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ECONOMIC ANALYSIS OF COMPRESSION DRYING GREEN WOOD CHIP FUELS

Bill Callas

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INTRODUCTION

The forest products industry continues to increase its use of wood residue for energy. Substantial economic benefit already comes from combustion of wood residues, but by improving the efficiency with which wood fuel is converted to energy, significant additional potential exists for some situations. Improving conversion efficiency can reduce fuel consumption and operating costs, and increase energy system capacity.

One of the easiest ways to improve energy conversion efficiency is through reducing wood residue moisture. Research by the University of Minnesota's Department of Forest Products has developed a compression drying press for green wood chip fuel (Haygreen, 1981 and 1982; Haygreen and Steklenski, 1985; Liu and Haygreen, 1985).

An 18-month study funded by the U.S. Department of Energy, evaluated the energy requirements and operating parameters of a large laboratory compression drying press for industrial energy applications (Haygreen and Steklenski, 1985). This press is capable of processing charges of 4 cubic feet of fuel chips at ram face pressures up to 10,000 psi. Results indicate that compression drying is technically feasible and can result in a significant conservation of energy.

This paper analyzes the economic feasibility of a proposed industrial compression drying press by using existing research data (Haygreen and Steklenski, 1985). The economic feasibility of fuel-chip drying is highly site specific, and depends on the type and operation of the boiler, fuel characteristics, and effectiveness of the compression drying equipment.

While the compression drying process is intended for drying whole-tree chips, it's also suitable for processing bark or other manufacturing residue in a chip or large particle form.

The process may not be suitable for fine residues such as sawdust, or mixed residues which contain a large proportion of fine residues. These tend to plug dewatering slots in the press (Haygreen and Steklenski, 1985).

This paper is an economic analysis of three possible industrial wood energy situations. Each results in benefits of a different type, and therefore requires separate economic analysis. The analyses of these scenarios show the economic feasibility of compression drying.

The Scenarios:

1) *A firm is purchasing whole-tree chips to produce energy.* Savings to the user are based on reduced fuel consumption when using compression drying. This may be the most common of potential applications of compression drying.

2) *A very wet, unburnable fuel is generated by a plant which faces disposal cost if it's not used.* In this situation, compression drying converts non-burnable residue into a usable fuel. Savings are measured by the cost of fuel without compression drying plus the cost of disposal, minus the fuel cost and operating cost with compression drying.

3) *A firm requires additional boiler capacity (15%) which could be provided by compression drying of fuel.* Compression drying will reduce the fuel's moisture content, increasing steam output without building additional boiler capacity. Assuming the plant already uses wood fuel, savings are determined by the annual operating and fuel cost with an additional boiler, minus the annual operating and fuel cost with compression drying.

METHODS & RESULTS

Detailed analysis of equipment and related capital costs was not completed due to the prototype nature of the compression dryer. However, discussion with the equipment manufacturer and supplier provided estimates for costs (Jobe, 1986). Because capital costs were estimated, a sensitivity analysis was included showing how variation in capital costs would have affected economic feasibility .

Three measures of economic feasibility were used in each analysis: simple payback, internal rate of return (IRR), and net present value (NPV). Each analysis was run on a before-tax basis. Depreciation was not taken into account, and no salvage value was assigned to the compression drying equipment.

The appendix provides the basic data used in each economic analysis (tables 23-25). Each scenario is for a boiler with steam capacity of 50,000 pound-per-hour (pph). It's a size typical to many forest products industries, and has an economic life of 10 years. Scenario 3 also assumes an additional 7,500 pph boiler. It is assumed that in all scenarios the boiler runs at only 70 percent capacity, because the fire box volume limits the amount of fuel that can be burned. Amount of fuel required is assumed to be a function of MC. MC is calculated on a green basis, not oven-dry. The appendix includes calculation methods and defines terms used in the analysis (table 22).

In all scenarios, neither cost nor revenue was assigned to the handling and disposal of liquid expelled from the wood residue during compression. In the University of Minnesota research, the water was not thoroughly analyzed. It's uncertain whether it is either of any value, or will result in a cost.

SCENARIO 1

The firm in this scenario is purchasing whole-tree chips for energy. The chips are compression dried to a lower MC, thereby reducing the amount of fuel needed to produce the same amount of energy. Figure 1 illustrates the process flow. Alternative fuels such as gas or oil are not considered.

Figure 1. Process flow with compression drying in Scenario #1.

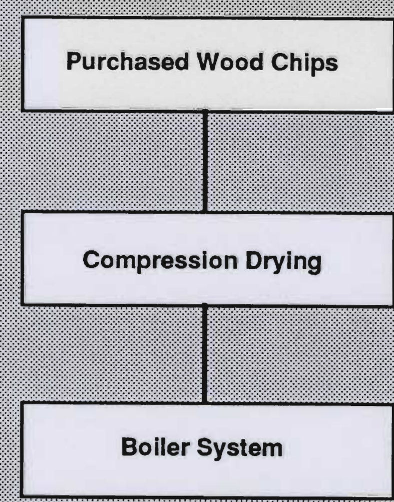


Table 23 in the appendix provides the initial data used in the economic analysis. The 50,000 pph boiler runs at 70 percent capacity. The compression drying press has a 40 cubic foot capacity. Fuel consumption is estimated for both green fuel and compression dried fuel. Fuel cost savings calculations are based on reduced fuel consumption. Total annual savings are calculated by subtracting operating costs for compression drying from fuel cost savings. Calculation of estimated fuel consumption and annual savings are shown in appendix table 22. Table 1 presents the results from the initial economic analysis for scenario 1.

Table 1. Economic output from Scenario #1 with an initial MC of 60%, fuel cost of $10 per ton and capital cost of $750,000.

TOTAL ANNUAL COST SAVINGS	$63,988
NET PRESENT VALUE	($428,858)
INTERNAL RATE OF RETURN	-2.8 %
PAYBACK PERIOD	11.72 years

Figure 2 and table 2 present the relationship between input MC and economic feasibility when the initial MC averages from 54-66% with output MC of 40%. Economic feasibility is extremely sensitive to changes in input MC (figure 2). The higher the input MC of the fuel the more economically feasible it is to compression dry. Output MC of the compression dried fuel is sensitive to changes but not to the degree of input MC (figure 2 and table 3). Economic feasibility is reduced as output MC increases.

Table 2. The effect of initial MC on economic return from compression drying, assuming an output MC of 40% - Scenario #1.

Initial MC (green)	IRR %	NPV	PAYBACK (years)
54%	-36	($734,769)	247.1
60%	-3	($428,858)	11.7
66%	21	$180,808	4.0

Table 3. The effect of output MC on economic return from compression drying, assuming an input MC of 60% - Scenario #1.

Output MC (green)	IRR %	NPV	PAYBACK (years)
36%	1	($362,615)	9.7
40%	-3	($428,858)	11.7
44%	-7	($508,066)	15.6
48%	-14	($604,458)	25.9
52%	-32	($724,307)	146.5

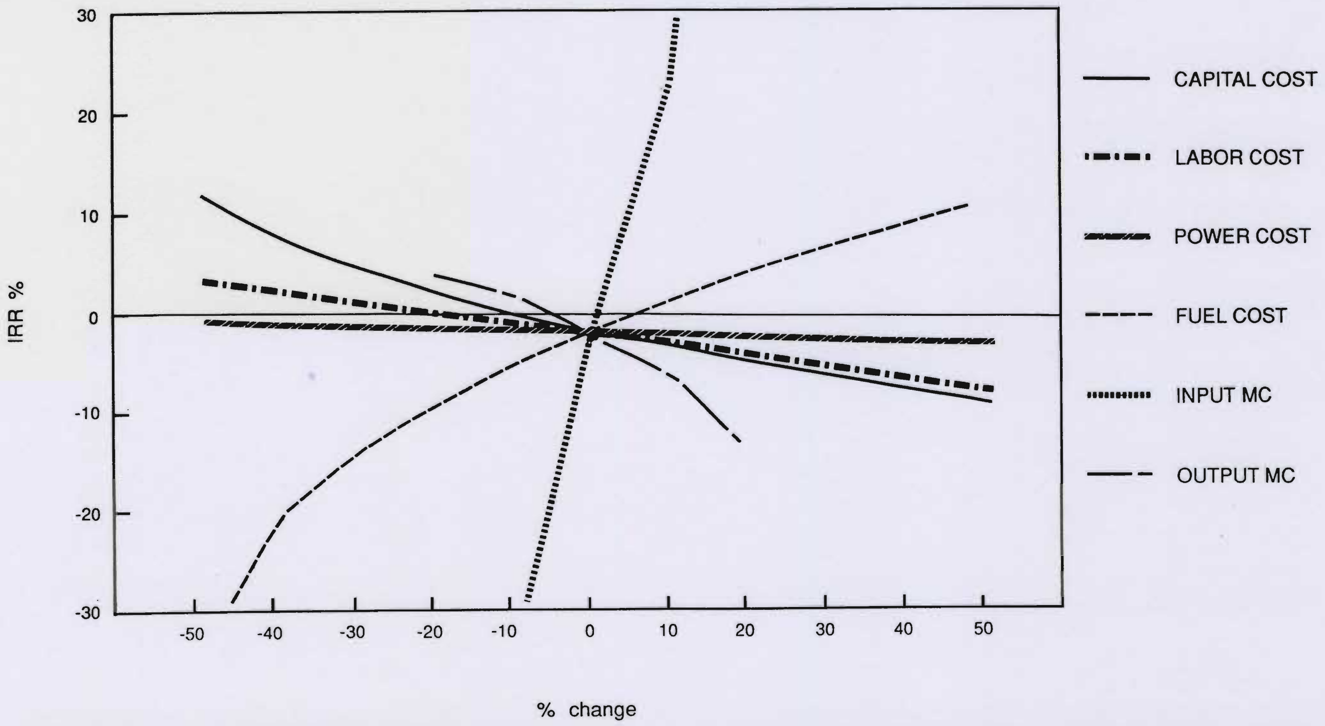
Capital costs are estimated at $750,000 for a compression drying press, including all equipment, transportation, and installation. The effect on economic feasibility of changes in capital cost is shown in figure 2 and table 4. For example, if the cost of the press is reduced to $450,000 the IRR increases from -2.8% to 7%. Changing the capital cost of the press does not significantly affect the feasibility of the project unless this cost increases or decreases dramatically.

Table 4. The effect of capital cost on economic return from compression drying - Scenario #1.

Capital cost	IRR %	NPV	PAYBACK (years)
$375,000	11	($53,858)	5.9
$450,000	7	($128,858)	7.0
$525,000	4	($203,858)	8.2
$600,000	1	($278,858)	9.4
$675,000	-1	($353,858)	10.5
$750,000	-3	($428,858)	11.7
$825,000	-4	($503,858)	12.9
$900,000	-6	($578,858)	14.1
$975,000	-7	($653,858)	15.2
$1,050,000	-8	($728,858)	16.4
$1,125,000	-9	($803,858)	17.6

As wood fuel cost increases, the economic feasibility of compression drying increases signifi-

Figure 2. Economic sensitivity analysis for Scenario #1.



cantly. The initial analysis on a wood chip cost of $10 per wet ton results in an IRR of -2.8%. Figure 2 and table 5 present the relationship between wood chip fuel cost and the IRR. As fuel cost approaches zero, the economic feasibility of the project drops significantly. The cost of fuel for the boiler is an important variable in considering the economic justification for compression drying.

Table 5. The effect of wood chip fuel costs on economic return from compression drying - Scenario #1.

Fuel costs ($ per ton)	IRR %	NPV	PAYBACK (years)
5	-34	($729,009)	179.3
6	-21	($668,979)	46.5
7	-15	($608,949)	26.7
8	-10	($548,918)	18.7
9	-6	($488,888)	14.4
10	-3	($428,858)	11.7
11	0	($368,828)	9.9
12	3	($308,797)	8.5
13	6	($248,767)	7.5
14	8	($188,737)	6.7
15	10	($128,706)	6.1
20	21	$171,445	4.8

Economic return is relatively insensitive to changes in annual labor and power costs as shown by figure 2 and in tables 6 and 7. Therefore, these variables are not very important in determining the economic feasibility of this first scenario.

Table 6. The effect of annual labor costs on economic return from compression drying - Scenario #1.

Labor cost	IRR	NPV	PAYBACK (years)
$20,115	2	($327,877)	8.9
$24,137	1	($348,067)	9.4
$28,160	0	($368,257)	9.9
$32,183	-1	($388,447)	10.4
$36,206	-2	($408,637)	11.0
$40,229	-3	($428,827)	11.7
$44,252	-4	($449,017)	12.5
$48,275	-5	($469,207)	13.4
$52,298	-6	($489,397)	14.4
$56,321	-7	($509,587)	15.7
$60,344	-9	($529,777)	17.1

Table 7. The effect of annual power costs on economic return from compression drying - Scenario #1.

Power cost	IRR %	NPV	PAYBACK (years)
$4,693	-2	($405,296)	10.9
$5,632	-2	($410,007)	11.1
$6,571	-2	($414,718)	11.2
$7,509	-2	($419,429)	11.4
$8,448	-3	($424,140)	11.6
$9,387	-3	($428,851)	11.7
$10,325	-3	($433,562)	11.9
$11,264	-3	($438,273)	12.1
$12,203	-4	($442,984)	12.3
$13,141	-4	($447,695)	12.5
$14,080	-4	($452,406)	12.6

In summary, the use of compression drying in scenario 1 does not appear economically feasible unless wood residue fuel costs are significantly higher than $10 per ton. The most important variables which determine economic feasibility are initial fuel MC and fuel cost.

SCENARIO 2

Scenario 2 assumes a plant is currently generating wood residues above 68% MC (green), too wet to burn, (Ince, 1979) which must be disposed of at a cost. In this situation compression drying converts non-burnable residue into a burnable fuel. Initially, the plant is buying green wood chips to meet energy needs. Assumed also is that enough wet residue is available, if dried to 45% MC, to provide half the plant's annual energy needs. The other half continues to be obtained from purchased green wood chips.

The raw material flow with compression drying is illustrated in figure 3. Savings would be the difference between the cost of compression drying and the cost of buying additional fuel, plus the avoided disposal cost of unused wet fuel. Assumed in the analysis are $10 per ton outside fuel cost, that 50% of the energy needs are met by the wet fuel, and disposal costs are $5/ton. Initial MC is assumed to be 60% for the purchased fuel and 68% for the wet fuel. Table 24 in the appendix provides the basic data used in the economic analysis. Table 8 presents results from the initial analysis for scenario 2.

As in scenario 1, costs or revenues from the liquid expelled from compression drying have not

Figure 3. Process flow for Scenario #2, which uses purchased and in-house fuel.

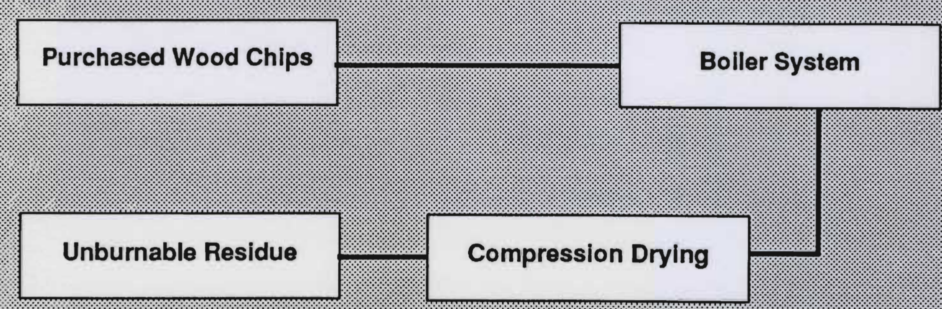


Table 8. Economic output from scenario 2 with an initial wet fuel moisture content of 68%, fuel cost of $10 per ton and capital cost of $750,000 with 50% of the annual fuel requirements met from wet fuel.

TOTAL ANNUAL COST SAVINGS	$485,401
NET PRESENT VALUE	$1,686,114
INTERNAL RATE OF RETURN	64 %
PAYBACK PERIOD	1.5 years

been considered. Use or disposal of these liquids is an especially important issue in this situation because a large amount may be generated due to the initially high MC. Approximately 4 million gallons would be generated per year at the stated conditions. Their associated costs or revenues could significantly affect economic feasibility.

As in the first scenario, increases in the delivered cost of fuel positively affect economic feasibility (figure 4 and table 9). For example, if fuel cost increases from $10 per ton to $15 per ton, IRR increases from 64% to 88% However, if the cost decreases to $5 per ton the IRR decreases to 40%. Fuel costs are an important determinate of economic return, but even at fuel costs of $5 per ton the project looks extremely feasible.

With the use of both purchased (60% MC) and compression dried (68% input MC) fuel, it's important to look at the effect of input MC content changes in both fuels. Figure 4 and tables 10 and 11 show the relationship between economic feasibility and changes in initial MC of

Table 9. The effects of wood chip fuel cost on economic return from compression drying - Scenario # 2.

Fuel cost ($ per ton)	IRR %	NPV	PAYBACK (years)
$5	40	$802,302	2.4
$6	45	$979,065	2.2
$7	50	$1,155,827	2.0
$8	55	$1,332,589	1.8
$9	59	$1,509,352	1.7
$10	64	$1,686,114	1.5
$11	69	$1,862,877	1.4
$12	74	$2,039,639	1.3
$13	79	$2,216,401	1.3
$14	83	$2,393,164	1.2
$15	88	$2,569,926	1.1

purchased fuel, and of unburnable wet fuel, when the output MC of the compression dried fuel is 45%. Assumed is wet unburnable wood residue MC between 68-75%. The narrow range of this variability minimized the affect on the economic feasibility analysis.

Initial MC of purchased fuel is more critical to economic feasibility. Lower MC means lower IRR.

The MC of purchased fuel is typically in the 50-60% range. Change in the output MC of wet fuel does not have a significant effect on economic feasibility of the project, as can be seen in figure 4 and table 12. Changes in the input MC of purchased fuel is therefore very important in determining economic justification. Input and output MC of the wet fuel is less critical.

Figure 4. Economic sensitivity analysis for scenario #2

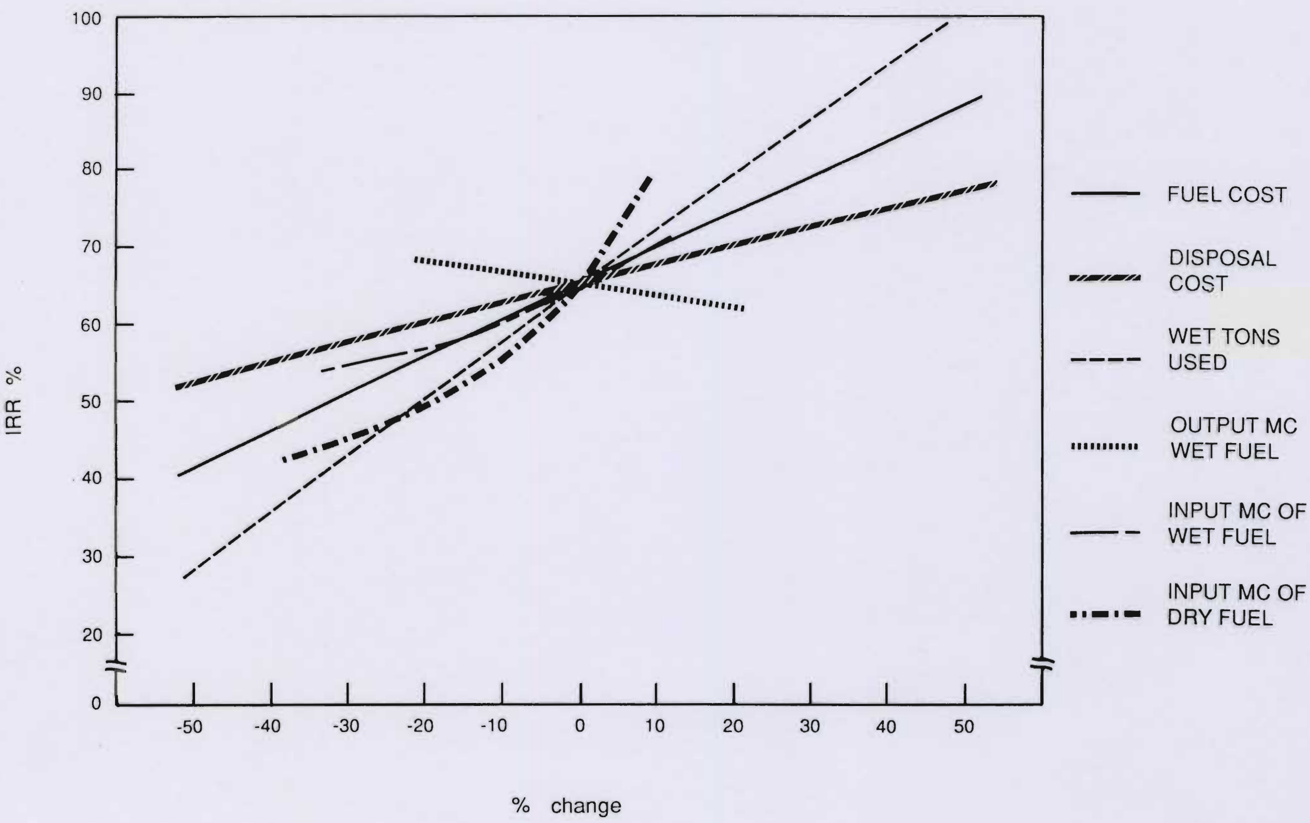


Table 10. Effect of input MC of wet fuel on economic return from compression drying, assuming an output MC of 45% - Scenario #2.

Input MC (green)	IRR %	NPV	PAYBACK (years)
68%	64	$1,686,114	1.5
75%	71	$1,941,819	1.4

Table 11. The effect of input MC of purchased fuel on economic return from compression drying - Scenario #2.

Input MC (green)	IRR %	NPV	PAYBACK (years)
36%	40	$818,115	2.4
42%	44	$944,012	2.2
48%	48	$1,110,879	2.0
54%	55	$1,342,602	1.8
60%	64	$1,686,114	1.5
66%	79	$2,248,024	1.3

Table 12. The effect of output MC of wet fuel on economic return from compression drying, assuming an input MC of 68% - Scenario #2.

Output M.C. (green)	IRR %	NPV	PAYBACK (years)
36%	67	$1,780,405	1.5
41%	66	$1,736,825	1.5
45%	64	$1,686,114	1.5
50%	63	$1,626,366	1.6
54%	61	$1,554,927	1.6

The most important variable in determining economic feasibility is the amount of unburnable wet fuel available for compression drying. The initial analysis assumes that half of the energy needs are to be met by wet fuel. As the amount of available wet residue decreases, so too does economic feasibility (figure 4 and table 13). A decrease in the amount of wet fuel available would also result in additional costs for the purchase of wood chips to meet the energy demands.

If wet fuel provides only 25% or less of a plant's energy needs, the project may not be economically feasible. But, the project would have a significant rate of return if 75% of energy requirements could be met by wet fuels.

Table 13. Effect of in-house wet fuel availability (oven dry weight) on compression drying economics - Scenario #2.

In-house fuel available(tons)	IRR %	NPV	PAYBACK (years)
6,042	26	$328,496	3.5
7,250	34	$600,019	2.8
8,459	42	$871,543	2.3
9,667	49	$1,143,067	2.0
10,876	57	$1,414,590	1.7
12,084	64	$1,686,114	1.5
13,293	72	$1,957,638	1.4
14,501	79	$2,229,162	1.3
15,709	86	$2,500,685	1.2
16,918	93	$2,772,209	1.1
18,126	101	$3,043,733	1.0

The final variable analyzed is the assumed disposal costs for unburnable residues. Initial analysis assumes a disposal cost of $5 per wet ton. Table 14 and figure 4 show the effect of changes in disposal cost on economic return, assuming that other initial variables don't change. Economic feasibility increases as the disposal cost increases. Even assuming no disposal cost the IRR is still projected at a relatively high 38%. Economic return is somewhat sensitive to changes in disposal costs, but even with no disposal costs the project still appears economically justified.

Table 14. The effect of annual disposal costs of unburnable residue on economic return from compression drying - Scenario #2.

Disposal cost ($ per ton)	IRR %	NPV	PAYBACK (years)
0.00	38	$738,501	2.5
2.50	51	$1,212,307	1.9
3.00	54	$1,307,069	1.8
3.50	57	$1,401,830	1.7
4.00	59	$1,496,591	1.7
4.50	62	$1,591,353	1.6
5.00	64	$1,686,114	1.5
5.50	67	$1,780,876	1.5
6.00	69	$1,875,637	1.4
6.50	72	$1,970,398	1.4
7.00	75	$2,065,160	1.3
7.50	77	$2,159,921	1.3

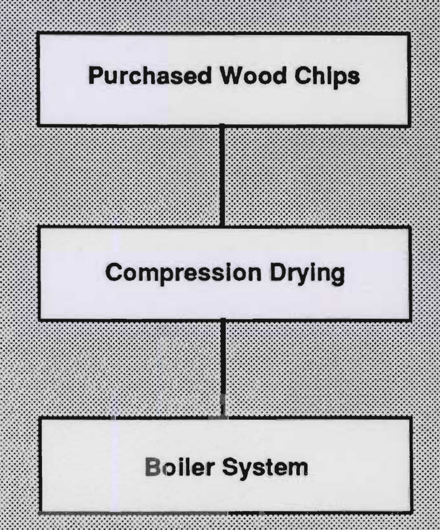
Economic return in scenario 2 is most sensitive to fuel costs and the amount of wet residues available for compression drying. Input MC of wet fuels also affects return, but the analysis assumes that output MC is constant with higher input MC. In reality, as input MC increases so should the output MC, but to a much lesser degree. Therefore, the feasibility of the project decreases along with the decrease in percent utilization of wet fuels. Furthermore, as fuel costs decrease or if burnable (without compression drying) in-house fuels are used, the economic feasibility of compression drying is reduced.

SCENARIO 3

Scenario 3 is based on a plant which requires 15% more boiler capacity from its existing wood burning energy system. The increased capacity could be provided either by compression drying wood fuel or through installation of a new boiler. Compression drying will reduce the MC of the fuel thereby increasing steam output without the need for additional boiler capacity.

Figure 5 illustrates the raw material flow utilizing compression drying. Assuming the plant is already using wood fuel, savings are determined by subtracting the annual operating and fuel cost associated with compression drying from the

Figure 5. Process flow with compression drying in scenario #3



annual operating and fuel cost associated with using an additional boiler. Table 25 in the appendix provides the basic data used in the economic analysis and table 15 presents the economic results from the initial analysis.

Table 15. Economic output from scenario 3 with an initial MC of 60%, fuel cost of $10 per ton, and capital cost difference of $313,930.

TOTAL ANNUAL COST SAVINGS	$172,638
NET PRESENT VALUE	$552,498
INTERNAL RATE OF RETURN	54.27%
PAYBACK PERIOD	1.8 years

As with the first two scenarios, economic feasibility is very sensitive to changes in fuel input MC. This relationship is shown in table 16 and figure 6. Initial analysis is calculated with input MC at 60%, resulting in an IRR of 54%. But, if input MC is reduced to 48% the IRR would decrease to 15%, assuming an output MC of 40%. Therefore, input MC is an important factor in determining economic feasibility. Output MC changes do not significantly affect project feasibility. In most cases, MC will vary over only a narrow 40-48% range (table 17).

There are two possibilities for capital expenditures in this scenario. Either a new boiler, or compression drying is used to provide the desired 15% capacity increase. Therefore, when calculating economic feasibility, the difference between the capital costs is used.

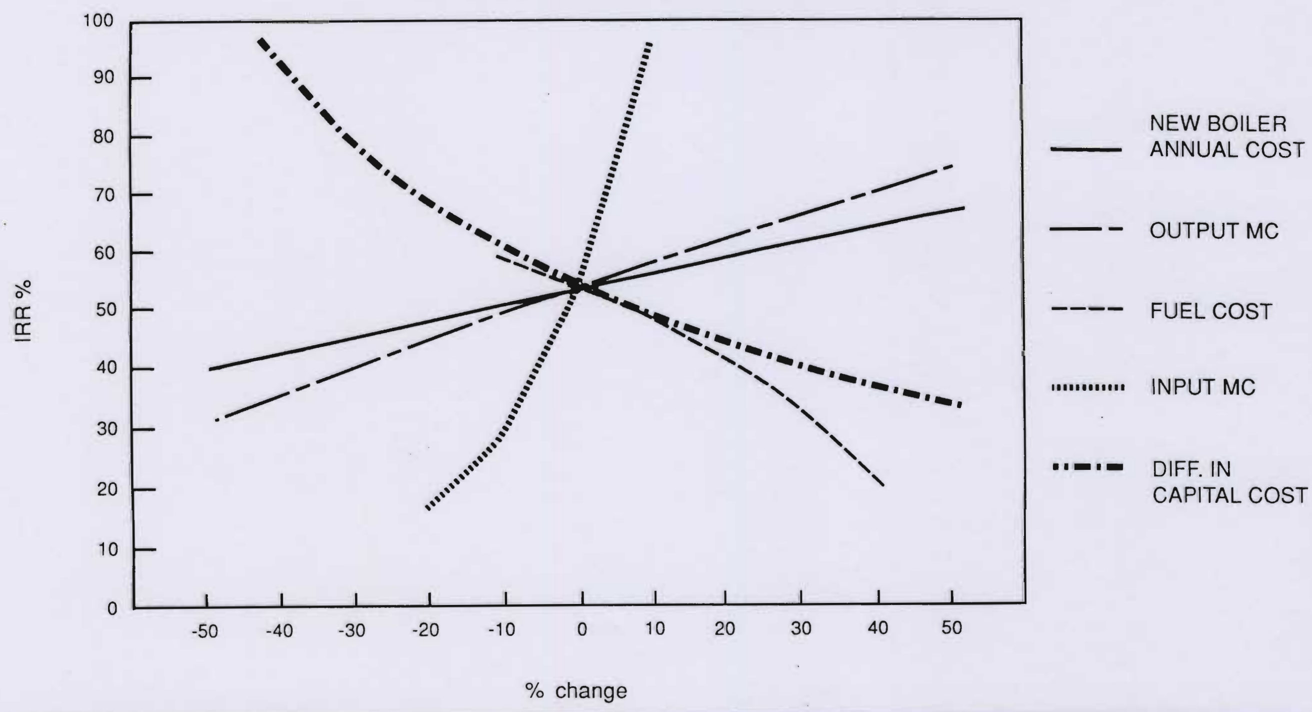
Table 16. The effect of input MC on economic return from compression drying, assuming an output MC of 40% - Scenario #3.

Input MC (green)	IRR %	NPV	PAYBACK (years)
48%	15	$5,439	4.9
54%	30	$200,699	3.1
60%	54	$552,498	1.8
66%	99	$1,253,613	1.0

Table 17. The effect of output MC on economic return from compression drying, assuming an input MC of 60% - Scenario #2.

Output MC (green)	IRR %	NPV	PAYBACK (years)
36%	59	$622,768	1.7
40%	54	$552,498	1.8
44%	49	$468,474	2.0
48%	42	$366,222	2.3
52%	33	$239,087	2.8
56%	21	$76,727 4.0	

Figure 6. Economic sensitivity analysis for scenario #3



Initial analysis assumes a capital cost of $750,000 for compression drying and $436,070 for the new boiler. This leads to a capital cost difference of $313,930. Capital and annual operating costs for a new boiler are based on data reported by Steklenski and Haygreen (1983). The difference in capital cost is an important variable, and a change in that difference can significantly affect economic feasibility (figure 6 and table 18).

Table 18. The effect of capital cost difference between compression dryer and new boiler on economic return from compression drying - Scenario #3.

Capital cost difference	IRR %	NPV	PAYBACK (years)
$156,965	110	$709,463	0.9
$188,358	92	$678,070	1.1
$219,751	78	$646,677	1.3
$251,144	68	$615,284	1.5
$282,537	61	$583,891	1.6
$313,930	54	$552,498	1.8
$345,323	49	$521,105	2.0
$376,716	45	$489,712	2.2
$408,109	41	$458,319	2.4
$439,502	38	$426,926	2.5
$470,895	35	$395,533	2.7

The economic feasibility of compression drying changes significantly as the cost of fuel changes. Initial analysis was based on a fuel cost of $10 per ton. Figure 6 and table 19 show the cost of delivered wood chip fuel to be an important variable when considering the economic feasibility of compression drying. As the cost of wood chip fuel decreases, so too does the rate of return for the project. The process appears economically justified even when fuel costs are as low as $5 per ton.

Annual operating cost of a new boiler is another variable in determining economic feasibility. Initial analysis assumes an annual operating cost of $90,700 resulting in an IRR of 54%. If annual operating costs can be halved to $45,350, the IRR decreases to 39% (table 20).

Initial fuel MC and the difference in capital cost have the most impact on economic return in this case. New boiler annual costs and fuel costs are important, but to a lesser extent. Return is least sensitive to output MC of compression dried fuel due to the fact that the MC is most likely to be in the 40-48% range.

Table 19. The effect of wood chip fuel costs on economic return from compression drying - Scenario #3.

Fuel cost ($ per ton)	IRR %	NPV	PAYBACK (years)
5	31	$207,324	3.0
6	36	$276,358	2.7
7	40	$345,393	2.4
8	45	$414,428	2.2
9	50	$483,463	2.0
10	54	$552,498	1.8
11	59	$621,533	1.7
12	63	$690,567	1.6
13	68	$759,602	1.5
14	72	$828,637	1.4
15	77	$897,672	1.3

Table 20. The effect of new boiler annual labor costs on economic return from installing a new boiler instead of using compression drying - Scenario #3.

Labor costs	IRR %	NPV	PAYBACK (years)
$45,350	39	$324,897	2.5
$54,420	42	$370,417	2.3
$63,490	45	$415,937	2.2
$72,560	48	$461,457	2.0
$81,630	51	$506,978	1.9
$90,700	54	$552,498	1.8
$99,770	57	$598,018	1.7
$108,840	60	$643,538	1.6
$117,910	63	$689,058	1.6
$126,980	66	$734,579	1.5
$136,050	69	$780,099	1.4

CONCLUSION

Economic feasibility of fuel-chip drying, assuming commercial development of compression drying equipment, will be highly site specific. The type and operation of the boiler, fuel characteristics, and the effectiveness of compression drying equipment must all be considered.

The economic feasibility of three different scenarios has been summarized, with projected economic returns shown in table 21. Each scenario was economically independent and, therefore, not directly comparable. The analysis has, however, shown the feasibility of each project independently. Economic justification depends on the minimum acceptable rate of return and on certain intangible variables.

In all three scenarios the most important variables determining economic feasibility are initial MC of the fuel to be compression dried and the cost of fuel. In scenario two the amount of wet fuel available for compression drying is also important. The capital cost difference between investment in compression drying equipment and additional boiler capacity is relevant in scenario three.

Given the assumptions made in this analysis, compression drying of high MC unburnable wood residue, and use of compression drying to increase boiler capacity, appear economically attractive. But, compression drying of purchased wood chips does not look economically justified, especially when the initial MC of the fuel is below 55 percent on a green basis.

It should be pointed out that there are many more possible situations which may change the economic feasibility of a project. A site specific study should be made for each case.

Table 21. Summary of projected economic returns from compression drying for three scenarios.

	SCENARIO 1	SCENARIO 2	SCENARIO 3
TOTAL ANNUAL COST SAVINGS	$63,988	$485,401	$172,638
NET PRESENT VALUE	($428,858)	$1,686,114	$552,498
INTERNAL RATE OF RETURN	-2.8 %	64 %	54.27%
PAYBACK PERIOD	11.7 years	1.5 years	1.8 years

LITERATURE CITED

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APPENDIX

Table 22 - Calculation method for economic analysis.

Press Capacity $= \frac{\text{Charge Capacity (890 oven dry pounds)}}{1 - \text{Moisture Content (Output MC)}}$

Hourly Capacity $= \frac{\text{60 minutes}}{\text{Cycle Time}} \times \frac{\text{Press Capacity}}{\text{2000 lbs./ton}}$

Operating Hours $= \frac{\text{Annual Fuel Consumption}}{\text{Hourly Capacity}}$

Required Days/Shifts of Operation (8 Hours Per Shift) $= \frac{\text{Operating Hours}}{8}$

Gross Heating Value = (1 – Moisture Content) x Higher Heating Value

Combustion Efficiency $= \frac{\text{Recoverable Heat Energy}}{\text{(higher heating value} \times \text{(1 – moisture content)}}$

Annual Fuel Consumption $= \frac{\text{Hours of Operation} \times \text{Load Factor} \times \text{System Heat Capacity}}{\text{Combustion Efficiency} \times 2000 \times \text{Gross Heating Value}}$

Annual Fuel Cost = Fuel Cost x Annual Fuel Consumption

Annual Fuel Cost Savings = Annual Fuel Cost (wet fuel) – Annual Fuel Cost (dry fuel)

Transportation, Foundation and Connection Cost = Capital Cost x 0.25

Maintenance Cost = Capital Cost x 0.01

Power Consumption = Press Operating Hours x 50 Kilowatts x $0.07 KWH

Labor Cost = Press Operating Hours x $15 Per Hour

Total Annual Cost Savings =
Annual Fuel Cost Savings – (Maintenance Cost + Power Consumption + Labor Costs)

Total Capital Cost = Equipment + Transportation, Foundation and Connection Cost

Simple Payback Period $= \frac{\text{Total Capital Cost}}{\text{Total Annual Savings}}$

Table 23. Initial data used for economic analysis of Scenario #1.

BOILER CHARACTERISTICS		
pounds-per-hour (steam)	50,000	
hours per year	8,000	
load factor	0.7	
system heat capacity	50,375,000	btu
project life	10	years
COMPRESSION DRYING PRESS CHARACTERISTICS		
press capacity-cubic feet	40	
cycle time (minutes)	3	
press capacity	1,467	lbs/charge
hourly capacity	14.67	tons
required operating hours/year	2,682	
required operating days (8 hours/day)/year	335	
INPUT FUEL CHARACTERISTICS		
fuel cost (cost/ton)	$10	
fuel MC	60	%
bulk density (O.D. lbs/ft³)	22	
higher heating value	8,500	btu/lb
gross heating value	3,400	btu/lb
combustion efficiency	58	%
annual fuel consumption	70,973	tons
annual fuel cost	$709,727	
OUTPUT FUEL CHARACTERISTICS		
fuel MC	40	%
higher heating value	8,500	btu/lb
gross heating value	5,100	btu/lb
combustion efficiency	70	%
annual fuel consumption at 0% MC	23,605	tons
annual fuel consumption at 40% MC	39,341	tons
annual fuel consumption at 60% MC	59,012	tons
annual fuel cost	$590,115	
annual fuel cost savings	$119,612	
CAPITAL COST		
capital cost	$600,000	
transport,foundation and connect	$150,000	
TOTAL	$750,000	
ANNUAL COSTS		
maintenance	$6,000	
power consumption	$9,388	
labor costs	$40,235	
TOTAL	$55,623	

Table 24. Initial data used for economic analysis of Scenario #2.

BOILER CHARACTERISTICS				
pounds-per-hour (steam)		50,000		
hours per year		8,000		
load factor		0.7		
system heat capacity		50,375,000	btu	
economic life		10	years	
MISCELLANEOUS INFORMATION				
residue disposal cost/ton		$5		
percent utilization of wet residues		50%		
O.D. tons of wet fuel available for compression drying		12,084	tons	
COMPRESSION DRYING PRESS CHARACTERISTICS				
press capacity-cubic feet		40		
press cycle time (minutes)		3		
press capacity		1,600	lbs/charge	
hourly capacity		16	tons	
required operating hours/year		2,767		
required operating days (8 hours/day)/year		346		
INPUT FUEL CHARACTERISTICS	**WITHOUT CD**	**PURCHASED FUEL**		**WET FUEL**
fuel cost (cost/ton)		$10		
fuel MC		60 %		68 %
bulk density (O.D. lbs/ft³)		22		
higher heating value.		8,500		8,500
gross heating value		3,400		2,720
combustion efficiency		58 %		50 %
annual fuel consumption (tons)	70,973	35,752		37,763
annual fuel costs	$709,727	$357,524		
OUTPUT FUEL CHARACTERISTICS				
fuel MC		45	%	
higher heating value		8,500	btu/lb	
gross heating value		4,675	btu/lb	
combustion efficiency		68	%	
annual fuel consumption		21,971	tons	
residue disposal cost		$188,814		
CAPITAL COST				
equipment cost		$600,000		
transport, foundation and connect		$150,000		
total		$750,000		
ANNUAL COSTS				
maintenance		$6,000		
power consumption		$9,387		
labor costs		$40,229		
TOTAL		$55,616		

Table 25 . Initial data used for economic analysis of Scenario #3.

BOILER CHARACTERISTICS	EXISTING BOILER	NEW BOILER
pounds-per-hour	50,000	7,500
hours per year	8,000	8,000
load factor	0.70	0.70
system heat capacity (btu)	50,375,000	7,556,250
economic life (years)	10	10
COMPRESSION DRYING PRESS CHARACTERISTICS		
press capacity-cubic feet	40	
press cycle time (minutes)	3	
press capacity	1,467	lbs/charge
hourly capacity (tons)	14.67	
required operating hours/year	3,085	
required operating days (8 hours/day)/year	386	
INPUT FUEL CHARACTERISTICS		
fuel cost ($/ton)	$10	
fuel MC	60	%
bulk density (O.D. lbs/ft^3)	22	
higher heating value	8,500	btu/lb
gross heating value	3,400	btu/lb
combustion efficiency	58	%
annual fuel consumption	81,619	tons
annual fuel costs	$816,186	
OUTPUT FUEL CHARACTERISTICS		
fuel MC	40	%
higher heating value	8,500	btu/lb
gross heating value	5,100	btu/lb
combustion efficiency	70	%
annual fuel consumption (oven dry weight)	27,145	tons
annual fuel consumption at M.C.-40%	45,242	tons
annual fuel consumption at M.C.-60%	67,863	tons
annual fuel cost	$678,633	

CAPITAL COST	PRESS	NEW BOILER
equipment cost	$600,000	
transport, foundation and connect	$150,000	
TOTAL	$750,000	$436,070
Capital cost difference between CD and new boiler	$313,930	
ANNUAL COSTS		
maintenance	$6,000	
power consumption	$9,387	