ESO 1330

RENEWABLE ENERGY POTENTIAL OF OHIO'S FORESTS

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December 1986

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Introduction

Fuel price increase of the seventies have encouraged Ohio's industrial sector to look for new, less costly feedstocks to substitute for fossil fuels. Enforcement of stricter air pollution standards has speeded up the substitution process. Wood is one feedstock often proposed as an alternative, renewable fuel. Wood's attractive characteristics are its renewability, low sulfur content, and abundant supply, particularly in Southeastern Ohio. In contrast to other biomass feedstocks (Abdallah, Shenk, Rask, Ott), the use of wood as a boiler fuel has received limited economic analysis in Ohio (Cathcart). A 1984 study by resource economists, Gowen and Hitzhusen at Ohio State University compared the use of wood, natural gas, and coal as boiler fuels in three Ohio case plants assuming varying levels of land and air pollution standards. The method of comparison is discounted cash flow financial analysis combined with a constrained optimization model for economic (social costs and returns) analysis.

Background of Study

Natural gas, fuel oil, and coal have been Ohio's traditional boiler fuels since the late 40's (ODOE, 1981). Until the mid-70's, natural gas and coal were less expensive per energy input than forest chips and almost as low as wood wastes (Figure 1). However, the 1973-74 oil embargo, natural gas deregulation, and the resulting fuel substitution effects created upward pressure on fuel oil, natural gas, and coal

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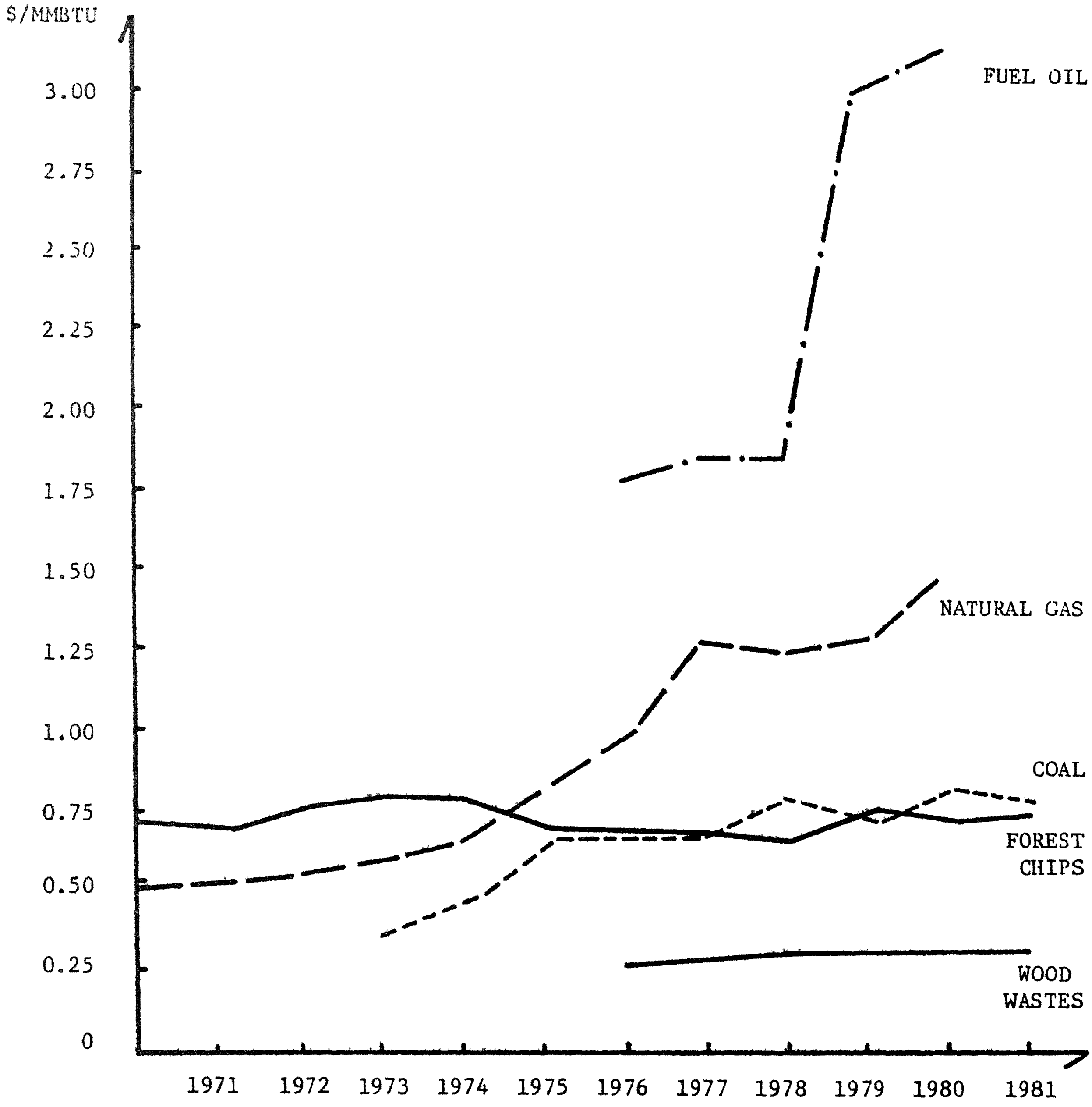

Figure 1: Delivered, Real Fuel Prices for Industrial Users in Ohio (Index: 1970=100)

prices. In contrast to fossil fuel prices, the costs for pulpwood or forest chips and wood wastes remained stable over the decade. By the late 70's, forest chip costs were equal or below coal costs.

Stricter land and air pollution standards are under consideration due to the two social costs associated with coal use, land destruction from surface mining and air pollution. These costs are receiving increased state and federal attention and are slowly increasing market prices through stricter pollution regulations. Forster (1982) estimated that the costs of reclaiming surface mined land in Ohio could add \$1.03 to \$3.64 per short ton to the total costs of coal production. As 71 percent of the total coal currently used in Ohio is from surface mines, this social cost may be important to coal energy users as well as coal producers (ODOE, 1981).

Coal users may also be affected by stricter air quality standards. In the past, Ohio's coal users have faced pollution standards which could often be met through mixing low sulfur imported coals with Ohio's high sulfur coal. In many cases, boilers were often small enough and/or located in nonmetropolitan areas where mixing was unnecessary. Although coal is still the major industrial energy source in Ohio, a shift in the type of coal burned has occurred over time, reflecting tighter air pollution standards. Low sulfur, imported coal rose as a percentage of total coal use from 47 percent in 1970 to 55.7 percent by 1981, with imports coming primarily from the Eastern U.S. (ODOE, 1982).

Physical Wood Energy Potential

Given the relative fuel prices, potentially stricter pollution standards, and wood's low sulfur content, wood feedstocks could provide private as well as social gains to Ohio's energy users and society. Wood for energy may come from three basic sources: wood manufacturing residues, Ohio's forest lands, and intensively managed wood energy farms. Using 1978 data, a study by Battelle estimated that Ohio's total residues (e.g., sawmill, logging, and unused low-quality wood) would produce 8.34 trillion BTU's annually if fuel prices were high enough to bid all wastes away from current users (Hall et al.). Given that logging and low-quality wood residues are difficult to collect, sawmill residues are the best short-term sources. However unused sawmill residues, residues not already used for energy or other markets, are equivalent to only 1.6 trillion BTU's.

The most economical energy feedstock would be low-quality wood from Ohio's forest lands; the small diameter, poor quality wood not used by the sawtimber industry (Nevel and Redett). Currently, this wood is used by Ohio's pulpwood industry as woodships. Annual use in energy equivalents, 4.9 trillion BTU's, is far below annual potential, 159.4 trillion BTU's (Gowen, 1983). A third future source of wood energy could come from energy plantations. Few commercial plantations currently exist in the North Central region. Packaging Corporation of America (in Michigan) has the largest plantations in the region with hybrid poplars, and Stone Paperboard in Coshocton, Ohio has small, test plots of hybrid poplars. Woodchips, thus, represent the largest near term supply of wood energy in Ohio.

Two facts potential energy users want to know are (1) a realistic estimate of potential wood supply, and (2) a comparison of this wood potential to alternative biomass feedstocks. Hitzhusen et al. (1982) compiled a county-by-county biomass energy inventory to determine Ohio's biomass potential. As seen in Table 1, the sustainable wood energy potential, net of current pulpwood and

Table 1: A Comparison of Ohio's 1981 Industrial Energy Consumption and Ohio's Biomass Energy Potential (10^{12} x BTU's per annum)

Use/Potential	Amount
Energy Use[1]	
Coal[2]	613.3
Natural Gas	312.5
Electric[3]	7.3
Distillate/Residual	47.1
Other Petroleum[4]	183.1
Total Consumption	1,163.3
Biomass Energy Potential[5]	
Sustainable Wood	159.4
Municipal Solid Waste	69.0
Usable Crop Residues	64.3
Livestock Wastes	1.4
Total Biomass	294.1

[1] Source: Tables 3 and 5, ODOE, 1982 Energy Status Report, Columbus, Ohio, 1982.

[2] This coal figure includes the direct use of coal by industry of 437.5 Trillion BTU's plus its use of in electric generation, 175.8 Trillion BTU's. The latter is obtained by taking the percentage of electric generation which coal supplies, 96% in 1981, and multiplying this by the electricity use 183.1 Trillion BTU's (ODOE).

[3] To avoid double counting, electric generation figure has netted out the amount coming from coal.

[4] Other petroleum include diesel fuel gasoline, LPG, petroleum coking and petrochemical feedstocks.

[5] Source: Hitzhusen, F. *et al.*, *Ohio Biomass for Energy Annual Potential by County*, ESPR-5, Dept. of Agricultural Economics and Rural Sociology, The Ohio State University, April 1982.

sawtimber use[1/] is 159.4 trillion BTU's per year or 57 percent of the total biomass potential. Similar to crops (Ott), crop residues (Abdallah) and solid wastes (Shenk), wood has a regional advantage in Ohio's Southeastern forested region.

In comparing wood energy potential to Ohio's industrial energy demand (Table 1), the total potential is 26 percent of the annual energy supplied by coal and 51 percent of the energy supplied by natural gas, although the wood supply exceeds the annual distillate/residual oil use. This table suggest the present sustainable wood supply could not substitute fully for all of Ohio's current industrial energy demands but could be used, if economically feasible, as a partial substitute for coal to reduce pollution control costs or to displace natural gas, or fuel oil.

Methodology for Boiler Analysis

To conduct the analysis, three case studies of boilers operating in Southeastern Ohio are developed. Southeastern Ohio is chosen since it is the major wood producing region in the state. A boiler survey was conducted to provide information on average fuel use, daily swing loads, and fuel storage capabilities. Out of 42 surveys, 25 were returned and provided a diversified sample of Ohio's industries from which to draw case studies. The three case studies used in this research represent small (2.75 MMBTU/hr), medium (41.1

[1/] In 1978, pulpwood harvest removed about 20 million cubic feet of wood, approximately 22 percent of Ohio's total timber harvest. Other users of low-quality wood are the chipped board, steel industries and pallet manufacturers. However, their combined use is less than four percent of Ohio's timber harvest. Pulpwood demand rose from only four percent of Ohio's timber harvest in 1951 to 28 percent in 1968 and has stabilized since then at approximately 25 percent or a fourth of the total harvest in 1978 (Nevel and Redett).

MMBTU/hr), and large (71.1 MMBTU/hr) boilers. These three represent a small, private firm, a medium-sized private industrial plant and a medium to large sized public institution. Annual boiler demand is assumed to be 90, 80, and 80 percent of capacity for the small, medium, and large boilers, respectively.

To conduct the financial and economic analyses of wood, natural gas, and coal-fired boilers, two quantitative methods are used. First, a unconstrained discounted cash flow analysis is used in the financial analysis to compare life-cycle boiler costs assuming minimal pollution control. Second, a constrained optimization model of coal and wood-fired boilers' discounted cash flows is used in the economic analysis to internalize particular social costs into fuel prices. The use of discounted cash flows, life-cycle costs, allows sensitivity analyses to be made regarding future fuel prices, thereby capturing a critical variable of uncertainty in the analysis.

The distinction between financial and economic analysis comes from project analysis literature (Gittinger, Dasgupta and Pearce). Financial analyses refer to studies of the returns to equity capital for a private investor. In contrast, economic analyses include at a minimum the internalization of some currently uncompensated values society bears or gains from the investment.

The distinction between private and social costs may change over time. For instance, in this study's financial analysis, two costs are internalized that have been viewed as social costs. These are annual sustainable forest yields and minimal air pollution compliance costs. Annual sustainable yields are assumed to be maintained through higher transport costs by forest chip users since an industry or institution should not deplete its forest resource base near the installation. Annual sustainable yields means yearly harvests do not exceed the annual forest growth or replenishment rates. In the financial analysis, air pollution compliance costs only meet currently mandated standards. The economic analysis internalizes sustainable yields for forest chip use but also internalizes the costs of coal surface mining reclamation and a range of stricter air quality standards. The latter are internalized through use of an optimization model.

An overview of boiler types and costs as examined in this study is shown in Figure 2. Generally, any total costs stream for a boiler consists of fuel acquisition costs plus boiler operating/maintenance and capital costs. Three types of boiler fuels can be used, wood, natural gas, and coal.[2/] Three forms of wood are analyzed in the study --wood wastes, wood chips harvested from Ohio's forests (forest chips), and wood chips obtained from wood plantations (plantation chips). Wood feedstocks are burned in either combustion boilers or wood gasifiers. Only small and medium gasifier cases are developed due to current size constraints of gasifiers. Direct combustion boilers are used for all coal systems and gasifiers are used for the natural gas cases. A detailed discussion of the cost estimation techniques and the optimization model can be found in Gowen and Hitzhusen.

[2/] Fuel oil is not considered in this study based upon its small industrial use in Ohio, three percent (ODOE, 1981a), the fact that many industries which use it do so out of a particular processing necessity, and that Cathcart has already shown fuel oil to be substantially more expensive than wood, natural gas, or coal.

Figure 2. Combination of Fuels, Costs, Energy Conversion Technologies and Boiler Sizes Used In Study

Fuel	Costs: Financial Analysis	Costs: Economic* Analysis	Energy Conversion Technologies	Boiler Sizes
Wood Wastes	Demand, transport Boiler operating Boiler capital	Air pollution	Wood Combustion	Small Medium Large
			Wood Gasification	Small Medium
Forest Chips	Stumpage, harvest, transport Boiler operating Boiler capital	Sustainable yield Air pollution	Wood Combustion	Small Medium Large
			Wood Gasification	Small Medium
Plantation Chips	Site prep, planting harvest, transport Boiler operating Boiler capital	Air pollution	Wood Combustion	Small Medium Large
			Wood gasification	Small Medium
Natural Gas	Acquisition Boiler operating Boiler capital	None	Gasification	Small Medium
Coal	Acquisition Boiler operating Boiler capital	Reclamation Air pollution	Combustion	Small Medium Large

*Plus all costs in Financial Analysis column.

Results of Boiler Analysis

A comparison of fuel acquistion costs by input and output heat content is made in Table 2. All costs represent delivered costs, including transportation, to the boiler installations. Two coal price levels are developed since current prices fall below pre-recession (1982) trends by about $10 per short ton. The pre-recession coal prices refer to projected 1982 prices based on 1978-1981 coal price patterns (Gowen, 1983).

As seen in Table 2, wood wastes ($0.97-1.94/MMBTU output) are the cheapest fuels per energy output followed by coal ($1.70-2.69/MMBTU output), forest chips ($3.27-4.17/MMBTU output), natural gas ($5.00-5.20/MMBTU output), and finally energy plantation chips ($5.38-7.20/MMBTU output). These acquisition price relationships are extremely important to the economic feasibility of the particular fuel. For instance, the lowest forest chip price is over one and a half times the cheapest coal price per energy output. This suggests there need to be: (1) substantial savings in boiler operating and/or capital costs, (2) high social benefits from using wood as a sulfur reducing fuel with coal, and/or 3) future cost reducing technology in chip harvesting for forest chips to compete with coal.

First-year average boiler costs, shown in Table 3, indicate there are no substantial cost differences between wood and coal fired boilers. Significant boiler cost differences appear between wood combustion versus wood gasification systems, with the latter being cheaper. Like wood gasification, natural gas boiler costs are almost half coal or wood combustion systems but natural gas fuel costs are the highest among the three feedstocks. Because expected fuel prices are critical to the long-run feasibility of a fuel, three fuel price growth scenarios (low, most likely and high) are developed based on studies by the U.S. Department of Energy, Chase Econometrics, DRI, and Ohio DOE.

Table 2. Fuel Acquisition Costs Per Unit of Energy Received and Delivered

Fuel	Current Unit Price	Cost per BTU Received[1] ($/MMBTU Input)	Cost per BTU Delivered[2] ($/MMBTU Output)
Wood			
Wastes	$6-12/gt	0.64-1.28	0.97-1.94
Forest Chips			
Small	$18.33/gt	2.16	3.27
Medium	$21.21/gt	2.49	3.78
Large	$23.37/gt	2.75	4.17
Plantation Chips	$67.40-90.13/gt	3.55-4.75	5.38-7.20
Coal[3]			
Ohio High Sulfur			
Current	$31.00/st	1.38	1.72
Pre-recession	$42.12/st	1.88	2.35
Washed Ohio			
Current	$34.20/st	1.36	1.70
Pre-recession	$45.22/st	1.80	2.25
Low Sulfur Eastern			
Current	$43.47/st	1.80	2.24
Pre-recession	$52.04/st	2.15	2.69
Natural gas[4]	--	3.90-4.10	5.00-5.20

Sources: Tables 3 and 7; gt - green ton, st = short ton

[1] Average heat contents of Ohio high sulfur, cleaned, and Eastern low sulfur coals are 22.4, 25.1, and 24.2 MMBTU/short tone (ODOE). BTU received is the fuel's input energy content before conversion.

[2] Wood boiler efficiency is 66%, thus received or input heat must be adjusted by .66; coal efficiency is .80 and natural gas is .78. BTU delivered is the output or actual useable energy produced by a conversion system after accounting for conversion inefficiencies.

[3] Coal prices are obtained from ODOE, coal companies, and case study users

[4] Natural gas prices used in the table are actual 1982 case study prices.

Table 3. Annual Capital, Operations/Maintenance, Labor, and Fuel Costs For Wood, Natural Gas, and Coal-Fired Boilers by Boiler Sizes

Boiler Size & Annual Costs	Wood Combustion	Wood Gasification	Natural Gas	Coal
	\$1000/year			
Small (2.75 MMBTU/hr.)				
Capital[1]	50	28	24	58
OM	20	6	10	20
Labor	40	5	20	40
Fuel[2]	72 (43.5)	72 (43.5)	99	33 (48)
Medium (40.1 MMBTU/hr.)				
Capital[1]	320	208	218	420
OM	200	50	150	150
Labor	200	160	100	200
Fuel[2]	1,068 (778)	827 (603)	1,554	517 (693)
Large (71.1 MMBTU/hr.)				
Capital[1]	584	---	---	729
OM	375	---	---	375
Labor	200	---	---	200
Fuel[2]	1,879 (980)	---	---	871 (1,168)

[1] Annual capital represents equal annual payments on debt service assuming 15 percent interest on equipment (equipment mix and costs are found in Appendix G).

[2] Wood costs in parentheses are for wood wastes; for coal, the costs in parentheses indicate costs if pre-recession price trends had been maintained in 1982.

An annual inflation rate of 8 percent for years 1-10 and 10 percent form years 10-20 is used with a set of four discount rates, 10, 13, 15, and 25 percent in the financial and economic analyses. See Gowen and Hitzhusen for detailed presentation of these results plus breakeven and sensitivity analyses.

Minimal land or air pollution compliance costs may not reflect future regulatory conditions faced by Ohio boiler users. A range of stricter air quality standards and the inclusion of coal's reclamation costs are internalized into an optimization model of wood, coal, and wood/coal boilers' discounted costs. The optimization model presents the boiler manager with the choice of using wood or coal (Ohio high sulfur, cleaned, or imported low sulfur) and various pollution abatement equipment with which to meet a given sulfur and particulate emission level. A range of pollution levels is developed to determine the effects on optimal fuel mix and costs due to varying pollution standards (See Gowen and Hitzhusen).

In the financial analysis, wood wastes are the cheapest feedstocks followed by coal, forest chips, natural gas, and energy plantation chips. Given current relative prices for coal, wood, and natural gas, only wood wastes in either wood conversion technologies (gasification or combustion) are always financially competitive with coal. Under current or pre-recession (pre-1982) coal prices, forest chips are presently competitive with coal only when burned in the small gasifier and in the medium gasifier at higher discount rates (15%). Forest chips, however, are financially infeasible compared to coal if burned in all three sizes of combustion boilers even at higher (pre-recession) coal prices.

The present economic advantage of wood wastes as the attractive wood feedstock for combustion boilers is put in perspective by its supply constraints. Using Hall's estimates of Ohio's wood waste potential (Hall, et al.), sawmill and logging residues could provide about four percent of Ohio's 1982 industrial natural gas demand and three percent of Ohio's direct industrial coal demand (ODOE, 1982). Besides its limited supply, current prices for wastes would be expected to rise if a large wood energy market developed. However, since the break-even price difference between wood wastes versus coal conversion is approximately $2.00/MMBTU output (wood gasification) or $1.00/MMBTU output (wood combustion), average wood waste prices could go up 50 to 100 percent before wastes would be financially infeasible.

In contrast to wood combustion, wood gasification systems using either wood wastes or chips are financially quite attractive when compared to natural gas or coal boilers. Only the medium scale gasifier using forest chips was financially infeasible compared to coal at current or pre-recession coal prices, although it became feasible at a 15 percent discount rate assuming pre-recession coal prices. This result suggests wood gasification could be the most competitive wood conversion technology in the immediate future.

In the economic analysis, tightening pollution standards for combustion boilers does not make forest chips competitive with cleaned Ohio or imported Eastern coal at current coal prices. Whereas wood wastes are also the cheapest feedstocks in the economic analysis, only when pre-recession coal prices are used do forest chips become economical. Raising coal prices to pre-recession levels and tightening pollution standards in the economic analysis results in forest chips being feasible for the medium but not large boiler. If pre-recession coal prices are assumed, forest chips are mixed with cleaned coal in the medium boiler when current air pollution standards are reduced to 50 percent or lower of current standards. Chips, however, are not used until the tenth year in the large boiler scenario even if pre-recession coal prices are used.

In general, enforcing stricter pollution standards at current coal prices shifts combustion fuel reliance from cleaned Ohio to a mixture of cleaned and imported Eastern coal, changes pollution control equipment, and raises annual costs. Ohio's high sulfur coal never enters the solution for either boiler. Annual costs rise due to the use of more expensive pollution control equipment and the mixing of more costly imported low sulfur coal of forest chips with cleaned coal. Varying discount rates and fuel price growth levels do not have much affect on these general patterns.

In comparing wood fuel feasiblity, hardwood plantations are simply not economical as boiler fuels given current relative fuel prices. A major reason for their infeasibility is the high planting and site preparation costs. These costs make up over 55 percent of total costs. In comparison, stumpage costs for forest chips represent only eight percent of total harvest and transportation costs. Technological breakthroughs for increasing yields and/or decreasing costs appear necessary before wood plantations in Ohio can be competitive with forest chips or coal.

Policy Implications

The results of this study have policy implications for four general areas, forestry, coal mining, environmental regulation, and Ohio's energy future. Each general area would be affected if wood energy use increases and a tightening of environmental standards occurs in Ohio. These implications, of course, are constrained by the limited ability to generalize from three case studies to all boiler users in Ohio.

With regards to the forest industry, the lack of economic and financial viability of forest chips over coal given current coal prices suggest Ohio's loggers will not have a significant industrial energy market in the near or perhaps intermediate future. While some boilers may switch from natural gas to wood, the present excess supply of and low prices for wood wastes mean these wood sources should be used before forest chips. Forest chips appear economical only if pre-recession coal prices return and stricter air quality standards are enforced. Even then, chips are economical only for the medium boiler size. For Ohio loggers, the wood boiler market simply does not become strong unless important coal price and environmental regulation changes occur. Given that forest chips are economical only at much higher coal prices, low quality wood producers may need to look to other markets for expansion such as the residential fuelwood market.

In contrast to forest chips, Ohio's wood wastes, although limited in supply, have an important energy role in providing small to medium energy users with a sustainable low cost fuel. Hall et al. stresses the importance of Ohio's waste wood supply as another energy source for boiler users. Although limited in supply, its importance to particularly small to medium scale users will be critical in terms of annual cost savings. Wood product industries could gain from the sales of their waste products to these energy users.

The dominance of cleaned or low sulfur imported coal in the economic analysis' optimization model, at either current or stricter air pollution standards, has important implications for Ohio's coal mining industry. If the enactment and enforcement of stricter pollution standards occurs, Ohio's high sulfur coal industry could face a serious drop in demand. To prevent a loss in coal revenues plus secondary impacts in employment and income on the coal mining region, the state will need to encourage cleaning a greater percentage of Ohio's coal. At present thirty-five coal cleaning facilities exist in Ohio with a potential of cleaning far more than is currently being cleaned. These plants are being underutilized due to the low demand for cleaned coal and problems involved in coordinating coal company interactions. If stricter pollution laws are enforced, cleaned coal may become financially more attractive than uncleaned Ohio coal since the latter coal requires high flue desulfurization costs. This implicit price difference may be sufficient to overcome current problems in the coal cleaning industry. If not, public policies may be needed to encourage cleaning of Ohio coal due to the latter's regional and economic impacts.

The importance of environmental regulations on changing optimal fuel mixes and the maintenance of sustainable harvests has been shown by this study. Stricter air quality regulations will impose increasing costs on boiler operations and alter the boiler fuel dependence to different types of coal. While the state may be interested in the secondary impacts (employment and income) associated with a decrease in Ohio coal use, private energy users will be motivated by the lower costs of cleaned or imported coal versus the cost of expensive pollution abatement equipment. As environmental regulation forces the adoption of pollution abatement equipment, concurrent emphasis on research and development to decrease the costs of such technologies might also be considered.

While this study does not forsee the use of forest chips as a competitive boiler fuel in the near future, except perhaps in small or medium gasifiers, environmental policy implications also emerge from the costs of maintaining sustainable harvests. Reducing cutting cycles to only twenty years through overcutting of forests, extremely short rotation lengths for Ohio, would rapidly reduce the long-run quality and supply potential of Ohio's forests.

Given the long-run effect on Ohio's forests from this reduction and the fact that only two to three dollars per green ton may be saved in total transportation costs by this reduction, it could be that the private market valuation of maintaining sustainable harvests does not reflect its user cost or long-run scarcity value. If a strong wood chip energy market were to develop, environmental regulation might be considered if the state felt it socially desirable to maintain a sustainable wood supply in Ohio.

This study suggests that coal rather than wood will have an important energy role for Ohio in the coming decade. Wood wastes may be a low cost, important fuel alternative for small to medium industries or institutions, but wastes from wood manufacturing firms simply cannot provide a significant proportion of Ohio's boiler energy needs. Only when stricter pollution standards exist and pre-recession coal prices are resumed do forest chips appear economical in combustion boilers. However, energy policies encouraging research and development of wood gasification, as compared to combustion, could provide Ohio with a financially viable alternative to coal boilers that might utilize forest chips. Even though wood gasification appears the most commercially attractive wood energy conversion, the potential forest energy use will probably never exceed Ohio's coal use unless wood plantations become economical. Thus, coal can be expected to play an integral role in Ohio's energy future even if wood chips become competitive in the future.

In conclusion, only wood wastes and wood gasification wood energy supply and conversion technology appear economical at present. Given currently depressed coal and fossil fuel prices, the short-term viability of wood chips and expansion of its market to the energy area simply does not appear plausible. However, if future energy prices exceed pre-recession trends, economic recovery strengthens, and stricter air pollution standards are enacted and enforced, wood may be a socially desirable boiler fuel.

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