

INDUSTRIAL ENERGY AND ELECTRICAL POWER FROM WOOD RESIDUES

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Although wood residues are widely used in the USA and other countries to produce industrial process heat, to generate electricity, and for space heating, such uses are not yet common in developing countries.

About 75% of the standing volume of trees harvested for timber in developing countries ends up as logging residue in the forest or as mill residue in sawmills and other woodworking plants. The annual volume of logging residues is somewhat larger than the 240 million cubic meters of saw logs and veneer logs harvested annually in all developing countries. About half of the logs harvested become mill residues. Although some logging and mill residues are used for domestic fuel and for charcoal production, vast quantities of potential wood fuel are burned for disposal or allowed to rot.

During the 1970s and 1980s development assistance agencies, international organizations, and national agencies have sponsored many studies and projects designed to maintain adequate supplies of fuel wood in developing countries and to promote more efficient use of the available fuel wood. These activities have focused primarily on wood harvested in forests for fuel and on the use of fuelwood for domestic cooking. Development assistance organizations have stressed the need for programs for the sustained management of forests that would

provide continuing supplies of fuelwood as well as timber.

A few international agencies have examined the use of wood fuels by small rural industries. Most of these studies have focused on wood harvested for fuel. Only a few address the use of the residues from lumbering, saw mills, or wood product factories.

- US and other manufacturers of wood energy equipment have focused primarily on domestic markets. They have made little effort to adapt equipment or systems to conditions in developing countries such as the need to minimize capital costs, and to maximize employment. At present, however, several US firms are actively exploring opportunities in developing countries to market their extensive experience in the USA with wood residue energy systems.
- Most of the commercially available equipment in developed countries have been designed for the handling, preparation, and combustion of pulverized wood fuels (ground bark, saw dust, shaving, and solid residues that have been chipped or hogged). The use of pulverized wood fuels is rare in developing countries. Most boilers and furnaces in these countries have been designed for firing with roundwood or stickwood.

- Information on wood energy systems and equipment in developed countries is not widely available in developing countries. A major purpose of this paper is to provide an overview of current technology and examples of facilities in the USA and in developing countries that are producing industrial process heat or electric power from wood residues.
- Most medium-sized and large lumber mills in the USA burn mill residues to produce steam for kiln drying of lumber. Most saw-mills in developing countries air-dry lumber, although in some countries interest in kiln drying is growing as a means of increasing the export market and value of lumber.
- Unlike in the USA, developing countries seldom use wood residues for electric power generation, despite the acute power shortage in many of these countries. Factors that have limited power generation with wood residues include, inadequate funds and foreign exchange for modernization of sawmilling and woodworking industries, the lack of incentives for such investments in some countries due to low-cost or subsidized energy, the absence of grid connection of other power customers at many sites where residues are accumulated, and policies of many governments and electric utilities that discourage power generation for the grid by private firms.

Despite these limitations, several trends and developments point to the greater use of wood residues for industrial energy and power in developing

countries in the 1990s. Growing recognition of the need for sustainable long-term management of forests is raising interest in maximizing the utilization of the trees that are harvested. A number of governments have adopted new programs and policies designed to expand the use of domestic energy resources and to increase role of private firms in providing electric power for the grid. Many governments and industries in developing countries are reassessing energy options, and there is rising interest in some countries in using wood residues as fuel for the kiln drying of lumber.

In the USA in 1980s, wood residues energy systems have clearly demonstrated that they can provide significant net saving in energy costs for forest product industries, and public institutions can contribute significantly to the supply of electric power for the public grid.

In the 19th and early 20th centuries, most sawmills were operated with steam engines supplied by wood fired boilers. By the middle of 20th century, most steam engines had been replaced by diesel engines or by electric motors, but they still provide power for sawmills in a few countries.

In **Thailand**, researchers at **Prince of Songkhla University** estimated recently that around 2,000 steam engines provide mechanical power for sawmills and rice mills. Steam is usually generated in a horizontal locomotive-type firetube boiler. At one sawmill in Thailand, 60 kg/hr of wood waste is burned to produce 650 kg/hr of steam for a 52 HP steam engine. At a larger Thai sawmill, 100 kg/hr of wood residues is burned

producing 700 kg/hr of steam for a 78 HP engine.

Most of these steam engines in Thailand are horizontal, compound-cylinder models with common piston rod connecting the pistons. Although efficiencies are low, the engines are reliable and durable. Many of the engines have been on operation for over 30 years. At least seven companies in Bangkok custom build steam engines to fit the power requirements and fuel supply of the buyer. Some engines have cylinder bores as large as 45.7 centimeters (18 inch) and flywheel diameters as large as 4.8 meters (16 ft). A low speed 35 HP steam engine costs about \$11,000 while a 101 HP engine costs \$27,500 [1].

* Steam engine power systems fueled with sawmill residues were installed in the mid-1980s at two sawmills in **Honduras** under FAO's Wood for energy Project, which promotes the development of small rural power systems. Both installations include a "locomobile" a boiler/engine unit resembling a locomotive, which was widely used earlier in this century. One engine, at the National School of Forestry Science (ESNACIFOR) sawmill at Siguatepeque is rated at 64 kW (85 HP). Another one rated at 36 kW (50 HP) is installed at Chaguite Grande, a small forestry village, provides electricity for a sawmill operated by an association of workers and for the village. In both systems, a belt drive links the large flywheel with a generator.

The locomobile system at the ESNACIFOR sawmill burns 0.19 tonnes of wood wastes per hour and 334 tonnes

during 1,750-hour annual operating period. The system produces 67,200 kWh/year, an average of about 38 KW/hr and 201 kWh per tonne of wood wastes. An economic analysis indicated that the installed capital cost of the ESNACIFOR system (\$76,660) was nearly twice that of a diesel generating set of comparable capacity (\$39,980). Due to the high capital cost per kilowatt of capacity (about \$2,000/kW), the short annual operating period, and the \$10/ton opportunity cost of wood residues, the unit cost of power from the locomobile system was high (\$0.35/kWh) although lower than that from a diesel system with the same annual operation and output (\$0.43/kWh) [2].

* Large steam engines build by **Mernak S.A.** are reported to be producing power from the wood residues at sawmills in at least three African countries. The large steam engines are similar to models that were widely used for industrial purposes early in the 20th century. The generator is powered by a belt drive from one of the engine's two large flywheels.

* A 1.2 MW cogeneration system in **Africa** built by **Spillingwerk Gmbh** uses Spilling steam motors, which combine some characteristics of a piston-type steam engine and some of a diesel engine. The Spilling system provides electric power and steam for wood drying at a sawmill that processes tropical hardwoods on the Sanga River in the Central African Republic. The mill produces 5.2 t/hr of chips, sawdust and slabwood with 40% to 60% moisture. A screw conveyer feeds chips and sawdust from the 150 cubic meter fuel bunker to the step grate furnace; slabwood is added to the furnace manually via an air lock.

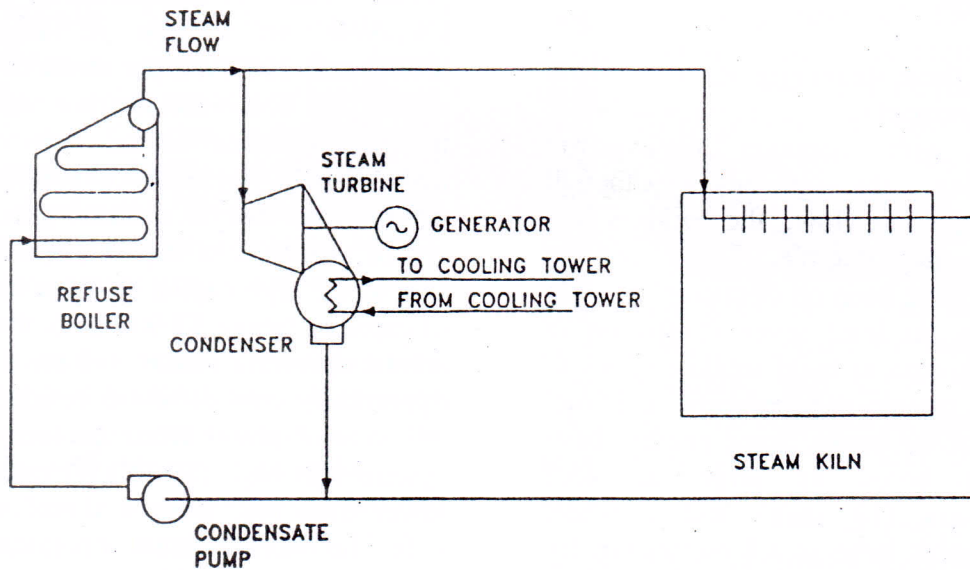


Figure 1. Cogeneration in a sawmill with condensing turbine cycle. (Source: *Design Manual for Small Steam Turbines*, TVA)

The three-pass boiler produces 17,000 kilograms (37,500 lb) of steam per hour at 18 bar (264 psi). Most of the steam is used in two four-cylinder Spilling steam motors; each drives a 600 kW synchronous generator. The steam consumption is 13.3 kg/kWh. The total power output (1,200 kW) is used in the sawmill and in the homes of employees. Exhaust steam from the Spilling motors at 0.5 bar (7.3 psi) is used for wood drying.

Electric Power Generation With Condensing Turbines

In a system with a condensing turbine cycle (Figure 1) exhaust steam is not used for process heat. The turbine exhaust flows to an air condenser or to a condenser cooled by water. Because the steam enters the turbine at a high pressure and is exhausted from the turbine at low or negative pressure, the

energy in the steam is fully utilized for electricity generation.

A design manual published by Southeastern Regional Biomass energy program indicates that a typical single-stage condensing turbine/generator with a 17 bar (250 psi) boiler pressure and 0.7 bar (-10 psig) condensing pressure uses 14.2 kilograms (31.5 lb) of steam to generate a kilowatt-hour of energy [3]. Systems operating at higher pressures require less steam per kilowatt-hour. Wellons, Inc., a major builder of wood-fired boiler systems indicates that a condensing turbine with 20 bar (300 psi) inlet pressure and 10 cm Hga (4 in Hga) exhaust uses 6.8 kilograms (15 lb) of steam per kilowatt hour. Condensing turbines at several Indonesian plywood factories use 5.45 kg/kWh (12 lb/kWh) at 34 bar (500 psi) [4].

The actual steam rate (measured in kilogram per kilowatt-hour) of steam turbines varies considerably and depends

on the inlet and outlet steam conditions and the size, speed, and design of the turbines. Data for specific cases is available in engineering handbooks or from turbine manufacturers.

economizer and a combustion air preheater. The fuel rate is about 2.25 t/MWh (2.5 ton/MWh). This output per tonne of fuel is more than twice that of a backpressure (noncondensing) turbine with the same fuel and inlet pressure but an exhaust pressure of 1.36 bar (20 psi) [9]. The UNDP/World Bank team in Ghana calculated that a 1.2 MW system using fuel with 34% moisture and operating at 23 kg/cm² (327 psi) would produce 350 to 385 kWh/t (312 to 343 kWh/ton) of fuel [10].

A condensing turbine is appropriate for a facility that has no requirement for process heat, a boiler capacity substantially in excess of process steam requirements, or a residue supply sufficient to fuel separate boilers for process steam and for power generation [11]. Condensing turbine systems operated by three U.S. forest products industries are described below. (Four other power plants with condensing turbines are described later in this paper under "Power for the Grid").

* **Pate Lumber Company**, which operates a sawmill, dry kilns and planer mill in **Carrollton, Alabama**, produces 40,000 cubic meters (17 Mbf) of lumber annually. Until the late 1980s most of its sawdust was being sold as fuel or poultry bedding, but continuing sales were doubtful and the firm was concerned about high future disposal costs. In 1989 Pate contracted with Southern Engineering and Equipment Company for a residue power plant.

Wellons indicates that a 20.4 bar (300 psi) condensing turbine system burning fuel with 50% moisture should produce around 440 kWh/t (400 kWh/ton) of fuel. A typical Wellons plant includes an

The system was designed to burn 45 t/day (50 tonnes/day) of green sawdust and 18 t/day of bark. Due to a favorable market for bark for landscaping, no bark is burned at present. The 400 HP firetube boiler operates at 9.5 bar (140 psi). The steam is used in a condensing turbine linked to an induction generator with a capacity of 350 kW. Exhaust steam is condensed in a surface condenser cooled with water from an evaporative cooling tower. The cooling system uses 20 to 25 gallons (75 to 84 liters) per minute from the local public water system. Pate continues to burn dry planer shavings in a separate 250 HP boiler to provide steam for lumber-drying kilns.

The new power plant (boiler, turbine, generator, and other equipment) cost about \$400,000 or about \$1,140/kW. If it burned both sawdust and bark, it could eliminate the mill's previous \$10,500 monthly power bill and pay for itself in about 3 years [6]. Without the bark, the power bill is about \$3,500/month and the payback period will be somewhat longer.

* Before installing a 1 MW cogeneration system, the **Huey Forest Products** in **Arenzville, Illinois**, deposited its daily output of 72.5 tonnes (80 tons) of wood wastes in a landfill. The new system is designed to burn 36 tonnes of bark, 54 tonnes of sawdust, and 7 tonnes of waste wood everyday. The fuel is pulverized in a processor/grinder and a five-knife chipper. It is fed by screw conveyers to a

Dutch oven furnace and watertube boiler that produces 13,608 kg/hr (30,000 lb/hr) of steam at 17 bar (250 psi). The steam is used in a condensing turbine linked to a 1,000 kW generator that meets all of the mill's power requirements. Surplus steam at 1 bar (15 psi) heats five lumber-drying kilns [5].

* **The M.C. Dixon Lumber Company of Eufala, Alabama**, produces about 2,000 cubic meters (850,000 Bf) of lumber per week. In 1979 a cogeneration system was installed by Southern Engineering and Equipment Company. The Wellons watertube boiler burns sawdust, bark, and planer shavings at 45% moisture. Average output is 22,680 kg/hr (50,000 lb/hr) at 20 bar (300 psi). Most of the steam is used in two condensing turbine generators producing a total of 2500 kW. Some of the steam is used in two steam-heated drying kilns. Dixon Lumber formerly paid \$35,000 a month for natural gas for a single kiln as well as about \$25,000 per month in electricity costs. The total residue power system cost about \$2 million but produce net savings in energy costs of about \$373,000 per year. The pay back period was about 5.3 years [6].

Southern Engineering and Equipment Company, which installed two of the power systems described above, expects to provide a 500 kW condensing turbine system for a mahogany sawmill in Honduras in 1991. The sawmill's existing 5,806 kg/hr (12,800 lb/hr) boiler is hand-fired with slabwood and provides steam at 12 bar (175 psi) for lumber drying. Up to 1,100 kW of power is provided by two diesel generating sets. The boiler is being prepared for automatic firing with pulverized residues, and surplus steam will be used

in the new turbine. If the initial unit operates satisfactorily, a second boiler and turbine may be installed to eliminate the use of diesel power.

A survey for the U.S. Agency for International Development in 1988 indicated that seven Indonesian plywood factories generate electric power in wood-fired power plants with condensing turbines. Three of the factories have large boilers that produce 50 to 60 t/hr of steam at about 35 kg/cm² (497 psi) and around 380°C (716°F). The turbines in these plants produce 6.0 to 6.8 MW and meet all of the power requirements of the plywood factories. Four other Indonesian plywood factories have smaller systems with boilers producing 20 to 30 t/hr of steam at pressures ranging from 19 to 34 kg/cm² (270 to 483 psi). The turbine generators produce from 2.2 to 2.5 MW. Each of these factories also has from two to seven diesel generators providing total outputs ranging from 225 kW to 1,450 kVA [7].

* **MechMar Energy, Malaysia**, has built three power plants fueled with wood wastes at forest products industries in Malaysia. A power plant producing 1,000 kW from chipped wood wastes was installed in 1988 at Syarikat Minho Kilning's facility in Kapar, Selangor. A second unit producing 1,200 kW was installed at the same facility in 1990.

MechMar's latest plant was commissioned in March 1991 at Hong Kong Teak's timber moulding factory at Kulasi, Johore, Malaysia. A shredder produces wood chips from log ends, center cores, shavings, and bark. About 3,538 kilograms (7,800 lb) of chips per hour are burned in a Titan Towler boiler

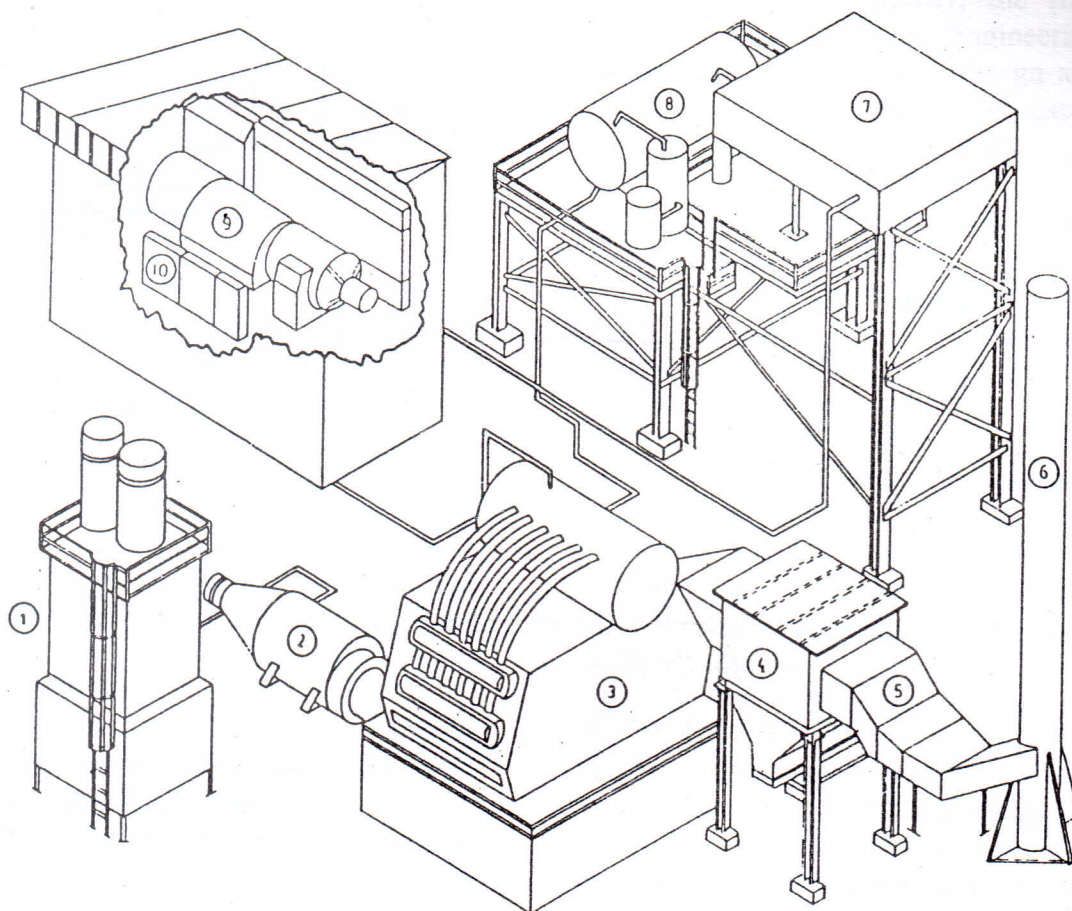


Figure 2. Schematic diagram of a mini power station with condensing turbine, Malaysia. It includes a (1) fuel silo, (2) cyclonic burner, (3) Towler watertube boiler, (4) multiclone dust collector, (5) chimney ducting, (6) stack, (7) condenser, (8) deaerator, (9) turbine, and (10) electrical switchgear. (Source: MechMar Energy Sdr. Bhd., Malaysia)

that is designed with a water cooled pinhole grate. The condensing turbine uses 11,203 kg/hr (24,700 lb/hr) of steam at 22.4 bar (325 psi) and drives an alternator producing 1,400 kW. Exhaust steam is condensed in a tube-in-shell condenser with a two-cell, crossflow type cooling tower. MechMar estimates that if the factory operates 24 hours a day and 30 days/month and the cost of grid power remains stable, the power plant will pay for it self in about 2 years. A MechMar power plant with a cyclonic burner is shown in Figure 2.

* A 1,200 kVA wood residue power plant was installed in 1989 at **Tanzania's** largest timber product mill, **SAO Hill Sawmill, Ltd.** The mill complex includes a sawmill processing 60,000 cubic meters of logs annually, two planing mills, two pressure treating plants, a pole peeling plant, and associated shops producing prefabricated houses, furniture, and other items. These facilities generate about 30,000 cubic meters of wood residues annually. The total power requirement (up to 700 kW)

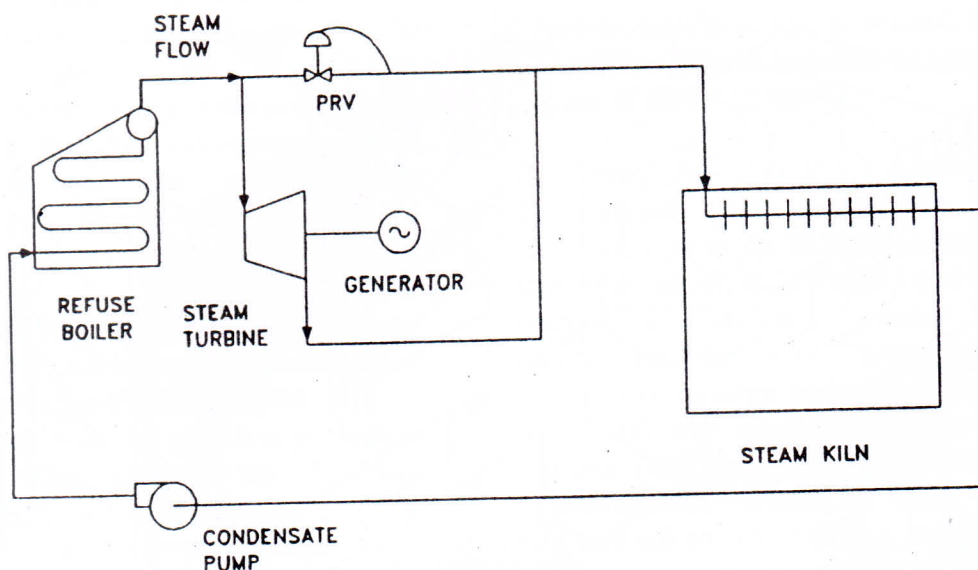


Figure 3. Cogeneration in sawmill with noncondensing turbine (Source: *Design Manual for Small Steam Turbines*, TVA)

was previously met with diesel generating sets.

The new power plant was installed with assistance from NORAD (the Norwegian development agency) through the Norwegian Forest Industry and Environmental Consulting Company. The power plant burns saw mill slabs and sawdust with 30% to 50% moisture and dry scraps and shavings from the wood processing shops with only 10% to 20% moisture.

The power plant includes a large furnace of refractory brick, an inclined water-cooled grate, and a fire tube boiler producing steam at 26 bar (382 psi) and 800°C to 1050°C (1472° to 1832° F). An automatically controlled fan provides the amount of combustion air needed to maintain the steam pressure at a preset level. The turbine inlet pressure is about 23 bar (1,338 psi). The turbine is linked to a 1,500 RPM generator producing

1,200 kVA. At present exhaust steam flows to condensers, and condensate is recirculated. In the future some of the exhaust steam will be used for kiln drying of lumber to meet special requirements in the building and furniture industries [8].

Cogeneration Of Electric Power And Process Heat

In a cogeneration system with a noncondensing or "backspace" turbine, exhaust steam from the turbine is used for process heat (usually in steam heated kiln for lumber drying as shown in Figure 3). To permit its further use, the steam is normally exhausted at a somewhat higher pressure than in a condensing turbine cycle. For this reason, a noncondensing turbine produces less electricity per kilogram of steam than a condensing turbine.

The Design Manual for Small Steam Turbines specifies that a single-stage noncondensing turbine using steam at 17 bar (250 psi) and exhausting process steam at 1.0 bar (15 psi) needs about 20.8 kilograms (43.6 lb) of steam to produce a kilowatt-hour of power, in contrast of 14.2 kg/kWh for a condensing turbine at the same inlet pressure [9]. Wellon Inc. indicates that a backpressure (noncondensing) turbine system burning fuel with 50% moisture with a 20 bar (300 psi) inlet pressure and 1.3 bar (20 psi) exhaust pressure would need about 18 kilograms (40 lb) of steam per kilowatt-hour. This system would produce about 165 kWh/t (150 kWh/ton) of fuel, less than half the output of a condensing turbine with the same fuel and boiler pressure.

Cogeneration systems with noncondensing turbines are appropriate in forest products industries that need both process heat and electric power and have a serious waste disposal problem and thus consider high fuel consumption rates an advantage. Such systems have been installed in a considerable number of lumber and millwork firms in the USA that need steam for lumber-drying kilns.

Some examples:

* **Savage Lumber Company of Doyle, Tennessee**, produces 35,000 cubic meters (15 MBf) of hardwood product annually, including flooring, dimension lumber, and hardwood for furniture. The firm generates about 45 tonnes (50 tons) of hardwood wastes per day. Until 1990, some of the residues were burned in a suspension burner and boiler to produce steam for the firm's lumber-drying kilns, some were sold to paper mills, and large

quantities were dumped and left to rot. Under a project assisted by the Tennessee Valley Authority, the firm contracted with Southern Engineering and Equipment Company to design and install a cogeneration system to use a larger percentage of these residues.

The new system uses about 25 tonnes (28 tons) of residue per day, about half of the mill's residue output. Two thirds of the fuel is very dry sawdust and planer savings (6 to 8% moisture) from the kiln-dried lumber processed in the firm's dimension lumber mill. The remaining 40% is green sawdust from the sawmill at about 80% moisture. The wet and dry sawdust is mixed before firing to keep the moisture content low enough for satisfactory firing in a suspension burner.

The 300 HP (10.5 GJ/hr) boiler produces steam at 15 bar (225 psi), that is fed to a backpressure (noncondensing) turbine. It drives a 200 kW induction generator that provides about 30% of the mill's power requirements. Exhaust steam from the turbine at 1 bar (15 psi) heats the firm's lumber-drying kilns as well as the mill buildings. The cogeneration installation is expected to pay for it self in less than 3 years.

* **Brattleboro Kiln Dry Milling Company (BKD) of Brattleboro, Vermont**, a subsidiary of a lumber company, operate 16 dry kiln that were formerly heated by an aging wood-fired boiler. Faced with steadily climbing rates for grid power, BKD contracted with Ewing power systems to design and deliver a cogeneration package.

The new system burns green wood scraps from the parent company's sawmill plus dry scraps and shavings

from BKD's millwork production. The fuel is stored in a 52 foot (15.8 m) tall silo and is fed to the boiler by a variable-speed metering system that adjust the fuel feeding rate to BKD's varying demand for steam. A new 660 HP boiler currently produces about 6,350 kg/hr (14,000 lb/hr) of steam at 15.4 bar (220 psi). It is fed to a backpressure (noncondensing) turbine linked to an induction generator with a capacity of 380 kW. Exhaust steam from the turbine at 0.7 bar (10 psi) heats the lumber-drying kilns.

The amount of electric power generated at BKD at any time depends on the steam demand at that time, but does not exceed the firm's power demand. During Vermont's cold winters, more steam is needed to heat the kilns, so the boiler is fed at a higher rate and the cogeneration system produces more than half of the electric power used in the mill [10].

* **Dean Lumber Company Inc.** of **Gilmer, Texas**, produces about 236 cubic meters (100,000 Bf) of lumber per day. In the early 1980s the firm was paying \$12,000 to \$15,000 per month for electric power and up to \$15,000 per month for natural gas for two lumber kilns. Wood residues were trucked 200 kilometers (125 miles) and sold as fuel to paper mill, but these sales generated little net income after trucking costs. In 1985 the firm contracted with Wellons, Inc. for a complete new wood waste cogeneration system.

The Wellons single-cell cycloblast furnace burns 11 cubic meters (400 ft³) per hour of softwood sawdust and bark with 30% to 40% moisture. The boiler produces 9,072 kg/hr (20,000 lb/hr) of steam at 21 bar (310 psi) that is fed to a

noncondensing turbine. The generator produces 500 kW and meets about 60% of the power requirements of the sawmill. Exhaust steam at 1.36 bar (20 psi) is used in three lumber-drying kilns. The system has saved the firm about \$8,000 to \$10,000 a month in power bills and now also saves \$30,000 per month in natural gas bills, because it is providing heat for an additional kiln. Payback for the system is estimated at about 7 year.

Many pulp paper plants in North America have cogeneration plants burning wood wastes. A recent survey indicated that over 1,800 MW of power was being generated with biomass fuels in 13 states in the southeastern U.S., mostly in cogeneration systems in pulp and paper plants [11]. Two examples of large cogeneration systems:

* A 16 MW cogeneration system burning wood wastes was installed in 1982 at the **Stone Container Corporation's** paperboard mill at **Coshocton, Ohio**. Residues are purchased from nearby sawmills and furniture plants at about \$14/t (\$13/ton). About 70% of the fuel is sawdust; the rest is bark and other mill residues. The fuel is delivered in 27-tonne (30-ton) trucks and unloaded on two hydraulic truck dumpers. It is conveyed to two large hoppers, to a metal detector that removes tramp iron, and to a rotating disk screen classifier that that removes any piece of wood over 7.6 centimeters (3 in). Over size pieces go to a grinder (hog) for size reduction.

About 1,090 t/day (1200 tons/day) are burned in a Babcock and Wilcox pile-burning boiler design to accept fuel with 50% moisture. The system has a

capacity of 16 MW of electric power and 181,440 kg/hr (400,000 lb/hr) of processors steam. It provides 40% of the mill's electric power 83% of the mill's process heat. The wood energy system cost \$35 million, but it saves over \$ 20,000 a day in energy costs and paid for itself in three years [12].

* **St. Joe Products Company's** mill at **Port St. Joe, Florida**, produces 1,270 t/day (1,400 tons/day) of Kraft linerboard that is used in corrugated containers. The mill's present cogeneration system includes six turbines supplied with steam by four boilers. A 272,160 kg/hr (600,000 lb/hr) boiler replaced several smaller units in 1983. It burns 1550 t/day (1700 tons/day) of biomass fuel and 200 barrels /day of #6 fuel oil and produces steam at 85 bar (1,250 psi) and 485⁰ c (905⁰ F).

About 30% of the biomass fuel is chips and bark generated in the mill; the rest is purchased through fuel dealers and consists of bark, sawdust, shavings from nearby mills and hardwood chips from whole tree chippers. The maximum power output of the total system is reported to be 40 MW, but actual output depends on the mill's need for process steam. Exhaust steam is extracted from the turbines at pressures of 14, 9.8 and 4.9 bar (200, 140, and 70 psi) and use as process heat in the mill. The company indicates that increased use of biomass and improved boiler efficiency has reduced the use of fuel oil by approximately 1,000 barrels per day [13].

In developing countries, the cogeneration of electric power and process heat has been rare in the forest

products industries due to the lack of a requirement for process heat at most sawmills, the low cost of subsidised power from the grid, and other factors.

In Ghana all but three of the major sawmills are located on the grid, and the relatively low price of grid power has limited incentives for investment in cogeneration systems. In 1986 the UNDP/World Bank team found only one off-grid mill with an operational cogeneration system, although two others had generating capacity that was unused for technical or economic reasons.

* **Gliksten W.A., Ltd.**, a state owned mill in **Ghana** producing lumber, plywood, and veneer, generates 13,000 cubic meters of residues annually. In 1986 all of the residues were burned in four 1950-vintage locomotive-type boilers to produce 3.5 t/hr at 15 bar (220 psi). The steam was fed to two turbogenerators rated at 635 kVA and 437.5 kVA. Additional power was provided by a 690 kVA diesel set. In 1986, the firm was planning to install transformers allowing use of power from the nearby grid and to abandon power production at the mill.

* During the same period a privately owned mill on the grid, **Specialized Timber Products (STP)**, was installing a 6.4 t/hr residue-fired boiler and a 480 kVA back pressure (noncondensing) turbine. STP planned to burn all of its residues (20,000 m³/year), meet 80% of its power needs, and provide process heat to six 150 cubic meter kilns and two steam pits. The principle reason for the investment in cogeneration was interruption of grid power, which cost

the firm \$33,000 in lost production in 1985.

Power For The Grid

In the 1980s, a large number of wood fired power plants have been built in the USA to generate power for the grid. This trend has been stimulated by the passage of "PURPA" legislation in 1978 that requires electric utilities to buy power from private companies at an "avoided-cost" price, i.e., the costs the utility avoids through the power purchase. A survey for the U.S. Department of Energy in 1985 listed 107 existing and planned wood waste power plants with a total capacity of 1,792 MW. Only about 180 MW of this capacity was in plants owned by electric utility companies, while 1,611 MW was provided by city-owned electric plants, cogeneration plants in various industries, and independent power companies. Nearly half of the plants had capacities below 10 MW (Figure 4).

Although updated national figures are not available, the number of U.S. power plants fueled with wood residues and other biomass fuels has continued to expand. California leads the nation with over 950 MW produced with biomass fuels. Over 1,800 MW are produced with such fuels in 13 southeastern states. Some estimates indicate that the national output with biomass fuels, including many large plants burning urban solid wastes, has reached 9000 MW.

Five power plants in the USA that produce power from the grid from wood residues are described below. These example involve several types of fuels, steam pressures, and levels of power

output. The first three are at large sawmills: One is a cogeneration plant with a noncondensing turbine, while the other two have condensing turbines. The final two examples are "stand-alone" plants (also with condensing turbines) that are not located at forest products industries.

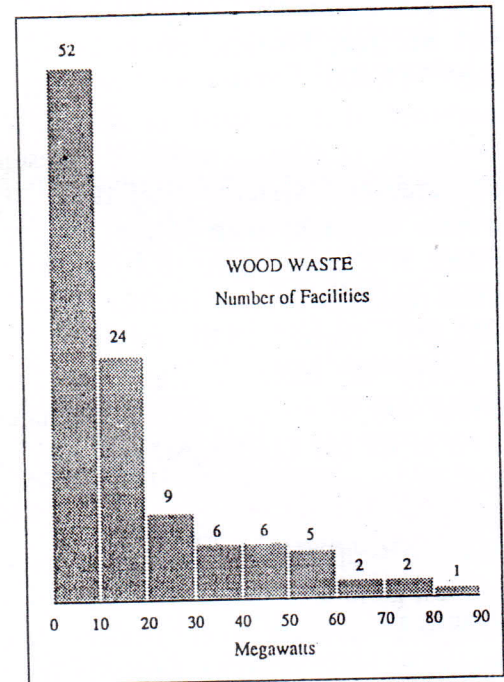


Figure 4. Wood waste power plants, USA, 1985. (Source: *Electric Power from Biofuels*, U. S. Dept of Energy)

* A 10 MW cogeneration plant at the large **Kinzua Corporation** sawmill at **Heppner, Oregon**, provides process heat for lumber drying and generates power for sale to the grid. About 78% of the fuel is generated in the Kinzua mill, with 22% purchased from nearby mills. Fuel is fed to the boiler by a pneumatic stoker system with variable-speed fuel metering augers and is burned on a stationary, water-cooled grate. The Deltak boiler produces 54,432 kg/hr

(120,000 lb/hr) of steam at 40.8 bar (600 psi) and 401 °C (755 °F). It is used in a General Electric 10 MW extracting (noncondensing) turbine. About 16,783 kg/hr (37,000 lb/hr) of steam is extracted at a pressure of 12.9 bar (190 psi) for use in the kiln drying of lumber. The use of this exhaust allowed Kinzua to discontinue the use of its existing wood waste boiler, with annual savings of about \$25,000. All of the power is sold to the local electric utility Portland Electric General Company.

* **Big Valley Lumber Company in Bieber, California**, produces 472 cubic meters (200,000 MBf) per day of kiln-dried pine lumber used in finishing mills. Prior to 1983 the driest waste was burned in a low pressure boiler to produce steam for lumber drying and for the generation of power for use in the mill; bark and other wet residue was burned for disposal in a teepee burner that also required the use of some fuel oil. A cogeneration plant was built in 1983 with assistance from a revolving biomass energy loan fund administered by the California Energy Commission. The plant burns the equivalent of 180 tonnes (200 tons) of dry mill residues daily. The pile-burning boiler produces 27,216 kg/hr (60,000 lb/hr) of steam at 44 bar (650 psi) that is fed to a 10 MW Westinghouse condensing turbine. About 2 MW is used in the Big Valley Mill, and up to 7.5 MW is sold to the Northern California utility, Pacific Gas and Electric. Energy savings and revenues from power sales paid for the power plant in about 4 years.

* A 5 MW power plant operated by **Catalyst Energy Corporation at North Powder, Oregon**, generates power for the grid with mill residues from the

nearby Idaho Lumber Corporation sawmill. The moisture content of the hogged fuel is reduced from about 37% to 25% in a rotary fuel dryer heated with boiler exhaust gas.

Up to 8 t/hr (9 tons/h) of the dried fuel is burned in a fluidized bed gasifier provided by Energy Product of Idaho. Hot gas flows through a refractory-lined hot gas duct to the boiler, where it is ignited. The boiler produces up to 60,000 lb/hr (27,000 kg/hr) of steam at 29 bar (425 psi) and 440°C (825°F). The condensing turbine is linked to a 6,250 kVA generator. The capital cost of the power plant was \$7.4 million (\$1,480/kW).

* The **Biomass Power Corporation of Dunnellon, Florida**, operates two 7 to 8 MW "stand-alone" power plants in Florida that are fueled primarily with sawdust purchased from local sawmills. Each plant burns about 77,000 tonnes (85,000 tons) per year of green sawdust (40% moisture) mixed with 13,600 tonnes (15,000 tons) peanut hulls (6% moisture). The fuel is trucked to the plants in semi trailer trucks and unloaded with hydraulic truck dumpers.

Each of the Florida plants has a boiler producing up to 40,800 kg/hr (90,000 lb/hr) of steam at 14 bar (200 psi). It is fed to condensing turbines producing 8,000 kW at the Jefferson City plant and 7,500 kW at the Madison City plant. The power is sold to the regional electric utility company. Each of the power plant cost about \$11 million (around \$1,400/kW).

* A 10 MW "stand-alone" power plant at **Burney** in the forested mountains of **Northern California** burns about

68,000 dry tonnes (75,000 tons) of waste wood annually. Half of the fuel is logging residue including branches and tops, chipped forest residues, and rejected logs. The other half is mill residue from nearby lumber mills including sawdust, shavings, hogged residues, bark, and chips.

The fuel receiving area at Burner can unload up to 60 trucks per day, each with about 23 wet tonnes (25 tons) of fuel. A hydraulic ramp tips each tractor and trailer to a 60 degree angle, dumping the fuel in to a hopper. Ferrous metals are removed by a magnetic separator. A disk screen separates large pieces of wood that are reduced to less than 10 centimeters (4 in) by a chipper. The fuel is partially dried in a dryer using hot exhaust gases from the plant's boiler.

The plant at Burney burns 13.6 t/hr (15 tons/hr) of fuel with 40% moisture to produce up to 47,678 kg/hr (105,000 lb/hr) of high pressure steam at 61 bar (900 psi) and 440°C (825°F). Particulates are removed by a multiclone dust collector and an electrostatic precipitator. The superheated steam drives a multi-stage condensing turbine and a 11.4 MW generator. The net output of about 10 MW is sold to the regional electric utility, Pacific Gas and Electric Company. The Burney plant is a joint venture of subsidiaries of Pacific Lighting Energy Systems and Ultrasystems, Inc.

In Virginia, Multitrade Limited partnership is developing the world largest wood-fueled electric power plant. The plant is projected to be in service by 1993. It will burn 1,600 t/day (1,800 tons/day) of wood wastes and whole tree

chips. Two turbine generators will produce up to 79.5 MW, which will be sold to the regional utility company, Virginia power, under a 25 year contract.

Research for this report has not identified any power plant in a developing country that is providing power for the grid through the combustion of logging of mill residues. The "dendro-thermal" power plants planned in the Philippines in the early 1980s were to obtain wood fuel from the harvesting of fast-growing trees in energy plantations. The plantation did not produce as rapidly as expected, and the five completed 3 MW plants have utilized additional fuel provided by entrepreneurs from private woodlots and public forests. Some of this fuel may be logging residue. Mill residues have apparently not been used as fuel for any of the dendro-thermal plants in the Philippines.

One of the options examined by the NUDP/World Bank team for power production with mill residues at the Mim Timber Company in Ghana involved the net sale of about 1 GWh of power to the grid. The option involved the installation of a new boiler, a 1.2 MW condensing-turbine generator, and other equipment at a total capital cost of about \$3 million. The analysis showed that the investment would not be financially attractive and the economic cost of the power would be equal to, or slightly higher than, available hydroelectric power.

Off-Grid Power For Rural Electrification

In the future, two distinct types of wood waste power plants may provide power

for rural electrification in developing countries. One type of plant would be located on or near the grid and would sell power to the national or regional electric power agency. Such a plant could be within a forest products industry or could be a stand-alone plant that purchases residues from nearby woodworking industries. This type of plant has been discussed in the previous section.

A second type might be located in a forest products facility in an off-grid area, providing power for the facility as well selling surplus power to the nearby community, a rural electrification cooperative, or another industry. In such a project, the size of the power plant must match both the available supply of wood wastes and the total local demand for power.

The amount of power that can be generated with a quantity of wood waste depends on (a) the fuel value of the residue, which is determined mainly by its moisture content, (b) the efficiency of the boiler and turbine, (c) the type of turbine cycle, (d) the steam pressure. Some data on prospective outputs with various turbine cycle and pressures has been provided earlier in this chapter.

The potential gross power output and the net power available for sale at a specific forest products industry can only be determined through a careful and site-specific analysis of the fuel characteristics, fuel supply, present equipment, assumed new equipment, and power requirements at that mill.

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