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Biomass Drying and Dewatering for Clean Heat & Power

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Disclaimer

While the information included in this guide may be used to begin a preliminary analysis, a professional engineer and other professionals with experience in biomass drying should be consulted for the design of a particular project.

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Executive Summary

As prices for biomass fuels increase, it is especially important to use them efficiently. In both incineration and gasification, biomass drying increases efficiency and improves operation. This guide provides general information about drying biomass fuels, one element of getting the most out of biomass-fired combined heat and power projects.

Even maintaining a flame in a boiler can be difficult if the fuel is too wet. While some types of gasifiers can tolerate higher moisture contents, most biomass gasifiers require less than 20% moisture content for operation. In addition, biomass often requires pelletization, which may require even lower moisture contents than are required by gasifiers and boilers.

Dryer types used in drying biomass fuels include rotary, conveyor, cascade, and flash dryers. When selecting a dryer and designing a system, it is important to consider many factors in addition to energy efficiency, such as environmental emissions and operation and maintenance concerns. Overall efficiency may be improved by sizing the boiler and dryer together, incorporating other energy efficiency measures, taking advantage of heat recovery from the boiler or gasifier and other waste heat sources in the facility. Dryers and boiler stack economizers can be used in conjunction with each other in some systems to take maximum advantage of recovered heat from the boiler. Heat may also be recovered from the dryer for use in the facility.

Wet feedstocks can be dewatered prior to drying by drying beds, filters and screens, presses, and centrifuges. Alternatives to thermal drying and dewatering should also be considered. Moist feedstocks might be mixed with drier materials to achieve an acceptable moisture content of the mixture. Some lower moisture feedstocks can be sufficiently dried simply by storing in a covered area and turning periodically. Others, such as rice stalks or sawdust from cabinet shops, do not need drying at all.

As a renewable energy source, biomass-fired energy systems may qualify for financial incentives depending on location. Avoided carbon emissions can also be traded on exchanges such as the Chicago Climate Exchange.

While this guide may be used to begin a preliminary analysis, a professional engineer and other professionals with experience in biomass drying should be consulted for the design of a particular project.

Why Dry Biomass?

Drying biomass fuel improves combustion efficiency, increases steam production, reduces air emissions and improves boiler operation. In a boiler or gasifier, moisture in the fuel must first be heated and evaporated, carrying with it a large quantity of heat up the stack. While a fuel dryer also consumes energy in heating and evaporating moisture, the drying is more efficient in equipment designed especially for this purpose. If heat for the dryer is recovered from the boiler flue gas or gasifier—or from other waste heat sources—efficiency is further increased.

For wood chips with a moisture content (MC) of 45%, the maximum boiler efficiency with standard equipment is about 74%. If the same standard equipment is burning dry wood (~10% to 15% MC), the efficiency can be as high as about 80%. These efficiency improvements have corresponding steam production increases of 50% to 60%.

A biomass-fired boiler will perform better when fuel has an optimum dryness. If the fuel is too wet, it may be impossible to even keep the flame lit. With dry fuel, the flame burns hotter and more evenly, facilitating complete combustion.[1] Also, a smaller quantity of ash is produced, reducing the cost of ash disposal.

Boiler air emissions are reduced with a drier fuel, although emissions from the dryer must be considered. More complete combustion results in a lower quantity of fly ash up the boiler stack. In addition, excess air can be reduced significantly, which reduces air velocities through the boiler and hence particulates in the flue gas.

Drying biomass fuels reduces transportation costs. In addition, dry biofuels are less subject to microbiological degradation in storage.

[1] Dry wood burns at a flame temperature of 2300 to 2500°F, while green wood burns at about 1800°F (NREL).

Biomass Fuel Characterization

Biomass characteristics vary widely even for the same type of material, depending on many factors. Samples of the biomass to be dried will be required to design a dryer for a specific application.

Biomass fuels may be derived from many sources, including forestry products and residue, agriculture residues, food processing wastes, and municipal and urban wastes. The waste produced by our cities, farms and industries represents a vast energy resource that, if tapped, could avert much of the need for energy crops. Waste—or "co-product"—streams that can be incinerated or gasified include:

- Forest products industry wastes such as residue from logging, thinning, lumber milling and furniture manufacturing. Sludges from paper manufacturing. Bark and wood waste are often used as "hog fuel," which refers to wood that has been prepared by processing through a "hog" (a mechanical shredder or grinder).

- Agricultural wastes such as the stalks, chaff, and "stover" (dried husks and leaves) from field crops and weather-damaged crops. Crop residues are primarily derived from grain crops such as corn, wheat and rice. "Bagasse," the residue remaining after sugarcane stalks are crushed to extract their juice, is used as a fuel. Biomass fuels have also been derived from cotton, sugar cane, and fruit and nut crops.

- Food and beverage processing waste such as trimmings, peelings, husks, floor waste, and "pomace" (the pulpy material remaining after the juice has been pressed from fruit, such as apples).

- Municipal and urban wastes such as construction and demolition debris, yard and tree trimmings, solid waste. Wood pallets, packaging materials, and leftover food from restaurants, supermarkets, schools and hospitals.

Table 1 summarizes measured moisture contents of a variety of materials,[2] although we must keep in mind that characteristics of any particular sample will vary. In general, high moisture content biomass includes aquatic biomass such as algae, municipal wastewater sludge, farm animal wastes, pulp and paper mill sludges, and food and beverage processing waste. Freshly harvested terrestrial biomass such as hardwoods, softwoods and herbaceous materials typically have moisture contents of 40% to 65%. On the high end, the moisture content of wood products in the temperate rain forests of the Pacific Northwest is commonly 65% for much of the year. Agricultural crop residues that have been exposed to open air drying, such as straws, corn cobs, hulls and shells,

[2] A database of the characteristics of wood- and agriculturally-derived biomass is available online from the Commonwealth Scientific and Industrial Research Organisation of Australia at http://www.det.csiro.au/science/energyresources/biomass.htm.

often have 15% moisture content or less. Municipal solid waste usually contains 10% to 30% moisture.

Moisture Requirements

Moisture content is critical in incineration, gasification and pelletization.

With the exception of suspension-firing furnaces, wood-fired boilers and furnaces require fuel moisture contents below 55% to 65% in order to sustain combustion. For wood-fired incineration, the optimum moisture content is generally much less, between about 10% and 15%.

Maximum moisture contents required for gasification depend on the gasifier type. Most biomass gasifiers are downdraft fixed bed type because these are most suitable for small sizes and produce low quantities of tars. Downdraft fixed bed gasifiers cannot tolerate moisture contents above about 20%. Updraft fixed bed gasifiers and fluidized bed gasifiers can tolerate higher moisture contents of 50% and 65%, respectively. Moisture contents can be as high as 95% in gasifiers using the supercritical water process, but this type of gasifier is still in the research and development phase.

Biomass may require pelletization to facilitate feeding and handling, to reduce transportation costs, to homogenize mixed substrates, and/or to achieve a uniform size to improve gasification or incineration. Pellet mills generally require moisture contents of less than 15% to produce stable and durable pellets.

Table 1. Moisture Content by Weight of Several Biomass Feedstocks As Received

Feedstock	Moisture Content by Weight (%)
Food wastes: Fruits	
Apple pomace [5]	72
Cherry [2]	37.8
Orange peels [2]	10.8
Melon shell [2]	27.6
Nuts	
Black walnut shell [2]	11.6
Peanut Hulls [5]	9
Peanut Skins [5, 6]	8
Vegetables	
Wet potato wastes [6]	86
Other	
Fish waste [3]	76
Fruit & vegetable waste - grocery store [3]	88
Forest Products:	
Pine chips [1]	54.6
Pine sawmill waste [1]	11.3
Construction waste [4]	12-17
Pulp & Paper Mill Sludges [8]	50-70
Agricultural wastes	
Rice husks [1]	10 (as received); 8.5 (air dried)
Corn cob	43 [2], 10 [6]
Soy hulls [5]	9
Lactating cow manure	88 (as excreted) 98 to 99.7 (from milk house or parlor)
Freshwater and Marine Biomass [7]	>95
Municipal waste	
Sewage sludge – biosolids [4]	90-97
Septage – biosolids [4]	98
Municipal solid waste [4]	12-32

(1) "Biofuel Database," Commonwealth Scientific and Industrial Research Organisation, www.det.csiro.au/science/energyresources/biomass.htm

(2) Jekayinfa1, S.O. and O.S. Omisakin, "The Energy Potentials of Some Agricultural Wastes as Local Fuel Materials in Nigeria" cigr-ejournal.tamu.edu/submissions/volume7/EE%2005%20003%20Jekayinfa%20final%20Oct2005.pdf

(3) Esteban, M.B., et al, "Evaluation of fruit–vegetable and fish wastes as alternative feedstuffs in pig diets," dx.doi.org/doi:10.1016/j.wasman.2006.01.004

(4) "Biomass," Institute for Environmental Research and Education, www.iere.org/documents/biomass.pdf

(5) McCann, Mark A. and Robert Stewart, "Use of Alternate Feeds for Beef Cattle," University of Georgia, 2000, pubs.caes.uga.edu/caespubs/pubcd/l406-w.htm

(6) Stanton, T.L. and S.B. LeValley, "Feed Composition for Cattle and Sheep," Colorado State University Extension. www.ext.colostate.edu/PUBS/livestk/01615.html

(7) Klass, Donald L., *Biomass for Renewable Energy, Fuels, and Chemicals*, Academic Press, 1998.

(8) K. C. Das and E.W. Tollner "Composting Pulp and Paper Industry Solid Wastes: Process Design and Product Evaluations," Proceedings of the 1998 Composting in the Southeas Conference, http://www.p2pays.org/ref/12/11563.pdf

Dewatering Equipment

Overall efficiency can often be improved by dewatering wet feedstocks prior to thermal drying. On the downside, mechanical dewatering equipment itself can consume a large amount of energy and have high maintenance requirements, which must be weighed against the reduction in drying energy. Dewatering equipment includes drying beds, filters and screens, presses, and centrifuges. Depending on the material and the specific type of equipment, mechanical dewatering equipment may quickly reduce moisture content to as little as approximately 50%. More commonly, such a low moisture content cannot be achieved with mechanical dewatering equipment. Passive dewatering methods, such as using filter bags that are impervious to rain but allow moisture to seep out, can achieve moisture contents as low as 30% at low cost, but long periods of time – on the order of two to three months – may be required.

Types of mechanical presses include belt filter presses, V-type presses, ring presses, screw presses and drum presses. In a belt filter press, for example, the material is sandwiched between two porous belts, which are passed over and under rollers to squeeze moisture out. Belt presses are used in many industries, including wastewater treatment. A drum press consists of a perforated drum with a revolving press roll inside it that presses material against the perforated drum. This kind of press has been used with many materials, including hog fuel and bark.

In a bowl centrifuge, the material enters a conical, spinning bowl in which solids accumulate on the perimeter. Belt filter presses have lower capital, energy and O&M costs and have longer lives than centrifuges. Depending on the material, centrifuges can achieve lower moisture contents—65% to 85% moisture content compared to 76% to 88% moisture content for belt presses when drying municipal sludge. The savings associated with achieving a lower moisture content can offset the higher first cost of a centrifuge.

Biomass Dryers

There are many types of dryers used in drying biomass, including direct- and indirect-fired rotary dryers, conveyor dryers, cascade dryers, and flash or pneumatic dryers. Selecting the appropriate dryer depends on many factors including the size and characteristics of the feedstock, capital cost, operation and maintenance requirements, environmental emissions, energy efficiency, waste heat sources available, available space, and potential fire hazard.

Fuel dryers use superheated steam, hot air, or hot water as drying media. Air dryers derive heat from their own burners, from boiler flue gas or from waste heat recovered from the exhaust of process heating in the facility. Water is often heated by waste heat recovery as well and can be transferred over longer distances from process equipment to the dryer than can air. Steam dryers use steam from the boiler.

Dryers may be generally classified as either indirect- or direct-fired. In direct-fired dryers, flue gas or hot air is passed directly through the medium to be dried. In indirect-fired dryers, the heated medium is not passed directly through the material to be dried, but through tubes or other heat exchangers inside the dryer. Indirect-fired dryers may use flue gas or steam. Indirect dryers are well suited for drying fine and dusty materials.

Open-Air Drying

Some materials, such as park trimmings or husks and stalks, can be allowed to dry naturally by storing in a covered, open area or by taking advantage of open-air solar drying. The final moisture content of air-dried materials usually varies from about 15% to 35%, depending on the size and characteristics of the material and ambient conditions. Open-air drying is slow and depends on weather conditions. The pile may need stirring or turning to facilitate drying. Open-air drying is generally not suitable for high water content feedstocks since they tend to decompose quickly.

Perforated Floor Bin Dryers

Small biomass projects may only need a perforated floor bin dryer to dry the feedstock in batches. In this simple dryer, hot gases from the dryer’s burner or flue gas recovered from boiler or gasifier are passed through the perforated floor into a large bin containing the feedstock. The depth of the feedstock in the dryer should not exceed 1 or 2 feet. The feedstock usually requires mixing after drying to achieve uniform moisture content.

Rotary Dryers

In a rotary dryer, material is fed into a slowly rotating cylinder. Longitudinal flights inside the cylinder lift the feedstock and allow it to cascade down through the drying medium. Rotary dryers are in wide use and have a long, proven history in many industries and are the most commonly used dryer in drying hog fuel. On the other hand, high clay content paper sludges tend to ball up in a rotary dryer. Coarse bark has also been found to be problematic in rotary dryers.

- **Direct-Fired Rotary Dryers**

  Continuous-feed, direct-fired rotary dryers are the most common type of dryer for hog fuel, sawdust and bark, and many other materials. In general, the highest temperature possible without scorching the fuel results in greater dryer efficiency. An inlet temperature of around 800°F is optimum for hog fuels dried in a rotary drum direct dryer. Moister fuels will require somewhat higher temperatures than drier fuels. But temperatures as low as 500°F can be used with acceptable efficiencies in these dryers. Exhaust temperatures of about 150°F are typical.

  Compared to rotary steam-tube indirect-fired dryers (see below), direct-fired dryers have lower operation and maintenance costs and higher availability (i.e. less down time for maintenance.) Lower temperature dryers such as conveyor dryers and cascade dryers have several advantages over direct-fired rotary dryers. In comparison, direct-fired rotary dryers have greater emission of VOCs and particulates, lower opportunity to recover waste heat, and have greater fire hazard especially after the dryer and in shutdown. Exhaust from the dryer may need to be passed through a cyclone, baghouse filter, scrubber or electrostatic precipitator to remove particulates.

- **Indirect-Fired Rotary Dryers**

  Steam-tube dryers use steam from the power boiler to dry the fuel, passing the steam through tubes located inside the drum. Since this steam would otherwise be used to generate electricity, it does represent an energy cost. Indirect-fired dryers are less efficient than direct-fired dryers because they introduce an inefficiency associated with transferring heat from the steam tubes to the material.

Conveyor Dryers

In conveyor dryers, the feedstock is spread onto a moving perforated conveyor to dry the material in a continuous process. Fans blow the drying medium through the conveyor and feedstock, either upward or downward. If multiple conveyors are used they can be in series or stacked (i.e. “multi-pass). Conveyor dryers are very versatile and can handle a wide range of materials. They are not as commonly used in drying hog fuel but have several advantages, along with some disadvantages, compared to the more commonly used rotary dryers.

Conveyor dryers are better suited to take advantage of waste heat recovery opportunities because they operate at lower temperatures than rotary dryers used in hog fuel drying. Rotary dryers, for example, typically require inlet temperatures of at least 500°F for drying hog fuel, but more optimally operate around 800°F. In contrast, the inlet temperature of at least one commercially available vacuum conveyor dryer can be as low as 10°F above ambient, although more typically conveyor dryers operate at higher temperatures between about 200°F and 400°F. Because of their lower temperatures, conveyor dryers can even be used in conjunction with a boiler stack economizer to take maximum advantage of heat recovery from boiler flue gas. In this scenario, an economizer first recovers heat from the boiler flue gas. Then exhaust from the economizer is used for fuel drying.

Their lower temperature also means that there is a lower fire hazard. Emissions of volatile organic compounds (VOCs) from the dryer will also be lower. An advantage conveyor dryers have over many other dryer types is that the material is not agitated. This means there may be fewer particulates in its emissions. On the other hand, fines may need to be screened out first and added back into the dryer at a later point, since they can fall through the belt's perforations.

The footprint of single-pass conveyor dryers is typically larger than a comparably sized rotary dryer. Multi-pass conveyors in which conveyors are arranged one above the other with material cascading down from upper conveyors to lower conveyers, save considerable space. Multi-pass dryers are very common in many industries due to their small footprint and lower cost.

The capital cost of conveyor dryers and rotary dryers is often comparable. However, a conveyor dryer may require less ancillary equipment for treatment of emissions; so for new installations the overall cost may be less. Operation and maintenance (O&M) costs are higher than for rotary dryers. Multi-pass dryers are more complex than single-pass dryers and so have greater O&M costs than single-pass dryers.

Cascade Dryers

Cascade dryers have been widely used for biomass drying in Europe, especially in Sweden. They can be thought of as a type of fluidized bed dryer. The material is introduced into a flowing stream of hot air in an enclosed chamber. It is carried upward by the air and then cascades back to the bottom to be lifted again. Material is drawn out through openings in the side of the chamber.

Cascade dryers operate at intermediate temperatures between those of conveyor and rotary dryers. They have a smaller footprint than rotary and conveyor dryers. A disadvantage is that they are more prone to corrosion and erosion of dryer surfaces and so have higher maintenance costs.

Flash Dryers and Superheated Steam Dryers

In flash dryers (a.k.a pneumatic dryers), the feedstock is suspended in an upward flow of the drying medium, usually flue gas. Flash dryers are appropriate for drying a wide variety of materials.

Flash dryers are generally cost effective only at larger scales. Electricity use by flash dryers is greater than that of other dryer types because high air flows are required to keep the material suspended. Flash dryers require a small particle size and so shredders may be required, also increasing electrical use.

Flash dryers have a small footprint. On the downside, they are subject to corrosion and erosion problems and have a fire risk after the dryer and in shutdown.

Superheated steam dryers are very similar to flash dryers, except the drying medium is steam from the boiler instead of flue gas. The steam is fed directly into the dryer, i.e. not through a heat exchanger as in steam-tube dryers. Its temperature stays above the saturation temperature, so the steam does not condense, transferring only sensible heat to the biomass. A larger quantity of steam at a lower temperature and pressure leaves the dryer than enters it.

Superheated steam dryers can operate in a closed-loop with low-pressure steam from the dryer being reheated and injected back into the dryer. Since a larger quantity of steam exits the dryer, the excess must be bled off. If this excess steam is recovered for use in another process, a large fraction of the energy is recoverable. The material must be fed into the dryer by a pressure tight feeder, such as a rotary valve or plug screw feeder. Superheated steam dryers have no air emissions, no fire hazard and a small footprint.

Considerations in System Design

For optimum efficiency and operation, how a fuel dryer operates in conjunction with other equipment in the facility must be considered. Considerations include heat recovery from the boiler or gasifier and process equipment in the facility, interactions between a fuel dryer and economizer, sizing a boiler for drier fuel, and the need for a back-up boiler in the case of a dryer outage.

Heat Recovery

Drying requires a large energy input to produce the necessary heat, so design of a system should consider opportunities to recover process heat. In both incineration and gasification, heat may be recovered from the boiler's flue gas or the gasifier's hot product gas. Heat may also be recovered from the turbine exhaust. In a pulp and paper mill, heat may be recovered from the paper machine, the pulp dryer, the smelt dissolving tank, hot effluent streams, and from waste low-pressure steam. Even if this equipment is located some distance from the dryer, a pipe loop can be used to transfer steam or water from 1000 feet or so.

When recovering boiler flue gas for a low temperature dryer, the possibility of high saturation must be considered since flue gas contains moisture and lowering the temperature increases relative humidity.

Dryers and Boiler Economizers

The energy contained in the boiler flue gas can be recovered to dry fuel in a flue gas dryer, but can also be recovered by an economizer to preheat boiler feedwater. Of the two, an economizer has a lower first cost and is generally more cost effective than a fuel dryer and so should be installed as a first step. Nevertheless, both can be used in conjunction with each other when using a lower temperature dryer. Vacuum dryers and low temperature conveyor dryers can effectively use waste heat at the lower temperatures exhausted after a stack economizer. This means both measures can take advantage of boiler flue gas, optimizing heat recovery.

Interactions between the dryer and economizer must be considered in an energy analysis. Boiler flue gas temperature is lower when using drier fuels: about 350°F or more without a fuel dryer versus about 220°F with a fuel dryer. Therefore, the energy available for recovery by an economizer is reduced if a fuel dryer is used.

Sizing the Dryer and Boiler or Gasifier Together

A fuel dryer should be sized so it is well matched with the boiler or gasifier. When burning dry fuel, less boiler heat transfer surface area is required for the same amount of heat transfer due to increased flame temperature. For an existing boiler, steam production will be increased. In a new installation, a smaller boiler will be required.

In addition to smaller heat transfer surfaces, the boiler fire box can be smaller due to more complete combustion. Since less ash is produced, the downstream ash handling system can be smaller. The reduced first cost of a smaller boiler will offset some of the first cost of the dryer.

Boiler Operation in a Dryer Outage

A boiler sized to burn dry fuel will be undersized when burning wet fuel. If there is a dryer outage, a fossil-fuel-fired back-up boiler may be required to make up for the reduced capacity of the biomass boiler.

Incorporating Other Energy Efficiency Measures

Using a fuel dryer is an energy efficiency measure in itself. There are further measures that can be taken to improve the efficiency of the drying process. These include:

- With flue-gas dryers:
  - Recirculation of the drying gas to ensure high saturation of the exhaust.
  - Latent heat recovery by using flue-gas condensers

- With superheated steam dryers
  - Recovery of low-pressure steam. Low-pressure steam can be recompressed to a higher pressure if there is not a need for low-pressure steam in the facility.
  - Recovery of volatile organic compounds (VOCs) from the exhaust condensate, which can then be burned in the boiler as fuel.

Considerations in Selecting a Fuel Dryer

In selecting a fuel dryer, factors to consider include energy efficiency, environmental emissions, feed and discharge systems, fire hazard and the potential for marketable byproducts.

Energy Efficiency and Heat Recovery

Low temperature dryers, such as conveyor dryers, can best take advantage of heat recovery opportunities. Drying of biomass under vacuum reduces the boiling point of the water in the wet material and so reduces the temperature required for drying, increasing opportunities for heat recovery. Vacuum dryers generally use hot water as the heat source and so heat can be more easily transferred to the dryer from process equipment.

If excess steam can be put to good use, superheated steam dryers are very energy efficient.

Environmental Emissions

Volatile organic compounds, such as terpenes and other wood oils, are exhausted from hog fuel dryers and must be monitored. In addition, particulate emissions from the dryer may need to be reduced by utilizing filtration or other type of particulate removal system. Direct-fired rotary dryers have greater emission of VOCs and particulates than indirect-fired dryers. Conveyor dryers have lower emissions of VOCs and particulates than rotary dryers. Flue-gas dryers can have more emission problems due to VOCs than steam dryers because air flow is less and volatile organic compounds are more easily condensed out in the steam dryer. Superheated steam dryers have no emissions.

Note that *over*-drying not only reduces dryer efficiency but also increases the release of VOCs, resulting in blue haze being emitted from the dryer. Blue haze is released when the temperature of the feedstock rises above the boiling point of water. Smaller particles may be over dried and larger particles under dried in some dryers. Look for dryers where particles are naturally entrained in the air flow when they reach the optimum dryness.

Feed and Discharge Systems

Superheated steam dryers have more problems with leakage from the feeding and discharge systems compared to flue-gas dryers. This results in superheated steam dyers having lower availability; that is, more down time for maintenance.. Plug-screw feeders have worked better than other types of feeders but need to be replaced frequently due to wearing.

Fire Hazard

Superheated steam dryers have no fire hazard. In other types of dryers, fire hazard is lower in dryers that operate at lower temperatures, such as conveyor dryers. Fires result from ignition of dust or combustible gases, either inside the dryer or after the dryer. To reduce the potential for fire with hog fuel, the drying medium should not have an oxygen concentration greater than 10%.

Corrosion and Erosion

Corrosion and erosion are more problematic in flash, cascade and superheated steam dryers than in rotary and conveyor dryers. Paper sludges can have very high ash content, which contributes to erosion especially in dryers with high velocities.

Marketable Byproducts

The VOCs emitted when drying wood are in reality wood oils. Wood oils are used in cosmetics and other products and so may be marketable. Wood oils are best recovered from superheated steam dryers. Wood oils can also be burned in the boiler as fuel.

Boiler Operation & Maintenance Considerations

Burning drier fuel in a boiler can impact boiler operation and maintenance. Considerations include excess air requirements, sulfuric acid formation and ash fusion temperature.

Excess Air

Excess air can be dramatically reduced with drier fuels due to more complete combustion. Since excess air impacts boiler efficiency, be sure to adjust excess air to the lowest practical volume. With moist fuels, 80% excess air may be required to prevent smoke formation in wood-fired boilers. Excess air can be reduced to about 30% with dry fuel.

Sulfuric Acid Formation

If flue gas cools below the dew point, sulfur trioxide can condense and form sulfuric acid. This can seriously corrode equipment and ductwork downstream of the boiler. This is a concern with either wet or dry fuels. However, when burning dry fuels, the flue gas will be cooler and so sulfuric acid formation becomes more of a concern. Sulfuric acid formation increases maintenance costs unless more expensive, corrosion-resistant materials are used.

Ash Fusion Temperature

When burning drier fuels, the flame burns hotter. Some material components turn to glass and build up as slag on surfaces when temperatures rise above their fusion temperature. In particular, the fusion temperature of ash may be approached with the higher flame temperatures. Generally the ash fusion temperature of wood fuels will be safely above the flame temperature. But ash from contaminants of construction debris may have a lower fusion temperature. In addition, high silicon content biomass, such as some straws, may have lower fusion temperatures.

Cost Effectiveness

Fuel drying can be cost effective even at a small pulp and paper mill, provided heat recovery is used to capture waste heat generated in the facility. Other design factors will also influence cost effectiveness, so a complete analysis must be performed for each case. Manufacturers' representatives will often perform such analyses for a plant or at least provide a ballpark figure.

Another factor to consider in assessing cost effectiveness is the type of fuel that is avoided. If a dryer reduces the use of fossil fuels, it is generally more cost effective than if it reduces biomass fuel consumption. Also, any avoided disposal costs (of, for example, waste wood and ash) should be factored in.

Other factors that can significantly improve cost effectiveness include selling carbon credits (or avoiding possible carbon taxes in the future), financial incentives, and power production and electricity prices.

Carbon Credits for Biomass CHP

Using biofuels reduces carbon dioxide emissions to the extent that it offsets fossil fuel use. Carbon credits can be sold privately or on exchanges, such as the Chicago Climate Exchange (http://www.chicagoclirnatex.com/). Credits can be sold through a broker, such as the Environmental Credit Corporation (http://www.envcc.com). A broker shares in sales, subject to negotiations.

Carbon dioxide emission reductions due to avoidance of electricity, natural gas, diesel or liquid propane gas use are given in Table 2. To convert the carbon dioxide emissions in kilograms or pounds into carbon equivalents, multiply by 12 and divide by 44.

Table 2. Carbon Dioxide Emissions for Selected Energy Sources

	lb CO2 per kWh	lb CO2 per MMBtu
Natural Gas *	0.42	123
Diesel Oil *	0.55	161
Liquid Propane Gas *	0.46	135
Delivered Electricity **	0.921	270

* "Conversion Factors," Carbon Trust, www.carbontrust.co.uk/resource/conversion_factors/ (March 2007)

** This is the average emissions associated with delivered electricity for the Northwest Regional Power Grid, which consists of Idaho, Montana, Oregon, Utah, Washington and parts of California, and Wyoming, Emissions data, Environmental Protection Agency, epa.gov/cleanenergy/documents/eGRID2006V2_1_Summary_Tables.pdf

Incentives for Biomass Projects in the Northwest

Biomass fuels are a renewable energy source because biomass is produced on a short time scale. Therefore, projects using them may qualify for incentives on the federal, state and local levels with funding from government, utilities or private organizations. Financial and other incentives for renewable energy and energy efficiency projects are summarized in the DSIRE database at www.dsireusa.org, which is regularly updated. The following summaries are based on information from the DSIRE database as of April 2008.

Note that most of the incentives summarized below also apply to other renewable energy sources and to energy efficiency measures that may not be mentioned, since this summary focuses on biomass renewable energy. Eligibility requirements and other details may be omitted in these summaries. Check the DSIRE database for more detailed summaries, as well as sources for more information.

- **Northwest Region**

  Bonneville Environmental Foundation (BEF): BEF is a not-for-profit organization that accepts proposals for funding for renewable energy projects, including biomass projects, located in Oregon, Washington, Idaho or Montana. Projects that generate electricity are preferred. BEF may provide grants, loans, convertible loans, guarantees, and direct investments in renewable energy projects. These grants and investments may range from a few thousand dollars for small installations, to significant investments in central station grid-connected renewable energy projects.

- **Alaska**

  Golden Valley Electric Association - Sustainable Natural Alternative Power (SNAP) Program: The SNAP program encourages members to install renewable energy generators and connect them to their utility's electrical distribution system by offering an incentive payment based on the system's production on a $/kWh basis.

  Note: Alaska's Power Project Loan Fund does not support biomass energy systems.

- **Idaho**

  Renewable Energy Project Bond Program: Non-utility developers of renewable energy projects in Idaho are allowed to request financing from the Idaho Energy Resources Authority. Renewable energy is defined very broadly as "a source of energy that occurs naturally, is regenerated naturally or uses as a fuel source, a waste product or byproduct from a manufacturing process including, but not limited to, open or closed-loop biomass, fuel cells, geothermal energy, waste heat, cogeneration, solar energy, waterpower and wind."

Renewable Energy Equipment Sales Tax Refund: Idaho offers a sales-and-use tax rebate for qualifying equipment and machinery used to generate electricity from renewable energy sources, including biomass. Purchasers qualify for a rebate only if the equipment is used to develop a facility or a project capable of generating at least 25 kW of electricity.

Low Interest Energy Loan Programs: The Idaho Department of Water Resources administers low-interest loan programs for active solar, wind, geothermal, hydropower and biomass energy projects. Use of a renewable energy resource must be the least cost alternative. Renewable energy projects that are intended to sell the energy generated or the commodity produced are not eligible.

- **Montana**

Alternative Energy Investment Tax Credit: Commercial and net metering alternative energy investments of $5,000 or more are eligible for a tax credit of up to 35% against individual or corporate tax on income generated by the investment.

Alternative Energy Revolving Loan Program: The Alternative Energy Revolving Loan Program (AERLP) provides loans to individuals, small businesses, local government agencies, units of the university system, and nonprofit organizations to install alternative energy systems that generate energy for their own use.

Renewable Energy Systems Property Tax Exemption: Montana's property tax exemption for recognized nonfossil forms of energy generation or low emission wood or biomass combustion devices may be claimed for 10 years after installation of the property.

NorthWestern Energy - USB Renewable Energy Fund: Montana requires all electric and gas utilities to establish funds for low-income energy assistance, weatherization, energy efficiency activities, and development of renewable energy resources. NorthWestern Energy periodically provides funding to its customers for renewable energy projects through this fund. In 2006, NorthWestern provided funding for approximately 50 renewable energy projects including wind and solar systems for residents and businesses. Most of the projects included a public education or demonstration component to increase awareness of renewable energy.

- **Oregon**

Business Energy Tax Credit: Oregon's Business Energy Tax Credit (BETC) is for investments in energy conservation, recycling, renewable energy resources, or less-polluting transportation fuels. The tax credit is 50% of the total cost, with a maximum credit of $10 million taken over five years. Through a pass-through option, a project owner may transfer a tax credit to a pass-through partner in return for a lump-sum cash payment. Pass-through allows non-profit organizations, schools, governmental agencies, tribes, other public entities and businesses with and without tax liability to take advantage of the Business Energy Tax Credit.

Energy Trust - Open Solicitation Program: The Energy Trust of Oregon's open solicitation program supports grid-connected renewable energy projects that do not already have an established Energy Trust incentive program. The program does not fund R&D or pre-commercial activities. It will support new, commercial technologies in established applications; existing commercial technologies in new applications; projects that can replicated elsewhere; and market defining demonstrations of commercial technology. Projects must be located in the Oregon service territory of Pacific Power or Portland General Electric, or have a power purchase agreement with one of those utilities.

Small-Scale Energy Loan Program: The Oregon Small Scale Energy Loan Program (SELP) offers incentives to renewable energy systems, including biomass systems. Though there is no legal maximum loan, the size of loans generally ranges from $20,000 to $20 million.

Net Metering: Oregon's municipal utilities, electric cooperatives and people's utility districts must offer customers net metering. Biomass energy systems are eligible. Net-metered systems must be intended primarily to offset part or all of a customer's requirements for electricity.

Note: Oregon's property tax exemption for renewable energy systems does not provide incentives to biomass projects except those that generate methane.

- **Washington**

  Renewable Energy Standard: Washington requires all electric utilities serving more than 25,000 customers to offer customers the option of purchasing renewable energy. Biomass energy projects must be based on animal waste or solid organic fuels from wood, forest, or field residues, or dedicated energy crops that do not include wood pieces that have been treated with chemical preservatives.

  The Energy Freedom Loan Account: Low-interest loans and grants in research and development of new and renewable energy sources are provided through this account. Financial assistance may be awarded by the board for research and development of new and renewable energy and biofuel sources.

  Net Metering: Washington's net-metering law applies to systems up to 100 kilowatts (kW) in capacity. Biomass energy systems that are eligible are those based on biogas from animal waste or combined heat and power technologies.

  Notes: Washington's renewable energy production incentives do not apply to biomass projects, except anaerobic digesters. Washington's sales tax exemption does not apply to biomass projects, except those using landfill gas.

- **Federal**

  Biomass energy projects may be eligible for the federal government's Renewable Energy Production Incentive (REPI) and the Renewable Electricity Production Tax Credit. The U.S. Department of Energy's Energy Efficiency and Renewable Energy Office's website contains a summary of the REPI program, as well as information on eligibility and how to apply: www.eere.energy.gov/repi. In December 2006, the credit was extended through December 31, 2008.

  The Energy Policy of 2005 (EPACT) established renewable energy purchasing goals for federal agencies. While this policy does not provide incentives to specific projects, it helps improve the market climate for renewable energy in general.

  Solicitations for grants from all agencies within the federal government are available on the website http://www.grants.gov/.

- **Private Foundations**

  The Energy Foundation (http://www.ef.org/home.cfm) is a partnership of major donors who seek to advance energy efficiency and renewable energy. They support "new technologies that are essential components of a clean energy future."

  The Climate Trust offers incentives to renewable energy projects. For more information, visit their website at http://www.climatetrust.org/solicitations1.php.

On-Site Power Production and Electricity Prices

Different selling arrangements are now emerging for on-site generation that can improve the cost effectiveness of CHP systems compared to an arrangement that solely avoids the cost of purchasing power from the grid. Two examples are:

- Grays Harbor Paper in Aberdeen, Washington sells their on-site generation to Puget Power while buying their power from Grays Harbor PUD.

- The Sierra Pacific mill in Burlington, WA produces 28 MW of power. Seattle City Light helps wheel this power to the Sacramento, CA Municipal utility. Seattle City Light uses some of this power for its winter peak needs.

Other Information Resources

The following resources are available for more information on biomass-fired combined heat and power systems.

CHP Application Centers

The U.S. CHP Technical Assistance Partnerships and the seven regional CHP Technical Assistance Partnerships provide assistance to facilities considering CHP. These centers can offer technology, application and project development information, case studies and other publications, workshops and other educational opportunities, and contacts for local resources.

- U.S. CHP Technical Assistance Partnerships
  http://www1.eere.energy.gov/manufacturing/distributedenergy/chptaps.html

- Southwest CHP Technical Assistance Partnerships
  Arizona, Colorado, New Mexico, Oklahoma, Texas, Utah, and Wyoming.
  http://www.southwestchptap.org/

- Mid-Atlantic CHP Technical Assistance Partnerships
  Delaware, Maryland, New Jersey, Pennsylvania, Virginia, West Virginia, and Washington D.C.
  http://midatlanticchptap.org/

- Midwest CHP Technical Assistance Partnerships
  Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin
  http://www.midwestchptap.org/

- Northeast CHP Technical Assistance Partnerships
  Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont
  http://www.northeastchptap.org/home/home.php

- Northwest CHP Technical Assistance Partnerships
  Alaska, Idaho, Montana, Oregon, and Washington
  http://www.northwestchptap.org/

- Pacific Region CHP Technical Assistance Partnerships
  California, Hawaii, and Nevada
  http://www.pacificchptap.org/

- Southeast CHP Technical Assistance Partnerships
  Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, South Carolina, North Carolina, Tennessee
  http://www.southeastchptap.org/

U.S. Environmental Protection Agency

The U.S. Environmental Protection Agency's CHP Partnership (http://www.epa.gov/chp/index.html) works to support the development of new CHP projects and promote their energy, environmental, and economic benefits.

Dryer Manufacturers and Suppliers

Several manufacturers and suppliers of dryers are listed below, with excerpts from their webpages illustrating their experience in the forest products industry.

The Northwest CHP Technical Assistance Partnerships and its cooperating agencies do not endorse, recommend or favor these manufacturers and suppliers and do not guarantee the accuracy of information obtained from them summarized below. This list of manufacturers and suppliers may not be all inclusive.

Aeroglide
100 Aeroglide Drive
Cary, NC 27511
www.aeroglide.com/wood.html
Aeroglide manufactures both rotary and conveyor dryers for wood products. Aeroglide acquired National Drying Machinery Co.

Andritz Inc. (Austrian)
1115 Northmeadow Parkway
Roswell, GA 30076-3857
Phone: +1 770 640 2500
www.andritz.com
For a list of other North American offices, including several in the U.S., refer to http://www.andritz.com/ANONIDZ3937C8542CD9BCA8/ppp/ppp-service-2004/ppp-service-locations/ppp-service-contacts-adresses-na.htm.
Their "major customer segments are: wood processors, mechanical pulp producers, chemical pulp producers (including chemical recovery applications), market pulp producers (baling and handling applications), recycled fiber producers, tissue producers, paper/board producers (stock preparation applications), and the panelboard industry." Andritz's webpage does not include hog fuel as a material they dry, but their dryers are listed as being used for hog fuel in the dissertation available at http://lib.tkk.fi/Diss/2007/isbn9789512286492/isbn9789512286492.pdf.

Barr-Rosin Inc. (Canadian)
255 38th Avenue, Suite G
St. Charles, Illinois 60174 • USA
Tel: 630-659-3980 • Fax: 630-584-4406
E-mail: bri@barr-rosin.ca
http://www.barr-rosin.com
"Barr-Rosin is a leading supplier of industrial drying systems and offers numerous systems and technologies to dry wet materials, ranging from granules, cakes, and powders to sludges, slurries, and solutions." For forest industries, refer to http://www.barr-rosin.com/applications/pulp_paper_sawmill_plant.asp

Barr-Rosin (www.barr-rosin.com) manufactures both direct and indirect rotary dryers, among other types of dryers.

Berlie-Falco Technologies Inc. (Canadian)
Distributor for Swiss-Combi: www.swisscombi.com (Swiss)
1245, Industrielle Street
La Prairie (Quebec)
Canada, J5R 2E4
Tel. (450) 444-0566
Fax (450) 444-2227
www.berlie-falco.com/
Swiss Combi's webpage does not include hog fuel as a material they dry, but their dryers are listed as being used for hog fuel in the dissertation available at http://lib.tkk.fi/Diss/2007/isbn9789512286492/isbn9789512286492.pdf.

Swiss Combi manufacturers low temperature belt dryers and rotary dryers.

Bruks-Klockner Inc. (Swedish)
5975 Shiloh Road, Suite 109
Alpharetta, GA 30005
http://www.bruks-klockner.com
"The Bruks Klöckner bed dryer is an environmentally friendly low-temperature dryer for chips, sawdust, bark and the like." Bruks-Klockner is a subsidiary of FTG Forest Technology Group, which specializes in technologies for the forest industry.

Bruks Klöckner is Swedish owned with an office in the U.S.. They have a low-temperature bed dryer for chips, sawdust, and bark that operates at temperatures of 80 to 110°C.

Charles Brown (U.S.)
4465 Rea's Bridge Rd.
Decatur, IL 62521
(217)422-8608
http://www.charlesbrowncompany.com/index.html
"We offer a broad product line of continuous rotary dryers for a variety of industries such as aggregates, grain, food processing, and petro-chemical, to name a few. All of our rotary equipment can be expertly designed and sized for any requirement no matter what the application."

ESI Inc. of Tennessee
1250 Roberts Boulevard
Kennesaw, GA 30144
Phone: 770-427-6200
Fax: 770-425-3660
Email: info@esitenn.com
Web Site: www.esitenn.com
"ESI's Steam & Power *SPECIAL FORCES*® own a proprietary biomass drying technology that is used to dry biomass and paper mill sludge. ESI has installed this technology in several biomass and paper mill sludge-fired projects, resulting in significant increases in boiler steam flow capacity and load following capability while simultaneously reducing air emissions and the use of support fossil fuels. Many times, the installation of a biomass dryer is a significantly less expensive alternative to the installation of new boiler capacity."

ESI supplies cascade dryers.

International Applied Engineering Inc.
1165 Allgood Road, Suite 6,
Marietta, GA 30062
Tel: (770) 977-4248
Fax: (770) 977-2832
http://www.iaeinc.com/
"IAE personnel have worked on every aspect of operations and maintenance of biomass-fueled power plants from the most basic and standard programs to complex legal and performance issues concerning the plant-wide performance of contracted operations and maintenance providers."
International Applied Engineering supplies cascade dryers.

M-E-C Company (U.S.)
P.O. Box 330
1400 West Main Street
Neodesha, Kansas 66757 USA
Phone: 1 (620) 325-2673, Fax: 1 (620) 325-2678
http://www.m-e-c.com
"M-E-C Company designs, manufactures, installs and maintains industrial drying systems for a wide range of wet materials." Industries served include the forest products industry and biomass energy industry.
M-E-C manufactures direct-fired rotary dryers.

The Onix Corporation (U.S.)
4140 Tuller Road
Suite 101
Dublin, Ohio 43017
614-798-1740
Fax: 614-798-1748
http://www.theonixcorp.com/index.html
"The Onix Corporation is a manufacturer of industrial wood combustion, rotary drum drying, wood-fired boilers, wood-fired industrial air heating and pollution-control equipment. The Onix Corporation designs recycling solutions for many industrial problems. This equipment is currently employed by the agricultural, pharmaceutical, pulp and paper, feed, and forest related industries."

The Onix Corporation manufacturers direct-fired rotary dryers.

Thermal Energy International (Canadian)
36 Bentley Avenue
Ottawa, Ontario Canada
K2E 6T8
Phone: 613-723-6776, Fax 613-723-7286
www.thermalenergy.com
"Our bioenergy solutions help industries displace the use of expensive fossil fuels and achieve even greater energy cost savings by improving the value of the biomass fuels, converting waste products into valuable biomass fuels and increasing steam production and throughput of biomass plant operations by up to 35%."

Thermal Energy International is the distributor for "Dry-Rex" dryers, which are low-temperature vacuum belt dryers. (The Dry-Rex dryer was formerly available from Mabarex.) Both Mabarex (www.mabarex.com) and Thermal Energy International (www.thermalenergy.com) have experience with heat recovery and drying bark and hog fuel. Thermal Energy International specializes in heat recovery in general and so would be able to assist you in implementing other conservation measures as well. See the article about the Dry-Rex dryer in the *Bioenergy Update* (July 2003), available at http://www.bioenergyupdate.com/magazine/security/Bioenergy%20Update%2007-03/bioenergy_update_July_2003.htm.

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Bishop, Jim, "Dewatering Technologies: Municipalities can choose from a variety of options," Water Environment Federation website, July 2006. http://www.wef.org/NR/rdonlyres/6ECA6AB7-F3E7-4238-880B-92E6B8D82E95/0/SpecialSection_July06.pdf

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