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WOOD FUEL FIRED ELECTRIC POWER GENERATING PLANTS

Summary & Report, Volume 1

By
Donald W. Pingrey
Norman E. Waggoner

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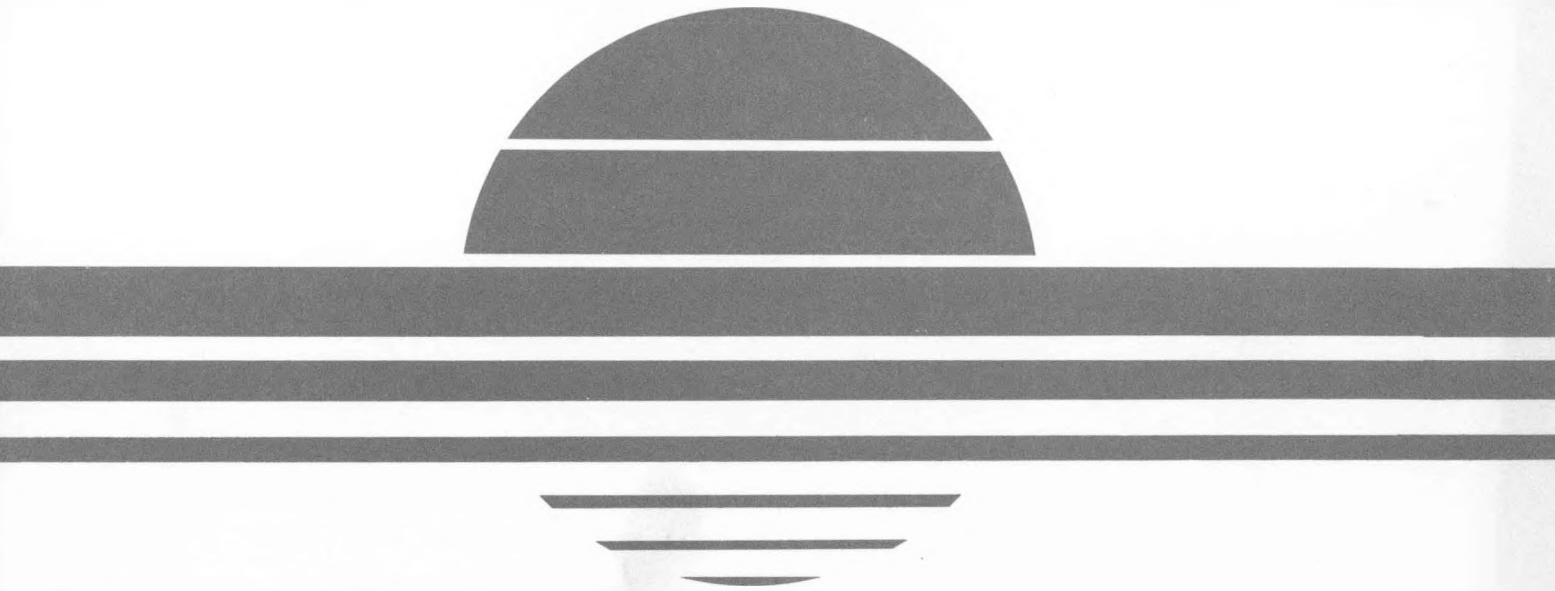
Nor'West-Pacific Corporation
Seattle, Washington



U.S. Department of Energy

Solar Energy

WOOD FUEL FIRED ELECTRIC POWER GENERATING PLANTS

ABSTRACT

A questionnaire study was made of the forest projects, pulp and paper and other industries who burn wood for fuel to produce electricity from steam.

In the fall of 1977, 4453 inquiries were sent out to industry and government to locate wood-burning electrical power production facilities. From all these sources we located 288 probable industries with power production capability and received a 30 percent response locating 68 industries who filled out our detailed questionnaires. We later obtained 6 questionnaires by screening a new pulp and paper directory from a mail out of 156 questionnaires. Six questionnaires arrived after the cut-off date for compilation of data, mostly from pulp and paper industry. This information would significantly add to the data base.

A study of the information obtained from the questionnaires indicated that:

1. Electrical generating facilities were being operated continuously in the pulp and paper and other industries, but only about one-half of the forest products industry mills did so.

2. Fossil fuels comprised about 54.5% of fuels used for electric generation by the pulp and paper industry but only 1 or 2% of the fuels used by the forest products and other industries who burned woody residues.

3. Of the 39 pulp and paper mills reporting only 5 were not co-generating as opposed to the forest products industry where 20 out of the 27 responding mills were not.

4. All mills used their wood wastes and about one-half of the mills purchased waste wood residues from others at an average price of about $6.00 per ton (wet).

5. Questionnaires were returned locating 82.6 MW of electrical production capability from 24 forest products industry mills. Questionnaires were returned locating 1010.6 MW of electrical power production capability from 36 pulp and paper mills.

6. The electrical power production capability of the pulp and paper industry was estimated to be about 3600 MW. The same capability for the forest products industry was estimated to be 800 MW.

The study inciated that while the pulp and paper industry was using and purchasing wood residues to reduce energy demands, the forest products industry generally was not using its available wastes and generating capacity to produce electricity. The production and sale of electrical power produced from wood residues at the rates being offered by the electric utilities, were too low to stimulate interest or show a profit.

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SUMMARY

This study had essentially a data gathering objective in which we had hoped to learn how and where wood-waste residues were used as fuels to produce electrical energy. We had hoped to gather enough information in which to assess the potential of the wood products industries to produce power and ease the energy shortage.

The responses to our canvass of the Forest Products Industry, Pulp and Paper Industry and Electrical Utilities was generally poor with questionnaire responses coming back from only 25 to 35% of those sent questionnaires. The results are summarized in Table 1. The data as recorded by states are in Appendix B.

Many of the statistics reported in the study are of questionable validity. Most of the respondees did give a telephone number. If significant importance were attached to any response the information could be verified by a phone call.

One basic weakness in the study was the questionnaire form. There were problems with the language usually because the forms were not explicit.

For instance, one problem with the questionnaire was in the fuel drying totals to the question, "Is the fuel dried before use?" We had to separate answers from the secondary wood manufacturers, who use kiln dried wood, from those of the papermills who had pre-drying equipment to handle their very wet green fuel. Our alteration to the basic data may be considered by some as tampering with the results; however, we feel it was necessary to differentiate between the two types of responses.

DATA TYPE	ALABAMA	ALASKA	ARKANSAS	CALIFORNIA	FLORIDA	GEORGIA	HAWAII	LOUISIANA	MAINE	MASSACHUSETTS	MICHIGAN	MINNESOTA	MONTANA	NEW HAMPSHIRE	NEW MEXICO	NORTH CAROLINA	OKLAHOMA	OREGON	SOUTH CAROLINA	TENNESSEE	VERMONT	VIRGINIA	WASHINGTON	WISCONSIN	TOTALS
PRESENT NUMBER OF PLANTS REPORTING	2	1	2	2	2	6	3	3	7	2	3	1	2		1	2	1	13	1	2	1	2	6	4	69
FUTURE PLANTS THAT REPORTED	2					1								1			1								5
A. ELECTRICAL GENERATING PLANT (No. of Mills In Classification)																									
1. Type of Duty																									
Continuous	4	1	2	2	2	6	3	3	5	1	2	1	2	1	1	2	2	8	1			1	3	4	57
Peaking									1	1											1				3
Standby									1		1							1		1			1		5
Other						1												4		1		1	2		9
2. Operating Status																									
Permanently In Service	3	1	2	2	2	5	3	3	6	1	2	1	2		1	2	1	7	1		1	2	3	3	51
Temporarily In Service										1								1							2
Temporarily Out-of-service						1			1									2		2			2		8
Permanently Out-of-service											1							3					1		5
Easily Reactivated																									
Major Rebuilding Needed																		2					1		3
< Minor Repairs											1							1							2
Outdated & Unusable																									
B. STEAM BOILER PLANT																									
1. Number of Boilers (low ≤ 500, hi ≥ 500)	3	5	15	7	11	22	5	9	18	4	7	2	11	1	2	11	4	36	2	3	3	10	15	12	218
Number using high pressures(as shown)	3	5	8	5	11	18		9	6		1		5			1	4	13	2		3	4	3	9	134
Number with low pressures "			7	2			5		11	4	5	2	6	1	2	10		23		3		6	12	3	102
Number with high temperatures "	3	5	15	6	11	18	5	9	15	2	6	2	8	1	2	11	4	18	2		3	8	7	12	170
Number with low temperatures "										2			2				1	16		3			6		30
2. Numbers Using Other Fuels:																									
Auxiliary Fuel - None	1					1			4		1		1				1	8		2		1	3		23
Auxiliary Fuel - Oil	2	1	2	1	2	5	3	2	2	2						2	1	1	1		1	1	3	1	33
Auxiliary Fuel - Gas	1		1	1		2		3				1	1		1		1	1	1						14
Auxiliary Fuel - Coal	1					2					2	1				1		1						2	10
Other Fuel - Bagasse							3																		3
Other Fuel - Black Liquor			1		2	2		1	2				1			1	1					1	1	2	15
Some Other Fuel																									
C. TURBINE GENERATION																									
1. Numbers of Turbines	9	3	4	6	7	16	6	5	7	3	4	1	6	3	2	12	2	22	2	1	3	8	14	12	158
Condensing Type	1		2	5		4	1	2	3	1	1		3	1	2	4		15		1	3	2	8	1	60
Extraction Condensing Type		2			5	5	3		2		2		2	1		1		2				2	1		28
Non-Condensing Type	8		1		1	2	2	2	2	2		1	1	1		2	2	5	2			2		4	40
Extraction Non-Condensing		1	1	1	1	1		1			1					5						2	1	1	16

STUDY OF WOOD FIRED ELECTRIC GENERATING POWER PLANTS CATEGORIES AND NUMBER OF PLANTS, BOILERS & TURBINES NWPC

	ALABAMA	ALASKA	ARKANSAS	CALIFORNIA	FLORIDA	GEORGIA	HAWAII	LOUISIANA	MAINE	MASSACHUSETTS	MICHIGAN	MINNESOTA	MONTANA	NEW HAMPSHIRE	NEW MEXICO	NORTH CAROLINA	OKLAHOMA	OREGON	SOUTH CAROLINA	TENNESSEE	VERMONT	VIRGINIA	WASHINGTON	WISCONSIN	
2. No of Steam Engines	1								1	1	1									1					5
3. Inlet Pressures, PSIG																									
Less than 300	1								4	3		1	1	3		1		12				1	6	1	34
301 to 500			1	3	1	1	5		1		3		2		2	8		2				4	2	1	36
501 to 700	6				3	3		1	2				3			2		7	2		3		2	2	36
Over 700	2	3	3	3	3	7		4	1		1					1	2					3	2	1	36
4. Ages of Turbines, Years																									
Less than 20	1	3	3	3	2	7	2	3	2	1	2	1				1	1	2	2			2		3	41
21 to 40			1	3	5	9	3	2	5	1	1		4	2	1	6		9			3		2	5	62
Over 40	1						2		1				1	1	1	3		8		1		1	6	3	29
5. Megawatt Output-Generators																									
Less than 2	2						1		4	1	1		2	3				6		2		1	2		25
2.1 to 10		2	1	3	2	8	5	1	1		3	1	4		2	9	1	12			3	5	6	3	72
10.1 to 50	8	1	3		1	3			3		1						1	4	2			2	5	1	35
50.1 to 100								1																	1
Over 100																									
WOOD FUELS (Numbers of Plants)																									
1. Product Wastes	4	1	2	2	2	7	3	3	7	2	3	1	2	1	1	2	2	12	1	2	1	2	6	4	73
Whole Trees	1							1	1												1				4
2. Purchased from Others	3		1	1	2	5	1	2	2	2			1	1		2		6	1	1	1	1	2	3	38
In-House Waste Source	2	1	1	2	1	5	3	3	4	1	3	1	1		1	1	2	11		2		2	6	2	55
3. Some Fuel Hogged	4	1	2	2	2	7		3	6	2	3	1	2	1	1	2	2	11		1		2	6	4	65
Some Fuel Not Hogged									1					1					1	1	1				5
Some Fuel Already Fine Sized							2		1					1				3		1					8
4. Fuel Dried Before Use																									
Yes		1					1		1			1											1		5
No	2		2	2	2	7	2	3	6	2	3		2	1	1	2	2	12	1	2	1	2	5	4	66
5. As Burned Percent Moisture																									
Less than 20%	1					1				2	1									1					6
21 to 40%						2	1		1									2							6
41 to 60%	2		2	2	2	4	2	2	5		1	1	2	1	1	2	2	8	1	1	1	1	5	4	52
Over 60%		1																							1
6. As Burned Percent Ash																									
Less than 1%	2					1	1						2					2			1	1	1	2	13
1.1 to 2%		1	2			1			2	1	1			1			1	4					1	1	16
2.1 to 3%					1	3	2									1			1						8
Over 3%						1		2	1			1					1	1							8

STUDY OF WOOD FIRED ELECTRIC GENERATING POWER PLANTS CATEGORIES AND NUMBER OF PLANTS, BOILERS & TURBINES

NWPC

	ALABAMA	ALASKA	ARKANSAS	CALIFORNIA	FLORIDA	GEORGIA	HAWAII	LOUISIANA	MAINE	MASSACHUSETTS	MICHIGAN	MINNESOTA	MONTANA	NEW HAMPSHIRE	NEW MEXICO	NORTH CAROLINA	OKLAHOMA	OREGON	SOUTH CAROLINA	TENNESSEE	VERMONT	VIRGINIA	WASHINGTON	WISCONSIN	TOTALS OR AVERAGES
7. Thousands of Tons Burned Annually	367	185	621		358	886	301	789	335	20	67	17	189		54	107	410	437	164	22		91		163	5581
Thousands of Units Burned Annually				518						5			77					371					329		1300
8. Price of Wood Fuel in $ per Ton	6.84				6.00	5.45	11.00			9.75				6.00				11.00	6.35	8.00	12.00			3.80	7.84
Price of Wood Fuel in $ per Unit									5.40	11.25			10.00					4.24					4.50		7.08
9. Hauling Distances Reported (No. of Plants)																									
Less than 5 miles										2								1		1				1	3
5.1 to 20 miles							1											2					1		6
20.1 to 50 miles						3			1				1	1			1				1	1	1	2	12
50.1 to 100 miles	1		1		1	1		1	1	1								1	1						9
Over 100 miles						1						1													2
E. POWER & ENERGY DATA (Numbers of plants)																									
1. Electrical Energy Produced In KWH/Mo																									
Less than 100,000									2	1	1							1				1	2		8
100,001 to 1,000,000									2	1		1		1				4		1			1		11
1,000,001 to 5,000,000							3	1							1		1	4					2	1	13
5,000,001 to 10,000,000				1		1			1		1		2										1	1	8
More than 10,000,001	2	1	2	1	2	4			1								1	1	1			1		2	19
2. Peak Power Production In Megawatts																									
Less than 5						1	1		3	1		1		1	1			5		2			1		17
5.1 to 20			1	1		2	2	1	1		1		2				1	1	1				3	1	18
20.1 to 50	1	1			2			1	2							1	1					1		2	12
50 to 100						2		1																	3
3. Average Power Production In Megawatts																									
Less than 5							1		3	2		1		1				7		1			1		18
5.1 to 20		1	1	1		2	2	1	2		1		2				1		1				2	3	20
20.1 to 50	1			1	2			1	1							1	1					1			9
50.1 to 100						2		1																	3
4. Percent Power Used at Plant																									
Less than 10%																		1						1	3
11 - 89%				1		1	1			1			1											1	6
Over 90%	2	1	2	1	2	6	2	3	7	1	1	1	1	1	1	1	2	7	1	1		2	3	2	51
5. Percent Power Sold (If above 1%)																									
Less than 10%				1			1		1								1	2							6
11- 89%				1		1	1			1			1												5
Over 90%																		2						1	3

STUDY OF WOOD FIRED ELECTRIC GENERATING POWER PLANTS : CATEGORIES AND NUMBER OF PLANTS, BOILERS & TURBINES

NWPC

When listing the information from the questionnaires and tabulating the information we found that certain information was being reported accurately and some was not. Initially, we recorded all data until we became aware of some fact that showed us that it was unreliable. If we were able to separate useable information from that which was not we did so.

In general we found that much of the wood residues generated from the Forest Products Industry (sawmills, plywood mills and other related primary wood products processors) were being hauled to the Pulp and Paper Industry (P & P) mills where the residues were being burned to produce energy for the paper industry.

We found that the P & P Industry were diligently using wood residues continuously to produce electricity in contrast with the Forest Products Industry (FPI) who maintained less than half of their turbine generators continuously in service.

We found that FPI produces only about 1/10 of the power that the P & P Industry produces and evidently they cannot get enough money for their electrical production from the power companies to make selling it worth while. The FPI's electrical power generating plants are small averaging only 3 MW while the P & P plants are much larger averaging 28 MW.

To show some of the characteristics of the Pulp and Paper Industry Mills and the Forest Products Industry Mills, the mills were listed separately as shown in Appendix C.

The information was summarized for each industry using the forms attached to the lists.

The highlights of the survey results are discussed in the following sections.

of the Forest Products Industry 1977. The response to the mailing was about 25% showing 1/3 of the turbines as being inactive. Projecting these figures one gets about 800 KW as the Industries power production capability. Of the 16 mills producing electrical power that reported an average of 46 MW were made with 87% of the power being used in-house and 13% being sold to utilities. The average monthly power production was 19,600 MWH from 17 mills reporting this.

7. All wood products industry mills reporting used wood wastes for fuel, none used whole trees. Sixty-five percent did not purchase any wastes from other mills or operations. Only one mill indicated that it did not have an in-house source of waste materials. All but two mills either hogged their wastes or indicated that some of the wastes were already fine-sized.

8. The average mix of wood wastes was 29% sawdust, 4% sanderdust, 35% bark, 19% shavings, 4% chips and 9% other residues. The secondary wood producers burned an average of 90% shavings based on a sample of three.

9. Six mills indicated they were using dried fuel but none appeared to pre-dry their fuel. The average moisture content of the fuels was 37.3% from all primary and secondary processors reporting, but 43% when the secondary wood producers were eliminated. The average ash content reported was 1.3%. The average number of BTU/lb. of fuel burned on a dry basis was 8700.

10. The tons of wood wastes burned annually by 19 primary wood processors was 1,573,000 tons or an average of about 83,000 tons per mill. The median value burned would be about 66,000 tons per mill. The prices paid by four primary and secondary wood processors for waste wood to burn was $7.75 per ton and by 3 primary wood processors was $6.08/unit.

FOREST PRODUCTS INDUSTRY MILLS

Based on a sampling of 27 Forest Products Industry wood processors the completed forms indicated:

1. Only 14 mills were continuously producing power; 4 mills produced standby power, 2 produced peaking power and 7 were a part time operation either scheduled or unscheduled. Eleven of the power production facilities were in-service, 9 were temporarily in or out of service, 4 were permanently out of service - 1 requiring minor repairs and 2 requiring major rebuilding.

2. The number of steam boilers per mill was 2.1. The average boiler efficiency was 64.6% with extremes reported from 50 to 85%.

3. The auxiliary fuel most often used was oil, however, the auxiliary fuel amounted to only 2% of the total fuel burned. Nineteen mills reported using no auxiliary fuel at all representing 86.4% of the mills responding.

4. Twenty-two mills used turbine-generators, 5 used steam engines. Of those mills using turbine generators there were an average of 1.6 per mill of which 77% were condensing types, 6% were extraction condensing types, and only 17% were non-condensing types. No extraction non-condensing types were found in the information reported.

5. A sampling of the first 12 Forest Products Industry mills shown on page 1 of the Appendix C was made to determine steam pressure characteristics. This showed that the turbine generators of 3 mills operated on boiler pressures of 400 to 675 psig and the remaining turbines in the other 9 mills operated at pressures between 295 and 123 psig. The sawmills generally used lower steam pressures than the pulp and paper industry mills.

6. The amount of electrical energy capable of being produced by 24 of the mills was only 82.6 MW or about $3\frac{1}{2}$ MW for the average mill. We have not been able to confidently project the number of primary or secondary wood products mills in the United States with power production capability. We received 89 post cards indicating wood-burning power-producing capability from the Post's directory

PULP AND PAPER INDUSTRY MILLS

Based on a sampling of 39 papermills the completed forms indicated:

1. Thirty-six mills continuously produced power and were in service; one mill was on standby and one was permanently out of service. Another mill produced power only to burn up excess wastes. The mill that had the turbine-generator out of service, required major rebuilding to reinstate it.

2. The number of boilers per mill ranged from 1-12 with 4 being the average number per mill. The average boiler efficiency reported was 68.6 percent with extremes reported from 40-84 percent.

3. The auxiliary fuel used most often was oil with 24 mills using it. Gas was next with 13 mills supplementing their energy needs with it. Coal was used by 9 mills. Sixteen of the mills mentioned burning black liquor for fuel which contributed a very significant percentage of the mills total energy. We found 34.6 percent of all the pulp and paper industries energy needs were satisfied by oil, 7.2 percent by gas and 12.7 percent by coal making a total of 54.5 percent being supplied by fossil fuels. The remaining 45.5 percent came from in-house or imported wood residues and black liquor. (Based on a weighted average of equivalent wood burned at each mill).

4. All 39 mills reported turbine data, however three did not add enough data to classify the turbine types. We often ignored the categories on the questionnaire forms because they did not adequately define the types of turbines used. Based on the information NWPC engineers classified the turbines as follows:

Full Condensing Types	20
Extraction Condensing Types	22
Non-Condensing Types	31
Extraction Non-Condensing Types	16
Unable to Define Classification	8
Bottoming Types	2
Total from 39 mills	99
Average per mill	2.54

5. A sampling was made of the first 12 mills shown on page 1 of Appendix C to determine steam pressure characteristics of operation. Out of the 12 mills there were 30 turbine generators or $2\frac{1}{2}$ per mill. Fifteen operated on 825 to 850 psig steam, 7 on 600 psig steam, 6 on 1250 psig steam and 2 on 400 psig steam: all relatively high pressure systems.

6. The electrical energy capable of being produced by 36 of the 39 paper mills was 1010.6 MW or 28.1 MW per mill. The number of paper industry mills with this capability in the United States were estimated as follows:

From an initial mailing of about 765 addresses who received post card inquiries and a later follow-up with questionnaires to those who responded favorably, we were able to locate 57 pulp and paper industry mills with electrical generating capability from wood wastes. By carefull screening of Post's Pulp and Paper Directory we located another 55 who failed to respond to our previous mailings. An "unknown" list was prepared from the Directory consisting of 139 names of firms who did not have enough data shown in the directory to either reject or show positively that they had electric power-generating, wood-burning capability. Out of the 139 names we had 7 who reported having the capability and 37 who denied it. From this ratio we projected that 15 out of the remaining 95 "unknowns" would have electricity-generating wood burning capability.

The final estimate of pulp and paper industry mills with wood and/or black liquor burning capability:

Source	Plants
Those who sent questionnaires	41
Those located by post card survey	16
Those screened from Post's directory	55
Those projected from "unknowns"	15
January 1978 estimate of mills with capability	127

The electric power producible from 127 of these mills at the sampled 28.1 MW production per mill is 3568 MW of which 46% or 1641 MW is from wood residues or black liquor. The average papermill produced 17.3 million KWH per month. The average electricity production rate was 23.4 MW per mill from the 29 mills in the sample reporting this data. The percentage of power produced and used in-house amounts to 99.4 percent of that produced. Of the remaining 0.6 percent,.3% sold for an average of 1.18¢ per KWH and.3% was given away.

7. All 39 paper industry mills used wood wastes for fuel, and only three used whole trees. Thirteen of the mills did not purchase wastes from others and 30 of the mills indicated they had an in-house source

of fuel. All mills used hogged fuel or chips and only 2 mills indicated that the fuel was already fine-sized prior to delivery.

8. The average mix of the waste wood fuels used was as follows:

Wood Fuel	Percentage
Sawdust	17.2
Sanderdust	2.0
Bark	73.3
Shavings	2.7
Chips	2.1
Other Wood Products	2.7

9. Only 4 mills indicated that fuel was dried and 34 mills indicated no drying. The average as burned moisture content reported was 47.4%. The average ash content of the fuels was 2.8% and the average heat value in BTU's/lb of fuel burned on a dry basis was 8120.

10. The tons of wood waste fuel burned annually by 33 paper industry mills was 5,921,000 or 179,000 tons per mill (units were converted to tons by multiplying by a factor of 2.0). The average cost of wood fuel was $6.05 per ton and $16.10 per unit. The average hauling distance for imported wastes was 66 miles. The Forest Products Industry, the Pulp and Paper Industry and the Other wood burning electrical power plants are separately summarized in Table 2. Appendix C shows how the data was tabulated from the questionnaires.

TABLE 2

A COMPARISON BETWEEN PULP AND PAPER INDUSTRY, FOREST PRODUCTS INDUSTRY, AND OTHERS
(Data base given in parenthesis)

ELECTRIC GENERATING PLANT	Pulp & Paper	Forest Products	Other
Number of mills in sample	39	27	8
Number on continuous duty	36	14	7
Number on standby	1	4	0
Number on peaking duty	0	2	1
Number on other duty or under construction	2	7	0
Number of mills w/generators in service	36	11	7
Number of mills w/generators temporarily in or out-of-service	1	9	0
Number of mills w/generators permanently out-of-service	1	4	0
Number of future generators under construction	1	2	1
STEAM BOILERS			
Total number of boilers	147 (37)	52 (25)	14 (7)
Number of mills using only wood as fuel	3	19	1
Percent of total fuel that oil comprises	34.6 (28)	1.0 (17)	.6 (5)
Percent of total fuel that gas comprises	7.2 (28)	.9 (17)	0 (5)
Percent of total fuel that coal comprises	12.7 (28)	0 (17)	.4 (5)
TURBINE GENERATORS			
Total number of turbine generators	99 (39)	35 (22	24 (8)
Total number of steam engines	0	5	0
Number of condensing turbines	22 (39)	27 (22)	11 (8)
Number of extraction condensing turbines	22 (39)	2 (22)	4 (8)
Number of non-condensing turbines	31 (39)	6 (22)	3 (8)
Number of extraction non-condensing turbines	16 (39)	0 (22)	0 (8)
WOOD FUELS			
Number of mills using product waste	39 (39)	26 (26)	8 (8)
Number of mills purchasing waste	25 (38)	8 (23)	5 (8)
Number using hogged fuel	38 (39)	23 (25)	3 (4)
Percent sawdust in wood fuel	17 (37)	29 (25)	-
Percent sanderdust in wood fuel	2 (37)	4 (25)	-
Percent bark in wood fuel	73 (37)	35 (25)	-
Percent shavings in wood fuel	3 (37)	19 (25)	-
Percent chips in wood fuel	2 (37)	4 (25)	-
Percent other wood in wood fuel	3 (37)	9 (25)	-

	Pulp and Paper	Forest Products	Other
Number of mills where fuel is dried	4 (38)	6*	1 (8)
Percent moisture as burned	47 (37)	37 (20)	47 (8)
Percent ash as burned	2.8 (29)	1.3 (8)	2.1 (8)
Average heat value in BTU/lb (dry)	8120 (38)	8700 (15)	8610 (8)
Average number of tons/mill burned annually (1000's)	166.4 (28)	33.2 (12)+	104.9 (5)
Average cost paid per ton for wood residues	$6.05 (11)	$7.75 (4)	$6.75 (4)
Average cost paid per unit for wood residues	$16.10 (3)	$6.08 (3)	$5.48 (1)
ENERGY & POWER DATA			
Millions of KWH produced per mo./mill	17.2 (31)	.9 (22)	5.6 (7)
Peak electric power reduction in MW/mill	27.0 (28)	2.9 (16)	14.7 (6)
Average electric power production in MW/mill	23.4 (29)	2.8 (15)	7.3 (6)
Percentage of electricity produced used in-house	99.4 (33)	86.9 (20)	66.0 (7)
Percent of electricity produced that is sold	.3 (33)+	13.2 (20)	33.3 (7)
Average selling price as firm power in ¢/KWH	-	1.5 (2)	3.8 (2)
Average selling price as surplus power in ¢/KWH	1.28 (2)	1.1 (5)	2.1 (3)

*See explanation in text.

+ See Summary in Appendix C. Does not include values of those mills reporting in units.

CONCLUSIONS

Some of the more significant results were:

1. A large amount of electrical power was being produced from burning wood wastes mostly in the Pulp and Paper Industry.

2. Almost all of electrical power generated was used in-plant by the Pulp and Paper Industry.

3. A significant amount of electric power could be generated by the Forest Products Industry who are not presently fully utilizing their electrical production capability nor their excess wood wastes.

4. A large amount of the excess wood wastes from the Forest Products Industry is being transported by surface methods to the Pulp and Paper Industry to supplement their energy needs.

5. About 80 to 90 percent of the energy from sawmill wood wastes could be used in-house to reduce the need to buy electricity from the power companies.

The above conclusions indicate a need for incentives to industry to enable them to fully use wood residue resources such as:

1. A tax benefit similar to the present investment credit program. (Our discussions with various firms in the wood products industry indicate this would have to be at least 30 to 40 percent of the initial equipment cost).

To implement greater power production from wood wastes, financial assistance is needed to allow industry to finance the costly power plants. These plants can often be made to pay out in energy savings in ten to twenty years, but not soon enough to make the expenditure a good short term business investment.

2. General information from the Forest Service indicates that a substantial amount of wood residues remain in the forest after logging. These residues can be removed and used as fuel. A cost benefit should be made to businesses who carefully remove the forest residues when cutting trees and produce chips that are used for fuel. This practice would greatly increase the amount of wood residues available for fuel and reduce the Forest Products and Pulp and Paper Industry's heavy use of fossil fuels.

3. The Forest Service indicates that many forests are without present commercial value such as ones with over-ripe trees, diseased trees and species of no commercial value. Electric generating facilities which are somewhat dependent on wood products industry wastes should be encouraged to perform whole tree logging in marginally profitable forests to make certain that they will not be "cut off" from their wood fuel supply because the Wood Products Industry and Pulp and Paper Industry took all the fuel.

4. Many mills could more efficiently use their power production facilities and waste wood supplies if they could sell the power at a modest profit. A program is needed to encourage electrical power networks to pay better than surplus power rates for off-peak power generated from burning wood wastes and residues. They should also be encouraged to promote, so called, "wheeling arrangements" to help industries who need small quantities of relatively expensive power.

5. Electricity generated by the Pulp and Paper Industry is usually produced fully using the benefits of co-generation. Steam is used twice: to produce electric power and then to heat or operate various processes. Cooling towers or ponds are not required; and therefore, thermal pollution of water is not a factor as it is in most utility owned power plants. The EPA should acknowledge and encourage co-generation by appropriate incentives wherever practical.

STUDY OF WOOD FUELED ELECTRIC GENERATING PLANTS

INTRODUCTION

The purpose of the study was to determine how extensive the wood-fueled electric power generation was throughout the U.S. and how the wood fuels were used and handled in the production of electrical energy. The study also intended to assess the potential for using wood residues for generating power as well as the ability of industry to solve emergency power deficiencies on a local scale.

The study covered all known major users of wood-fuels such as the pulp and paper industry and the wood or forest products industry. Wood burning power or municipal utilities, other industries and a resort were also contacted.

The study was authorized by the Fuels from Biomass Branch in August 1977 under an ERDA requisition G-06-77-2595 and later supplemented by a DOE requistion RL-E-77-0626.

The study consisted of sending out about 4500 letters with self-addressed franked return post cards or letter forms to wood oriented industry, governmental and private power groups, and air pollution control agencies. The information obtained from this mailing located probable wood-burning electric power producers. Some 450 probable power producers were sent detailed questionnaires andwheninformation was returned to us it formed the data base for the study.

INITIAL PREPARATION AND MAILINGS

In September of 1977 the plans were formulated for the conduct of the study, sample letters and forms were forwarded to the Fuels from Biomass Group in Washington, D. C. for their approval. Mailing lists were being prepared that were principally directed to the wood or forest products industries and the pulp and paper industry.

LISTS OF ADDRESSES

Later in the fall of 1977 the mailing lists were prepared which consisted of the following categories:

Addressee Category	Number Listed	Address Source
Primary Wood Producers(screened)	2244	Post's DFPI[1]
Primary Wood Producers (unscreened)	670	" "
Secondary Wood Manufacturers	268	" "
Pulp & Paper Mills	761	Post's P&PD[2]
Air Pollution Control Agencies	302	APCA Agency Dir.[3]
State Energy Offices	54	St. of Wash. Listing[4]
Federal Energy Agency Directors	10	Government Manual[5]
Public & Private Power Groups	114	Electric World Directory[6]
Total	4453	

The Post's Directoryof Forest Products listed some 5500 wood products industry plants. We eliminated all mills which we felt were incapable of generating enough wood waste to produce at least 1 megawatt per hour of electr icity by selecting sawmills producing 4 or more million board feet per year and plywood mills producing more than 8 million feet per year. Plants treating wood (creosote) and those making garden mulch only, were also eliminated.

We finally contacted 761 of the 1543 pulp and paper industry mills or offices. The completeness of their directory allowed us to eliminate 782 addresses.

The city, county and state Air Pollution Control Agency addresses were completed from the Air Pollution Control Association Directory. The State Energy Agency address lists were completed from a listing of State and Territorial Energy Agencies obtained from the Washington State Energy office in Olympia.

The Federal Energy Office Directors were obtained by listing the addresses of the 10 Regional District Offices. The public and private electric power system pools and utility coordinating groups were taken from the Electric World Directory and included everyone listed in those categories.

FORM APPROVAL

After the comments on our proposed forms and letters were returned from the Fuels from Biomass Branch of ERDA the final language and layout of the forms were completed. Eleven papermills that we were reasonably sure of having turbine generators were selected to try out the "Wood Products Industry Questionnaire" form as follows:

Papermills	Location	Filled Out Form	Commented
Ketchikan Pulp Co.	Ketchikan, AK	No	No
Alaska Pulp Co.	Sitka, AK	Yes	Yes
Crown Simpson Pulp	Eureka, CA	No	No
Louisiana-Pacific Corp.	Samoa, CA	Later +	Yes
Publishers Paper	Newberg, OR	Yes	Yes
Pope & Talbot	Oakridge, OR	Yes	Yes
Crown Zellerbach	Camas, WA	No	Yes *
ITT Rayonier	Hoquiam, WA	Yes	No
Crown Zellerbach	Port Angeles, WA	No	Yes *
St. Regis Paper Co.	Monticello, MS	No	No
Georgia-Pacific	Crossett, AR	Later +	No

We received four completed forms from the 11 mailed; this was the first indication that our responses were not going to be very good. Crown Zellerbach engineers gave us comments on how to prepare the form, but they were reluctant to fill out the form for our use. Later,

Footnote:
* Corporate headquarters engineering comments
+ Filled out form during regular mailing

corporate officers of Weyerhaeuser, Kimberly Clark and Willamette Industries contacted us to find out what we were doing. They offerred general advice but did not fill out the forms. In December the masters of the final letters, the returnable post cards, the two different letter forms for the non-wood products addressees were sent to Oakridge, Tennessee for printing, collating and mailing. A copy of the accompanying letters, the reply post cards, the questionnaires sent to "Air Pollution Control and Energy Agencies" and the questionnaires sent to "Utilities Considering or Using Wood Fuel" may be found in Appendix A along with the assembling and collating "Instructions for Mailing".

One possible hinderance to obtaining a good response occurred because the 4500 reply post cards contained a "First Class, Permit No. 3, Oak Ridge, Tenn." return permit that according to postal regulations could only be used if the card were mailed in Oak Ridge, Tennessee. We think all of them came through the mails anyway, because none were returned to Oak Ridge, no postage due notices or requests were delivered to us. A significant number of cards arrived that were stamped over the permit number by the wood products industry mill's mail room employees who were familiar with postal regulations.

RESPONSE TO THE INITIAL MAILING

By March 10, 1978 we had received the following post card responses:

Response	Primary Wood Producers	Secondary Wood Manufacturers	Pulp & Paper Mills	Totals
Yes, our generator is active *	49	1	30	80
Yes, our generator is inactive *	30	0	0	30
Yes, our generator is on standby *	9	0	1	10
No electricity producing capability+	577	49	163	789
No, but we have a generator +	17	5	11	33
Returned to Sender Mail	30	11	6	47
Total Mailing	2914	268	761	3943
Total Response, percent	24.4	23.9	27.8	25.0

* Mill has capability of using wood as a fuel to produce electricity
+ Mill incapable of producing electricity from burning wood wastes

The questionnaire responses from Governmental Agencies and Public and Private Power Groups were as follows:

RESPONSES FROM OUTSIDE THE WOOD PRODUCTS INDUSTRY

Group	Total Mailed	Helpful Responses	No Help Responses	Return to Sender	Percent Responding
Air Pollution Control Agencies	303	37	137	0	59%
State Energy Agencies	56	8	16	0	54
Federal Energy Agency Directors	10	1	4	0	60%
Public & Private Power Groups	113	3	27	6	33%

The responses ultimately were about 60% for the governmental agencies and the address lists were fairly good because only a few pieces of "return to sender" mail was received.

In addition, we located about 6 comprehensive studies on this subject done in:

California by the Energy Regulatory Conservation & Development Commission[7]
Oregon by the Department of Environmental Quality[8]
Washington by Puget Sound Power & Light[9]
New England by the Federal Energy Administration[10]
U.S. in general by Federal Energy Regulatory Commission[11]
Alaska by Alaska Power Administration[12]

At this time we determined that there may be some resistance to replying in the case of private power groups and even the mills. It could be that their operations might be in violation of some regulation by the Federal Energy Regulatory Commission[11] that requires that the electrical power production information be filed with that commission. One respondee stated, "all industries which own or operate generators must file a FPC-Form 12- Industrial Electric Generating Capacity, on an annual or monthly basis".

By March 10, 1978 the second mailing had been prepared and the formal questionnaire entitled "Study of Wood Fired Electric Power Generating Plants, Wood Products Industry Questionnaire" was sent to 288 possible wood burning power plant owners capable of producing electricity. When the 1978 Post's Pulp and Paper Directory was reviewed, we found that 156 probable wood burning power plants were either new or had not responded so these were sent questionnaires. Care was taken to avoid duplication in mailing lists obtained from different sources. As of

April 21, 1978 we had the following responses to the formal questionnaires:

Referral Source	No. Mailed	Data Furnished	Negative Response	Returned To Sender	Authority Questioned
Primary and Secondary Wood Producers	43	6	4	0	0
Government Agencies & Power Groups	90	15	22	1	1
Post Card Respondees (No w/generators)	33	0	9	0	1
Post Card Respondees (Yes w/generators)	122	34	8	3	2
1978 Post's Pulp & Paper Directory Mailing	156	6	21	4	0
Totals	444	61	64	8	4

The response to the second mailing was about 30 percent as of April 21 after the formal questionnaires had been out about 40 days.

A third mailing to the pulp and paper industry was made during the data tabulation phase of the study in May 1978 when we more carefully interpreted the Post's Pulp and Paper Directory and found an additional 19 probable mills with wood-burning electric-generating capability. Questionnaires were completed by 5 mills with a 26% response from this mailing. The data arrived in June, too late to be included in the statistics. It is shown in Appendix C.

RECORDING AND TABULATION OF DATA

Proper use of the data to determine a particular relationship depends on the care taken to obtain the information and how well it was reported. The forms were not completed with care in many instances.

By May 19, 1978 we had received 74 completed questionnaires. The data had been taken from the questionnaire forms as they arrived and tabulated just as it came off the forms; however, we found many problems and contradictions in performing this task. For instance, much of the turbine information was sandwiched into the available blanks, incomplete and not provided on attached sheets as we had requested. Also many responses contained new and different situations that did not lend themselves to our categorization. After several attempts we finally arrived at a record form with an attached coding sheet that covered the range of data we obtained. See Appendix B.

First, we were able to obtain the number of values falling between certain limits, the number having a yes or no response and the number of occurrences of some practice. We found several responses that were the same on all questionnaires, these are listed here:

1. The generators always produced 3 phase power at 60 Hertz.
2. Almost everyone wanted a copy of the report so this information was not recorded.

The numbers of values falling between certain limits, the number of yes and no responses and the number of occurrences of some practice were recorded by states and summarized on Table 1.

Secondly, we provided a limited amount of information on each wood-burning electric-generation application giving the particulars on the turbine-generators and auxiliary and wood fuels. Data were entered by states so that they could be found easily by those requiring more detail.

Information obtained but not summarized on the forms because of various reasons was:

1. Boiler temperature and pressures often differed for each boiler listed. There were only two spaces on the form in which to fill in this information. We could not tell which pressure and

temperatures went with each other and/or to which boiler any set of conditions were related. Similar information was required for each turbine-generator and since we had asked for a listing of this information, we had more confidence in the accuracy of the inlet pressures to the turbine generators so this information was recorded.

2. The turbine generators were rated by the manufacturers at specific power factors under some particular test conditions. These all varied between .8 and 1.0. We recorded this information but felt that it added nothing to our tabulations without all the other test information that went with it.

3. Water rates for the turbine generators were usually provided from the manufacturer's literature for certain inlet, extraction and exhaust conditions. The conditions were seldom the same. The water rates for each exhaust and extraction pressure had to be related to the proper turbine and its operating conditions. We didn't record the information on any of the final forms.

4. Occasionally when reporting other fuels burned simultaneously with wood, some other fossil fuel was lumped together with black liquor with the percentage of the two given. We couldn't tell how much oil or gas was used. In this case, the response was entered as "yes" instead of as a percentage of the particular fossil fuel.

5. Due to many forms of wood fuels reported and the fact that most were simply reported as wood residues or hogged fuel, all physical forms of wood fuels were recorded as undefined woody residues in Sections E.4 and 5.

Thirdly, we noticed definite differences between Pulp and Paper Industry Mills and the Forest Products Industry Mills. To illustrate this difference, a separate tabulation of the important applicable characteristics of the mills of these two industries was made. This information is shown in Appendix C. (A confidential compilation of selected mill responses). The information from the two industries, plus the remaining "Other" categories is shown in summary in Table 2.

QUESTIONNAIRE FORM CRITIQUE

There were problems with some of the replies because of interpretation of the language on the forms and the number of spaces in which to reply. Considerable effort was made to shorten the form so that it would be less of a task to complete it. At the same time we tried to get the maximum amount of desired information. Comments are made by sections A through F as they appeared on the form (See Appendix A.)

A. Electric Generating Plant - General

1. Using the question "For what type of service is the plant used?", if the unit was permanently out of service we considered it as "Other". We found that a number of forest products mills ran the electrical generating plant only when the mill was operating or when they needed to incinerate their excess wood wastes. Some plants were under construction and management didn't know how they would use it. All of these types of service were considered "Other". Some generalizations were made by the engineers on whether a response such as "continuous duty" was really that. For example, in the case of a wood and bagasse burning sugarmill that operates for 8 or 9 months out of the year: this was considered continuous duty.

2. Under the question "What is the operating status of the plant", most checked and there were few problems with "a. permanently in service". Closer examination of the categories "b. temporarily in service "or "c. temporarily out-of-service" indicated to us that there was little difference between the two when one considered the possible situations faced by the responder. Some of these were: day shift operation, seasonal operations, or operation whenever needed.

When a generator was "d. permanently out of service" there were few problems with that category. There was a language problem under the subcategory "how may it be reactivated?"

was " Major building needed"; this should have read "Major rebuilding needed". Some may have felt that a building was needed.

Many knew they had a generator but didn't know what was wrong with it or why it was in storage. The categories didn't provide spaces for these types of answers.

B. Steam Boiler Plant

1. The number, operating pressure and temperature of boilers did not permit enough space to record this data. Paper mills usually had several boilers of which 1 or 2 burned hogged fuel This led to a number of pressure and temperature responses that defied categorizing. Some respondees looked at the next question and saw that it related to wood fuel so they only provided information on the wood fired boiler (s). Where this was done we had to leave the response out of our averages.

2.Generally the "Overall efficiency with wood fuel" question was answered properly. The responses may be of some value. We did get a few 80% plus efficiencies that do not seem possible with our knowledge of wood fired boilers. We recorded them as stated. The efficiencies may have been obtained from manufacturers literature and the efficiencies may not represent the fuels now being burned. Other reported efficiencies may be test data from the complex ASME tests that have been performed on the actual boiler.

A few respondees gave efficiencies over 100%. These responses were probably referring to the boiler's rated capacity rather than it's efficiency. The over 100% responses were all rejected and not recorded.

3. The "other fuels burned simultaneously with wood" entries were interpreted in two ways: as the percentages applied to the hog fuel boilers or as a percentage applied to all boilers. In almost all cases we found that they applied to all boilers, so when we knew that entries applied to only the hog fuel boiler they were not shown nor were totals or averages reported in the study. This item severely detracts from the credibility of fossil fuel statistics reported in the study. We deduced that 54% of the fuels burned by the pulp and paper industry were fossil fuels. If someone answered with percentages for only the hog fuel boiler then the percentage

we reported is too high.

Respondees should have had a place to check when no other fuel was burned other than wood or wood product wastes. Many respondees did not answer the question and we could not tell the difference between a response saying no other fuels burned and one where the information was unknown or left blank. Many respondees solved the problem for us by answering "None".

C. Turbine Generation

1. The types of turbines listed under C.1 was generally adequate for the sawmills, but the pulp and paper industry respondees didn't use the categories and rightfully so. Most of the larger power plants gave full particulars on their turbines with inlet, extraction and outlet pressures. They also listed information requested in questions 1 to 4 of this section. With this information we were able to set up new classifications for handling the non-condensing and extraction-type turbines now popular in the co-generation operating modes. How we handled the problem is discussed in 2 of the next section.

2. The total number of turbines question was usually answered carefully and turbine ages were either given by the year constructed or by actual age. We rejected all other information in the statistics such as rebuilding and modification.

The operating temperature and pressure space allotment on the form was inadequate. We knew this and asked for an additional data sheet where a plant had more than one turbine. This request sometimes fell on deaf ears because finding it required more effort to dig out the information than the responder wanted to give. However, many very conscientious "central engineering" type personnel faithfully gave us the complete and exact detail on the turbines used.

We classified the turbines as condensing, extraction condensing, non-condensing and extraction non-condensing types and ignored the classifications on the forms under C.1. TURBINE GENERATION. Topping turbines became either extraction-condensing or extraction non-condensing types. Bottoming turbines became condensing types.

3. The water rate information was usually good for a particular application but because of the

many types of turbines and variable taps and rates of extraction, the water rates were usually unknown at the operating conditions or not easily obtained. Water rates, where reported, were first tabulated but the information merely supports that piece of data and water rates were never summarized because most of them did not fit a particular set of conditions.

4. The electrical characteristics of the generator were often different for each turbine generator at the responding plant. When reported, this information was valuable and reasonably complete. Many respondees indicated two or more turbine-generators with only 1 set of generated electrical power characteristics. They sometimes combined and summarized their "Rated Output in MW", and therefore this information was included as if it were the total MW output. We think that we have reported this information accurately, doing it by carefully considering responses in Section E. The power factors as the generators were rated were usually given. Voltages, Hertz and phase were usually given and the form proved adequate.

The data on rated electrical power produced neglects power factors because the generators were rated at various power factors between .8 and 1.0. All generated power reported was at 60 HZ and 3 phase and the form was adequate to prove this.

D. Wood Fuels

1. The source of wood fuel was usually answered by checking "product waste". This was assumed to include any wood by-product: paper, sludge and black liquor. "Whole trees" was seldom checked except by 3 pulp and paper mills and the City of Burlington, Vermont. The category may have been misconstrued by one paper mill respondee who thought they used whole trees, meaning all of the trunk of the tree. By whole trees we meant that needles and leaves were burned to produce steam, as anticipated at the proposed plant at Burlington, Vermont.

The "d. Other" category was often filled with an entry defining some other product waste. Often the word "chips" was entered on the form which we reported. We do not know if the chips were a useable raw material or a reject or waste material. The "other" wood fuel category entry was recorded and generally the only fuel forms we reported independently were chips and bagasse.

There were few problems with the source of wood choices such as "Purchased from Other" and "In-house Waste By-products". The third "Other" category, was never checked.

2. The "Is the fuel hogged?" was an ineffective question. We had checks for "yes", "no", and "already fine sized" in all possible combinations. The responses have been recorded as stated, but the information obtained adds little to our knowledge. It added little information because the respondee knew that most all fuel was hogged, occasionally some was not hogged, and some arrived already fine sized. Some checked every category but many did not, and, this fact makes the data suspect. For instance, we know one Oregon paper mill does not hog its purchased fuel because it is already hogged. "Do you hog some of your fuel?", would have been a better phrasing of the question. Again, the limited space on the form was working against us.

3. The percentages from "Physical Forms of the Wood Fuel" responses were good except for "category e.". We received several new categories of wood, many of which we were able to categorize, especially from the secondary wood manufacturers and New Englanders. We categorized these as "Other Wood".

Chips can mean hogged fuel, stock for paper or whole tree debris from a mobile chipping machine. We created a new category for chips and lumped these together. Possibly we should have categorized them as "clean chips" and "dirty chips" to represent the different types.

4. The phrasing "Is the fuel dried before use?" told us that some of the fuel was dried or that they actually employed a special drying process prior to burning. We were after the latter information, because we knew that certain mills in Alaska and the Northern States of the U.S. actually had to dry the fuel before they could burn it. The secondary wood processors (manufacturers) for example, answered that their fuel was dried before use, which was true. We separated the two "Is the fuel dried before use? Yes," responses into: those dried to 35-60% moisture that also burned at the same percent moisture, as "mills with dryers"; from those plants burning mostly air or kiln dried wood wastes with lower than 35% moisture contents. The plants

burning air or kiln dried wood waste were designated by a (No) response to the question. The "Yes" response now means that fuels are predried in a dryer or similar device prior to burning. The wood fuel analysis as burned question presented us with some easily correctable responses for tabulation. Moisture, ash and heat values were accurately given by some respondees as ranges of values. These were tabulated by averaging the extremes of the range. The heat value was sometimes given on a wet basis. This entry was tabulated by dividing the heat value by 1 minus the percent moisture expressed as a decimal.

5. We received "quantity of wood burned annually" information on all types of wood fuels such as sawdust, sanderdust, etc., as intended but most of the mills merely reported it as wood waste or hogged fuel. To obtain meaningful useage information we had to categorize all waste wood entries as simply "wood wastes" and record them in tons or units.

6. The fuel costs were usually given in wet tons or units; occasionally we had a bone dry ton entry and these were converted to wet tons by using the percentage moisture figures given previously, thereby decreasing the reported cost. Many respondees left the item blank and some stated the information was confidential. Some respondees used cubic yards which had to be converted to units, some used cords.

7. The fuel hauling distances in miles were often given as a range (indicating more than one source of fuel). The extremes of the range were averaged when this occurred.

E. Power and Energy Data

This category was generally completed and proved to be the redeeming feature of the study. Where the time frame was not reported as shown on the form, the information was converted to that shown on the form. There were few respondees who indicated that the selling price of power to a utility was confidential. The surplus and firm power categories may not have conformed to specific contract arrangements that the mills had for the sale of power; but, usually one or the other was

used and often one was marked not applicable when entries were made.

F. General

1. Some persons tired before completing the form. Usually the respondee left his name and address so we could call him for clarification; however, only local calls were made.

2. The "Clarification of Entry Comments" lines were a great help in tabulating the results. The information given here was always treated as over-riding any other response given. Much of the information given would have had to be rejected if it had not been for this section.

3. Many of the respondees did not care if the plant name and location was kept confidential.

4. Almost every one indicated that they wanted a copy of the report.

DISCUSSION

The Pulp and Paper, Forest Products and the other industries as a group produce different waste by-products that are burned as fuels. The wastes are burned in different types of furnaces/boilers some requiring supplementation with fossil fuels or drying of the fuels prior to feeding to sustain combustion. Other wastes need only the wood waste to sustain the burning reaction. In order to describe how the various waste woody fuels are obtained a brief description of the processes that produce them has been prepared. To understand how the furnaces of the boilers receive and burn the fuels, a short explanation of the boilers and how they operate has been made. To understand how turbine-generators produce electrical power from the steam generated in the boiler, a short explanation of turbine generators and types has been provided.

CHARACTERIZATION OF THE WOOD-FIRED ELECTRICAL-GENERATING PLANTS FUELS

The sources and forms of woody fuels differ according to the industry producing them and the particular wood process.

Sawmill log processing waste residues that are generally used as fuels are sawdust from cutting off the logs and sawing the rough lumber and shavings from the planing of the lumber. Bark, slab and edgings may come off the log together or the bark may be removed separately. Trim and cull wastage occurs after the lumber has been cut but usually prior to surfacing.

Plywood log processing waste residues generally consist of lillypads, bark, sawdust, trim, cores and sanderdust.

Pulp processing wastes consist of bark, black liquors, sludges and rejected pulp chips.

There are many different kinds of hardboard, particleboard, paperboard and paper products mills that may produce a product from scratch or use materials from another mill. All may produce trim and scrap wastes from their own processes plus some of the ones characteristic of the basic pulp and sawmill wastes.

Our study left a blank for only sawdust, sanderdust, bark, shavings and any other waste the respondee wanted to list. Respondees often listed other wood forms than these.

Generally we found that the Forest Products and Pulp and Paper Industries use bark as the major fuel form with sawdust second and shavings third; and, that these three wood forms make up 80 to 90% of the wood residues used as fuel. In-house waste by-products were the principle source of fuel. Pulp and paper mills were generally deficient, not having enough wastes to meet energy needs, and therefore, 2/3 of the pulp and paper mills sampled purchased wastes from others.

The forest products industry sawmills generally produced enough fuel to meet their needs, but the plywood, board mills and secondary manufacturers did not; and, these made up the 1/3 of the Forest Products Industry mills that purchased wood wastes.

CHARACTERIZATION OF THE BOILERS USED

The Pulp and Paper Industry uses boilers for chemical recovery and production of steam. About 4/5 of the boilers serve industries using the Kraft (Sodium Sulfate) process; the remaining 1/5 use the sulfite process. In a typical Kraft mill the logs are debarked; the log reduced to chips; the chips are charged to a digester; the chips are cooked under pressure in a solution of sodium hydroxide and sodium sulfide until the lignin binder that holds the cellulose fibers together is removed. The spent cooking liquor, after the fibers are removed, is concentrated in a multiple effect evaporator then a direct contact evaporator. This strong black liquor is mixed with salt cake (sodium sulfate), heated and sprayed on the walls of the recovery boiler. The dissolved lignins and suspended woody constituents are burned with the aid of fossil fuels. The sodium constituents in the liquor are recovered as molten smelt.

The sulfite process employs an acid process where lignins are burned in a recovery boiler. There are four different types of processes for recovery of the sulfite and these processes are too complex to describe here. In general about 15% of the total heat input to a magnesium base recovery boiler is supplied by fossil fuels. The stack gases from this process contain about 1% sulfur by weight. This chemical is recovered at a high efficiency.

In addition to the recovery boilers, power boilers use either fossil fuels or wood residues to supply steam needs for cooking and digesting the wood chips. Drying processes and other steam needs require large quantities of steam.

Our survey found that boilers in papermills were usually high pressure and high temperature steam generators; the bark (in-house and imported) made up 73 percent of the wood fuel burned at the mills. The remaining 27 percent was assumed to be imported from other wood products industry mills or were forest residues.

The Forest Products Industry boilers are power boilers used to generate steam for drying lumber and other processes. Our survey found that sawmill boilers were usually lower in pressure and slightly lower in efficiency than the Pulp and Paper Industry boilers. The hog fuel boilers are usually provided with some fossil fuel for auxiliary firing, but as the survey showed, they seldom use it.

Most present day hog fuel boilers are stoker fired. The smaller boilers usually have fixed grates with larger boilers using traveling grates. Older boilers are usually of the "Dutch Oven" type where fuel is fed onto a burning pile of material. The stoker fired boilers generally produce a greater heat release per square foot of furnace grate area.

Drying of fuels is generally required when the moisture content of the fuel is above 70 percent. Our survey showed that four papermills and one wood burning sugarmill dried their fuels.

CHARACTERIZATION OF TURBINE-GENERATOR UNITS

The turbine-generators found in industry vary widely in type and use. This is partly because they were usually built into an existing plant and were chosen to best suit the prevailing steam conditions at the time of use. Many are obtained second hand and re-installed at some compromise in efficiency.

As categorized in the survey, full condensing turbines are those which exhaust all of their steam to a condenser at some pressure below atmospheric. Non-condensing turbines, sometimes referred to as back pressure turbines, are those which exhaust at pressures above atmospheric with the remaining heat in the exhaust steam being used in some other process where it is eventually condensed. The extracting condensing turbine is one which has one or more openings between inlet and exhaust from which varying amounts of steam at intermediate pressures may be withdrawn for use in some other process. The remaining steam flows through the turbine to a condenser. The extraction non-condensing machine is one having extraction outlets but exhausting at some pressure above atmospheric.

The lower pressure, full condensing units will generally be found in the Forest Products Industry while the higher pressure units of either the extracting or back pressure types (exhausting at pressures greater than atmospheric) will usually be found in the Pulp and Paper Industry. This is because the Pulp and Paper Indus try has a process that is inherently more capable of using consistent large quantities of steam than the drying processes which provide the bulk of the steam load in the Forest Products operations in either kilns or veneer dryers.

The steam turbines drive generators to produce electrical power that is 60 Hertz, 3 phase at a .8 to 1.0 power factor, in voltages from 460 to 13,200. Voltages are shown in the State summaries in Appendix B.

END NOTES

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Other Entries

50. In an effort to reduce the amount of paper in the report, Appendix A was reduced in scope. It is available upon request to the Fuels from Biomass Branch of the Department of Energy.

51. Much of the material in Appendixes B and C is confidential. These Appendixes have been eliminated in those reports prepared for general use.

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