse,

T = Maximum Temperature Inside - Minimum Temperature Outside, and

HLV = Heat Loss Value for the Covering[2].

Air Exchange Filtration Heat Loss

The second type of heat loss is due to air being infiltrated through the greenhouse. An estimate of air infiltration heat loss is calculated using the following expression:

(2) Air Exchange Filtration Heat Loss = .22 x T x V x A

where:

T = Maximum Temperature Inside - Minimum Temperature Outside,

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[1] BTU's are British Thermal Units and represent a measure of the quantity of heat, defined since 1956 as approximately equal to 1,055 joules, or 252 gram calories. It was defined formerly as the amount of heat required to raise the temperature of one pound of water 1º F.

[2] The Heat Loss Value varies by material, such as glass or plastic.

V = Volume of the greenhouse, and

A = Air exchange per hour for the greenhouse cover.

The volume of the greenhouse is calculated as the end area (A+B+C) x length of the greenhouse (Figure 2).

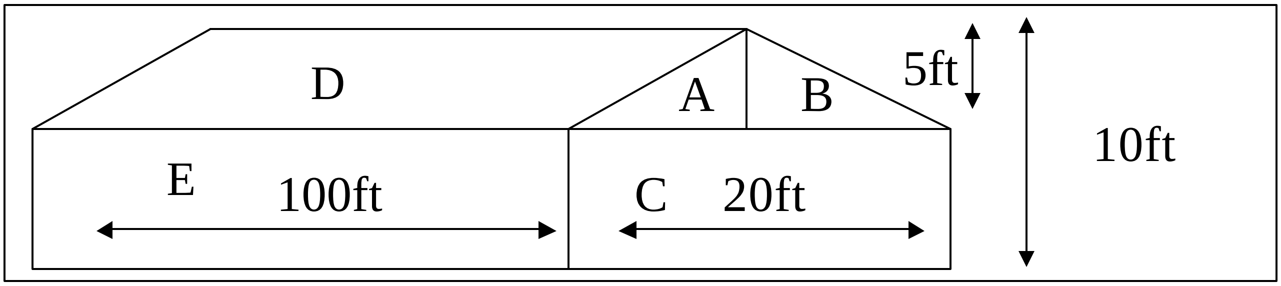

Figure 2. Example Greenhouse: Even Span Structure.

Wood Residues as an Energy Source and Costs Comparisons

The BTU's per pound of wood vary according to the type of wood, whether hardwood or softwood, the efficiency of the residue burner system, and the moisture content of the wood. The wood residues required can be altered on the basis of the residue burner system's efficiency. For example, if a system is 70% efficient, more residues will be required than an 80% efficient system. According to Panshin and Zeeuw, the BTU's generated by wood vary with moisture content as:

(3) BTULB = [H x (100-MC/7)/(100+MC)] x EFFIC

where:

BTULB is BTU’s per pound,

H is the BTU's per pound produced by bone-dry wood[3], about 8500 for hardwood and 9000 for softwood,

MC is the moisture content percentage, and

EFFIC is the burner system's efficiency (expressed as a percent). The cost of wood per BTU can be calculated as (BTULB x 2000) x $/ton.

Investment Decision

The question of how much the producer could afford to invest in a wood burning system arises. Net Present Value can be used to assess the financial viability of investing in a wood burning system.

(4) $$NPV = -I + \sum_{i=1}^{n} \frac{CF_i}{(1+r)^i}$$

For equation 4, I represents the initial investment in the wood heating system, CF_i is the expected net cash flow in year I (savings compared with using an alternative energy source for each year), r is the discount rate (current interest rate), and n is the time horizon of the project (how long the heating system is expected to last).

The costs of installing a wood burning furnace system would include the furnace (and building if not self contained), digging a trench, piping, and plumber costs. The costs of operating the wood furnace would include labor involved in loading and cleaning out the furnace. The labor and maintenance costs should be compared with other sources of heat, such as electricity, gas, liquid propane, or fuel oil.

Results for an Example System

Heating Requirements for Example Greenhouse

Using the example of an even span structure that is 100 feet long, 20 feet wide, and 10 feet tall as shown in Figure 2, the heat conduction loss value can be calculated

[3] Bone dry is the standard measure of wood residue. In general, bone-dry wood has zero percent moisture while

(equation 1). Total Surface Area is calculated as: TSA = 2 x E (areas of two sides) + 2 x [A+B+C] (area of front/back) + 2 x D (area of roof). For Figure 2, the total surface area is TSA = 3,536 square feet[4]. If the maximum temperature inside is 80 degrees and the minimum temperature outside is 15 degrees, then T = 65 (80-15 = 65). The heat loss value for 4 mm polycarbonate is about .70 (Texas A&M University, Department of Horticultural Sciences). For this type of greenhouse, the Heat Conduction Loss Factor would be 3536 x 65 x .70 or 160,888 BTU's per hour. Likewise, the end area of the greenhouse in Figure 2 is 150 square feet and the length is 100 feet, so the volume is 15,000 cubic feet. An estimate of 0.75 air exchanges per hour on a plastic covered greenhouse was used to calculate air exchange filtration losses (Texas A&M University, Department of Horticultural Sciences). The Air Exchange Filtration Heat Loss is then .22 x 65 x 15,000 x .75 or 160,875 BTU's (equation 2).

The total loss would then be 166,088+160,875 or 321,763 BTU's. This includes both heat conduction loss and air exchange filtration heat loss. A heating unit with this BTU capacity would be needed to heat the greenhouse in this example. Prices for 350,000 BTU output heating units (conventional fuels, such as gas or fuel oil) ranged from about $1,300 to $3,000 depending on the type.

Costs by Alternative Energy Types

Greenhouse heating costs are not only affected by the type and size of greenhouse and temperatures, but also by the type of energy used and the efficiency of the heating unit used. A BTU is equivalent to the following values displayed in Table 5.

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green wood contains 50% moisture.

[4] Surface area calculators for greenhouses are available on the Internet at http://www.littlegreenhouse.com/area-calc.shtml.

BTU equivalents in Table 5 are based on burner system efficiencies of 80 percent for electricity and fuel oil, and 75 percent for the natural gas and liquid propane.

Table 5. BTU Equivalents for Various Energy Sources, Unit Price, and Cost/BTU

Fuel Type	1 BTU Equivalent		Unit Price	Cost/BTU
Electricity	1/2730	KWh	$.03	$.0000110
Natural Gas	1/75,000	Therms	$.68	$.0000091
Liquid Propane	1/67,500	Gallons	$1.32	$.0000196
Fuel Oil	1/112,000	Gallons	$1.29	$.0000115

Prices for the various fuels are estimated at $.03 per kWh for electricity, $.68 per therm for natural gas, $1.32 per gallon of liquid propane gas, and $1.29 for fuel oil (Knoxville Utilities Board and local contacts).

Heating Example Greenhouse with Hardwood Residues

The following example calculates savings compared with other energy sources and estimates whether these savings might justify investment in the wood burning system. An important consideration in using hardwood residues is how they compare in cost with the other commonly used energy sources examined above. The following example assumes a burner efficiency of 70 percent and a wood moisture content of 40 percent.

For hardwood residues, an estimate of BTU's per pound is about 4007.14, and for softwood residues about 4242.85 (equation 3). Converting this to tons gives 8,014,280 BTU's per ton for hardwood and 8,485,700 BTU's per ton for softwood. Given the example greenhouse, which required 321,763 BTU's per hour, residue needs would be about .040149 tons of hardwood and about .037918 tons of softwood.

Values for wood residue prices are based on a 2000 survey of wood products producers. Undelivered price estimates from the survey results were $16.37 per ton for coarse green hardwood residues, $7.36 per ton for green hardwood sawdust residues, and $7.97 per ton for green hardwood bark residues. The undelivered prices for green softwood residues are $14.80 per ton for coarse green softwood residues, $8.21 per ton for green softwood sawdust residues, and $9.67 per ton for green softwood bark residues. Delivered prices will depend on the distance between the delivery source and the delivery destination.

Using Warren County as a destination county and the surrounding counties having available coarse hardwood residues (Cannon, Coffee, Grundy, Van Buren, and White), an average delivered green hardwood residue (coarse) price of $23 is estimated with The Wood Transportation and Resource Analysis System (WTRANS) Program (English, Jensen, Menard, Park, and Wilson).

The hardwood residue requirements to obtain a BTU of heat are about .00000012478 tons, giving an energy cost of about $.00000287 per BTU. This cost per BTU compares very favorably with the costs per BTU from the other fuel sources presented in Table 5. The cost differential between residues and other forms of energy are presented in Table 6. Comparing wood with these other fuels shows about an average 76 percent savings in energy costs. These cost differentials do not include labor costs associated with keeping the wood burner supplied with fuel wood or the equipment costs, nor the investment in the wood burner.

Table 6. Cost Difference of Using Other Energy Sources Versus Hardwood Residues

Fuel Type	Cost Difference/BTU	Percent Savings With Wood*
Electricity	$0.00000812	73.88%
Natural Gas	$0.00000620	68.35%
Liquid Propane	$0.00001669	85.32%
Fuel Oil	$0.00000865	75.08%

*Average is 75.6%

Investment in Wood Burner Systems

Often wood burning systems are added on to an existing heat distribution network. This would mean the network would be usable no matter the source of energy used. In this case, the costs to the grower of a wood chip combustion system using water as a heat transfer include a building, equipment (hopper, combustor, etc.), digging a trench, piping, and plumbing (for connecting the combustion system to the existing heat distribution network). The piping runs between the combustion unit and the greenhouse to be heated (for example, polyethylene pipe[5], surrounded by insulation, inside a larger sewer pipe) (Natural Resources Canada). The existing heating system may be used as a backup for the wood burning system.

An estimate of the dollars per square foot under cover based on the energy bill of nursery/greenhouse operations in Tennessee was calculated at $.94 per square foot of greenhouse space. (This number could be higher or lower, because primarily greenhouse operations will likely have higher energy costs, and these estimates include energy costs of both covered and uncovered areas). Adjusting this for 6 percent inflation from the 1998 costs yields a cost of $1.00 per square foot (Bureau of Labor Statistics). For the example 2,000 square foot greenhouse, the estimated energy costs would be about $2,000 per year. Using 76 percent as of an average value for savings (Table 6), these costs (not including investment in facilities and equipment) could be reduced to about $480 if wood were used as fuel.

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[5] Plastic or steel in plastic pipes are cheaper to purchase, install, and maintain for small commercial biomass heating systems and are appropriate for water temperatures less than 203^0F.

In the calculations displayed in Table 7 using equation 4, CF for each year is the savings from using wood or $1,520 less the additional costs of operating the wood unit (estimated at 10% of $1,520), which gives $1,368. The real discount rate is assumed at 6.2 percent[6], and horizon is the expected life of the unit is 15 years (Federal Reserve Board; Natural Resources Canada; Giroud, Lowe, and Samson). If the NPV is zero or greater, then the investment is financially viable since it generates a return equal to or greater than the next best alternative. If NPV is not positive, then the investment is not financially viable. In order to make the investment in the wood burning unit financially viable, the unit must cost $13,114 or less to install.

Table 7. Cash Flow and Discounted Value of Cash Flows Generated by Savings from Heating with Wood

Year	CF (Expected Annual Savings)	Discounted Value of $CF_i = \frac{CF_i}{(1+r)^i}$
1	$1,368	$1,288
2	$1,368	$1,213
3	$1,368	$1,142
4	$1,368	$1,075
5	$1,368	$1,013
6	$1,368	$953
7	$1,368	$898
8	$1,368	$845
9	$1,368	$796
10	$1,368	$750
11	$1,368	$706
12	$1,368	$665
13	$1,368	$626
14	$1,368	$589
15	$1,368	$555
		$13,114

Costs for an example system are provided below. The system below is a self-contained outdoor heating unit that does not require construction of a building.

[6] Five-year average of prime lending rate subtracted from change in CPI over the last five years.

However, some heating furnaces, which cost less, would require that a building be constructed. An example price of that type of furnace was around $1,800 (up to 150,000 BTU's output or $3600 for 300,000 BTU's output). Costs are also estimated for digging a trench and laying the pipe to connect the furnace with the greenhouse to be heated. Estimates are based on commercial sources and a study by Girourd, Lowe, and Samson.

Table 8. Estimated Costs of Installing An Outdoor Wood Burning Furnace

Equipment/Service		Estimated Cost
Burner		$4,000
Digging Trench		$90
Piping		$3,500
Plumber		$350
	TOTAL	$7,940

In addition, if storage for the wood were not already available, the producer would need to provide a covered area to keep the wood dry. The technical specifications on one system examined stated that the furnace would need to be loaded about every 12 hours. The systems also must be periodically cleaned out. Additional costs might include a wood chip hopper or storage bin and a feeder auger to transport the chips to the combustion chamber.

Conclusions

The economic viability of heating a greenhouse with wood residues, such as wood chips depends on the level of capital required to purchase and install the wood fuel heating system and accessibility of low cost sources of wood residues. The results from this study suggest that wood heating can be a viable economic alternative to other sources. Residue pricing in this analysis was an average delivered across county lines. In some counties, adequate supplies of residues would likely be available at much lower transportation costs. Recall that the price of coarse residues, if not delivered, was about $16. A consideration in heating with wood fuel is also whether the source would be available year round. In addition, wood fuel systems require more daily labor to keep the system fed with fuel than with other types of fuel systems. A worksheet to assist greenhouse producers in making the decision regarding whether to convert some or their entire greenhouse heating to a wood source is provided in the Appendix.

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APPENDIX

WORKSHEETS TO EVALUATE WOOD AS A FUEL SOURCE

CAPACITY OF BURNER UNIT NEEDED

Heat Loss

Heat Conduction Loss

(1) Heat Conduction Loss Factor = TSA x T x HLV

where:

TSA = Total Surface Area Exposed on the Greenhouse

T = Maximum Temperature Inside-Minimum Temperature Outside

HLV = Heat Loss Value for the Covering (Varies by material, such as glass).

Air Exchange Filtration Heat Loss

(2) Air Exchange Filtration Heat Loss = .22 x T x V x Air Exchanges per Hour.

The volume of the greenhouse is represented by V. The volume of the greenhouse is calculated as the end area (A+B+C) x length of the greenhouse.

TOTAL HEAT LOSS = Heat Conduction Loss + Air Exchange Filtration Heat Loss

_____________ BTU's.

PROJECTED COSTS TO INSTALL SYSTEM

(Assuming a Heat Distribution System is Already in Place)

Building (if needed)	$___________
Burner Unit	$___________
Other Equipment	$___________
Trench Digging	$___________
Piping	$___________
Plumber	$___________
Other	$___________
TOTAL	$ ___________

TOTAL INVESTMENT is $ ___________

TOTAL VALUE OF DISCOUNTED CASH FLOWS is $ ____________

IF TOTAL INVESTMENT IS GREATER THAN TOTAL VALUE OF DISCOUNTED CASH FLOWS, NOT FINANCIALLY FEASIBLE. IF TOTAL INVESTMENT IS EQUAL TO OR LESS THAN TOTAL VALUE OF DISCOUNTED CASH FLOWS, IS FINANCIALLY FEASIBLE.

WORKSHEET TO EVALUATE WOOD AS A FUEL SOURCE

COSTS PER BTU WITH OTHER FUELS

Current Fuel Type:____________________

Price per Unit of Fuel :___________

Efficiency of Current Heating Unit: _________ %/100 = __________ (decimal point)

BTU's per Unit of Fuel:

Liquid Propane Gas BTU = 1 Gallon x 90,000

Natural Gas BTU = 1 Therm (or 100 cubic feet) x 100,000

Fuel Oil BTU = 1 Gallon x 140,000

Electricity BTU = 1 kWh x 3,412

BTU Per Unit of Fuel: BTU's Per Fuel Unit x Efficiency of Heating Unit =__________

Cost per BTU: Fuel Price x Fuel Required per BTU = $___________

COSTS PER BTU WITH WOOD

BTU's per Pound of Wood Fuel:

BTULB = [H x (100-MC/7)/(100+MC)] x EFFIC =__________%

where:

BTULB is the BTU's per pound,

H is the BTU's per pound produced by bone dry wood, about 8500 for hardwood and 9000 for softwood,

MC is the moisture content percentage, and

EFFIC is the burner system's efficiency (expressed as a percent).

Cost per BTU: (BTULB x 2000) x Price of wood in $/ton =___________ $/ton

SAVINGS

Percent Savings per BTU: [Cost per BTU (Current Fuel)-Cost per BTU (Wood)]/Cost per BTU (Current Fuel = _________ % Savings Per BTU

Estimated Energy Costs for Last Year $ ___________

Projected Annual Savings: Estimated Energy Costs Last Year x (% Savings Per BTU/100) = $__________

Less Any Additional Costs Associated with Maintaining the Unit (Loading Fuel, Cleaning, Repairs) $ ___________

Projected Annual Savings: $ ___________

INVESTMENT DECISION

Expected Life of the Wood Heating Unit ______ Years

Current Interest Rate in Decimal Form ________ (Example 8% would be .08)

Cash Flow Each Year = Projected Annual Savings

Discounted Cash Flow = [(Cash Flow Each Year)/[(1+Interest Rate)$^{\text{Year \#}}$]

Example: Projected Annual Savings Year 1/[(1+Interest Rate)^{1}]

YEAR	Projected Annual Savings	Discounted Cash Flow
1		
		TOTAL = $