Review of Biomass Fuels and Technologies

Yakima County Public Works
Solid Waste Division

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EXECUTIVE SUMMARY

This report provides a review of biomass opportunities and barriers within Yakima County, Washington. The report contains information on biomass fuels and technologies, and provides profiles of selected biomass-to-energy projects. This report was prepared under the guidance of the Yakima County Department of Solid Waste with funding support from the U.S. Department of Agriculture (USDA) Forest Service.

Yakima County is interested in the economic benefits and job creation that a biomass project could offer. Locating a biomass project in the County could also provide other benefits to the County and its citizens, such as reducing landfill use, promoting forestland management and fire prevention activities, and mitigating odor and environmental issues from dairy and livestock wastes.

The USDA Forest Service is interested in promoting alternative uses and markets for forestry wastes resulting from the hazardous forest fuel loading reduction activities of the National Fire Plan. The Forest Service, as well as other public and private entities involved with forest management, currently has few options available other than on-site stacking and burning of the residues.

This report considers moderate-sized, centralized biomass-to-energy facilities, as opposed to distributed or micro-scale biomass conversion projects for individual homeowners, farms, or dairies. Distributed biomass projects, as well as non-energy projects such as composting, may be beneficial to the environment and to individuals, but they will not provide the level of economic benefit, job creation, or forestry waste consumption that the County and the Forest Service are seeking.

This report is organized in four parts:

- **Biomass Fuels** begins by categorizing and defining the common biomass feedstocks. Two fuels that could be instrumental to a Yakima County biomass-to-energy project, forestry residues and dairy industry waste, are reviewed in detail. Municipal solid waste (MSW) is also reviewed.
- **Biomass Technologies** reviews the three primary processes used in biomass-to-energy facilities: combustion, gasification, and anaerobic digestion. A summary table at the end of the section describes each technology in terms of its feedstocks and products, gives the status of the technology, and lists considerations for Yakima County.
- **Biomass Project Profiles** reviews selected regional biomass projects that are either under development, currently operating, or have stopped operation. Projects were selected for review based on their relevance to Yakima County in terms of fuel, technology, and scale.
- **Conclusions and Recommendations** presents conclusions based on the research conducted for this report and identifies the next steps the County can take if it

wants to pursue involvement with a biomass-to-energy project. This section also identifies the general locations within the County that may be the most logical sites for a biomass-to-energy facility.

Benefits of Biomass-to-Energy

Biomass-to-energy facilities present many benefits. Biomass is a renewable resource, and generating electricity and other energy products from biomass offsets consumption of fossil fuels. Biomass is typically waste material from another industry, such as logging or dairy operations, and converting it to energy not only reduces disposal, but also mitigates environmental impacts that these wastes can have on air, groundwater, and surface water quality.

Barriers to Biomass-to-Energy

In contrast to the benefits, there are significant barriers to biomass-to-energy facilities. Biomass fuels have low energy densities, and collection and transportation can be cost prohibitive. Using biomass to generate electricity is technologically well established, but the price paid for electricity seldom offsets the full cost of the biomass fuel.

Future Opportunities for Biomass-to-Energy

Where opportunities for biomass initiatives exist around the world, these are primarily the result of tightening environmental regulations and increasing waste disposal costs. Increased landfill costs, restrictions on land-application of raw manures, and curtailment of open burning of forest residues are all circumstances that would make biomass-to-energy a more attractive solution. Parts of the world where environmental restrictions are more stringent and energy prices are higher, such as Europe, are looking to biomass-to-energy facilities as an opportunity to solve both issues. It does not appear that Yakima County has yet reached this point, but certain trends indicate that indicate biomass-to-energy facilities will eventually become a necessity and will be a sound economic investment.

Specific Yakima County Biomass-to-Energy Issues

Although heavily forested areas occur in the western part of Yakima County, other locations throughout the Pacific Northwest have access to much greater volumes of woody fuels at significantly lower collection and transportation costs. In an open market, Yakima County is at a disadvantage for woody fueled biomass-to-energy compared to these other locations. Unless entities such as the USDA Forest Service were to make a long-term commitment (for example, for the life of a power plant) to supply a significant volume of forestry residues at a fraction of the cost of collection and transportation, a Yakima County biomass-to-energy project would be a significant economic gamble. If the supply of woody fuels could be obtained, well established and very reliable combustion technologies are available that could be used to generate electricity and steam.

The dairy industry of Yakima County produces more than enough manure to feed a large-scale centralized anaerobic digestion facility. Anaerobic digestion of dairy manure has substantial environmental benefits. It could mitigate the nutrient overloading of farmlands, reduce water quality issues, and have a positive impact on dairy odor and fly reduction. However, the energy production from anaerobic digestion is relatively low and it would be difficult to recover the capital cost of such a project simply through the sale of electricity and fiber byproduct. The facility would almost certainly need to collect significant tipping fees to maintain economic feasibility, and as long as there are lower cost options for manure disposal, dairy operations may be reluctant to bear the costs of manure transportation and the tipping fees.

Section 1
BIOMASS FUELS

Biomass fuels are organic materials produced in a renewable manner. Two categories of biomass fuels, woody fuels and animal wastes, comprise the vast majority of available biomass fuels. Municipal solid waste (MSW) is also a source of biomass fuel.

Biomass fuels have low energy densities compared to fossil fuels. In other words, a significantly larger volume of biomass fuel is required to generate the same energy as a smaller volume of fossil fuel. The low energy density means that the costs of fuel collection and transportation can quickly outweigh the value of the fuel. Biomass fuels are typically consumed on-site or transported short distances only (e.g., less than 50 miles).

Biomass fuels tend to have a high moisture content, which adds weight and increases the cost of transportation. The moisture content also decreases combustion performance. Anaerobic digestion, however, is one biomass-to-energy technology in which the moisture content is actually necessary for the process as opposed to a hindrance to it.

Due to the low energy value, and because biomass is typically a waste product, biomass fuels are usually supplied to a biomass-to-energy facility with a tipping fee, rather than as a purchase by the biomass facility. The tipping fee varies according to the value of the fuel and the cost of processing it. MSW commands the highest tipping fees. Woody fuels have the lowest tipping fees, or may be purchased when a supplier can provide large and steady quantities. However, even when woody fuels are purchased by a biomass project, the purchase price may only be a portion of the total cost of collecting and transporting the fuel.

There are two primary factors to be considered in the evaluation of biomass fuels:

- Fuel supply, including the total quantities available, the stability of the supply or of the industry generating the fuel, and competitive uses or markets for the fuel.
- Cost of biomass fuel collection, processing, and transportation, and who pays these costs.

This section discusses three sources of biomass fuel: woody fuels, animal waste, and MSW. These discussions include the issues of fuel supply and costs. These fuels are summarized, along with their respective benefits and barriers, in Table 2 at the end of this section.

1.1 Woody Fuels

Wood wastes of all types make excellent biomass fuels and can be used in a wide variety of biomass technologies. Combustion of woody fuels to generate steam or electricity is a proven technology and is the most common biomass-to-energy process.

Different types of woody fuels can typically be mixed together as a common fuel, although differing moisture content and chemical makeup can affect the overall conversion rate or efficiency of a biomass project. There are at least six subgroups of woody fuels. The differentiators between these subgroups mainly have to do with availability and cost.

- **Forestry residues—**in-forest woody debris and slash from logging and forest management activities.
- **Mill residues—**byproducts such as sawdust, hog fuel, and wood chips from lumber mills, plywood manufacturing, and other wood processing facilities.
- **Agricultural residues—**byproducts of agricultural activities including crop wastes, vineyard and orchard prunings or turnings, and rejected agricultural products.
- **Urban wood and yard wastes—**residential organics collected by municipal programs or recycling centers and construction wood wastes.
- **Dedicated biomass crops—**trees, corn, oilseed rape, and other crops grown as dedicated feedstocks for a biomass project.
- **Chemical recovery fuels (black liquor)—**woody residues recovered out of the chemicals used to separate fiber for the pulp and paper industry.

1.1.1 Forestry Residues

Forestry residues have been the focus of many recent biomass studies and feasibility assessments due to increasing forest management and wildfire prevention activities under the National Fire Plan. The USDA Forest Service and the Bureau of Land Management have been tasked with reducing the hazardous fuel loading within the forests and the urban-wildland interface.

Forestry residues are typically disposed of by on-site (in-forest) stacking and burning. This results in substantial air emissions that affect not only the forest lands and nearby populations, but the overall regional air quality as well. Open burning can also cause water quality and erosion concerns.

The Forest Service and other public and private land management entities would like to have viable alternatives for disposing of their forestry residues in a more environmentally benign manner. An ideal situation, from the perspective of forest managers, would be the creation of a market for the forestry residues. The market they envision would generate revenues for the forest managers, which in turn would allow much needed expansion of the forest management programs.

In general terms, the quantity of forestry residues available throughout the Pacific Northwest is more than sufficient to support a biomass project. However, there are also significant barriers to using forestry residues as a biomass fuel. The barriers are due to variations in the supply cycle and to the cost of collecting and transporting the forestry residues.

Variations in forestry residue supplies are driven by the seasonal nature of forest activities, the trends in the commercial logging industry, and changing funding levels for forest management programs such as the National Fire Plan. The logging industry in the Pacific Northwest has experienced a decreasing trend for several decades, and although the timber harvest volume has stabilized in the past few years, there are no indications that it will ever recover to pre-1980 levels. The current focus on forest management initiatives aimed at reducing hazardous fuel loadings has recently increased the availability of residues, but this activity is subject to federal funding fluctuations and shifting political attitudes toward forest management.

A major study for the U.S. Department of Energy (DOE) was undertaken in 2001 to quantify logging residue and agricultural residue supply curves for the Pacific Northwest.[1] A residue supply curve is a supply and demand curve for a biomass fuel. The study systematically mapped forest lands on a county by county basis, and then calculated incremental collection and transportation costs to get forestry residues from those areas to centralized biomass processing facility locations. This study has been an important benchmark in the industry for quantifying forestry residue availability and cost.

Even though Yakima County has heavily forested areas along the western part of the County, this comprehensive study shows the potential forestry residue volumes within Yakima County to be significantly lower than other locations throughout the Pacific Northwest. The study focused its analysis on the 29 counties with the highest timber harvest levels, and Yakima County did not meet the study's minimum threshold for in-depth analysis of forestry residue availability. This does not necessarily mean that insufficient forestry residues within Yakima County preclude a biomass project fueled by forestry residues, but it does indicate that Yakima County is not an optimum location for such a facility from a region-wide perspective.

The costs of recovering the forestry residues are very high. The DOE study calculated that the cost of forestry residue recovery (skidding, yarding, loading, and chipping) starts at $30 per bone-dry ton (BDT) and can increase to almost three times that much. Transportation costs further add to the total cost of the fuel, making the regional average cost of forestry residue fuels on the order of $60 to $80 per BDT or more for an area the size of Yakima County's heavily forested areas. A recent study of woody fuels availability in the Prineville, Oregon area determined the cost of forestry residues would be $30 to $44 per BDT based on a relatively small 50-mile maximum radius from the proposed biomass project. A study underway for the Lake Tahoe Basin on

[1] U.S. Department of Energy, "Logging and Agricultural Residue Supply Curves for the Pacific Northwest," prepared by Washington State University Cooperative Extension Energy Program under U.S. Department of Energy Contract No.DE-FC01-99EE50616 (January 2001).

the California-Nevada border has a preliminary calculation of $56 to $66 per BDT for a similar 50-mile maximum distance.

These costs for forestry residue fuels are prohibitive to a biomass-to-energy facility. The Tacoma Steam Plant lost money and ceased operation even though its wood waste primary fuel cost an average of less than $5 per BDT. The SEDI (Sustainable Energy Development, Inc.) Bioenergy Refinery project under development in La Grande, Oregon anticipates that it will be able to pay about $20 per BDT of delivered forestry residues, but it is also anticipating substantial subsidies for its wood-ethanol product, and a traditional biomass-to-electricity project would probably not be able to pay similar prices for feedstock. More information on these two projects is provided in Section 4 of this report.

1.1.2 Mill Residues

Mill residues are a much more economically attractive fuel than forestry residues, since the in-forest collection and chipping are already included as part of the commercial mill operations. Biomass facilities collocated with and integral to the mill operation have the advantage of eliminating transportation altogether and thus truly achieve a no-cost fuel.

Mill residues have long been used to generate steam and electricity in the Pacific Northwest. In Washington State alone, there are approximately 38 facilities that combust about 3 million BDT of mill residues per year to generate steam and electricity. All but two of these mill-residue-fired biomass projects are owned and operated by the mills or wood products companies that supply their fuel. The in-plant facilities primarily generate steam for lumber drying and processing. Any electricity produced is used to offset plant use, although a few facilities do sell excess electrical power to the local utility.

Yakima County has one such facility: the Boise Cascade Plywood Plant in Yakima. This biomass facility burns approximately 135,000 BDT of mill residues per year in a spreader stoker boiler to generate steam for the plant's plywood kilns and dryers.

It is unusual for a mill to offer its residues to an external biomass project, unless the mill has excess residues compared with its own energy consumption or unless it cannot process the residues themselves due to local environmental restrictions. One example of a mill residue biomass-to-energy facility not owned by a mill is Avista Utility's Kettle Falls Station in northeastern Washington. The facility is strategically located within an average distance of 46 miles from 15 different mills, and purchases approximately 350,000 BDT per year of residues to generate 46 MW of electrical power. The facility was conceived in the late 1970s when mills were facing stricter pollution regulations that required them to replace their wigwam burners. Rather than invest in new equipment, the mills were willing to enter into long-term contracts with the private electric utility to supply a biomass facility with mill residues. The facility continues to operate successfully, due in large part to its unique location in one of the most heavily forested areas in the Pacific Northwest.

Because Yakima County does not have a significant mill or wood products industry other than the Boise Cascade plywood facility, there are not sufficient mill residues within a practical distance to support a new biomass facility in Yakima County.

1.1.3 Agricultural Residues

Agricultural residues can provide a substantial amount of biomass fuel. Similar to the way mill residues provide a significant portion of the overall biomass consumption in the Pacific Northwest, agricultural residues from sugar cane harvesting and processing provide a significant portion of the total biomass consumption in other parts of the world.

One significant issue with agricultural residues is the seasonal variation of the supply. Large residue volumes follow harvests, but residues throughout the rest of the year are minimal. Biomass facilities that depend significantly on agricultural residues must either be able to adjust output to follow the seasonal variation, or have the capacity to stockpile a significant amount of fuel.

The 2001 DOE study mentioned previously identified 34 counties in the region with significant agricultural industries. Yakima County ranked 31st in this list, with an estimated agricultural residue availability of 62,300 tons per year. For comparison, the average across the 34 counties was 236,500 tons per year, with Whitman County ranking number 1 on the list at 1,173,850 tons per year. The study also identified 13 optimum biomass conversion sites based on the overall distribution of agricultural residue biomass throughout the region. With the exception of The Dalles, Oregon, all of the optimum sites are east of Yakima County. The optimum sites closest to Yakima County were Moses Lake and Richland.

The DOE study primarily focused on in-field residues remaining after harvests of wheat and barley. The study calculated an average minimum cost of about $40 per dry ton to collect and transport the wastes instead of burning or tilling. However, in Yakima County, turnings and prunings of orchards and vineyards make up a substantial portion of the agricultural residue. Unlike wheat and barley, these orchard and vineyard residues must be removed from the field, and the cost of collection and transportation of the residues is already part of the orchard and vineyard operation costs. It is possible that a biomass project in Yakima County could charge a tipping fee for these types of agricultural residues.

Nevertheless, the statistics from the DOE study indicate that Yakima County does not produce enough agricultural residues on its own to support a biomass project fueled entirely on agricultural residues, nor is it located centrally enough to draw residues from a wider geographical area. Agricultural residues could be a supplemental feedstock for a Yakima County biomass project, but not primary fuel.

1.1.4 Urban Wood and Yard Wastes

Urban wood and yard wastes are similar in nature to agricultural residues in many regards. A biomass facility will rarely need to purchase urban wood and yard wastes, and most likely can charge a tipping fee to accept the fuel. Yakima County is already collecting "clean green" wastes at its landfills at a tipping fee of $11.60 per ton, and reselling it or using it for landfill daily cover. This waste could be diverted to a biomass project, and although the volume currently accepted at the landfills would not be enough on its own to fuel a biomass project, it could be an important supplemental fuel and could provide more value to the County through a biomass project than it currently does as daily landfill cover.

1.1.5 Dedicated Biomass Crops

Dedicated biomass crops are grown specifically to fuel a biomass project. The most prevalent example of dedicated biomass crops are corn varieties grown for ethanol production. Fast-growing poplar trees have also been farm-raised for a biomass fuel, but this has not proven to be economically sustainable. Another dedicated crop example is soybean oils used in the production of biodiesel. Because these crops are created intentionally (and thus are not a waste product from another industry) this report does not evaluate the feasibility of using dedicated biomass crops as a fuel source.

1.1.6 Chemical Recovery Fuels

Chemical recovery fuels are responsible for over 60 percent of the total biomass energy consumption of the United States, and therefore must be mentioned in any analysis of biomass. However, the chemical recovery facilities are owned by pulp and paper facilities and are an integral part of the facility operation. Therefore, although this is an important fuel within the overall biomass industry, it does not have application for Yakima County.

1.2 Animal Wastes

Animal wastes include manures, renderings, and other wastes from livestock finishing operations. Although animal wastes contain energy, the primary motivation for biomass processing of animal wastes is mitigation of a disposal issue rather than generation of energy. This is especially true for animal manures.

Animal manures are typically disposed of through land application to farmlands. Tightening regulations on nutrient management, surface and groundwater contamination, and odor control are beginning to force new manure management and disposal practices. Biomass technologies present attractive options for mitigating many of the environmental challenges of manure wastes. The most common biomass technologies for animal manures are combustion, anaerobic digestion, and composting. Moisture content of the manure and the amount of contaminants, such as bedding, determine which technology is most appropriate.

With over 300,000 head of cattle (more than any other county in Washington) Yakima County has more than adequate volumes of cattle manure necessary for a biomass project. These cattle collectively produce roughly 4,500,000 tons of raw manure per year; and this does not include Yakima County's significant populations of sheep and other livestock.[2]

The dairy industry in particular is well suited to biomass-to-energy opportunities because of the large volume of manure that a milking cow produces, and because dairy operations have automated and frequent manure collection processes. Yakima County is the largest producer of dairy products of any county in the State, and the dairy populations within the County include approximately 75,000 to 85,000 active milking cows on about 80 separate dairies.

1.2.1 Dry Animal Manure

Dry animal manure is produced by feedlots and livestock corrals, where the manure is collected and removed only once or twice a year. Manure that is scraped or flushed on a more frequent schedule can also be separated, stacked, and allowed to dry. Dry manure is typically defined as having a moisture content less than 30 percent. Dry manure can be composted or can fuel a biomass-to-energy combustion project. If all the manure from Yakima County's 300,000 head of cattle was collected and dried, it would amount to approximately 550,000 tons of biomass fuel per year. This is more than adequate for a commercial-scale, centralized biomass combustion project.

Animal manure does have value to farmers as fertilizer, and a biomass-to-energy project would need to compete for the manure. Some dairy and livestock operations would not be interested in disposing of their manure at a biomass-to-energy project, especially if they were responsible for the cost of transportation and a tipping fee. However, the total volume of manure produced in Yakima County exceeds the amount of fertilizer required for the farmlands, and Nutrient Management Plans are beginning to limit the over-fertilization of farmlands. Therefore, although there are competitive uses for the manure and low-cost disposal options at this time, manure disposal is going to become more costly over time, and the demand for alternative disposal options, including biomass-to-energy, will only increase.

1.2.2 Wet Animal Manure (Dairy Manure Slurry)

Wet animal manure is typically associated with larger and more modern dairy operations that house their milking cows in free-stall barns and use a flush system for manure collection. The combination of free-stall barns and manure flushing collects all of the milking cow manure with every milking cycle, two or three times a day. The manure is significantly diluted through the addition of the flush water, but after separation of some of the flush water, the slurry is an excellent fuel for biomass-to-energy processing through anaerobic digestion technology.

The technology of anaerobic digestion is described in greater detail in Section 3.3 of this report, but in terms of biomass fuel, a manure slurry concentration of about 6

[2] This approximate number assumes 85,000 milking cows producing 112 pounds of manure per day, and 215,000 other head of cattle producing roughly 70 pounds per day.

percent solids is ideal. The average full-size, 1,400-pound milking cow produces about 112 pounds, or 13.5 gallons, of raw manure every day with a 12.5 percent solids concentration as excreted. Dilution with flush water to a 6 percent solids concentration for anaerobic digestion results in an average 28 gallons per milking cow per day. This is a significant volume of manure slurry, over 51 million gallons per year for a 5,000-head dairy. Yakima County has more than enough dairy manure slurry to supply a commercial-scale anaerobic digestion project.

For optimal anaerobic digestion, the manure slurry must be collected and transferred to the digester continuously, as the manure will begin to break down and release its energy immediately upon excretion. A digester located on the dairy site would use piped systems to accomplish the transfer of the slurry directly from the manure collection system to the digester. However, for a large-scale, centralized digester facility processing wastes from multiple dairies across the County, transportation of slurry at 6 percent concentration is prohibitive. A typical manure truck can carry a maximum of 4,000 gallons, which would equate to 40 truckloads every day for a moderate-sized, 5,000-head dairy. To mitigate the transportation issue, centralized digestion requires that the manure slurry be concentrated at the dairy and then re-diluted at the digester.

Denmark has led the world in centralized anaerobic digestion, and other European countries have successfully implemented centralized digestion as well. Their success demonstrates that the logistics of manure transport can be overcome and that centralized digestion is technologically viable. Manure for these facilities is routinely hauled an average of 1 to 12 miles in vacuum tanker trucks with 3,000- to 8,000-gallon capacities.

1.2.3 Other Animal Wastes

Renderings, fats, and other wastes from animal finishing can also be used in a biomass-to-energy project. These wastes typically have value for refeeding or other applications. One potentially valuable use of these wastes is in the production of biodiesel. Biodiesel is typically manufactured by blending methanol (produced by anaerobic digestion or other technologies) with vegetable or corn oils. However, animal renderings can replace the oils. Threemile Canyon Farms, described in Section 4 of this report, is considering such a biodiesel production facility.

1.3 Municipal Solid Waste

Municipal solid waste (MSW) in not technically a biomass fuel, but because of its alternative nature and “waste” status, MSW is often included in biomass discussions and statistics. The organic portion of the MSW is a biomass fuel, but it is impossible to completely sort and filter MSW to obtain only organics.

MSW can be converted to energy in three different ways:

- Mass burn MSW combustion

- Processing of MSW into refuse-derived fuel (RDF), and combustion of the RDF
- Landfilling of MSW and collection and combustion of the landfill gas (LFG).

MSW- and RDF-fueled waste-to-energy facilities may not qualify for the same tax treatment or subsidies as true biomass-to-energy facilities. Waste-to-energy facilities that burn MSW or RDF typically have higher levels of emissions and ash compared with other pure biomass fuel combustion facilities, and permitting and public acceptance of these facilities can be more difficult.

RDF is created from MSW by sorting and processing to eliminate as much noncombustible material as possible, and thus RDF has a higher energy value than MSW and will produce less ash. To create RDF, the MSW is shredded, separated by density to remove heavy noncombustibles, magnetically filtered to remove small ferrous metals, screened to redirect oversized materials back for re-shredding, and screened to remove undersized materials. The RDF may be compacted for transportation. It takes about 1.27 tons of MSW to create 1 ton of RDF.

LFG is produced by decomposing MSW. The landfill actually serves as the biomass conversion facility. LFG contains between 30 and 55 percent methane, which is then flared or converted to electricity. Although conversion of LFG to electricity is gaining popularity because the source of the gas is free and flaring the gas is wasted energy, conversion of MSW to LFG has one of the lowest conversion efficiencies and one of the slowest conversion rates of all biomass technologies. In approximate numbers, 1 ton of MSW in a landfill will take 20 years of LFG recovery to produce just 40 percent of the energy that the same ton of MSW will produce in a matter of minutes through RDF combustion. One reason for the difference in the energy recovery is that some non-organic portions of the MSW, such as plastics, will release substantial amounts of energy when combusted as RDF, but will not break down into LFG.

One advantage of MSW as a fuel is that Yakima County already has control over this waste stream. Also, MSW can command high tipping fees. For MSW waste-to-energy projects, the revenues generated by the tipping fees will normally exceed the revenues from production of electricity or steam. Tipping fees for MSW waste-to-energy can run as high as $100 or $200 per ton, or higher. Yakima County landfills currently charge a comparatively low $24.05 per ton, which would limit the revenues an MSW biomass project could obtain through tipping fees.

Another benefit of using MSW is that this type of project would redirect waste bound for the landfill, and would thus extend the useful life of the landfill.

1.4 Heat Rates of Biomass Fuels

Biomass fuels have different energy densities and heat rates. The heat rate is a relative indication of how much energy can be released through combustion.

Table 1 provides some generally accepted average heat rates for biomass and other common fuels. Heat rates can vary widely depending on the actual chemical makeup of the fuel and moisture content.

Table 1
Average Heat Rates of Biomass Fuels and Other Common Fuels

Fuel	Typical Heat Rate
Solid Fuels	
Green Forestry Residues	4,500 BTU per pound
Mill Residue (hog fuel, typical)	5,500 BTU per pound
Mill Residue (sawdust, 6% moisture)	8,500 BTU per pound
Agricultural Residues (dry, 15% moisture)	7,500 BTU per pound
Dry Animal Manures	6,500 BTU per pound
Municipal Solid Waste (MSW)	4,500 BTU per pound
Refuse-Derived Fuels (RDF)	6,000 BTU per pound
Coal	*12,000 BTU per pound*
Fuel Oil	*19,000 BTU per pound*
Gaseous Fuels	
Landfill Gas (LFG)	490 BTU per cubic foot
Digester Gas (Biogas)	620 BTU per cubic foot
Natural Gas (typical)	*900 BTU per cubic foot*
Methane	*1,000 BTU per cubic foot*
Propane	*2,500 BTU per cubic foot*

Note: Fossil fuels are shown in italics on this table.

1.5 Biomass Fuel Summary

Table 2 summarizes the advantages and disadvantages of the biomass fuels discussed in this section. It also briefly describes evolving opportunities that may make particular fuels more attractive for biomass-to-energy projects in the future.

Table 2 Biomass Fuel Summary

Biomass Fuel	Benefits of this Fuel	Barriers to this Fuel	Evolving Opportunities
Forestry Residues	▪ Large quantities exist throughout the Pacific Northwest. ▪ Processing the residue in a biomass facility reduces environmental problems from typical disposal practices. ▪ Can be combined with other woody fuels.	▪ Yakima County has lower forestry residue density compared with other areas of the Pacific Northwest. ▪ Total in-forest collection and transportation costs are prohibitive compared with the energy value of the fuel. ▪ Significant seasonal and annual variations in fuel supply. ▪ General downturn in commercial timber operations has reduced amount of forestry residues.	▪ Increasing residue quantities due to wildfire prevention activities (National Fire Plan, etc.). ▪ Environmental restrictions may limit traditional in-forest stacking and burning of residues. ▪ USDA Forest Service and other forest managers may subsidize collection and transportation costs.
Mill Residues	▪ Collection and transportation costs typically already absorbed in mill operations. ▪ High quality fuel for combustion. Typically lower moisture content than forestry residues. ▪ Processing the residue in a biomass facility reduces a waste disposal problem. ▪ Can be combined with other woody fuels.	▪ Yakima County has far less mill residues compared with other areas of the Pacific Northwest. Could only be a supplemental fuel. ▪ All existing mill residues are already being consumed. Obtaining residues from the one existing mill in Yakima County is unlikely.	▪ Existing Boise Cascade plant in Yakima could provide opportunities for collaboration, County supported expansion, or collocation of an additional County-owned biomass facility.
Agricultural Residues	▪ Orchard, vineyard, and agriculture processing residues can be a low-cost or tipping fee fuel. ▪ Processing the residue in a biomass facility reduces a waste disposal problem. ▪ Can be combined with other woody fuels.	▪ Yakima County has less agricultural residues compared with other areas of the Pacific Northwest. ▪ Quantities not large enough to make this a primary fuel; could only be a supplemental fuel. ▪ Seasonal variations in fuel quantities.	▪ Tightening regulations may limit traditional open burn practices for field crops.
Urban Wood and Yard Wastes	▪ County already accepts "clean green" at landfills and owns this fuel. ▪ Tipping fee fuel. ▪ Processing the waste in a biomass facility reduces landfill dependence and increases public participation. ▪ Can be combined with other woody fuels.	▪ Currently used for landfill daily cover. ▪ Quantities not large enough to make this a primary fuel; supplemental fuel source only.	▪ Increasing public support of "clean green" programs. ▪ County could expand program and offer curb or container collection.
Dry Animal Manures	▪ Very large livestock and dairy industry in Yakima County. ▪ Stable year-round fuel supply. ▪ Processing the manure in a biomass facility reduces environmental issues from land-applied manures. ▪ Could be combined with other fuels (woody fuels, etc.) for composting or combustion technologies.	▪ Transportation of manure is problematic and costly, although dry manure is more easily transported than wet manure. ▪ Dry manure only used for composting or combustion, not anaerobic digestion; cannot obtain benefits of anaerobic digestion compared with wet manure. ▪ Dairies using flush systems (typical of large dairies and the trend in the industry) could participate only if they dried the manure; not an optimal solution for flush dairies. ▪ Fuel not currently under County control.	▪ Stricter environmental controls may limit traditional land-applied manure disposal activities. ▪ Dairy industry is growing in Yakima, and the County may become more involved with leading solutions to strengthen the dairy industry.

Table 2 Biomass Fuel Summary (continued)

Biomass Fuel	Benefits of this Fuel	Barriers to this Fuel	Evolving Opportunities
Wet Animal Waste (Dairy Manure Slurry)	▪ Large dairy industry in Yakima County. ▪ Stable year-round fuel supply. ▪ Anaerobic digestion significantly reduces dairy odors, water quality problems, and environmental issues.	▪ Continuous transport of large volumes of wet manure is problematic and costly. ▪ Dairies using anything other than free-stall barns and flush manure systems would not be able to participate. ▪ Low energy value. benefits of anaerobic digestion for dairy manure slurry are mostly environmental, not economic. ▪ Fuel not currently under County control.	▪ Stricter environmental controls may limit traditional land-applied manure disposal activities. ▪ Increasing public concerns over dairy odors may drive changes in manure handling and disposal. ▪ Trend toward large dairies makes centralized manure slurry digestion more attractive. ▪ Dairy industry is growing in Yakima, and the County may become more involved with leading solutions to strengthen the dairy industry.
▪ Municipal Solid Waste (MSW) ▪ Refuse-Derived Fuels (RDF)	▪ Stable year-round fuel supply. ▪ MSW already under County control. ▪ Avoided landfill costs. ▪ Tipping fees, and possible revenue generation from import of fuels from other urban areas.	▪ MSW and RDF are not true biomass fuels, and a project may not receive the same tax treatment, subsidies, or financing. ▪ RDF requires further sorting/processing of MSW; new waste sorting procedures would be needed. ▪ Most common technology is combustion, but MSW and RDF do not typically burn as cleanly as other biomass fuels. Public perception problems with MSW incineration. ▪ Tipping fees at Yakima County landfills may not be high enough to support a waste-to-energy project.	▪ Landfill reduction becomes more important as capacity is approached. ▪ Successful waste-to-energy projects are beginning to reduce public opposition.

Section 2
BIOMASS TECHNOLOGIES

Biomass facilities convert biomass into a useable and more valuable product. Although biomass conversion is most often associated with electrical power generation, many other energy and non-energy products can also be produced from biomass.

Non-energy products include compost, wood pellets, charcoal, and fiber. This report does not consider non-energy biomass conversion for several reasons. First, a composting or wood pellet processing would be in direct competition with existing private companies. Second, composting and wood pellet processing would be unlikely to provide the level of economic benefit or job creation that the County is seeking through biomass opportunities. And third, although charcoal manufacturing can be profitable, it is a very competitive business dominated by large and well established producers.

Biomass can also be converted into biofuels such as methanol, ethanol, and biodiesel. Production of biofuels requires a more advanced and costly biomass facility, but the biofuel has a significantly higher selling price compared with electricity, steam, and non-energy products. Biomass ethanol is traditionally produced through the hydrolysis of corn and other high-sugar or high-starch crops. Hydrolysis was not considered as a viable technology for Yakima County because of fuel availability and economics; however, the production of ethanol through gasification is discussed in this report.

Steam and electricity are the most common outputs associated with biomass-to-energy facilities. Combined heat and power (CHP) projects generate both steam and electricity as marketable products, and can achieve high efficiencies. CHP is typically more economically viable than electricity-only projects, but a CHP facility must be located directly adjacent to a large user of steam. An obstacle to an electricity-only biomass project is the low price of electricity in the Pacific Northwest.

The energy products described here can be created from biomass fuels through several types of technology. The rest of this section discusses three types of biomass-to-energy technology that might be feasible given the availability of fuel sources and potential customers for energy products in Yakima County. These are combustion, gasification, and anaerobic digestion.

2.1 Combustion

Combustion is the oldest technology for biomass conversion, especially for generating heat and steam from woody fuel. A biomass combustion facility can produce steam, electricity, or both (CHP). A boiler furnace burns the biomass to create steam. If electrical output is desired, a steam-turbine generator is used to convert a portion, or all, of the steam to electricity.

Combustion technology is typically the lowest-cost biomass-to-energy technology to construct and operate, especially for woody fuels. Combustion boilers can be designed to burn almost any type of biomass fuel, including dry manure and MSW. Fuels can be mixed to cope with diversity in the fuel supply or to provide optimum combustion performance. Table 1 in the previous section provides average combustion heat rates of different fuels, and Table 3 provides average costs of combustion technologies.

Ash is a waste product of biomass combustion. The amount of ash produced depends on the fuel (e.g., MSW combustion results in far more ash than combustion of mill residues). Ash represents a disposal cost for the biomass facility. Sometimes ash can be land-applied or mixed into compost, but most often it is landfilled.

The four common combustion boiler designs are: pile burners, stoker-fired furnaces, suspension-fired furnaces, and fluidized bed furnaces.

- **Pile Burners—**Pile burners or "Dutch ovens" are the oldest and simplest boiler design, but have low efficiencies and poor combustion control. The advantage of pile burners is a simple and low-cost design and fuel flexibility. Although many older pile burners are still in operation, they are not recommended for modern commercial-scale biomass-to-energy projects.
- **Stoker-Fired Furnaces—**Stoker-fired furnaces can have sloping fixed grates, traveling grates, or vibrating grates. Fixed sloping grates are the simplest design, but have the least amount of fuel control. Traveling grates provide an improvement in fuel control, but have higher maintenance due to the moving parts. Vibrating grates, sometimes called "reciprocating grates," are very common in modern biomass combustion facilities. Of all the stoker designs, vibrating grates can handle the greatest variations in fuel types and mixtures, fuel size, and moisture content. Stoker furnaces are a proven and tested technology for biomass combustion.
- **Suspension-fired Furnaces—**Suspension-fired furnaces inject finely pulverized fuel in a high-speed air stream for combustion. The fuel burns while suspended in the air stream. This technology is common for coal-fired boilers and achieves high efficiency, but processing biomass into the finely pulverized powder is difficult and costly. The fuel for suspension-fired furnaces typically must be smaller than a 1/4-inch particle size and have a moisture content less than 15 percent. Suspension firing of biomass is normally only feasible in special situations where sawdust or other ultra-dry wood waste is co-fired or used as a retrofit fuel in a coal-fired boiler.
- **Fluidized Bed Furnace—**Fluidized bed furnaces are the newest furnace technology, although the technology has been widely used for several decades. The furnace bed consists of particles of sand and limestone or other inert materials. These furnace bed materials are fluidized (suspended) by high-velocity high-temperature air, and the fuel is injected into the turbulent

mixture. Fluidized bed combustors can be classified as bubbling fluidized bed (BFB) or circulating fluidized bed (CFB), depending on the air velocity. CFB combustors operate at high enough air velocities that the bed material is carried out of the combustion chamber with the hot gases and must be circulated back into the combustion chamber through cyclone separators.

One advantage of fluidized bed furnaces in biomass combustion is the ability to handle a wide range of fuels and moisture content. Fluidized bed furnaces achieve the highest thermal conversion efficiencies of any boiler technology because of more complete combustion of the fuel. More complete combustion also results in lower emissions and ash quantities compared to other combustion process. However, fluidized bed systems are expensive to construct and have significant maintenance requirements. The combustion air fans and additional mechanical load of the fluidized bed process also means that the facility consumes a higher percentage of the energy produced compared to other boiler types, although this is typically compensated for by the higher energy recovery out of the fuel. When used for biomass combustion, some fluidized bed furnaces have had corrosion problems with high-alkali fuels such as agricultural wastes and animal manures.

In spite of the apparent advantages of fluidized bed furnaces, stoker furnaces dominate the biomass combustion industry. Stokers have a proven track record for biomass combustion, and the lower construction and maintenance costs offset the possible incremental gains from fluidized bed technology.

2.2 Gasification

Gasification is the thermo-chemical reduction of a fuel without direct combustion. Gasifiers operate at high temperatures and pressures in an oxygen-depleted environment to convert a feedstock to a combustible gas.

The immediate product of gasification is synthetic gas, or “syngas.” Syngas consists of carbon monoxide and hydrogen, with smaller amounts of carbon dioxide and methane. Syngas will contain other compounds, such as sulfur and nitrogen, depending on the chemical makeup of the fuel. Raw syngas is not an end product, but requires further processing. Syngas can be burned to create heat, steam, or electricity. It can be converted to methane and fed into a natural gas distribution system. Syngas can also be converted to methanol, ethanol, and other chemicals or liquid fuels. Methanol produced through gasification can be further refined into biodiesel with addition of vegetable oils or animal fats. Slag is produced as a waste product of the gasification project. This is similar to the bottom ash produced by combustion, but gasification slag is denser and has a more “glassy” consistency compared with combustion ash.

Gasification is not limited to biomass fuels. Coal and other hydrocarbon fuels can be gasified, as can tires and refuse fuels. Almost any material can be “gasified” under the correct conditions. Historically, gasification has been part of the chemical and petroleum processing industry, and gasification has been used mostly in the production of chemicals.

The biomass gasification opportunities most often cited are fueled by forestry residues, agricultural residues, and MSW. Although low-efficiency and small-scale gasification of wood chips has been performed for decades, large-scale biomass gasification technology is still in the development and demonstration stage. Several small biomass gasification research and demonstration projects currently operate. Section 4 of this report describes a facility planned for La Grande, Oregon that would be one of the first commercial-scale biomass gasification projects.

The two most prevalent technologies for commercial-scale gasification are fluidized bed reactors and plasma arc reactors. Fluidized bed reactors operate on the same principles as fluidized bed combustors, but are controlled so that the fuel only gasifies and is not allowed to combust. Plasma arc reactors have been used to incinerate MSW and hazardous or medical wastes. Both technologies provide very high energy conversion rates. The choice of fluidized bed vs. plasma arc technology would depend on the fuel and application.

Gasification is receiving significant attention in both the biomass-to-energy and traditional fossil energy industries. In the fossil energy industry, gasification allows electrical generation from “dirty” fuels like coal to achieve emission levels similar to those of “clean” natural gas power plants. In the biomass-to-energy industry, gasification allows production of higher-value products such as methanol and ethanol.

The following paragraphs describe some of the emerging applications of gasification that may be appropriate for Yakima County.

- **Electrical Generation**—For generating electricity, integrated gasification combined cycle (IGCC) technology provides exceptionally high conversion rates. IGCC will generate the most electrical power per unit of biomass of any currently available technology. IGCC uses a combustion turbine fueled by syngas, with hot exhaust from the combustion turbine directed through a heat recovery steam generator (HRSG) to drive a secondary steam turbine. This combined cycle process is the same technology used for modern natural-gas-fired generating stations. IGCC is applicable to both fossil fuel gasification and biomass gasification.
- **Biomass-Ethanol**—Biomass-ethanol has traditionally been manufactured through hydrolysis of starchy agricultural feedstocks such as corn. Advanced technologies are being developed to produce ethanol through direct fermentation of syngas into ethanol. This technology advancement may make it viable to produce ethanol from low-sugar-content feedstocks such as forestry residues.

Gasification is an expensive technology to design, construct, operate, and maintain. Gasification facilities require considerable preparation and drying of biomass fuels, and also require substantial heat input into the gasifier unit itself. Studies have indicated that biomass gasification facilities, especially ethanol production facilities, benefit from economies of scale and need to be quite large to be viable. Although the

IGCC efficiency is attractive and ethanol production from syngas is promising, currently gasification faces significant economic and technological barriers.

2.3 Anaerobic Digestion

Anaerobic digestion is a process that uses bacteria to break down biomass in an oxygen-free environment. Anaerobic digestion is common in wastewater treatment and industrial waste processing, and can also be effective in treating animal manures and wastes. It is an especially effective way to process dairy manure slurry.

Anaerobic digestion produces biogas, sometimes called "digester gas," a mixture of mostly methane and carbon dioxide. The biogas can be flared, used to generate heat or electricity, or can be converted into biofuels such as methanol. The most common application is to use the biogas to power an internal combustion engine generator to produce electricity. Exhaust heat from the engine can be circulated back into the digester to increase the rate of biogas production.

Anaerobic digestion of dairy manure has many environmental benefits. In fact, the value of energy production is typically a secondary consideration compared with the environmental benefits. Digestion significantly reduces odors and flies, and reduces pathogens. The effluent of digestion is relatively clean and can be used for irrigation or dairy stall flushing with fewer environmental and health concerns compared with typical flush waters. Digestion also produces a high-quality fiber, which can be used for livestock bedding, compost, or soil enhancement as a rich fertilizer. This fiber has a marketable value, and in some digestion demonstration projects, the sale of fiber has generated as much revenue for the dairy as has the sale of electricity.

Anaerobic digestion of dairy manure is widely practiced in Europe because of stricter environmental regulations, lack of available farmland for disposal of manure, high energy costs, and proximity of urban populations to livestock and dairy operations (and thus greater odor and fly control concerns). Anaerobic digestion has been slower to gain acceptance in the North American dairy industry, but the barriers are economic rather than technical. Most industry experts agree that the development of dairy waste anaerobic digestion in North America will be driven by tightening environmental restrictions on manure handling and disposal rather than profit from selling electricity.

Many different types of anaerobic digestion systems are used to process industrial and other wastes. For dairy industry wastes, the three most common digesters are the covered lagoon, plug-flow, and complete mix. Covered lagoon and plug-flow systems are low-rate digesters, and are only applicable as integrated systems on individual dairies. Complete mix systems achieve faster conversion rates. There are several sub-categories of complete mix systems, which are defined by the number of stages, bacteria films, and operating temperatures.

Construction of a dairy manure digester represents a significant investment for an individual dairy farmer, and so far, no dairy in Yakima County has built such a project. However, a large-scale centralized digester processing the wastes from multiple dairies across Yakima County could possibly achieve economies of scale not available to the individual farms.

For a centralized dairy manure digester project, manure slurry would be transported by truck from the dairies to the digester. As mentioned previously in Section 1.2, the cost and logistics of transporting large quantities of manure has been prohibitive to centralized anaerobic digestion in the United States. It might be possible to locate the digester such that one or two dairies could pipe their manure rather than using trucks. The dairy operators would also need to be able to transport the processed effluent from the digester back to their dairies to offset the amount of fresh water required for the flush systems.

A centralized dairy manure digester would need to achieve high throughput rates and biogas production to be cost effective. Also, the facility would be rather large, as the volume of manure slurry is significant. Assuming 25 percent of the milking cow manure in Yakima County was transported to the digester on a daily basis, the influent to the project would be on the order of 550,000 gallons per day. Assuming a digestion process with a relatively fast 20-day average retention time, the anaerobic digestion system would need a capacity of 11.0 million gallons of manure slurry. For comparison, the three anaerobic digesters at the Yakima Regional Wastewater Treatment Facility hold a combined 1.6 million gallons of wastewater sludge.

Anaerobic digestion produces very small amounts of energy compared with other opportunities such as the combustion of woody fuels. As previously mentioned, the real benefit and motivation of digestion is the mitigation of a waste problem, not production of energy. Even at the large scale of 550,000 gallons per day, the anaerobic digester would only produce about 3 to 4 MW of electricity.

Energy Northwest has been analyzing the financial feasibility of large- and small-scale dairy waste digestion, and their analysis has indicated that to break even, a digester project would need to sell power at a wholesale rate of about $0.070 per kWh. Traditionally, the wholesale electricity rates for Washington State have been about $0.020 to $0.025 per kWh at the Mid-Columbia hub.[3] Duke Energy also undertook a major study in the mid-1990s, and calculated that a digester would need to collect tipping fees of at least $6 per ton to break even.[4]

An anaerobic digester project would not be economically successful based solely on the sale of electricity or steam. Sale of fiber would help to supplement the revenue of the facility, but the real economic balance would need to come from tipping fees charged to the manure suppliers.

2.4 Biomass Technology Energy Output and Costs

Table 3 provides typical statistics for biomass-to-electricity projects. The three combustion projects and the one gasification project are set to identical outputs of 25 MW. The gasification project requires about 10 percent less fuel to reach the same output because of the high efficiency of IGCC technology; however, the capital and operating costs for this technology are significantly higher. The MSW-fueled project

[3] Stan Davison and Steve Willman, Energy Northwest. Personal communication. June 24, 2003.
[4] Ivan White, Sunnyside, Inc. Personal communication. July 14, 2003.

has the highest capital and maintenance cost of all, but these high costs would be offset through tipping fees.

The most striking comparison is between the first four projects and the anaerobic digestion project. Anaerobic digestion requires over three times the amount of fuel by weight, but produces only about one-eighth the electrical output. The capital cost of the digester is similar to that of the gasification project on a per-kilowatt basis, but the operating cost is even higher.

Table 3
Energy Output and Costs of Selected Biomass-to-Energy Technologies

Technology	Fuel Type and Volume	Electrical Output	Capital Cost	Operating Costs
Stoker Furnace Combustion	Woody Fuels at 40.4% moisture 270,000 tons per year	25.0 MW Net 27.9 MW Gross	\$70.1 million (\$2,800/kW)	\$2.9 million/yr (\$0.014/kWh)
Fluidized Bed Combustion (CFB)	Woody Fuels at 40.4% moisture 269,000 tons per year	25.0 MW Net 28.3 MW Gross	\$82.2 million (\$3,300/kW)	\$3.2 million/yr (\$0.015/kWh)
Gasification (IGCC)	Woody Fuels at 40.4% moisture 240,000 tons per year	25.0 MW Net 27.9 MW Gross	\$114.5 million (\$4,600/kW)	\$5.2 million/yr (\$0.024/kWh)
Stoker Furnace Combustion	Municipal Solid Waste (MSW) 294,000 tons per year	25.0 MW Net 28.4 MW Gross	\$142.4 million (\$5,700/kW)	\$13.9 million/yr (\$0.068/kWh)
Anaerobic Digestion	Dairy Manure Slurry at 6% solids 20,000 milking cows 852,000 tons per year	3.0 MW Net 4.0 MW Gross	\$17.8 million (\$4,500/kW)	\$1.3 million/yr (\$0.036/kWh)

Notes: a. Stoker, CFB, and IGCC statistics from "Northwest Power Planning Council Biomass Briefing Paper" based on 1995 costs.
b. Digestion statistics based on "Dairy Waste Anaerobic Digestion Handbook" estimates for U.S. and European digesters, 2001.
c. Operating costs are for annual operations and maintenance and do not include the cost of fuel.

2.5 Biomass Technology Summary

Table 4 describes each technology in terms of its feedstocks and products and describes the status of the technology. The table then lists considerations related to implementing each technology in Yakima County.

Table 4 Biomass Technology Summary

Technology	Typical Fuels	Products	Status of Technology	Considerations
Combustion	▪ Woody Fuels (all) ▪ Dry Animal Manures ▪ Municipal Solid Waste (MSW) and Refuse-Derived Fuels (RDF)	▪ Steam ▪ Electricity	▪ Proven and reliable technologies. ▪ Stoker boilers are the most common technology, with proven performance record. ▪ Fluidized bed technology has been used, but is more costly and does not yet have the track record of stokers.	▪ Washington State's electricity prices are among the lowest in the nation. ▪ Selling steam is only an option if the facility is located adjacent to a major steam user. ▪ Combustion wastes include bottom ash and fly ash. Woody fuels have lowest ash production; MSW has highest.
Gasification	▪ Forestry Residues	▪ Electricity ▪ Ethanol	▪ No commercial-scale wood gasification plants in operation. Some have been proposed or are under development. ▪ Production of electricity through Integrated Gasifier Combined Cycle (IGCC) is one of the highest efficiency technologies available. ▪ Ethanol production through wood gasification is still in the demonstration stage.	▪ Washington's electricity prices are among the lowest in the nation. ▪ Facility must be large in order to be economically viable. ▪ Relatively expensive technology. ▪ Ethanol has a higher price than electricity, but production requires additional processes. ▪ Ethanol production by hydrolysis from dedicated corn crops is typically more economically viable than gasification of woody residues. ▪ Gasification wastes include gasifier slag, and minimal fly ash and emissions. Air emissions are similar to state-of-the-art natural gas fired power generation.
Anaerobic Digestion	▪ Dairy Manure Slurry	▪ Steam ▪ Electricity ▪ Methanol or Biodiesel ▪ Fiber	▪ Proven technology and widely accepted in Europe. Barriers in the North American market have been economic, not technical. ▪ Production of methanol and biodiesel are developing technologies.	▪ Washington State's electricity prices are among the lowest in the nation. ▪ Selling steam is only an option if the facility is located adjacent to a major steam user. ▪ Low rate of energy production relative to volume of fuel required. ▪ Facility must be large in order to be economically viable. ▪ Greatest value of digestion is in the environmental benefit and benefit to dairy operations, not energy production. ▪ Transportation of large quantities of manure slurries may be difficult. ▪ Fiber byproduct has significant commercial value.

Section 3
PROJECT PROFILES

This section provides information and statistics on six biomass-to-energy projects. The projects selected for this section were chosen because of their similarity to a potential Yakima County project in terms of fuel, technology, and scale.

The six projects are:

- Biomass One, Oregon
- Tacoma Steam Plant No. 2, Washington
- Mesquite Lake Resource Recovery Project, California
- SEDI Bioenergy Refinery, Oregon
- Threemile Canyon Farms, Oregon
- Spokane Waste-to-Energy Facility, Washington

This sample of biomass-to-energy facilities is not intended to be inclusive of all the projects in the Pacific Northwest that are currently operating or planned. The projects selected are large regional facilities. Two of the facilities are owned by city governments, but none are owned by electric utilities (the Tacoma Steam Plant was originally constructed by the City's electric utility, but is now owned by the City's solid waste department).

These six projects cover a full spectrum of biomass fuel and technology, and provide a representative sampling of the opportunities and barriers that have been experienced under circumstances similar to Yakima County. The six projects have the following characteristics:

- **Fuels**—Woody fuels (including forestry residues), dry animal manure, wet dairy manure, MSW, and RDF.
- **Technology**—Stoker-fired combustion, fluidized bed combustion, gasification, and anaerobic digestion.
- **Location**—Two in Washington, three in Oregon, and one in southern California. The California project was included, even though it is out of the immediate region, because it was dedicated to combusting dry animal manure.
- **Status**—Two projects have sustained successful operations for over 10 years, two projects were unsuccessful and have temporarily stopped operations (the facilities have been mothballed), and two projects are in the planning and development stage.

3.1 Project Profile 1: Biomass One

Technology:	Combustion (Vibrating Stoker Boiler, Steam Turbine Generator)
Fuels:	Woody Fuels (primarily mill residues)
Products:	Steam, Electricity
Capacity:	355,000 green tons per year (220,000 BDT per year)
Location:	White City, Oregon
Cost:	$50 million
Status:	Commercial operation since 1981

Biomass One is a privately owned facility that burns woody fuels in a stoker boiler to generate steam and electricity. The project has had a successful track record since its initial operation in 1981, with only one major shutdown to replace a problematic wet scrubber emission control system with an electrostatic precipitator.

Biomass One receives over 80 percent of its fuel from 70 to 75 primary suppliers across southwest Oregon. Local and regional mill residues account for about 50 percent of the fuel supply. Fifteen to twenty percent of the fuel supply comes from public drop-off at the site. The facility also burns 800 to 1,000 acres of pear orchard turnings per year. Biomass One picks up construction wood wastes from landfills in five counties in southwest Oregon and northern California. The landfills provide the sorting and filtering of the wood wastes. The facility burns a total of 355,000 green tons (GT) per year at an average moisture content of 38 percent.

Biomass One hauls about 25 percent of its fuel, and the rest is delivered to the site by the fuel suppliers. For fuels that Biomass One purchases, such as mill residues, every load is sampled for moisture content and the payment is based on bone dry tone (BDT) equivalent. A $5- to $50-per-load tipping fee is charged for public drop-off of yard and wood wastes, but this fee is substantially less than local landfill fees. Biomass One also has a program for curbside delivery and collection of 35-cubic-yard bins for construction residues and urban wood wastes, again at costs significantly lower than landfill-destined garbage bins.

For orchard residues, Biomass One will provide a tub grinder and haul the chips, and the orchard performs all clearing and delivery to the tub grinder location. Biomass One also provides a tub grinder and hauling for forestry residues, with the forest management agency responsible for in-forest collection and staging of residues at the grinder. Biomass One has obtained forestry residues in this manner from private land owners and forest managers, but so far, the USDA Forest Service and the Bureau of Land Management have not been significant suppliers.

The average fuel cost for Biomass One is around $20 to $22 per BDT including the net cost of transportation and equipment provided by Biomass One as well as offsetting factors such as tipping fees, bin rentals, and sales of decorative bark and wood chips.

Biomass One employs 64 people. Only 16 people are required for the power plant, and the remaining staff work in the wood waste yard and collection/transportation.

The plant is rated for 25 MW of electrical generation, and achieves an annual net production average of 22 average MW (aMW). The electricity is sold under contract to Pacific Power (the local electric utility).

Biomass One is a cogeneration facility, and sells about 35 million pounds of steam per year to an adjacent plywood mill. The revenue from the sale of steam is fairly minimal, only 1 to 2 percent compared with the revenue from electricity. However, the steam is low-pressure residual steam off of the turbine generator. The price paid for steam per BTU is set at approximately 80 percent of the cost per BTU of natural gas.

3.2 Project Profile 2: Tacoma Steam Plant No. 2

Technology:	Combustion (Fluidized Bed Boiler, Steam Turbine Generator)
Fuels:	Woody Fuels, RDF, Coal
Products:	Steam, Electricity
Capacity:	175,000 green tons per year (wood) 60 tons per year (RDF) 40 tons per year (coal)
Location:	Tacoma, Washington
Cost:	$45 million (1991) repowering of original 1931 coal-fired plant
Status:	Temporarily shut down since December 2001

The Tacoma Steam Plant was originally constructed in 1931 as a coal-fired plant. Several modifications and fuel changes have occurred throughout its troubled history. The plant first began co-firing biomass fuels with coal in 1991 after a $45 million repowering project to install bubbling fluidized bed (BFB) combustors.

Although the plant has a design capacity of 50 MW, even during the period of highest activity for the plant (1994–1997) it was only able to sustain an average output of just 11 MW to 13 MW due to technical issues, operating permit limitations, and maintenance and reliability constraints. The plant achieved best financial performance on a fuel mixture of approximately 75% wood, 20% RDF, and 5% coal (by weight).

Waste wood was the preferred fuel for the plant due to best combustion performance, minimal maintenance, and minimal emissions. Initially the steam plant purchased prepared (chipped) wood fuels from 100 authorized suppliers through a spot market. Because the woody fuel was delivered to the facility in conformance with City's technical fuel specification, the City did no wood fuel processing on site. Average cost of the delivered woody fuel was about $8 per green ton. In an effort to decrease the cost of its wood fuel supply, the plant later began accepting unprocessed urban wood and yard wastes from the public at tipping fees of $15 to $25 per ton. The tipping fee was about half the rate charged by other wood waste processing yards, but more than covered the estimated $5 to $15 per ton that on-site processing cost the City. Accepting unprocessed public wood wastes dropped the City's overall average wood fuel cost to a very low $2.50 per green ton.

RDF was provided to the steam plant by the City's refuse utility. Although the steam plant was not able to collect a tipping fee from the refuse utility for accepting the RDF, the refuse utility provided all sorting and processing of the raw municipal solid waste and delivered a combustible-ready RDF to the steam plant. The steam plant limited combustion of RDF to 30 percent of the total fuel by weight in order to maintain its status as a co-fired facility and avoid classification as a municipal waste combustor.

When operational, the plant required a staff of 21 to 22 employees.

Although the repowering of the Tacoma Steam Plant as a co-fired facility was hailed by the industry, even receiving *Power Magazine*'s 1991 Power Plant Award, the plant was not able to operate profitably. In spite of relatively low fuel costs, the plant could not break even due to the low prices paid to the plant for steam and electricity, the high operation and maintenance costs, and low heat rates (efficiency) of the repowered facility. The City operated the plant at an estimated loss of $3 million per year. The total impact of the loss was partially offset by a savings to the City's refuse utility in avoided landfill costs of about $1 million per year.

The City believes that the steam plant could become economically viable if it were allowed to combust fuels that would command a high tipping fee, such as industrial wastes, asphalt shingles, oil sludges, or laminates. Although the City believes that the fluidized bed combustors and existing emission controls could successfully combust these types of materials without substantial changes, the City has not been able to obtain the necessary permits.

3.3 Project Profile 3: Mesquite Lake Resource Recovery Project

Technology: Combustion (Fluidized Bed Boiler, Steam Turbine Generator)

Fuels: Dry Cattle Manure

Products: Electricity

Capacity: 350,000 tons per year

Location: El Centro, California

Cost: $53 million (1988) plus $22 million upgrade (1992)

Status: Temporarily shut down since December 1994

The Mesquite Lake project was designed to burn dry cattle manure in a bubbling fluidized bed combustor. The facility could incinerate 1,000 to 1,250 tons of manure per day and generated 18 MW of electricity. The manure was typically dry and aged manure at less than 30 percent moisture content, scraped from beef cattle feedlots and dairies. The manure came from as far as 170 miles away, including import from Mexico. The Mesquite Lake project could store 100,000 tons of manure fuel on-site.

Mesquite Lake initially paid $1 per ton for the manure delivered to its site, but this quickly changed to a $1 per ton tipping fee as the project struggled to be economically feasible. The project operators believe the avoided cost to feedlots and dairies for other manure disposal options was on the order of $6 per ton, and thus the tipping fees should have been even higher.

The Mesquite Lake project encountered numerous technical problems and equipment failures almost from day one. Fouling and corrosion problems were severe, and incomplete combustion caused the plant to exceed its carbon monoxide emissions permit. The plant shut down for major repairs and adjustments in 1990 after just two years of below-capacity operation. In 1992 the plant was shut down again and sold to a new owner who invested an additional $22 million in significant modifications and repairs to the 4-year-old plant. In spite of this, the plant continued to experience problems with boiler fouling and ash handling. Part of the problem was attributed to manure that had become rain-soaked and contaminated with mud during an exceptionally wet winter. The Mesquite Lake facility ceased operations in December 1994.

In June 2002, the idle Mesquite Lake project was purchased by Chateau Energy Group, who intended to abandon cattle manure in favor of combusting tires, which would command significant tipping fees. However, a subsequent change in California regulations eliminated tire combustion as a qualifying technology for important state classifications. Chateau Energy Group is now looking to install a plasma arc gasifier for the thermal conversion of tires to energy. The new technology would process 9 million to 10 million tires per year and generate 35 MW of electricity. Construction is planned to begin in 2004, with commissioning in 2005.

3.4 Project Profile 4: SEDI Bioenergy Refinery

Technology: Gasification (Fermentation and Combustion Turbine)

Fuels: Forestry Residues

Products: Ethanol, Electricity

Capacity: 300,000 green tons per year

Location: La Grande, Oregon

Cost: $100 million

Status: Under development

The SEDI (Sustainable Energy Development, Inc.) Bioenergy Refinery is a cutting-edge project in La Grande, Oregon that will convert forestry residues to ethanol and electricity. The facility will produce 15 million to 20 million gallons of ethanol per year and generate 15 to 20 MW of electrical power. The chosen technology is gasification with direct fermentation of the syngas to ethanol, and combustion turbine electricity generation. The gasifier will be a fluidized bed reactor.

This facility, if constructed, will be a major milestone in the biomass-to-energy industry. Right now, the only operating wood-to-ethanol gasification projects are small research and demonstration units. Similar projects have been proposed, but the SEDI Bioenergy Refinery has obtained a 60-acre site and could be one of the first in the world to attempt commercial-scale, for-profit operation.

The developers are working to secure financing, obtain permits, and negotiate fuel supply contracts with the USDA Forest Service, Oregon Department of Forestry, and private contractors. They are also in the process of negotiating electricity sales contracts with the Bonneville Power Administration (BPA) and Oregon Trail Electric Consumers Cooperative, and negotiating ethanol sales contracts with a national ethanol marketing company.

The Forest Service strongly favored a northeast Oregon location for the facility because much of the public and private forestlands in the area, including Wallowa-Whitman National Forest, have been devastated by Pine Shoot Beetle infestation, disease, and drought. The SEDI Bioenergy Refinery would support additional forest thinning activities through creation of a local market for the low-value, small-diameter timber and dead wood that is a serious wildfire concern for the Forest Service.

Although the SEDI Bioenergy Refinery would accept public drop-off of wood wastes through a tipping fee, the majority of its fuel would be purchased from forest managers at an estimated rate of $10 to $20 per delivered ton. The developer anticipates that purchased fuel would most likely be local, as transportation distances greater than 60 miles would become cost prohibitive to the supplier relative to the purchase price.

Once operational, the facility would employ between 50 and 75 workers. The SEDI project estimates that collecting the 300,000 green tons per year of woody fuels for the facility would require about 200 workers in the forests, earning $6 million to $8 million per year. The price paid by SEDI for the forestry residues does not fully balance the labor and other fuel supply costs (transportation, equipment, etc.), but would offset the costs of forest management normally borne entirely by the Forest Service and other agencies.

3.5 Project Profile 5: Threemile Canyon Farms

Technology:	Anaerobic Digestion
Fuels:	Dairy Industry Waste (Wet Manure Slurry)
Products:	Electricity or Biodiesel, Fiber
Location:	Boardman, Oregon
Capacity:	20,000 milking cows
Cost:	$15–$20 million
Status:	Under development

Threemile Canyon Farms is the largest dairy operation in Oregon. The dairy covers 93,000 acres near Boardman, and manages approximately 50,000 head of milking cows, heifer replacements, fat cattle, and steers. The dairy is developing an anaerobic digestion system to process the manure from its 20,000 milking cows.

The dairy's milking cows are housed in free-stall barns, and the manure is managed through a flush-type system. The milking cows generate about 250,000 gallons per day of manure, with a solids concentration of 12 percent. The dairy operates three milking cycles per day, and the manure flushes accompanying each milking cycle add 2 million to 3 million gallons of water to the raw manure each day. After the initial flush water separation, about 500,000 gallons per day of manure slurry remains with a 6 percent solids concentration. Currently the farm disposes of the manure through land-application on 35,000 to 40,000 acres.

Threemile Canyon Farms is pursuing development of the anaerobic digester primarily as a proactive approach to addressing a trend of tightening environmental restrictions. Although the farm intends for the project to be economically self-sustaining, any revenue generated by the project is secondary to the benefits of improved manure processing and disposal.

The specific design for the anaerobic digester system for Threemile Canyon is a "contact stabilization" system. Contact stabilization is a two-reactor (two-tank) process that achieves a higher throughput rate than a standard single-tank digester by using a fixed-film contact reactor to quickly digest liquid manure, and a second mixed suspended-film stabilization reactor to digest manure that has a higher solids concentration and takes longer to break down. The contact reactor achieves a 6- to 8-day detention period, while the higher concentration slurries in the stabilization reactor maintain a more traditional 20- to 30-day detention period. The estimated biogas production rate for the Threemile Canyon Farms project is 1.2 million cubic feet per day at a minimum, and possibly much more than that.

Portland General Electric (PGE) was the original developer for the project, which would have produced a 3.3 to 4.0 MW of electrical power by running reciprocating engine generators on the biogas. However, PGE has relinquished its "developer" role on several alternative energy projects in Oregon, including this Threemile Canyon Farms project, and the farm has determined that the forecasted prices of electricity are too low to recover the capital cost of the project. The farm is now is now pursuing the project on its own without any direct involvement from PGE (other than PGE's remaining interest to purchase electrical output), and is considering production of biodiesel rather than electricity. Although more costly to produce, the biodiesel would earn a much higher price than electricity.

Threemile Canyon Farms would produce the biodiesel from methanol derived from the digester biogas and animal renderings (instead of vegetable oils). Threemile Canyon Farms does not produce a large enough volume of renderings from its own operations to balance against the volume of methanol generated by the dairy manure digestion, and would need to import renderings. However, the farm believes that animal byproducts and renderings will be very easily obtained due to restrictions and reduction of the traditional practice of refeeding animal byproducts to livestock.

In addition to either electricity or biodiesel, Threemile Canyon Farms will use the fiber byproduct of the digestion process as bedding for its cattle, and will bag and sell the fiber. Estimated sales of fiber are significant in the overall economic model of the project.

The estimated costs of the project are $15 million to $16 million, not including significant indirect costs incurred by PGE and Threemile Canyon Farms in the development of the project. This estimated cost is for the original plan of electricity generation; additional equipment needed for the production of biodiesel will add another $3 million to $4 million to the project.

The digester equipment and its electrical generators, or biodiesel refinery equipment, will occupy about 16.5 acres. Because all of the manure will be piped, the site is considerably smaller than would be required for a similar-scale operation that also needed space for truck scales and tipping.

Due to automation and piping systems (rather than trucks), operation of the facility will not require a significant staff. The labor hours required for operation and maintenance of the biomass project will be insignificant compared to the labor hours already required for manure handling within the free-stall barns and milking parlors.

3.6 Project Profile 6: Spokane Waste-to-Energy Facility

Technology:	Combustion (Vibrating Stoker Boiler, Steam Turbine Generator)
Fuels:	Municipal Solid Wastes (MSW)
Products:	Electricity
Capacity:	300,000 tons per year
Location:	Spokane, Washington
Cost:	$110 million
Status:	Commercial operation since 1991

The Spokane Waste-to-Energy Facility incinerates unprocessed municipal solid wastes from the greater Spokane area to generate 26 MW of electrical power. The 22 MW of net power (after plant loads) is sold under a 20-year contract to Puget Sound Energy.

The facility has two 400-ton-per-day capacity boilers that supply a single steam turbine generator. The MSW storage building can hold 5,000 tons of fuel. The facility charges a tipping fee of $98 per ton of general MSW, or $165 per ton for specialty incineration.

The plant has had an exemplary operating and financial record. The facility is operated under a 20-year design-build-operate-maintain contract to a private company, and has a guaranteed capacity of 248,200 tons per year (85 percent). The plant consistently exceeds this rate (268,390 tons in 2001).

Ferrous metals are separated out of the ash and recycled. The combustion of 400 tons of MSW generates about 125 tons of ash and 10 tons of recovered metals. The ash is transported in specially designed container truck to a rail hub, and then by rail to the Klickitat County landfill.

The project cost $110 million to construct and is the largest capital project ever undertaken by the City of Spokane. The Spokane Waste-to-Energy facility occupies 52 acres, and employees about 47 workers.

3.7 Other Projects

Here are some other examples of biomass projects currently operating in the state:

- **Boise Cascade—**The Boise Cascade plywood plant in Yakima, previously mentioned in Section 1.1, is the only significant biomass-to-energy facility in Yakima County, and is the eighth-largest waste wood combustion facility (by volume) in Washington State. The facility burns its plywood manufacturing waste in a stoker boiler to generate steam for the plywood kilns and dryers; it does not produce electricity. The biomass boilers are integrated components of Boise Cascade's operation; they provide economical waste disposal and offset energy purchases that the facility would otherwise need to make.

- **Kettle Falls Station—**The Kettle Falls Station in northeastern Washington is another important biomass facility in the region, and was previously discussed in Section 1.1. The Kettle Falls Station was not included in the project profiles because the Biomass One facility in Oregon provides a similar technology but with a better match to Yakima County fuel resources. The Kettle Falls Station is owned by an electric utility, and this facility is about twice as large as the resources in Yakima County could support. The Kettle Falls Station also has a unique location with a local mill industry that far exceeds Yakima County's mill industry. Although Biomass One also depends significantly on mill residues, it burns other woody fuels as well. Nevertheless, the Kettle Falls Station is a very successful biomass-to-energy facility with a proven track record.
- **Simmons Densified Fuels—**Simmons Densified Fuels in Yakima is a non-energy biomass facility. The company processes sawdust and wood shavings into wood pellets at the average rate of 6,000 tons per year. The facility has a maximum capacity for 30,000 tons per year.

Washington State University compiled a directory of biomass-to-energy facilities in the state since 1987. The current directory was published in 2001, and provides a fairly comprehensive listing of facilities and basic data based on voluntary survey responses. Refer to "2000 Washington State Directory of Biomass Energy Facilities" in the appendix.

Section 4
CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Biomass Fuels

- Biomass fuels have low energy densities and typically cannot be transported over 50 miles before the cost of the transportation exceeds the value of the fuel.
- The cost of collecting and transporting biomass fuel is significant, and who pays the cost is critical to a project's financial feasibility.
- Unless a fuel source is very stable and can be guaranteed, biomass-to-energy facilities need be flexible in their ability to use a variety of fuels from a variety of sources and suppliers. Combustion technology allows more fuel variety than does anaerobic digestion or gasification.
- Yakima County may have sufficient woody fuel quantities for a biomass project, but Yakima County is not the optimal geographic location for such a facility. From a regional perspective, other locations throughout the Pacific Northwest have access to greater volumes of woody fuels at lower costs.
- The dairy industry of Yakima County produces enough manure to feed a large-scale centralized anaerobic digester. Wet manure from flush-type manure management systems is best suited for centralized biomass conversion.
- MSW combustion in Yakima County does not appear to be viable at this time. Revenue from combustion of MSW is primarily through tipping fees, and to be economically viable, a facility would need to collect garbage tipping fees approximately four times higher than current Yakima County landfill fees.

Biomass Technology

- Steam may be a better product from biomass-to-energy than electricity, as electricity prices in the Pacific Northwest are very low. Steam is produced at higher efficiency than electricity, and can be sold to users to offset natural gas consumption.
- To be able to sell steam, the biomass-to-energy facility needs to be located directly adjacent to the steam user. Potential steam users within Yakima County include Boise Cascade in Yakima, Darigold Dairy Fair in Sunnyside, Tree Top, Inc. of Selah, and possibly other industrial, large agricultural, or large commercial operations.

- Stoker-fired furnaces are the predominant technology for biomass combustion. Stokers have a long track record of proven performance, and have lower capital cost and operational expense compared with fluidized bed technologies.
- Forestry residues and other woody wastes are ideal fuels for stoker combustion, but a stoker can be designed to accommodate other dry biomass fuels as well.
- Anaerobic digestion of dairy manure has substantial environmental benefits; however, it may be difficult to transfer the environmental benefits into revenue for the biomass-to-energy facility. The rate of energy production from anaerobic digestion is low, and thus a digester must have additional revenue sources (such as tax credits, subsidies, or tipping fees) to achieve economic feasibility.
- Biomass gasification and the production of biofuels (ethanol, methanol, and biodiesel) do not appear to be viable at this time. The technologies are promising and in the future may present an opportunity to convert biomass to products with higher prices than electricity and steam. Currently, however, the technological and economic barriers are significant.

4.2 Recommended Opportunities

Based on the research of this report and the summary points listed above, two options appear to be most viable for a Yakima County centralized biomass biomass-to-energy facility.

4.2.1 Opportunity 1: Stoker Combustion of Woody Fuels

- Forestry residues as a primary fuel. Supplemental fuels of any available mill residues, agricultural residues, urban wood, yard wastes, and dry animal manures.
- This technology is the most widely developed and proven, and has a high energy conversion rate.
- Obtaining stable fuel supply quantities and prices will be critical.

Location Considerations:

- Logical location would be closer to the heavily forested western part of the County in order to minimize transportation costs of the forestry residue primary fuel.
- A location convenient to population centers would encourage a supplemental fuel supply of urban wood and yard waste from the public and generate tipping fee revenues for the project.
- A site adjacent to a steam user such as Boise Cascade in Yakima or Tree Top in Selah would make it possible to sell steam as well as electricity.

4.2.2 Opportunity 2: Anaerobic Digestion of Dairy Manure Slurry

- This fuel has an ample and stable supply within the County from large dairy operations using flush-type manure handling systems.
- Energy production is low, so primary revenues for the project must come from tipping fees.
- Environmental restrictions on current low-cost disposal options will determine how much dairies are willing to pay in transportation costs and tipping fees.

Location Considerations:

- Logical location would be toward the eastern part of the County to minimize transportation logistics with the large quantities of manure slurry.
- Best location would be close enough to at least one large dairy so that manure slurry could be piped rather than trucked.
- A site adjacent to a steam user such as Darigold Dairy Fair in Sunnyside would be economically beneficial. However, due to the relatively low energy production rate of anaerobic digestion, this is of secondary importance.

4.3 Next Steps

This report provides a high-level overview of biomass opportunities and technologies within Yakima County. Should the County decide to pursue direct involvement in a biomass-to-energy project, a more in-depth analysis and financial feasibility study would need to be conducted. Some of the key items that would need to be investigated further are:

- What types of forestry residue supply contracts could reasonably be negotiated with the USDA Forest Service and other public and private forestry managers? The important aspects of these contracts include long-term annual supply quantity guarantees and the cost of delivered fuel.
- Are dairy operators willing to pay a tipping fee to dispose of their manure at a centralized anaerobic digester? What are the specific triggers (e.g., future environmental regulations, nutrient restrictions) that would make traditional manure management and disposal practices more costly than transportation and tipping fees?
- In addition to tipping fees, are there other financial mechanisms for translating the significant environmental benefits of anaerobic digestion into revenues for the facility (e.g., taxes, subsidies, avoided cleanup costs)?
- What are the possibilities of steam sales to Boise Cascade in Yakima, Darigold Dairy Fair in Sunnyside, Tree Top in Selah, and other agricultural, industrial, or commercial operations?

- What power purchase rates and contracts could be reasonably expected for biomass-produced electricity? Are there any technical constraints on electrical power transmission in the region?

Other things the County can do to keep current on the topic and promote future biomass-to-energy opportunities include:

- Visit and monitor the various biomass projects being undertaken by others, some of which are described in Section 3 of this report. Closely follow the successes or shortcomings of these projects and technologies.
- At the state and federal government levels, promote awareness of biomass-to-energy. According to several individuals interviewed for this report, Oregon provides more financial incentives, tax credits, and low-cost loans for biomass-to-energy projects than Washington.

Appendix A
ABBREVIATIONS

aMW	Average Megawatt
BDT	bone dry ton
BFB	bubbling fluidized bed
BLM	Bureau of Land Management
BPA	Bonneville Power Administration
BTU	British thermal unit
CFB	circulating fluidized bed
CHP	combined heat and power
GT	green ton
IGCC	integrated gasifier combined cycle
kW	kilowatt
kWh	kilowatt-hour
LFG	landfill gas
MSW	municipal solid waste
MW	megawatt
PGE	Portland General Electric
RDF	refuse-derived fuel(s)
SEDI	Sustainable Energy Development, Inc.
USDA	U.S. Department of Agriculture

Appendix B
BIOMASS TERMINOLOGY

"Biomass Fuel" versus "Biofuel"

Biomass fuels are raw or partially processed biomass used as a feedstock to a biomass conversion project (e.g., forestry residues, dairy wastes, etc.). Biofuels are refined intermediate or end products produced from biomass conversion (e.g., biomass-produced methanol, ethanol, biodiesel, etc.). Biofuel typically refers to liquid fuels used for transportation purposes.

"Combustion" versus "Incineration"

The difference between combustion and incineration is primarily a difference in the purpose of the process. Incinerators burn waste materials for the purpose of disposal, and do not recovery energy from the process. Incinerators may even require substantial amounts of natural gas or fuel oil to fire the incineration process. Combustion is a process of burning a material in order to recover energy.

"Bone Dry Tons (BDT)" versus "Green Tons (GT)"

The biomass-to-energy industry measures woody fuels in units of BDT, which is an equivalent unit of weight corresponding to zero moisture content. Forestry managers typically use green tons (GT) as a unit of measure. The conversion from GT to BDT is BDT = GT × (1 – % moisture).

Moisture content of freshly harvested woody residues is on the order of 50 to 60 percent, but residues from wood manufacturing or construction can have lower moisture content (e.g., sawdust can have very low moisture). Overall, moisture content of wood wastes can be 20 to 60 percent by weight.

Appendix C
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Appendix D
PERSONS CONTACTED

The following people were contacted to collect information for this report but not to develop the report's findings, conclusions, or recommendations.

1. Eric Bair
   Compost Manager
   Quincy Farm Chemicals

2. Joe Barra
   Director of Distributed Resources
   Portland General Electric

3. Dick Bogaard
   Food Division General Manager
   R. D. Offutt Company (parent company of Threemile Canyon Farms)

4. Laurie Crowe
   District Technician
   South Yakima County Conservation District

5. Stan Davison
   Biomass Project Manager
   Energy Northwest

6. Gordon Draper
   Vice President
   Biomass One

7. Dana Dutcher
   President
   Chateau Energy Group (owner of Mesquite Lake facility)

8. Becky Kennedy
   Senior Office Assistant for Timber
   Department of Natural Resources, SE Region

9. James Kerstetter
Chief Scientist (retired)
Washington State University Cooperative Extension Energy Program

10. Bill Lamphere
Organics Division Manager
Quincy Farm Chemicals

11. Anton Mickelson
Northwest Dairy Association

12. Mike O'Leary
Operations
Chateau Energy Group (owner of Mesquite Lake facility)

13. Marc Rappaport
President
Sustainable Energy Development, Inc. (SEDI)

14. Pete Severtson
Organic Specialist
Department of Ecology

15. George Shelton
Assistant Regional Manager for State Lands
Department of Natural Resources, SE Region

16. Dave Sjoding
Division Manager for Renewable Resources, Distributed Generation, and Climate Change
Washington State University Cooperative Extension Energy Program

17. William von Segen
Forest Products, Rural Development
USDA Forest Service Cooperative Programs

18. Damon Taam
Spokane WTE Contract Manager
Spokane Regional Solid Waste System

19. Ivan White
    Director
    Sunnyside, Inc.

20. Gary Willis
    Powerhouse and Dry Kiln Supervisor
    Boise Cascade, Yakima

21. Steve Willman
    Biomass Project Engineer
    Energy Northwest

22. Terry Wittmeir
    Organic Specialist
    Department of Ecology