Renewing Rock-Tenn:

A Biomass Fuels Assessment for Rock-Tenn's St. Paul Recycled Paper Mill




Green Institute

Carl Nelson, Principal Investigator

March 2007

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St. Paul Port Authority
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Cover photos, from left to right: 1) Collecting forest residues in Northern Minnesota (IATP); 2) Rock-Tenn plant workers (St. Paul Port Authority); 3) Rock-Tenn recycled paper receiving area (St. Paul Port Authority); 4) Farmers with switchgrass crop (NREL)

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Executive Summary

The Rock-Tenn St. Paul mill is the largest paper recycling plant in the Upper Midwest, recycling 1,000 tons of paper per day and employing approximately 500 people. It is also one of the largest energy users in the Twin Cities. Since the mid-1980s, Rock-Tenn has received its process steam via pipeline from the Xcel Energy High Bridge coal-fired power plant near downtown St. Paul. The High Bridge plant is closing by the end of 2007, to be replaced by an adjacent natural gas-fired power plant currently under construction. Thus this source of steam will no longer be available, and Rock-Tenn must find another energy source.

A recent study commissioned by Ramsey and Washington Counties looked at the potential for combusting processed municipal solid waste, known as refuse-derived-fuel (RDF), to meet Rock-Tenn's energy demand. Any plant would likely not come on-line before 2012, given the long lead times for permitting, finance and construction. Rock-Tenn will use its four fuel-oil/natural gas backup boilers as an interim energy source.

Helping Rock-Tenn find another viable energy source is important to maintaining a stable manufacturing jobs base, improving how our region deals with solid waste, preserving our air quality, and increasing the sustainability of our energy sources. After extensive discussions during the first half of 2006, the Green Institute was contracted by a diverse group of private industry, governmental, and nonprofit organizations to conduct an independent assessment of biomass fuels other than RDF. A technical advisory committee of top biomass experts was also assembled to assist with the project. In addition to Rock-Tenn and the Green Institute, the project was sponsored by the City of St. Paul, Ramsey/Washington Counties, the St. Paul Port Authority, Eureka Recycling and Resource Recovery Technologies (RRT).

The Green Institute is a nonprofit dedicated to sustaining the environment and communities through practical innovation. We operate a $2 million salvaged building materials enterprise known as the ReUse Center/DeConstruction Services, which reclaims for resale more than 4,000 tons of material per year that would otherwise be landfilled. We also have active green building and community energy programs. Our staff have extensive sustainable energy experience through developing the state's largest solar electric system, starting a neighborhood energy conservation program, and conducting pre-development of a 20-megawatt biomass energy project with funding from the U.S. Department of Energy.

Available Quantities and Market Dynamics

A plant large enough to meet Rock-Tenn's current energy demand would require approximately 225,000 wet tons per year of mixed biomass from the sources considered here.[1] This estimated demand is roughly 90 percent of District Energy St. Paul/St. Paul Cogeneration's current use of biomass fuel. The project team considered five broad categories of biomass fuel as described below.

Urban Waste Wood

Urban waste wood comes from the following sources:

- tree residues from tree trimming, tree removal and land clearing for development
- construction and demolition wood
- waste wood from secondary wood processors, such as cabinet shops
- waste wood in the municipal solid waste stream

[1] Actual volumes will vary from about 175,000 to 250,000 wet tons, depending upon the moisture and heat content of the fuels, and the plant's thermal demand.

Although total quantities of urban tree residues in the Twin Cities can be large, available quantities are limited and highly variable. Urban tree residue amounts fluctuate considerably, depending primarily on storm events, consumer demand for tree trimming, housing development activity, and tree diseases. District Energy St. Paul/St. Paul Cogeneration is the largest consumer of tree residues, followed by mulch wholesalers. A significant quantity of mulch is used locally as well as being exported from the Twin Cities to other markets by wood processing companies.

Construction and demolition (C&D) wood waste has low moisture content, which makes uncontaminated C&D wood valuable for several markets, primarily the animal bedding market. Uncontaminated secondary wood from businesses such as cabinet and millwork shops in the Twin Cities area is also in high demand, leaving very little uncommitted wood from these sources. In contrast to these "clean" sources, composite wood (such as plywood), painted wood and other wood with industrial compounds are found in large quantities in the C&D and secondary wood waste stream. Appropriate combustion and pollution control equipment would be required to destroy the compounds and reduce emissions from these types of C&D wood.

There is significant wood waste in the municipal solid waste (MSW) stream, but it is challenging to extract this wood once it is commingled with other MSW sources. Policies to encourage diverting wood before it enters the MSW stream would increase wood availability for Rock-Tenn and other purposes.

Milling Residues: Oat Hulls

Oat hulls are the primary milling residue generated in the Twin Cities that would be appropriate for boiler fuel. Although significant quantities are generated, contracts are in place for nearly all of this resource, the majority of which is destined for other biomass energy projects.

Agricultural Residues: Corn Stover

Corn stover is the residue that remains on the field after harvesting the grain. The amount that can be collected is limited by the collection efficiency and by the portion that must be left on the field for ecological and soil health reasons. Experience with collecting, baling, storing and processing corn stover for boiler fuel is not extensive, but limited research suggests that it can be a viable biomass energy source. Many energy conversion technologies (e.g., boilers) are limited in the amount of high-alkali agricultural sources, including corn stover and grasses, they can use. Because of the short harvest window for corn stover, storage is a key logistical concern. Within 50 to 100 miles of Rock-Tenn, there is more than enough corn stover to provide all the fuel needs of the plant. However, over the next 20 years, significant quantities of corn stover will likely be diverted to liquid biofuel production such as cellulosic ethanol.

Dedicated Energy Crops: Grasses

Perennial grasses are not currently grown in large quantities for crops, but farmers could convert other farmland to grasses. Because grasses provide considerable environmental benefits compared to conventional row crops, farmers might qualify for payments through an agricultural program that promotes conversion to grasses. This would reduce the cost and increase the economic viability to Rock-Tenn of this fuel source. It could also apply to other perennial crops not considered here, such as willow trees. As with corn stover, storage is a key logistical issue with grasses.

Forest Residues

Residues generated from commercial logging operations are the most accessible source of forest biomass for boiler fuel. Guidelines are currently being developed to provide for the sustainable removal of this biomass source, which consists primarily of the tops and limbs of harvested trees. Although sources of logging residues are well outside of the metropolitan area, large quantities are available.

Other forest residue sources may be available to Rock-Tenn, though less data exists on their suitability. These include forest thinning, brushland sources, and ecological restoration of state, county and regional forests in and near the metropolitan area. Further research and discussion with stakeholders is necessary to fully evaluate these sources.

Table 14 from the main body of the report, replicated below, presents a summary of the project team's assessment of availability of biomass sources. "Mean quantity generated" is the estimated total amount generated in proximity to Rock-Tenn. "Current availability" deducts from this amount quantities unrecoverable and currently destined for other markets. Because various fuels have different levels of moisture (from 10 to 50 percent), we convert to dry tons to facilitate a fairer comparison among fuel sources. The project team also considered future demand from other sources and the long-term availability to Rock-Tenn, as Rock-Tenn will need access to reliable sources of fuel for at least 20 years. The project team also conducted a subjective assessment of the uncertainty of the mean estimates (the "+/-" columns) and calculated the proportion of plant demand that could be met with long-term fuel supplies.

Costs and Procurement Strategy

Rock-Tenn expects to use natural gas and fuel oil as interim fuel sources, but believes that a plant operation based solely on natural gas fuel is not economically viable. However, the economics of a natural gas plant provide a reference point for considering the economic viability of a biomass-fueled plant. Industrial natural gas prices are projected to be in the range of $5.50-$9/MMBtu[2] over the next 20 years, with significant potential for volatility from year to year. In comparing biomass with natural gas, it is necessary to consider the cost of non-fuel expenses (such as operation, maintenance, capital, and financing) as well as the fuel costs. The project team conducted a screening analysis of a several plausible scenarios for non-fuel costs for a Rock-Tenn biomass and natural gas plant, summarized in Figure 11 of the main report, and replicated below. For natural gas, non-fuel expenses are estimated to be near $1/MMBtu. Thus the reference price that a biomass plant would need to outperform is $6.50-$10/MMBtu (non-fuel costs + estimated fuel costs).

Non-fuel costs for a biomass plant are heavily dependant on financing assumptions, as well as assumptions regarding required pollution control equipment, involving both capital and operating costs. Total non-fuel costs for biomass are estimated to range from $6 -$13/MMBtu. Thus, to meet the test of beating natural gas generation cost, biomass fuel costs must range from a negative fuel cost to $3.50/MMBtu, depending on assumptions of natural gas costs and biomass non-fuel costs. The lower range of the biomass non-fuel costs assumes a project with secure fuel access and other factors reducing project risk and allowing access to low-cost financing, as well as limited pollution control equipment. The upper range assumes the use of advanced pollution control equipment, such as would be required for combusting RDF, contaminated C&D, and possibly other biomass fuels depending upon natural or human-caused contamination. Financing and other variables, such as grants or lower interest rates, may have potential for reducing costs (or increasing costs) from those presented here.

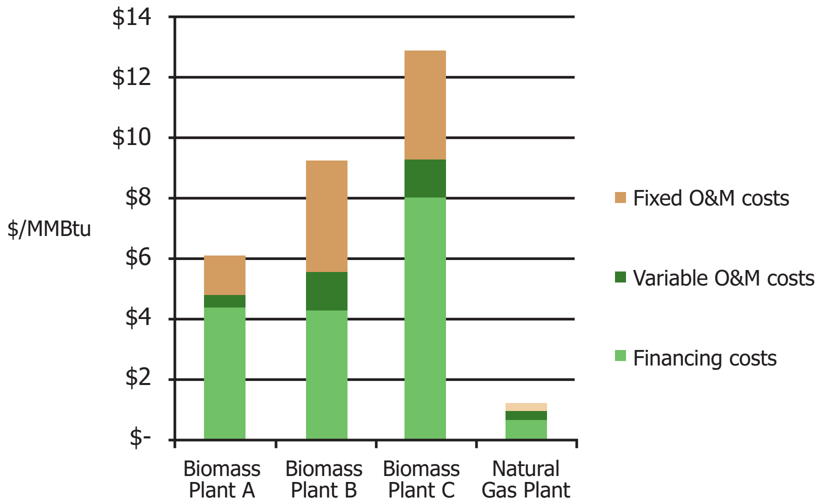
[2] MMBtu = million British thermal units, a measure of heat content. For reference, 1000 cubic feet of natural gas contains the heat equivalent of approximately one MMBtu.

Table 14: Summary of estimated quantities of non-RDF biomass available to Rock-Tenn

	Mean Quantity Generated			Current Availability	Long-term Availability		
Biomass Source	**Wet Tons**	**Dry Tons**	**+/-**	**Dry Tons**	**Dry Tons**	**+/-**	**Proportion of Plant Demand**
Urban waste wood							
Urban tree residue							
Tree trimming and removal	300,000	195,000	25%	--	--		
Land clearing	150,000	97,500	100%	--	--		
Subtotal Urban Tree Residue	*450,000*	*292,500*	*40%*	*26,000*	*5,000*	*200%*	*3%*
Secondary wood sources	132,000	118,800	30%	9,000	3,000	200%	2%
C&D wood							
Clean wood	77,500	69,750	25%	12,000	5,000	100%	3%
Other wood (composites/painted/treated)	313,000	281,700	25%	140,000	70,000	50%	45%
Subtotal, C&D wood	*390,500*	*351,450*	*25%*	*152,000*	*75,000*	*60%*	*48%*
Clean wood in the MSW stream	84,000	67,200	20%	0	0		0%
Other wood in the MSW stream	48,000	40,800	20%	0	0		0%
Subtotal all urban wood sources	*1,104,500*	*870,750*	*30%*	*187,000*	*83,000*	*60%*	*53%*
Milling residues: oat hulls							
Twin Cities	80,000	72,000	10%	9,000	4,500	200%	3%
Imported from Canada	25,000	22,500	20%	22,500	11,000	200%	6%
Subtotal	*105,000*	*94,500*	*15%*	*31,500*	*15,500*	*200%*	*9%*
Agricultural residues: corn stover	6,000,000	4,900,000	30%	400,000	60,000	50%	38%
Dedicated energy crops: grasses (assuming corn conversion)	0	0		0	60,000	50%	37%
Subtotal[3]	*6,000,000*	*4,900,000*	*30%*	*400,000*	*90,000*	*50%*	*56%*
Forest residues							
Logging residues	207,000	103,500	50%	90,000	30,000	75%	20%
Forest thinning/ecological restoration	n/a	n/a		n/a	n/a	--	--
Brushlands	95,000	47,500	100%	n/a	n/a	--	--
Subtotal forest residues	*302,000*	*151,000*	*75%*	*0*	*30,000*	*150%*	*20%*
Total, all sources	**7,511,500**	**6,016,250**	**40%**	**618,500**	**218,500**	**50%**	**138%**

[3] Subtotals of corn stover and grasses are not the total of their individual estimates, because some corn land is assumed to be converted for grass production, thus limiting the amount of corn stover available when totaled with grasses.

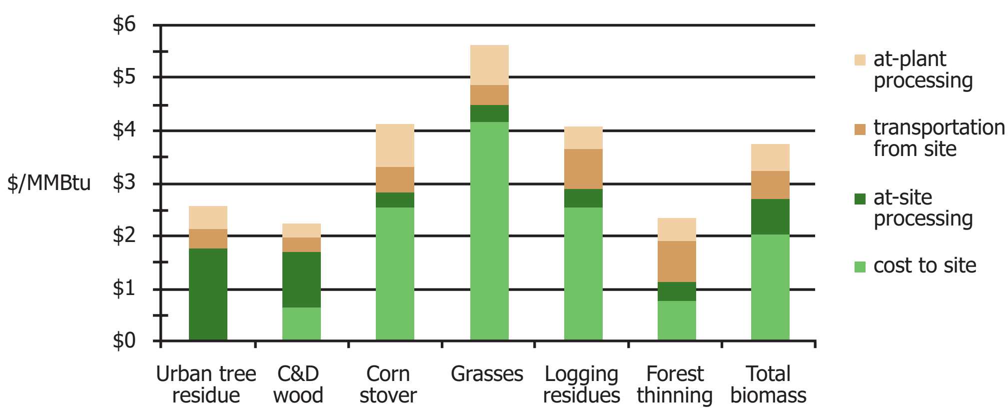
Figure 11: Comparison of estimated biomass and natural gas non-fuel operating and maintenance costs



Although it is beyond the scope of this study to consider financing issues, a cursory analysis suggests that several financing issues will be critical to the plant's success, including securing a long-term energy purchase agreement perhaps with several parties, securing fuel supply contracts, having an experienced operator, and access to low-cost debt financing. Recent state increases in renewable energy requirements for utilities and federal steps toward a carbon dioxide cap and trade program could help improve the financing outlook for the plant.

The project team developed a cost model for biomass fuels. The purpose of the model is to provide a rough estimate of the delivered cost of fuel under a given set of assumptions. The model is limited in that it does not consider supply and demand dynamics that can affect pricing, and is dependant upon a particular set of assumptions. Scenarios were developed from this model for providing 15 percent, 30 percent, 60 percent and 100 percent of the fuel needs of Rock-Tenn with biomass. Figure 20 from the text of the report, reproduced below, presents the results of the 100 percent biomass scenario.

Figure 20: Estimated fuel costs ($/MMBtu) for Scenario D, 100 percent urban wood waste, agricultural fuels and forest residues



It is important to remember that the fuel costs shown in the figure above must be added to non-fuel costs to estimate the ultimate cost of producing steam from these biomass sources.

Conclusions and Recommendations

The following conclusions and recommendations were developed by the project team in collaboration with the technical advisory committee (see Appendices A and B).

Availability of biomass:

- There are sufficient quantities of biomass fuel sources within 75 to 100 miles of Rock-Tenn to provide all of Rock-Tenn's energy needs. However, considering current and projected future demand for these sources, no single source of biomass considered in this study could supply all of Rock-Tenn's long-term fuel needs. The one possible exception is agricultural sources, which could be sufficient if a long-term fuel contract were signed with an entity (or entities) with the necessary capabilities and assets to securely back up a 20-year contract.
- All biomass options will necessitate highly controlled combustion practices and appropriate pollution control technology.
- Uncommitted urban tree residues are extremely limited, and in some years may be able to provide about 15 percent of Rock-Tenn's fuel needs, but annual availability fluctuates considerably and supplies cannot be relied upon.
- There is enough C&D wood to supply a significant proportion of Rock-Tenn's fuel needs, but the use of some C&D wood will trigger a higher threshold of environmental review and the possible need for additional pollution control equipment.
- Agricultural sources could provide at least one-third of Rock-Tenn's fuel needs (potentially more if long-term contracts were in place to offset the risk of increasing demand for biofuel production).
- There is increasing demand and pricing pressure for agricultural milling residues such as oat hulls, so this should not be considered a significant fuel source for Rock-Tenn.
- There is sufficient wood from logging residues and other forest sources within 100 miles to provide a significant portion of Rock-Tenn's fuel needs; but because of the distance, only a portion of this resource should be used.

Costs and Procurement Strategy:

- Obtaining low-cost financing will be critical to the success of the project.
- Maintaining supply-chain control over at least one-third of the plant's biomass fuel requirement will be essential.
- Conversion technology alternatives should be evaluated in part for their ability to use a wide range of biomass sources.
- Our modeling of fuel costs suggests that a 100 percent biomass option using a blend of the fuel sources considered in this study might cost approximately $4/MMBtu. Based on our screening analysis of non-fuel costs of biomass, this may be too expensive for the project to bear, even in our low-cost scenario of biomass non-fuel costs. This suggests that further work is necessary to find the ideal fuel mix and technology choice combination for a financeable project. In addition, some biomass sources, such as C&D wood, may incur other costs such as pollution control upgrades.

Recomendations

Ultimately, the development team will need to decide on a fuel mix and conversion technology that will result in a plant that can be financed and built. The information provided here is expected to help with that decision, but a broader consideration of issues as well as a comparison with the previous RDF study will be necessary. The following are recommended next steps for the development team:

- Conduct further analysis of C&D sources, including an assessment of pollution controls required and discussions with policymakers on future C&D policy changes.
- Consider the viability of a C&D source separation program.
- Work with other stakeholders who are convening a forest-thinning task force to develop a framework for capturing benefits of forest thinning while providing an additional biomass source for Rock-Tenn.
- Work with policy makers, environmental and conservation groups, and other stakeholders to further evaluate perennial grasses and other perennial crops and the potential for state or federal dollars providing a co-benefit payment to improve the economic viability of this source.
- Consider financing energy-efficiency upgrades at Rock-Tenn as part of the plant financing package.
- Begin discussions with farm organizations that may be able to contract for agricultural biomass fuels.
- Continue to refine urban tree availability estimates.
- Consider using innovative conversion technology such as gasification for meeting all or a portion of Rock-Tenn's thermal needs.

1. Introduction

1.1. Background on Rock-Tenn's St. Paul mill

Processing a thousand tons per day, the Rock-Tenn St. Paul mill in the Midway area of St. Paul is the largest paper recycler in the Midwest. Formerly known as Waldorf Recycling, the plant has operated since 1908 and was purchased by the Rock-Tenn Company (with headquarters in Norcross, Georgia) in 1996. Rock-Tenn Company had $2.1 billion in sales in 2006, and the St. Paul mill represents about 22 percent of Rock-Tenn's total U.S. capacity.[4] Energy is one of the largest inputs in the paper recycling process. Nationally, Rock-Tenn spent $133 million on energy in 2006, or about 7 percent of its total cost of goods sold. Natural gas represented 45 percent of 2006 total energy expenditures.[5]

Rock-Tenn will use existing boilers to burn fuel oil and natural gas as an interim energy strategy (St. Paul Port Authority picture)

The St. Paul site sits on 42 acres and has approximately 1.5 million square feet of building space. Four production lines (two recycled corrugated medium and two coated recycled paperboard) run 24 hours a day, 7 days a week. Rock-Tenn pays $25 million per year to receive recycled paper from across the Upper Midwest. The plant is one of the largest energy users in the Twin Cities metro area.

Rock-Tenn reports spending more than $20 million on energy annually for the St. Paul facility. In 1984, a 5½-mile steam line was constructed from the High Bridge coal-fired generating station near downtown St. Paul to provide energy for the facility. A steam turbine at Rock-Tenn produces up to 13 megawatts (MW) of electricity from the steam delivered from High Bridge, and approximately 85 MW of thermal energy is consumed by the plant.

The paperboard industry is a highly competitive, international industry, and Rock-Tenn can expect to have increasing competitive pressure in the future. The fastest-growing competition is from China, the second-largest producer of paper and paperboard in the world after the United States. It is not so much China's low labor costs, but rather its rapidly increasing base of state-of-the-art and highly efficient plants that is creating financial pressure on the generally older and less efficient fleet of U.S. plants. Chinese plants usually have the advantage of coal-based energy sources, as well as strong government subsidies to support expansion.[6]

Rock-Tenn employs nearly 500 people, 468 full-time employees (including 385 United Steel Workers union jobs) and 30 full-time contract employees. Ramsey County is home to 176 of Rock-Tenn's employees, and 83 of these live in St. Paul.

1.2. The search for an alternative energy source

In 2001, the Minnesota Legislature passed legislation that enables utilities to submit emissions reductions projects to the Public Utilities Commission (PUC) for approval. Approved projects are now allowed to recover the costs of those upgrades from ratepayers. In 2002 Xcel Energy submitted and subsequently received approval for a $1 billion

[4] Rock-Tenn Company 2006 Annual Report.
[5] Ibid.
[6] Derived largely from proceedings of a January 2006 conference in Vancouver sponsored by the Madison, WI Forest Products Laboratory and others entitled "China's Boom: Implications for Investment & Trade in Forest Products and Forestry," available at www.forestprod.org/internationaltrade-06powerpoints.html.

Metropolitan Emissions Reduction Project (MERP), which allowed Xcel Energy to recover costs for upgrading three metro-area coal-fired power plants. As part of MERP, Xcel Energy will demolish its existing coal-fired plant at High Bridge and replace it with a natural gas combined cycle plant. As a result of losing its coal-based source of energy in the second half of 2007, Rock-Tenn will have to begin operating its existing on-site fossil fuel boilers starting in the summer of 2007.

Rock-Tenn is in the process of extending until 2012 its permits to burn fuel oil and natural gas at existing boilers, which it used as an energy source before the steam line from High Bridge was built. As part of the permitting process to use these older boilers, Rock-Tenn has entered into a Memorandum of Understanding with the Minnesota Pollution Control Agency (MPCA) that states its intention to transition to a cleaner energy source.[7] The price volatility of natural gas and fuel oil makes it an unattractive long-term fuel choice. Rock-Tenn expects its energy costs to increase by approximately $4million - $6 million per year when it begins using its existing boilers. The Company has stated that a plant operation based on natural gas alone is not an economically viable option.

Shortly after the announcement that High Bridge would close, Rock-Tenn began considering its options for an alternative energy source. Rock-Tenn completed internal assessments and commissioned others from Cinergy Solutions, Market Street Energy, Golder Associates, Great River Energy and Foth & Van Dyke (now Foth). The City of St. Paul and the St. Paul Port Authority also took an active interest in finding a solution as well.

In the fall of 2005, the Ramsey/Washington County Resource Recovery Project (RWCRRP) met with Rock-Tenn to discuss the possibility of using a processed form of municipal solid waste, referred to as refuse-derived fuel (RDF) from the facility the RWCRRP financed in Newport. Foth was subsequently engaged to produce a report considering the feasibility of using RDF and waste wood from construction and demolition sources.[8] The report indicated that approximately 400,000 wet tons/year of RDF would be needed to meet Rock-Tenn's current energy needs, as well as producing some power for sale.[9]

One complication of developing a solution was that Rock-Tenn was reluctant to commit to solely owning and operating a large energy production facility that would typically be financed over a period of 20 years or more. Rock-Tenn therefore sought partners to help develop, own, and operate a potential facility. In November 2006, Rock-Tenn announced that it had reached an agreement with Market Street Energy, an affiliate of District Energy St. Paul, to have exclusive rights for six months to develop an energy facility to supply Rock-Tenn with steam. This facility could also be used to establish a district hot water heating system along the University Avenue corridor, or to supply electric power to the planned University Avenue light rail line.

1.3. Purpose and scope of this study

In the spring and summer of 2006 the Green Institute and others participated in discussions with Rock-Tenn about using non-RDF biomass sources. Rock-Tenn, along with a diverse group of public agencies, nonprofits, and private companies, agreed to help fund a study to more fully consider other biomass sources. In addition to Rock-Tenn and the Green Institute, the project sponsors are the City of St. Paul, St. Paul Port Authority, the RWCRRP board, Resource Recovery Technologies (RRT),[10] and Eureka Recycling. The Green Institute and

7 www.pca.state.mn.us/publications/mou-rock-tenn.pdf.

8 See bibliography for full reference. Report available at www.co.ramsey.mn.us/recovery/docs/R_Rock_Tenn_Analysis.pdf.

9 The biomass facility recommended by Foth would produce nearly twice the energy needed for Rock-Tenn's current operations. See section 4.2 for a further discussion of this issue.

10 RRT is a company recently formed by the operators of NRG Processing Solutions. RRT owns and operates the Newport and Elk River RDF facilities as well as numerous wood processing sites in the Twin Cities area.

the funding partners assembled a technical advisory committee to help review the research and to recommend next steps for Rock-Tenn and project developers (see Appendices A and B). The purpose of the study is to:

1) Assess the availability of non-RDF biomass fuel for use at the Rock-Tenn site;
2) Roughly estimate procurement costs at various annual consumption rates; and
3) Develop the building blocks for a supply-chain procurement plan.

The study is not intended to be the final answer to Rock-Tenn's energy needs, but rather a feasibility study of what proportion of Rock-Tenn's fuel needs can be met with several sources of non-RDF biomass. Further work and analysis will be required, and one of this study's goals is to help identify what further work will be necessary. Most successful biomass projects rely upon a mix of biomass fuels. Further partnerships and cooperation between diverse stakeholders will probably be necessary to successfully develop an energy facility at Rock-Tenn. Throughout this report "Rock-Tenn" refers variously to both the company and its partners in the effort to develop a biomass plant at Rock-Tenn.

2. Use of Biomass Fuels

2.1. Thermal and electric energy needs at Rock-Tenn

Rock-Tenn's demand for thermal (process heat) energy is one of the highest in the Twin Cities, averaging just over 225,000 pounds per hour of steam, or approximately 85 MW thermal (Figure 1).[11] Steam is currently delivered from the High Bridge plant at a temperature of 680°F and pressure of 600 psig. Temperature and pressure are reduced by a back-pressure turbine to 320°F/65 psig for use as process steam. The turbine has a peak capacity of 13 MW electric. The pressure is further reduced to 50 psig for providing heat for the buildings. Four fuel oil/natural gas boilers have the capability to serve as a back-up steam source. Rock-Tenn is planning to use these boilers for its interim energy needs once the High Bridge plant closes. The vast majority of steam at the plant is used for drying paper, as shown in Figure 2.

Figure 1: Average monthly steam demand at Rock-Tenn[12]

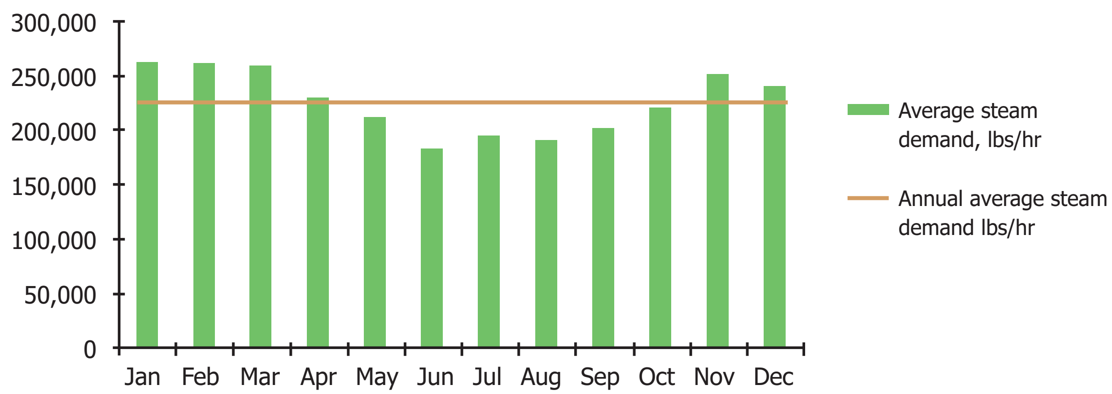
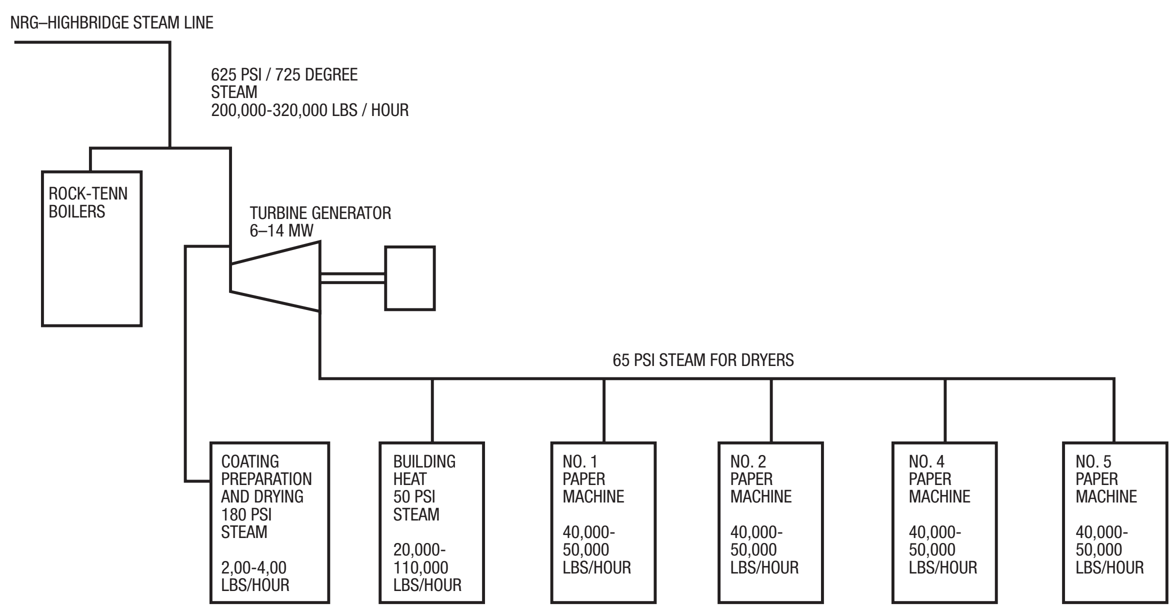


Figure 2: Rock-Tenn's St. Paul mill steam flow



[11] Delivered steam energy content of about 1340 Btu/lb, with net conversion of about 1175 Btu/lb steam after considering condensate return and losses.

[12] Source: Foth, 2006 (see bibliography).

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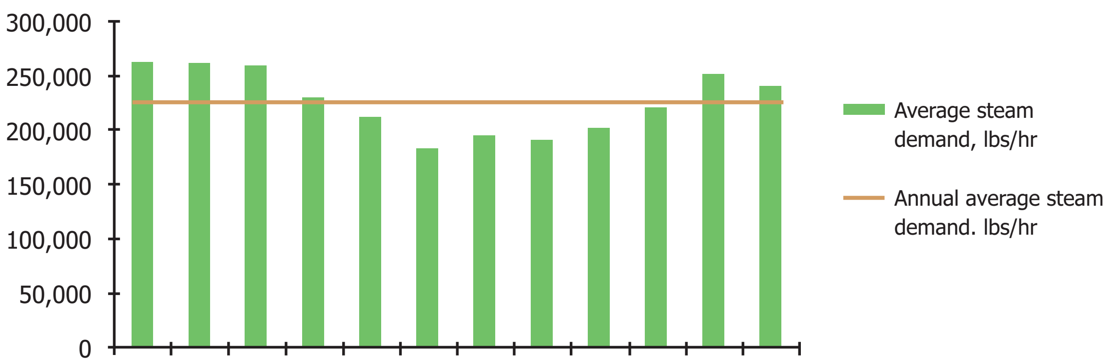

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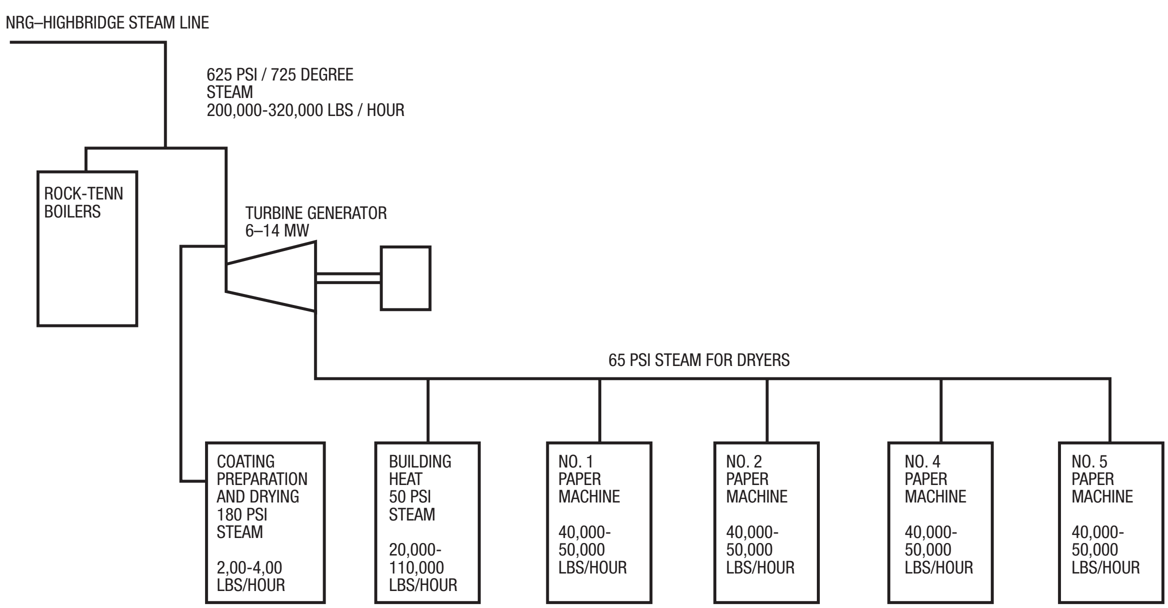


[11] Delivered steam energy content of about 1340 Btu/lb, with net conversion of about 1175 Btu/lb steam after considering condensate return and losses.

[12] Source: Foth, 2006 (see bibliography).

Rock-Tenn is currently implementing energy conservation investments in its operation, and evaluating doing further work. Discussions with plant personnel confirm that the system for building-space heating is quite inefficient, and this is one of the targets for efficiency improvements. The plant's current coal-based steam contract has a minimum-take requirement that has discouraged reducing energy consumption, which has resulted in deferring efficiency upgrades. Nonetheless, Rock-Tenn estimates that it has improved thermal energy efficiency by 30 percent over the last 21 years through upgrades. Based on several ongoing studies,[13] Rock-Tenn estimates additional efficiency gains of 5 to 15 percent are achievable, and it is currently working on implementing some of these improvements. Numerous studies have shown that investments in energy efficiency generally have a higher return on investment than investments in new energy generation. For the purposes of this study, it is assumed that Rock-Tenn's energy demand will stay at or near current levels.

2.2. Components of a biomass energy system

A biomass energy facility consists of a set of components that must function together to achieve the goal of providing affordable and reliable energy. For the purposes of this study, "biomass" includes plant material as well as other sources, such as RDF, that may be primarily composed of plant material but may also contain other components that are combustible but not renewable, such as plastics.[14] However, this study does not consider RDF, as this has been previously considered.

Though it is beyond the scope of this study to consider anything except feedstock supply, storage, transport and processing, all of the system components are presented below for the sake of context in the overall development of a biomass energy system.

2.2.1. Feedstock supply, storage, transport and processing

Ensuring a long-term, reliable fuel supply with the correct characteristics for the boiler system is imperative to the success of a biomass energy system. Biomass fuels have a range of combustion characteristics that can limit fuel usage of certain biomass sources for some boiler types.[15] A review of existing biomass plants conducted by the National Renewable Energy Laboratory (NREL) emphasizes the importance of ensuring an adequate and flexible fuel supply:

> Many biomass plants change fuels significantly over the years, as opportunities arise or old fuel sources dry up. These changes are often not predictable. The best strategy to deal with this problem is to have a plant design and permits that allow as much fuel flexibility as possible.[16]

In order to mitigate the risks associated with predicting long-term fuel supplies and demand from other sources, investors often require that the biomass plant have access to fuel supplies that are two to four times greater than what the plant actually requires. This often involves a strategy that incorporates several fuel sources.

[13] Rock-Tenn reports that it is currently considering or will implement the following efficiency opportunities: 1) A recently completed Minnesota Technical Assistance Program study that identified opportunities to reduce steam losses by 35,000 MMBtu/year which is currently 75 percent complete; 2) Opportunities to reduce building-heat losses; 3) A Six Sigma project to further reduce process steam demands with 23 action items to improve efficiency; 4) Increased efficiencies on the mill press sections; 5) Recovery and reuse of energy in waste water; 6) Recovery and reuse of energy in dryer exhaust; 7) Preheating the intake air in the winter months with recovered heat; 8) Improved control of heating loads; 9) Increased recovery of condensate and flash steam.

[14] Under Minnesota law, for the purposes of the Renewable Energy Objective, biomass includes RDF as well as plant sources of biomass (Minnesota Statutes § 216B.1691).

[15] In particular, the boiler's ability to handle high-moisture-content and alkaline fuels is important. Alkali and alkaline earth metals, in combination with other fuel elements such as silica and sulfur, and facilitated by the presence of chlorine, can cause boiler slagging and fouling problems (Jenkins, 1998).

[16] Bain et al., 2003 (see bibliography).

Once the source of biomass has been selected, it must be processed into a form that is acceptable for the boiler system. This usually involves size reduction through chipping or grinding and possibly screening to ensure uniform sizing. Metal and other undesirable materials may need to be removed. It may also be necessary to mix biomass of varying characteristics together to achieve a more homogeneous fuel mix. For example, high-moisture-content green wood chips may require blending with a drier fuel to achieve uniform moisture content. Air-drying biomass for a period of weeks or months to achieve moisture content reductions may also be a part of the fuel processing.

Because many biomass sources have seasonal fluctuations, it is often necessary to provide for significant on-site or offsite storage (one to three months). Rock-Tenn does not have sufficient undeveloped land available, so fuel storage would have to be largely managed off site. The NREL report identifies fuel processing as a challenge for many biomass plants, noting that a significant number of them spend considerable time and money, especially during the first two years of operation, to solve problems related to the fuel yard and fuel feed system.[17]

Transport of the fuel to the site involves another set of logistical issues. Truck and rail are the most common methods of transport. Receiving hours for delivery to the plant are often restricted, so although the plant may operate 24 hours a day, delivery may only be accepted during a 16-hour or less window.

Table 1: Feedstock characteristics to consider in designing a biomass fuels system

Characteristic	Why Important
Energy content (Btu/lb), dry basis	Determines suitability for producing energy; also, lower energy-content fuels require more transport per unit of energy produced. Most woody and agricultural biomass ranges from 7,500-9,000 Btu/lb (dry basis).
Moisture content (percent)	Moisture reduces energy value; different boilers have limitations on maximum moisture content; consistent fuel moisture content is desirable for best combustion
Fuel density (lbs/cubic yd)	Low-density fuels are more expensive to transport
Potential co-contaminants mixed with feedstock	May limit usage of fuel – for example, potential for lead paint in demolition wood; also may limit options for ash disposal (i.e., non-combustible metals in ash make undesirable as soil supplement)
Ash content, post-combustion (percent)	Determines quantities of ash that must be disposed of
Alkali content of fuel, in particular potassium	Can cause fouling and slagging problems in boiler and heat exchange equipment; many agricultural fuels have high alkali contents that limit usage in many boiler types; the presence of other elements, particularly chlorine and silica, can further catalyze alkali fouling problems.
Sizing of fuel as received at fuel yard	Determines additional fuel processing required
Long-term availability of fuel (20 yrs)	Financing of plant is typically over 20-year time-frame, so will need secure supply of fuel over that time frame
Long-term price of fuel ($/dry ton)	Influences financial viability of plant
Sulfur and heavy metal content of fuel	Can cause air emission issues. Sulfur produces the pollutant SO_2 in combustion. Generally very low in the biomass fuels considered here.

[17] Ibid.

Table 1 summarizes some of the major characteristics of potential biomass sources to consider in the design of a biomass fuels system.

2.2.2. Feedstock handling system

Once the fuel is delivered to the site, it must be stored until it can be used by the boiler, and then transported from storage into the boiler in a controlled and reliable manner. Some additional processing capability may be required, for example if additional grinding is necessary for some of the biomass delivered to the plant. This study will not give detailed consideration to the on-site handling system.

2.2.3. Boiler system to produce steam

Various technology options are available for converting the biomass into steam on the scale required by Rock-Tenn. Four of the most common boiler designs are:

- ***Stoker boiler.*** This is the oldest and most traditional boiler design, named for the way fuel is introduced to the boiler: by a stoker grate or traveling grate. Combustion occurs on a perforated grate at the bottom of a boiler. Air is introduced below the grate and reaches the fuel through the perforations. Biomass fuel is introduced on one end of the grate and carried across it. By the time the fuel reaches the other end, it has been reduced to ash and falls into an ash collection system. Although it is possible to burn higher-moisture-content fuels, emissions of NO_x and CO can be a concern for fuel moisture levels of 40 percent and above. District Energy St. Paul/St. Paul Cogeneration uses this type of boiler.
- ***Fluidized bed boiler.*** Biomass is introduced into the boiler with air blowing up from its cone-shaped bottom. The air suspends a bed of sand at the bottom of the boiler, which helps to mix the fuel for more complete combustion. This is a more expensive technology, but it can handle a wide range of biomass fuels, is very efficient, and has very low emissions even without any pollution control equipment because of the complete combustion. It can tolerate high moisture contents as well as a higher percentage of high-alkali fuels, making it one of the most flexible boiler systems available. Lime can also be introduced into the bed for further pollution control. Two main types of fluidized bed plants are employed: circulating fluidized bed and bubbling fluidized bed. The University of Minnesota steam plant has a circulating fluidized bed system. The bubbling fluidized bed design is somewhat less efficient and less expensive, but is frequently used for smaller boilers and is a common design in California. The proposed Midtown Eco Energy Plant in South Minneapolis is considering a bubbling fluidized bed design.
- ***Gasifier.*** Also referred to as a two-stage combustion boiler. In the first stage, the biomass is heated in a furnace and partially combusted in an oxygen-limited environment. The volatile portion of the biomass is converted into a combustible gas. The gas can be cleaned and introduced into a gas boiler to produce steam. There is less operating experience with gasifiers at the scale required by Rock-Tenn. Also, gasifiers often have restrictive requirements for fuel sizing and moisture content. In many gasifier designs, moisture content below 40 percent is required. The Central Minnesota Ethanol Cooperative has installed a small gasifier at its facility near Little Falls.
- ***Suspension boiler.*** Fuel is injected into the air in the middle of the boiler and is combusted before it reaches the boiler floor. This type of boiler requires a low-moisture-content fuel that has been size-reduced to a sawdust-like consistency. This is the type of boiler proposed for the Rahr Malting plant in Shakopee.

The choice of boilers determines what kind of biomass fuels can be used, and vice versa. The fuel sources are usually determined first, and then a selection is made for the best type of boiler for the fuel mix. In addition to the boiler, pollution control equipment will be required depending on the fuel characteristics. It is beyond the scope of this study to consider boiler options for a Rock-Tenn facility.

2.2.4. Steam use in a combined heat and power plant

Rock-Tenn currently co-generates power along with utilizing the thermal energy in its manufacturing process. Most of the power is generated from steam turbines, which require high-temperature, high-pressure steam, with a typical efficiency of 20 to 35 percent. In a standard power plant, the excess heat from the turbine is wasted. In a combined heat and power (CHP) application like Rock-Tenn's, this waste heat is used for on-site thermal energy need. This can result in capturing 80 percent or more of the total energy of the steam. The actual efficiency of the process is highly dependent upon available thermal loads. To obtain maximum efficiency from a steam turbine CHP system, the following conditions must be met:

- Thermal demand should be at least twice as large as the power produced by the generator[18]
- The facility must have relatively constant thermal demand, 24 hours a day, 7 days a week, 52 weeks a year

Rock-Tenn meets both of these criteria, and is a textbook example of the ideal CHP situation.

18 A typical industrial steam turbine might be capable of using 25 percent of available energy (25 percent efficient). To achieve total system efficiency of 75 percent, the thermal load available must be able to use 50 percent of available energy (steam turbine = 25 percent, thermal = 50 percent, waste = 25 percent).

3. Available Quantities and Market Dynamics for Biomass

Five types of biomass are considered in this study, which together make up a fairly complete list of plant-based biomass sources:[19]

- Urban wood waste
- Milling residues
- Agricultural residues
- Dedicated energy crops
- Forestry residues (from forests outside the Twin Cities)

The project team sought to identify the leading sources in each category for use at the Rock-Tenn facility, focusing on sources that are renewable biomass, relatively cost-effective to deliver to the plant, and available in sufficient quantities to be a significant source. While we have not covered every biomass source, we believe we have considered the most realistic sources of biomass that Rock-Tenn could use to fuel its plant.

For the biomass sources considered here, an estimated 150,000 to 175,000 dry tons would be necessary to meet Rock-Tenn's current fuel needs, depending on which fuels are used.[20] The moisture content of these fuels varies from approximately 10 percent to 50 percent, resulting in a total wet ton fuel demand of between 175,000 and 250,000 wet tons, depending on the fuel mix. Assumptions on fuel characteristics used in this report are in Appendix D.

To estimate total quantities of each biomass source generated within range of a Rock-Tenn facility that might be available for its use, we considered three factors:

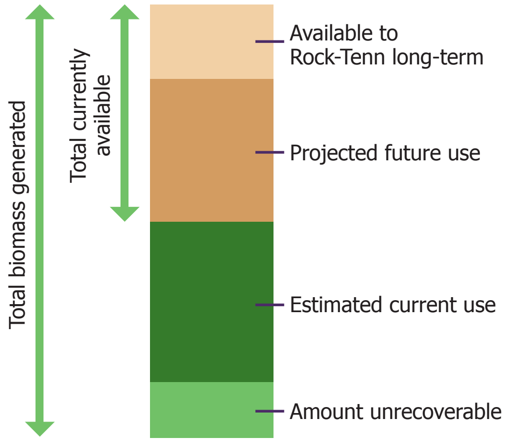
- ***Proportion of the biomass that is potentially recoverable.*** Not every single fallen tree branch in the Twin Cities would be available to Rock-Tenn, for example, but some would be.
- ***Currently committed quantities of biomass (current demand).*** This includes other boilers in the Twin Cities that would demand biomass fuel and other end markets that compete for biomass boiler fuel.
- ***Projections of future supply and demand.*** For future supply and demand, we assumed a 20-year horizon, which is a likely term for project financing.

For each biomass source, we estimate: 1) total biomass generated; 2) amount currently available, and 3) amount available long-term. These quantities are also summarized in Table 14 at the end of this chapter. Figure 3 demonstrates the relationships between these amounts and the factors listed above.

[19] Bain et al., 2003 (see bibliography).

[20] This assumes a 95 percent capacity factor for the facility, per the Foth 2006 report (see bibliography). The plant would require fewer total dry tons of biomass than of RDF because the heating value of clean biomass is typically higher than RDF, and ranges from about 7,500 Btu/lb to about 8,500 Btu/lb (dry basis). RDF is about 6,300 Btu/lb. (wet basis)

Figure 3: Estimating quantities of biomass potentially available to a Rock-Tenn facility



Our methodology for estimating each of these totals is source-specific. In the absence of solid information about future supply and demand, we frequently apply a "fuels multiple," the proportion of fuel a plant will use compared to what is currently available. The higher the fuels multiple, the smaller the proportion of fuel the plant will use, and the lower the risk to the plant of future fuel shortages. Thus if 150,000 tons of a biomass source is current available, applying a fuels multiple of 2 means that 75,000 would be available to Rock-Tenn long term; a fuels multiple of 3 results in 50,000 tons. The determination of an appropriate fuels multiple depends on expectations of future supply and demand, the extent to which the plant can "lock in" the available fuel supply with long-term supply contracts, and is somewhat subjective. However, fuels multiples of between 2 and 4 are commonly applied by industry analysts. There is considerable uncertainty in estimating these quantities, especially projected future use. The higher the uncertainty, the higher the recommended fuels multiple.

3.1. Urban wood waste

Urban wood waste is biomass culled directly from the urban forest as well as secondary sources of wood, such as from furniture manufacturers. Sources considered here include urban forest wood waste from tree trimming and land clearing, secondary wood sources, construction and demolition wood and wood in the municipal solid waste stream.

3.1.1. Urban tree residues *(tree trimming & land clearing)*

The project team spent considerable time assessing availability of urban tree residues. Our research efforts are summarized below. More detailed discussion and the sources of the estimates below are presented in Appendix C.

Tree service delivery to City of Plymouth site (Green Institute)

Tree-trimming residues are generated by private tree service firms, municipal and county government departments, electric utilities and residents. Private tree service firms are the largest generator of this waste, but with well over 100 established tree service companies operating in the metro area, and many more freelance contractors, their combined output is difficult to gauge. We estimate annual generation rates of tree trimmers to be between 200,000 and 400,000 wet tons per year, with a mean estimate of 300,000 wet tons.

Tree-trimming residues fluctuate annually depending on the number and severity of storms and the prevalence of diseases and pests, such as dutch elm disease, ash borer, and oak wilt, that often necessitate tree removal. For example, during the summer and fall of 2004, tree service firms and municipalities scrambled to keep up with a resurgence of dutch elm disease. Minneapolis alone lost nearly 10,000 elms in 2004, compared to an average of 3,000 to 4,000 a year during the past decade. Oak wilt is a persistent disease particularly for northern metro area counties. The emerald ash borer is a pest that forestry officials fear may migrate westward from Michigan, where ash populations have been devastated. About 10 percent of the trees in the metro area are ash. Should emerald ash borer reach the Twin Cities in the next 15 years as many anticipate, significant quantities of wood waste, both in the metro area and statewide, could be available to Rock-Tenn. However, because it is impossible to build a plant relying on these quantities and they would not last the duration of the plant, they are not included our estimates.

Land clearing is the other major source of urban tree waste. Specialized wood clearing companies remove large numbers of trees for land development. We estimate wood-clearing volumes to be 50,000 to 200,000 wet tons annually, depending on the level of residential development in the suburbs and exurbs. Due to strong regional growth projections for the area through 2030, our mean estimate is 150,000 wet tons/year. However, volumes can drop precipitously during times of slow construction, such as the current period.

Wood processors operate sites throughout the metro area and consolidate supplies of wood waste from the tree-trimming generators of the waste. These wood processors were also surveyed, but their totals were not included because it would be double-counting from the sources above.

As detailed in Appendix C and the following section on competing markets, roughly 60 percent of the urban tree residue base is presently consumed by District Energy Saint Paul and other biomass boilers. Another 30 percent goes to the landscaping mulch market (Table 2). It should be noted that a portion of the mulch is exported out of the Twin Cities to other markets. Some of the mulch may be produced by other sources of urban wood waste, such as secondary wood processors. The project team was unable to definitively identify the fate of the remaining approximately 10 percent of urban tree residues, but it is presumed to be buried, given away as free mulch, landfilled, or burned.

Table 2: Summary of current end markets for urban tree residue

End market	Wet tons
District Energy	260,000
Mulch	125,000
Lynn Busch	15,000
Other biomass boilers	10,000
Total	**410,000**

Based on these end markets, we estimate the current available quantity of urban tree residues to be 40,000 wet tons (summarized in Appendix C). Given the potential for other boilers coming on-line or increased usage of existing boilers, we estimate the long-term availability for Rock-Tenn to be one quarter of this amount, or 10,000 wet tons. However, if the emerald ash borer or a large storm were to come to the Twin Cities, this amount could be significantly larger in some years.

3.1.2. Secondary wood processing

Secondary mills manufacture finished wood products such as cabinetry, furniture, and windows. Wood residues from this sector include sawdust, shavings, chips, lumber scraps, and mixed waste. A 1994 DNR study estimated that up to 200,000 wet tons were generated annually in the Twin Cities region.[21] The project team conducted a survey to determine whether these quantities are still generated (see Appendix C), and we estimate that 134,000 wet tons of secondary wood waste might currently be generated in the Twin Cities annually.

We found, however, that nearly all of the clean wood waste is being used. Because secondary wood waste is clean and has very low moisture content, it is especially desirable for animal bedding. It goes to other markets as well, such as the mulch and boiler fuel markets. Boiler fuel is often used only during the heating season, however, so it may be possible to procure more quantities during the warmer months. Without the benefit of a comprehensive recent survey, we estimate that 10,000 tons may be available for Rock-Tenn, of which the plant may be able to rely upon one-third for the long term. Larger quantities of secondary wood with contaminants may be available, but the project team did not attempt to quantify this amount.

3.1.3. Construction and demolition wood

Construction and demolition (C&D) wood is generated when new buildings are constructed or when existing buildings are demolished or renovated. Most wood residues are commingled with other construction site waste and disposed of in construction and demolition landfills.

There are eight C&D landfills serving the greater Twin Cities area (see Table 3).

Table 3: C&D landfills serving the greater Twin Cities area

Landfill	Ownership	Location
Burnsville Dem/Con	Waste Management	Burnsville
Dawnway Demolition Landfill	Carl Bolander and Sons	Inver Grove Heights
Rich Valley Demolition	SKB	Inver Grove Heights
Rosemount Industrial Waste Containment Facility	SKB	Rosemount
Dem-Con Landfill	Dem-Con Companies	Shakopee
Elk River Dem/Con	Waste Management	Elk River
Vonco II	Veit Companies	Becker
Onyx/FCR Landfill	Veolia Environmental Services	Buffalo

The Solid Waste Management Coordinating Board (SWMCB) estimates that there were 1.55 million tons of C&D waste disposed at Twin Cities area landfills in 2005. This closely matches the five-year average (2001-2005) of 1.54 million tons.[22]

In the summer of 2006 the SWMCB issued a request for proposals for a characterization of C&D and industrial waste. The MPCA provided funding of up to $85,000 for the study. In addition to the SWMCB and MPCA, the Minnesota Solid Waste Administrators Association (MSWAA), working with the Association

[21] Minnesota Wood Waste Studies, Minnesota Department of Natural Resources, 1994, page 28.

[22] Solid Waste Management Coordinating Board, "Annual Results Report 2005," Approved June 28, 2006. Available at www.swmcb.org/files/ApprovedSWMCBAnnualResultsReport2005.pdf.

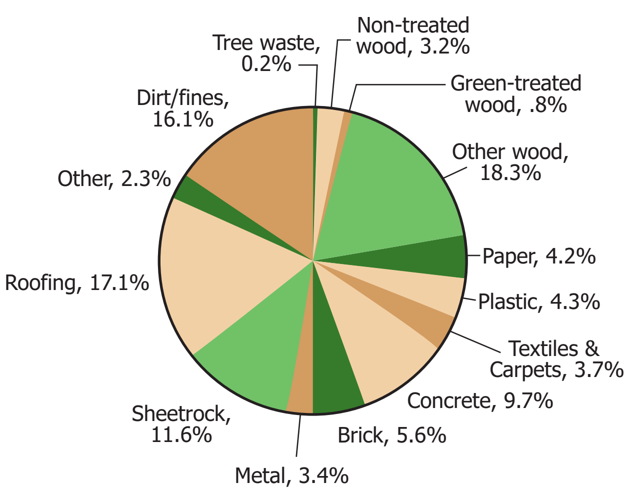
of Minnesota Counties (AMC), is also a partner for this project. In the fall of 2006, Foth was engaged to conduct the study, which is expected to be completed in August 2007.

The goal of the study is to "provide information for use by the Project Partners and other stakeholders in evaluating construction, demolition, and industrial wastes (CD&I) that can potentially be recovered for reuse, recycling, or creation of energy or compost."[23] The study will include waste sorts and specifically estimate metro and statewide quantities of wood available including cyclical and seasonal variations, provide an estimate of quantities currently being recovered by sector, consider potential contamination issues and fuel potential, and analyze currently employed and state-of-the-art technology available to recover reusable materials. In addition, policy options for increasing recoverable materials from the CD&I waste stream will be analyzed.

The project team received a draft report that included preliminary results of the Foth study's waste sorts.[24] The Foth study developed a sorting plan designed to be statistically representative of actual materials entering C&D landfills in Minnesota. Sorts of 100 loads were conducted at three sites in Dakota County (Rich Valley, Rosemount and Dawnway) from November 1-7, 2006. Preliminary results of the study are presented in Figure 4. The study indicates that 22.5 percent of all C&D is wood, most of which is "other wood" (plywood, particle board, painted wood, wood furniture and composite furniture). Non-treated wood includes dimensional lumber, pallets and other "clean" wood.

A similar waste sort was conducted by Foth in July and November 2002 in Des Moines, Iowa and also included in the draft report. "Non-treated lumber" is reported at 6.9 percent by volume and "other woods" (including green treated) is 22.3 percent, resulting in 29.2 percent total wood. These figures indicate slightly higher proportions of wood than the Twin Cities waste sort.

Figure 4: Results of Foth C&D landfill waste sort (by weight)[25]



In estimating quantities available based on this limited information, one approach would be to use the Minnesota and Iowa sorts as an upper and lower bound of the percentages available in the Twin Cities. Applying those percentages to the total quantity of C&D waste in the Twin Cities (five-year average, see

[23] "Request for Proposals for Minnesota Construction, Demolition, and Industrial Waste Study," issued by the Solid Waste Management Coordinating Board, July 21, 2006.

[24] Foth, "Minnesota Construction, Demolition, and Industrial Waste Study," draft, January 2007.

[25] Draft, subject to change. "Other" category includes glass (0.8 percent), Unused Product/Hazardous materials (0.3 percent), Incidental/Other (0.2 percent) and Electric Wastes (0.1 percent).

above) results in an estimate of 350,000 to 450,000 tons of wood waste per year, with a mean estimate of 399,000 tons (Table 4). Of this, 49,000 to 106,000 tons (77,500 tons mean estimate) is non-treated wood, while the majority (313,000 tons mean estimate) has some sort of contamination.

Table 4: Estimated quantities of wood available from Twin Cities C&D landfills (wet tons/year)

Type of wood	Estimated Quantities Applying MN Sort Percentages	Estimated Quantities Applying IA Sort Percentages	Mean Estimate
Non-treated wood	49,000	106,000	77,500
Green treated wood	12,000	n/a	
Tree wastes	3,000	n/a	
Other wood	282,000	344,000	313,000
Total wood	**347,000**	**450,000**	**399,000**

There are two methods of pulling these materials out of the C&D waste stream: 1) Source separate the materials and 2) Sort/process materials at a central facility, ideally either at a transfer station or co-located with a landfill.

Source separation at construction sites

Source separation results in the least contaminated and highest percentage recoverable wood. However, source separation is not practical for demolition wood. Residential construction is much better suited to source separation, because the new housing construction industry is relatively organized, and wood waste makes up a relatively high percentage of the total waste generated by the industry. In other studies, wood waste makes up 40 to 50 percent of all residential construction C&D waste (Table 5), which is higher than the aggregate of construction wood reported by Foth.

Table 5: Studies reporting construction wood waste from single-family construction

Study Sponsor and Year	Location	Percentage Wood (by weight)
Des Moines Metro Waste Authority (1994)[26]	Des Moines, IA	44%
National Association of Homebuilders (1995)[25]	Largo, MD, Anne Arundel Co., MD, Portland OR & Grand Rapids MI	42%
City of Seattle (1996)[25]	Seattle, WA	53%
State of Wisconsin (1997)[25]	Various sites in WI	39%
Houston/Galveston Area Council and TX Commission on Environmental Quality (2005)[27]	Houston, TX	39%
Average		**43%**

[26] As reported by Franklin Associates, 1998 (see bibliography).

[27] "Residential C&D Waste Study," Houston Advanced Research Center, for the Houston-Galveston Area Council and Texas Commission on Environmental Quality, July 31, 2005.

A 2002 study by URS Corporation, commissioned by the SWMCB, studied the composition and potential for recycling of waste from 114 housing units framed by Pulte Homes in Chanhassen and Apple Valley.[28] The study found that of the total wood waste generated, 59 percent was clean, non-treated dimensional lumber, 40 percent was engineered, and 1 percent was treated. Interior finishing C&D waste was not included in this study.

Based on the studies reported above and other sources referenced below, an estimate was derived that indicates approximately 28,000 tons per year of wood waste is generated by the residential construction industry in the metro area (Table 6). This represents about 10 percent of the total C&D wood waste availability estimated above.

Source separation could result in lower costs for disposal by generators of C&D wood, if sorting resulted in fewer containers taken to C&D disposal sites and if there was a market for C&D wood. Current gate-rate C&D landfill tipping fees are $35-$40/ton, but contract rates for large volumes can be closer to $15-$20/ton.

Table 6: Calculation to estimate clean wood waste and total wood waste available from metro-area residential construction

	Single family homes	Multifamily homes	Total
Units built in Metro / year (5 yr average)[29]	8,268	11,463	19,731
Average sq. ft. floor space/unit[30]	2,054	1,144	
Total waste generated, lb/sq. ft.[31]	4.38	4.38	
Total waste generated (tons)	37,190	28,719	65,909
Total tons wood available (at 43% of above)	15,992	12,349	28,341
Tons clean wood (at 59% of total wood)	9,435	7,286	16,721
Tons engineered wood (at 40% of total wood)	6,397	4,940	11,336
Tons treated wood (at 1% of total wood)	160	123	283
Total estimated wet tons (minus treated)	**15,832**	**12,226**	**28,058**

There is less data for remodeling C&D waste, but comparisons have shown that residential remodeling C&D activity generates more waste than residential new construction. Estimates vary from 1.25 (not including demolition wood) to over 4 times more wood than new construction (including demolition wood).[32] For the Twin Cities area, that would translate to 35,000 to 112,000 wet tons per year of wood waste. However, remodeling C&D wood waste would be more difficult to source separate, as remodeling C&D tends to mix waste construction materials with waste demolition materials, which are typically more contaminated than construction waste.

The trend toward advanced framing techniques in the construction industry is likely to decrease the amount of construction waste available over the medium to long term. Optimum value engineering (OVE) can reduce the

28 URS Corporation, "Construction Waste Report," Prepared for Solid Waste Management Coordinating Board, December 31, 2002. Percentages wood are by volume, not by weight. Treated wood is not included in the totals.

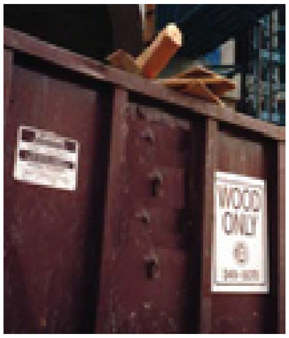
29 Metropolitan Council, "Council Survey of Residential Building Permits," 2001-2005.

30 U.S. Census data for average square foot floor area of units completed in Midwest region for 2005.

31 Derived from numerous studies and reported in Franklin Associates, 1998 (see bibliography).

32 The Franklin Associates 1998 report (see bibliography) references studies estimating total waste from residential remodeling C&D to be approximately 4 times as much as new residential construction, and estimating the total wood percent in residential remodeling at 45 percent, about the same as for new residential construction. McKeever estimates remodeling activity to generate 26 percent more recoverable wood waste than new residential construction based on research of building techniques and market estimates of construction and remodeling activity. McKeever, David, "Changes in the U.S. Solid Waste Wood Resource, 1990 to 1998," USDA Forest Service, Forest Service Products Laboratory, Madison WI, 1999.

amount of wood used for framing by 11 to 19 percent. Another benefit is the subsequent increased room for insulation, and demonstration projects applying OVE have shown reduced heating costs of nearly 30 percent.[33] The reduced material and labor costs alone assure that it is only a matter of time before the industry fully embraces OVE.



Policies can encourage on-site sorting of C&D materials (City of Portland, OR)

Another trend that could affect availability of construction wood is processing and using wood at the construction job site. This method involves grinding the wood and spreading the resulting mulch on-site. This method has grown in popularity due to increasing interest in "green building" techniques, such as the standards supported by the U.S. Green Building Council, which encourage waste reduction and recycling. On-site grinding can also provide another amenity (mulched landscaping) for the prospective homebuyer. However, this method is still in the demonstration stage and not yet widely adopted. Also, other recycling options for the wood would meet green building requirements, so it is possible that this practice will remain limited.

Transfer station sorting of C&D

Significant quantities of clean wood are already being removed from the C&D waste stream before reaching the landfill. Two facilities in the metro area, Shamrock Disposal and Broadway Resource Recovery (Atomic Waste), process C&D wood at their transfer stations, via a combination of mechanical and hand sorting methods. At least two C&D landfills, Dem-Con and SKB Rich Valley, sort some clean wood from incoming waste for processing into mulch. Many other C&D transfer stations will manually remove wood if there is a high percentage of wood in a load. This is consistent with the Foth study, which found clean wood to be a relatively small percentage of the total and to consist of small or contaminated pieces of wood. The Foth study also separately reported construction wood as a component of C&D and found clean wood to be about 22 percent of total wood available.[34] Given that generation rates of clean wood from construction are closer to 50 percent,[35] this also suggests that the clean wood is being taken from the C&D waste stream before being landfilled.

Large C&D processing facility

Foth analyzed a "high-tech" centralized system for sorting C&D waste.[36] Most sorting would be automated, but some would be manual. Capital costs were estimated at $11.1 million. Capacity would be up to 1500 tons/day, but because of seasonality of demand, it would not operate at full capacity year-round. Assumed annual throughput would be 250,000 tons, or roughly 15 percent of the total currently delivered to metro C&D landfills. Foth assumes that all of the materials that could be combusted would be recovered for boiler fuel (estimated at 50 percent, including plastics, paper, textiles and carpets), with 15 percent recovered for recycling and the remaining 35 percent landfilled. The total estimated cost is $37.91/ton to deliver the processed fuel to Rock-Tenn. This does not include any tipping fee revenue that might be received by the site for accepting C&D waste, or revenue from recycling of other materials (metals and aggregate). Adjusting for this revenue stream would result in a cost delivered to Rock-Tenn of about $17/ton.[37] Such a facility would be capable of supplying 125,000 wet tons/year to Rock-Tenn.

33 Factsheet on Advanced Framing Techniques (ToolBase TechSpecs), Partnership for Advancing Technology in Housing, 2006, www.toolbase.org/pdf/techinv/oveadvancedframingtechniques_techspec.pdf.

34 Clean wood was 3.8 percent of the total waste and total woods was 17.2 percent of total waste, thus clean wood is 22 percent of the total woods (3.8/17.2).

35 This is documented as shown above for residential construction, the biggest producer of wood. It is assumed that wood waste from commercial and industrial construction, although using less wood in general, would have similar proportions of clean wood to contaminated wood.

36 Foth, 2006 (see bibliography).

37 Assumptions: from Foth study, total projected annual cost is $9,477,200; recycled material revenue is estimated at $1,090,000 ($60/ton metals, $2/ton aggregate); tipping fee revenue estimated at $6,250,000 ($25/ton); total wood recovered at 50 percent is 125,000 tons/year.

Environmental considerations

A major issue with using C&D waste is potential contaminants, particularly with non-source separated materials. The main items of concern are:

- Composite wood, such as plywood and oriented strand board
- Painted or varnished wood
- Plastics, including plastic laminates and synthetic carpeting that may be attached to wood
- Pressure treated wood, including Copper Chromium Arsenate (CCA) and pentachlorophenol treated wood
- Other non-burnable debris co-mingled with the wood, such as nails, stones and wire
- Fines, likely to contain all of the materials above

The combustion of any of the above materials would likely trigger a higher level of review by regulatory agencies as opposed to only using clean wood. A study by the Northeast States for Coordinated Air Use Management, a consortium of state government regulatory agencies, concludes the following regarding using wood derived from C&D waste for combustion:[38]

- A review of the data shows that the use of appropriately processed C&D wood is similar in its emission profile to that of virgin wood
- It is likely that control equipment for plants opting to burn wood derived from C&D would be similar to or more stringent than that required for plants burning virgin ("clean") wood.
- The critical element in minimizing air emissions, especially air toxics, is the elimination of CCA- and penta-treated wood from the fuel and minimizing C&D fines.
- Requirements for comprehensive testing and sampling of the fuel at both the processing facility and the location of the end user will assure that the fuel quality is maintained.

Obtaining a significant amount of C&D wood residue will probably require a change in policy to encourage higher recycling rates. There are other reasons to consider policy changes as well. Although C&D landfills in Minnesota and many other states are minimally regulated and do not have to be lined, new research is demonstrating environmental concerns of landfilling C&D waste.[39] At least eight states are considering or in the process of implementing new C&D waste policies.[40] Some states have implemented policies that dramatically increase recycling of C&D waste. Massachusetts has instituted a ban on landfilling waste wood and other C&D materials. Local policies can also encourage reuse of C&D waste, such as Portland, Oregon's requirement of on-site recycling and development of a site plan as part of its permitting process. Portland's $35/ton tax on landfilled debris also helps encourage recycling. Nearly half of all construction firms in Portland reported recycling at least 75 percent of on-site waste in 2004 as a result of municipal policy.[41] Chicago also has a mandatory 50 percent C&D recycling rate.

Based on our preliminary investigation, we estimate that it would be possible to capture 15 percent of non-treated wood for Rock-Tenn, or 15,000 wet tons. With competing boilers and markets for this wood, we estimate only 5,000 of this might be available on a long-term basis. In contrast, we estimate it would be possible at the right price to divert half of the contaminated wood currently being landfilled to Rock-Tenn, or about 155,000 wet tons. Because this is mostly contaminated C&D for which there are no known markets, we estimate that 50 percent of this, or about 78,000 wet tons, would be available long term.

38 Northeast States for Coordinated Air Use Management (NSCAUM), "Emissions from Burning Wood Fuels Derived from Construction and Demolition Debris," May 2006. Available at www.nescaum.org/activities/major-reports.

39 William Turley, "A Watchful Eye: C&D Landfills Are Under Increased Scrutiny," Construction and Demolition Recycling, p. 48, July/August 2006.

40 States reported to be in the process of revising their regulations as of 2005 are California, Colorado, Kansas, Massachusetts, North Carolina, Ohio, South Carolina, and Washington (see footnote 27).

41 "Partnership Boosts Recycling for Contractors," Construction and Demolition Recycling, 10/31/2005.

As some of the issues discussed here will be addressed in further depth by the Foth study to be released in the summer of 2007, further analysis of this potential fuel source will not be considered here. Fully developing the potential of C&D as a significant fuel source will likely require an ongoing and iterative effort by the development team.

3.1.4. Waste wood in the MSW waste stream

In 2000, R.W. Beck completed a waste sort study for the SWMCB that estimated the quantities of wood entering the municipal solid waste (MSW) stream.[42] For the metropolitan area, the study estimated wood pallets at 3.6 percent, treated wood at 3.8 percent, untreated wood at 2.3 percent and woody yard waste at 0.4 percent. Untreated wood in R.W. Beck's study included painted, varnished, stained or adhesive-containing wood such as plywood. Treated wood included green (such as CCA-treated wood) or brown treated wood and railroad ties. In 2005, 2.1 million tons of MSW were either landfilled (1.1 million tons) or sent to a combustion or RDF facility (1.0 million tons).[43] Assuming the R.W. Beck study is still valid, about 132,000 tons of clean (84,000) or untreated (48,000) wood enters the MSW waste stream, of which half is already being combusted.

However, recovering wood from this segment presents a very challenging task. Sorting MSW prior to landfilling to recover the wood is essentially what RDF processing facilities already do with half of the metro MSW, without specifically separating wood. Because delivery to a C&D facility would be cheaper than the MSW option, it is highly likely that the quantities of wood from a given source are small, and that convenience of disposal is a prime consideration for the waste generator. Thus it would be harder to divert this wood for reuse without significant incentives to do so. Policy changes may someday make more of this wood available, but for now we do not include this as an available source for a Rock-Tenn facility. This source could be considered reserve capacity, however, because for the right price, direct generators or a third party would be motivated to capture this waste stream for Rock-Tenn. Policy changes, such as a waste ban, could also increase availability from this waste wood source.

3.1.5. Market cost structure and competing markets for urban wood waste

Competing markets for urban wood waste include animal bedding, mulch and other biomass boilers. Although the animal bedding industry consumes a significant portion of secondary wood and pallet wood, the project team found no evidence that it uses significant urban tree residues.

The market value of the region's urban waste wood varies widely and depends on where one is in the supply chain. Generators are often charged tipping fees to dispose of their residue. These fees, received by waste processors and landfills, may be as high as $80 per wet ton. In recent years, these fees have been declining due to increasing competition for waste wood. Waste processors recycle most of the residues (by chipping and grinding) for end products such as mulch and boiler fuel.

Bulk wholesale prices for mulch derived from Twin Cities sources range from $10 to $20 per cubic yard for locally produced mulch ($33-$67 per wet ton). These prices are supported by consumer demand for higher-priced imported alternatives (cedar and cypress mulch) but are also undercut by the increasing availability of free wood chips at municipal sites across the Twin Cities. Mulch producers and retailers strive to achieve product differentiation to create consumer demand for the higher end of the market. This is done through double grinding, promoting specific species, colorization, or making claims as to the quality of

42 R.W. Beck, "Statewide MSW Composition Study: A Study of Discards in the State of Minnesota," March 2000.

43 Solid Waste Management Coordinating Board, "Annual Results Report 2005," approved June 28, 2006.

wood. The mulch market is seasonal, with highest volumes sold in the spring and early summer, and sales slowing down considerably by fall. Pricing for animal bedding is at the upper end of mulch pricing, and can be more than $80/ton.

For price comparison, District Energy Saint Paul/St. Paul Cogeneration's base rate is $9.50/wet ton for chipped wood delivered to its fuel yard, but has recently reported paying more than double that amount for higher-quality fuels and during times of scarcity, such as winter months. Since this is still less than the price of mulch, most wood providers will sell their best-quality wood chips to the mulch market and bring the rest to District Energy.

Appendix C has a more complete discussion of these competing markets.

3.1.6. Other metro-area biomass projects

Other proposed and existing biomass projects in the metro area will impact the availability of urban waste wood. There are currently three existing projects (District Energy, University of Minnesota and Len Busch), one that will be constructed by mid-2008 (Koda Energy), and a final project still under development (Midtown Eco Energy).

District Energy St. Paul/St. Paul Cogeneration

The St. Paul Cogeneration facility, affiliated with District Energy St. Paul, is the largest consumer in the Twin Cities tree residue market. District Energy is a non-profit utility that supplies district heating services to downtown Saint. Paul. District Energy also has a for-profit affiliate, Market Street Energy, that is involved in development and operation of energy projects, including St. Paul Cogeneration. They operate one of the largest district heating and cooling system in the United States. Until several years ago this system was fueled mostly by coal and supplemented by fuel oil and natural gas.

District Energy supplies most of downtown St. Paul with heating and cooling (District Energy St. Paul)

St. Paul Cogeneration is a joint venture between Market Street Energy and Trigen-Cinergy Solutions (now part of Duke Energy). Although not solely a District Energy project, St. Paul Cogeneration is almost universally referred to as District Energy's biomass project, and that convention is followed here. The project secured a 25 megawatt (MW) power purchase agreement for an average price of 6.7 cents/kilowatt-hour (kWh, year 2000 dollars) from Xcel Energy as part of the Prairie Island biomass mandate.[44] In 2003 they started operation of the biomass plant, which has a maximum capacity of 310,000 pound/hour steam generation and 33 MW net electric generation.

As a cogeneration plant, the waste heat from electricity generation goes to the district heating system during the winter heating season. During non-heating months, the majority of the steam generated is used for electricity generation. The facility is permitted to use waste wood as well as agricultural sources, but has only used wood waste sources to date. The design capacity of the plant is 280,000 wet tons/year (170,000

[44] Nominal average price is 9.5 cents/kWh. As reported by Eilon Amit, Minnesota Department of Commerce, "Comments of the Minnesota Department of Commerce, Docket No. E002/M-03-306: Xcel Energy Proposed Plan for Implementing the Biomass Mandate Pursuant to Minn. Stat. §216B.2424 and Amendments to Power Purchase Agreements", March 28, 2003.

dry tons) of tree residues, which is over 12,000 semi-loads. As start-up and operational issues have been worked out, the actual usage of the plant has ramped up from 150,000 tons equivalent in 2003 to 260,000 tons in 2006. During the transition to biomass, the district heating plant continued to use coal, and still continues to meet some of its energy needs with coal. Moisture content of the biomass fuel ranges from 25-50 percent, with an average of 35 percent moisture.

District Energy's initial procurement plan was based upon direct delivery to the boiler by third parties. The third parties were large wood processors/consolidators in the metro area. Standard pricing was set at (and is still currently) approximately $9.50/wet ton for processed wood waste fuel. Other higher cost sources (more than double the cost due to transportation distance) have been relied upon during times when locally-derived biomass is scarce, as is being experienced at present. After starting operations, District Energy found the direct delivery arrangement to be unsatisfactory for reliable boiler operation. Both reliability and quality issues were experienced with third party providers. The providers either didn't deliver the promised quality or quantities or didn't deliver according to District Energy's required schedule. Because of extremely limited storage capabilities on-site (24 hours), and the need to operate the boiler around the clock, timing of the delivery is an important logistical concern. In spite of having a fuel specification in their contracts, the fuel was often not of sufficient quality necessary for reliable boiler operations. Debris and dirt were found in the deliveries, or the fuel was not sized properly.

Processing wood in a horizontal grinder into boiler-ready fuel at Pig's Eye site, St. Paul (Green Institute)

As a result of these issues, District Energy modified their business model to become more directly involved with the procurement of fuels. Another subsidiary, Environmental Wood Supply (EWS), now procures all of their wood fuel and delivers it to the facility. EWS is based on a large site (in excess of 10 acres, with additional storage area available seasonally) at Pigs Eye Landing, 10 minutes drive from District Energy. Processed wood is still delivered to Pigs Eye from third parties, but much of this fuel is screened and re-ground to meet the fuel specifications (4 inch minus). EWS owns horizontal and tub grinders and disk screens for processing wood. EWS also accepts unprocessed branches and logs directly at the site. In the past they have charged a market-rate tipping fee, but recently they have eliminated the tipping fee in an attempt to increase volumes of unprocessed wood delivered directly to the site. In addition to the Pigs Eye site, EWS seasonally operates a variety of other sites in cooperation with local municipalities throughout the metro area for the collection and processing of wood waste. This helps to provide a convenient drop off service for generators, while providing a more reliable source of fuel. EWS also provides processing and removal services for generators that need wood removed, such as after storm events.

EWS has found that seasonality can be an issue for fuel procurement, with winter usually being the most difficult time to procure wood waste. Two months of fuel supply at Pigs Eye is about the most they have been able to accumulate due to site capacity. In addition, ground wood in large piles can decompose and spontaneously combust and thus long-term storage poses logistical issues as well. When feasible, EWS arranges for producers to store wood off-site until it is needed and later delivered to Pigs Eye.

EWS has also found that availability can vary widely from year to year. After a storm event, quantities surge. There are also periods where it has been difficult to procure all the fuel required. During these times they've had to extend their supply chain beyond the immediate metro area to 100 miles out or further, including such areas as Red Wing and sources in Wisconsin and South Dakota. Currently, due to scarcity of tree residues and difficulty with accessing winter reserves of biomass stored at remote sites due to road access, District Energy has contracted with a logging company in northern Minnesota for 20,000 tons of biomass derived from logging residues. This supports their assertion that there are currently limited quantities of excess tree residues available.

University of Minnesota

The University of Minnesota Twin Cities Steam plant on the Mississippi River in Minneapolis completed construction of a biomass-capable boiler in 1999 as part of a $100 million major renovation of their campus heating and cooling system. The circulating fluidized bed boiler is operated by Foster Wheeler and capable of producing 200,000 pounds/hour of steam. Up to 16 MW of electrical power is produced from a back-pressure turbine, depending on the campus steam load. The electricity is used to power the heating plant and the balance is sent to campus. The steam is used for the campus heating/cooling system. Demand varies significantly according to the season, with a baseload of about 80,000 pounds/hour of steam, about the lowest level the boiler can produce. Maintenance of the facility is scheduled during the lowest demand times in May and October. The facility is permitted to use up to 70 percent natural gas, wood, or oat hulls with the balance of the fuel coming from coal and No. 2 fuel oil. Fuel oil must be burned when natural gas is curtailed. A long-term natural gas contract signed in 1993 at the Minneapolis Heating Plant has reduced the impact of high natural gas prices in recent years.

The facility has been permitted to use wood since it started operating and the boiler is capable of burning 30 percent or more wood. Wood specifications for the material handling system require two inch minus wood, which is smaller than District Energy's specification (four inch minus). The annual wood usage has grown somewhat since operations have started but hasn't reached above about 3 percent of total fuel usage. From some of their sources of wood they experienced build-up of material on their boiler tube walls, so they are cautious about what materials they accept. They have also had issues with improper sizing from some of their wood sources. Finding adequate quantities of compatible wood fuels sources has been difficult.

Recently the facility was granted a permit amendment to burn oat hulls and to test other agricultural sources. Originally they planned to design a separate pneumatic material handling system for oat hulls at a cost of $6-$7 million, but now they plan to save money by blending oat hulls with coal and using their existing material handling system. In December, 2006, wood and oat hulls comprised about 8 percent of the total fuel mix for the campus. The University has contracts in place for oat hulls for 2007, and currently about 25 percent of boiler heat is supplied by oat hulls without any boiler problems.

Koda Energy Project

The Koda Energy Project is a joint venture between the family-owned Rahr Malting company and the Shakopee Mdewakanton Dakota Community. Rahr Malting is the largest single-site malting facility in the world. The Koda Energy facility would supply thermal energy and some electric power to Rahr, and electric power to the Mdewakanton, which they could then use or sell to a local utility. Rahr Malting is an ideal co-generation site, with a large thermal energy demand (about one million MMBtu/year or about 30 MW thermal), currently supplied by natural gas. Electrical demand on-site averages 7.5 MW, and the plant will be built with a 16.5 MW (net) generator. Total efficiencies from cogeneration are projected to be 75 percent. Projected capital costs are about $55 million, with about $6 million in annual fuel costs.

The plant will use a suspension boiler, which requires fuel moisture content of less than 15 percent, unless natural gas is introduced to improve combustion. Hammermills for fuel processing will be on site, as the boiler fuel specification calls for sizing to a dust-like consistency. Three to four days of storage will be available on-site. Total annual fuel needs are about 175,000 green tons, at an expected moisture content of 10 percent (157,500 dry tons). Roughly one third (50,000 tons) will come from a malting by-product produced at the plant. The primary fuel source for the other two-thirds is expected to be low moisture content grain wastes such as oat hulls. Other dry, non-treated waste wood sources are also being considered, as are agricultural sources such as switchgrass. Most of their fuel sources are currently under contract. The turbine has been ordered for the project, and pending final permit approval, construction will start in the spring of 2007, with commercial operation expected by mid 2008.[45]

Midtown Eco Energy Project

The Midtown Eco Energy Project is a proposed biomass plant to be located in South Minneapolis at the site of a former garbage incinerator near Lake Street and Hiawatha Avenue. Initial feasibility work was conducted by the Green Institute. Project rights were sold in spring 2006 to a private developer, Kandiyohi Development Partners (KDP). Projected capital costs for the 23 MW facility are $98 million. During the heating season, a district heating system is expected to capture waste heat from electricity generation to heat the nearby Midtown Exchange complex, as well as other potential sites in the area. The City of Minneapolis has granted preliminary approval for $78 million in tax-exempt Empowerment Zone bonds, to be secured by a Power Purchase Agreement with an electric utility.[46]

The proposed 200,000-pound/hour bubbling fluid bed boiler will have an annual fuel demand of about 170,000 dry tons, expected to come predominately from urban wood waste sources (private tree trimming and removal, municipal tree operations, clean construction and demolition wood). The boiler is very flexible, capable of handling high moisture content fuels, with a similar fuel specification as District Energy St. Paul. The project reports having negotiated agreements for over 100,000 tons/year with local wood sources. An air permit application has been submitted to the Minnesota Pollution Control Agency, with a commercial operation date of 2009 expected by project developers.

[45] Personal correspondence, Paul Kramer, Rahr Vice-President, 1/24/07 & 2/22/07.

[46] See 10/25/2006 City of Minneapolis Department of Community Planning and Economic Development (CPED) recommendation: www.ci.minneapolis.mn.us/council/2006-meetings/20061103/docs/01-Midtown_Eco_Energy_Report_Public_Hearing_City_Council_Preliminary_Approval.pdf.

[47] Endres is also permitted to burn refuse-derived and mixed municipal solid waste including waste packaging material and petroleum coke.

Len Busch Roses

Len Busch is a flower wholesaler in Plymouth, off of Highway 55 and Highway 101. They have over 500,000 square feet of greenhouses, which they heat in the winter. They have used about 7,000 wet tons/year of wood in a 12,000 pound per/hour low pressure steam wood boiler. In January, 2007, they added another 13,000 pound/hour wood boiler to double their capacity to about 15,000 to 20,000 tons/year. To meet this demand, Len Busch will open up their site for delivery of tree wastes. Wood will be stored on-site until needed by the boiler.

Other biomass boilers

Some of the larger secondary wood processors combust their waste wood in on-site boilers. For example, Anderson Windows in Bayport uses waste wood from making windows for heating its facility. Although not a secondary wood waste generator, Endres Processing in Rosemount (adjacent to the SKB demolition landfill) also burns sawdust to provide heat for drying organic waste to turn into animal feed.[47] This provides additional justification for not considering secondary wood sources an available fuel resource for Rock-Tenn. Smaller existing or proposed boilers that fall beneath the permitting threshold may exist as well.

3.1.7. Urban/rural waste wood outside the metro area

The project team spent little time investigating this source. It is believed that a portion of this source is already being captured by existing Twin Cities wood processors, and that markets exist for a portion of the rest of it.

3.2. Milling residues: oat hulls

Oat hulls constitute the primary grain milling residue in the Twin Cities. Two General Mills cereal plants generate up to 90,000 dry tons of oat hull waste annually. The hulls are marketed through a General Mills by-products marketing division, and sales are generally made under short-term contracts with prices determined in a bidding process. Conversations with marketing personnel indicate that three- to five-year contracts are possible, but they are unwilling to commit to longer terms. The end uses for the hulls include boiler fuel, animal feed supplementation and, more recently, as a fiber additive for food and food supplements. The largest quantity goes to boiler fuel. General Mills has very limited storage for the hulls and must maintain a constant customer base or have the material removed for landfill disposal. Its supply has some monthly variation but is relatively constant over the year. It is able to grind the oat hulls at its facility for increased density in transport per customer request and at customer expense.

Conversations with General Mills indicate that much of this resource has been locked up until approximately 2010 to at least two different biomass plants, which they were unwilling to identify. Public sources indicate that one of these sources is U.S. Steel in Mountain Iron, about 200 miles north of the Twin Cities.[48] General Mills indicated that the "spot price" for oat hulls is around $30/ton FOB; however, this could change significantly in the coming years depending on demand. In early 2004, the University of Minnesota conducted a successful test combusting oat hulls with coal, and had anticipated securing a supply of oat hulls from General Mills.

48 Minnesota Daily, "Fuel for U OK-ed, Now No Supply," Angela Grey, February 28, 2006.

The project team also contacted other suppliers of oat hulls outside of the Twin Cities area. Can-Oat Milling is the largest oat processor in the world with mills in Saskatchewan, Manitoba, and Alberta, Canada. Can-Oat personnel indicated that they would be willing to supply quantities of 25,000 tons or more under long-term contract. The Saskatchewan and Manitoba mills are conveniently located on rail lines 950 and 500 miles respectively, from St. Paul. The Manitoba mill has a pelletizing facility, and plans are under way to build palletizing capacity at the Saskatchewan facility by the end of 2007. Grinding and pelletizing oat hulls significantly increases the density of the fuel and reduces transport costs. Even so, transport costs are estimated at $28-$40/ton by rail. As Rock-Tenn has rail access, it is assumed that rail delivery could be accomplished for this fuel source. Total costs of the pelletized fuel vary from $53 to $65 per wet ton (Table 7). Longer term, we estimate that Rock-Tenn could count on only half of the 25,000 tons currently available.

Table 7: Estimated cost of importing Canadian oat hulls to Rock-Tenn

	Cost/wet ton, Manitoba facility	**Cost/wet ton,** Saskatchewan facility
Value of hulls (minimum)	$5	$5
Grinding	$10	$10
Pelletizing	$10	$10
Rail transport	$28-$31	$36-$40
TOTAL:	**$53-$56**	**$61-$65**

Because much of the Twin Cities oat hull supply is currently tied up, we assume only about 10 percent (10,000 wet tons) could be available to Rock-Tenn, with perhaps half this volume available long term. At this low percentage, it would be important to know if the fuel could be easily blended with other fuels in the main fuel handling system (as the University of Minnesota is planning to do) or if using oat hulls would require a separate fuel handling system. A separate handling system would be an expensive endeavor for the ability to use this limited fuel source.

Although oat hulls are the largest source of agricultural milling residues, other milling residues may also be. For example, the Malt-O-Meal plant in Northfield is reported to have residues that would make a suitable biomass feedstock. There are also other sources of agricultural residues in the Twin Cities though they were not considered here for several reasons. First, many of these sources have alternative markets other than biomass fuels. Second, some are considering use of the residues for on-site boiler fuel. Finally, because a wide range of agricultural milling residues are suitable for Koda Power (discussed above), it is likely that this plant will corner much of the available sources.

3.3. Agricultural residues: corn stover

Corn stover is the residue left on the field after the grain is harvested, including the stalk, cobs and leaves. There has been much discussion of collecting stover for use as biomass energy, but only a few demonstration projects have reported experiential data. Although other conventional crops leave residues on the field, none leave as much as corn, and thus only corn stover is considered here. However, residues from other crops (soybeans, wheat, oats) could be another potential source of biomass.

3.3.1. Available quantities of corn stover

Because the yield of corn stover is dependent upon the yield of corn, stover availability can be estimated based on county-level reporting of grain yields. The ratio of stover yield to corn grain yield can vary, but is roughly 1:1, as assumed by the U.S. Department of Energy.[49] The corn stover yield available for collection, however, is limited by the amount that should be left in the field for erosion control and maintaining appropriate soil organic matter and nutrient levels. In addition, removal of corn stover can reduce the following year's yields through exposing the soil to increased evaporation rate and soil temperature. Tillage method, soil type and the slope of the field determine how much stover should be left on the field. Intensive tillage means that more stover must be left on the field to reduce erosion; fields employing no-till methods are less susceptible to erosion. Increasing no-till methods could therefore increase the amount of stover available for collection. There is currently no generally accepted method for determining how much corn stover should be left on the field.[50]

Baling corn stover after the grain has been harvested (NREL)

An additional limitation is the efficiency of removing the stover from the field. Current methods involve collecting the stover after it has been scattered on the field following harvest. Depending on the equipment and technique, reported collection efficiency can vary from 30 to 70 percent. As experience is gained with corn stover removal, and new techniques such as single-pass harvesting are developed, collection efficiency will probably be less of an issue.

We estimate available quantities of corn stover using the approach of two recent studies in Minnesota.[51] We estimate total stover availability based on reported corn yields for 2002-2004 as well as county data on soil types, rainfall, crop and rotation choices (including tillage method) to estimate sustainable harvest rates.[52] Technologically feasible removal is estimated at 40 percent,[53] and the lower of the amounts that can be removed and the technologically feasible rate are used to estimate total potential removal (Table 8).

[49] U.S. DOE-ORNL 2005 (see bibliography).

[50] An excellent review of issues related to corn stover removal is Wilhelm, 2004 (see bibliography).

[51] Petrolia, 2006, and Butcher, 2006, of Center for Energy and Environment (see bibliography).

[52] This factor was calculated by Marie Walsh, M & E Biomass, Oak Ridge, TN, 2005, from unpublished data furnished to University of Minnesota researchers, and reported by Petrolia, 2006 (see bibliography).

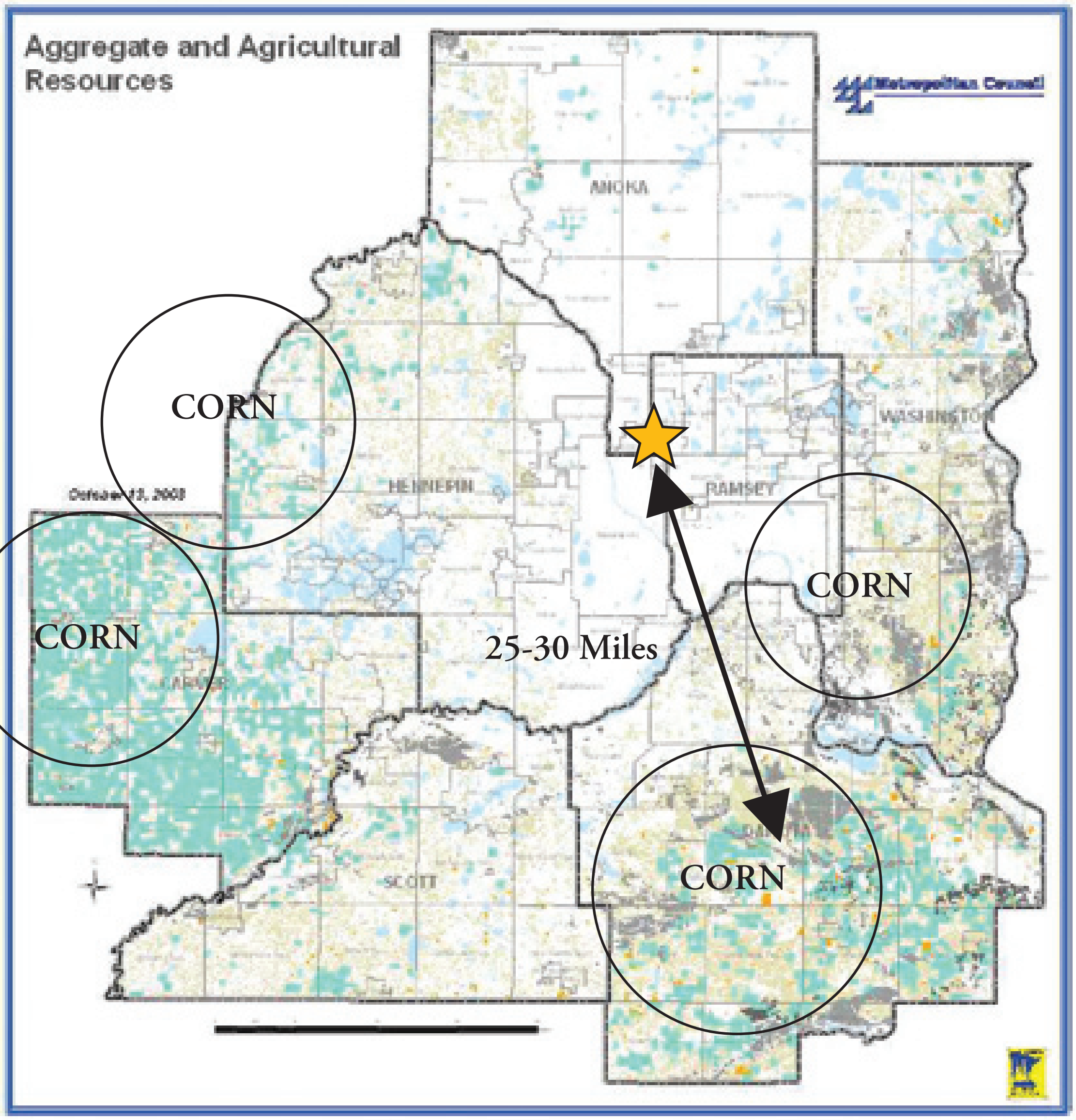
[53] Based on reported rates of removal, Schechinger, 1999 (see bibliography).

Table 8: Available quantities of corn stover (wet tons) in counties within 75 miles of Rock-Tenn

County	Total Stover on Field	Proportion That Must be Left	Amount That Can be Removed	Technologically Feasible Removal	Potential Removal
Anoka	17,844	49%	9,121	7,137	7,137
Benton	149,227	15%	126,759	59,691	59,691
Carver	213,075	44%	119,214	85,230	85,230
Chisago	60,353	51%	29,492	24,141	24,141
Dakota	348,234	73%	94,347	139,294	94,347
Dodge	422,406	33%	284,209	168,962	168,962
Goodhue	517,727	97%	13,002	207,091	13,002
Hennepin	49,504	78%	10,850	19,802	10,850
Isanti	87,935	55%	39,942	35,174	35,174
Kanabec	33,582	93%	2,439	13,433	2,439
Le Sueur	346,511	46%	187,250	138,605	138,605
McLeod	381,322	20%	305,245	152,529	152,529
Meeker	385,343	25%	288,801	154,137	154,137
Mille Lacs	51,008	58%	21,237	20,403	20,403
Nicollet	460,148	25%	347,375	184,059	184,059
Ramsey	677	100%	0	271	0
Rice	297,241	76%	71,641	118,897	71,641
Scott	143,849	81%	27,448	57,540	27,448
Sherburne	92,050	17%	75,973	36,820	36,820
Sibley	534,473	25%	400,491	213,789	213,789
Steele	407,141	38%	253,763	162,856	162,856
Wabasha	310,375	99%	3,413	124,150	3,413
Waseca	480,600	26%	356,387	192,240	192,240
Washington	71,122	86%	10,137	28,449	10,137
Wright	220,909	56%	97,918	88,363	88,363
Total:	**6,082,655**		**3,176,455**	**2,433,062**	**1,957,416**

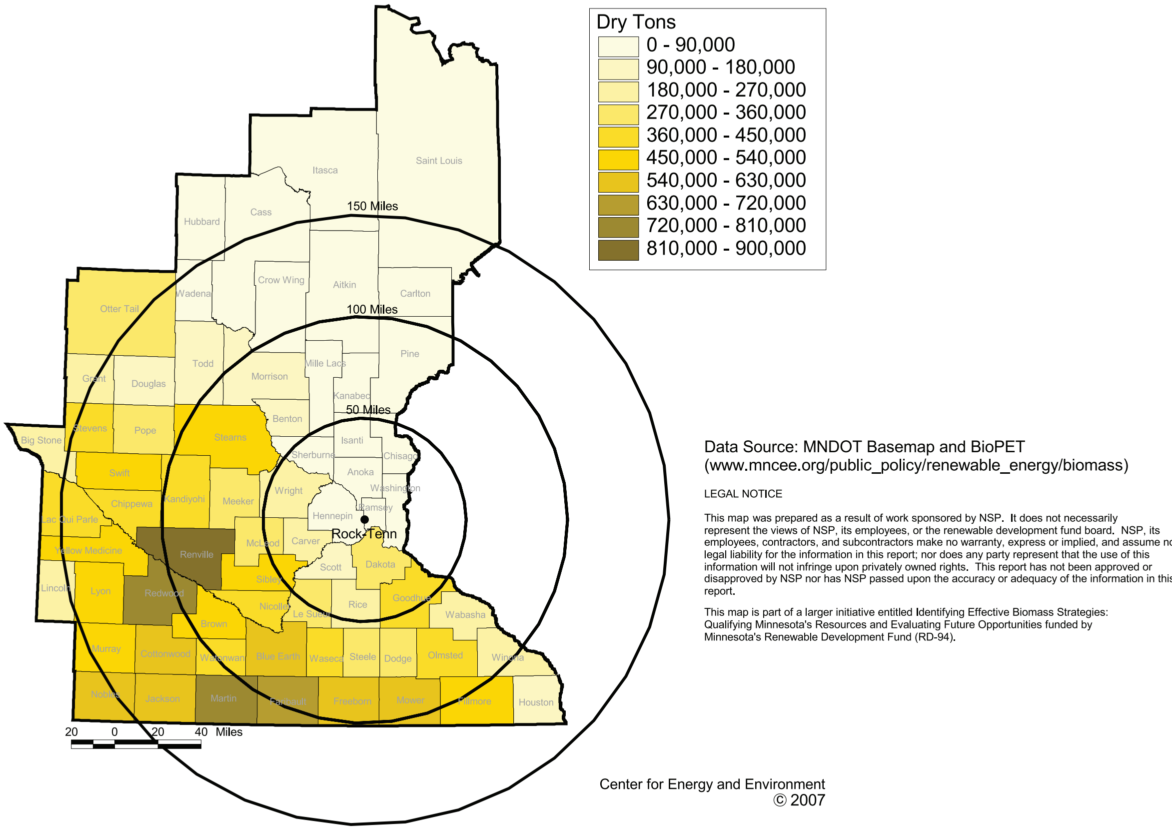
There are 1.9 million tons of recoverable corn stover in counties within 75 miles of Rock-Tenn. As shown by Figure 5 and Figure 6, the nearest sources in large volume are in Dakota, Carver, Hennepin and Washington Counties, with large quantities available further out. In total, the four meto counties above could potentially provide more than 200,000 wet tons of corn stover, which is sufficient to supply all of Rock-Tenn's fuel needs for a biomass boiler.[54]

Figure 5: Proximity of Rock-Tenn site to sources of corn stover



[54] Assuming 18 percent moisture content and 8191 Btu/lb energy content (dry basis) of corn stover.

Figure 6: Corn stover within 50 to 150 miles of Rock-Tenn (dry tons)



3.3.2. Market dynamics and competing markets for corn stover

Although corn stover is currently collected and used primarily for animal bedding and other non-boiler markets, there is much discussion and research on using corn stover as a biomass energy source, principally at ethanol plants. Minnesota has 16 corn ethanol plants, with a 2006 output of 550 million gallons, or about 20 percent of the gasoline used in the state (much of the state's ethanol production is exported). With five more plants under construction and expansion at existing plants, this capacity is expected to double to 1 billion gallons by 2010.[55] At that level, ethanol plants would consume 27 percent of all corn produced in the state. On a national level, the passage of the federal renewable fuels standard (RFS) in 2005 mandates biofuel production of 7.5 billion gallons/year by 2012, the vast majority of which is projected to be ethanol. As U.S. ethanol production in 2005 was 4 billion gallons, this means a doubling of national capacity over the next six years.

If the ethanol expansion continues at this pace, it will soon put a severe strain on corn for food and other products. The rapid expansion has already driven corn prices to record highs, and reduced world exports of corn from the United States.

In the short term, driven by the high cost of natural gas, most ethanol producers in the state are considering biomass to meet the thermal requirements of corn ethanol production. Corn stover is a prime candidate, but not the only source being considered. Of three Minnesota ethanol producers with biomass projects, only one has immediate plans for using corn stover for a portion of its fuel. Other fuel sources are mill residues (Central MN Ethanol Co-op), a syrup byproduct of ethanol production (CornPlus), dried distillers grains, wheat straw and wood wastes as well as corn stover (Chippewa Valley Ethanol Company).

[55] Minnesota Department of Agriculture, "Ethanol Plants in Minnesota," February 2007.

Assuming a worst-case scenario, if all the ethanol capacity in the state in 2010 were to use corn stover for process heating, this would require approximately 2.9 million tons of corn stover, assuming current thermal demands for ethanol production.[56] This is just under half of our estimate of the total potentially available stover in the state (7.0 millon tons) at the above assumed yields and collection technology. Increasing stover collection efficiency to 75 percent in areas where this is possible, as DOE assumes is likely long term, could increase state availability to 12.2 million tons.

Longer term, the ethanol industry anticipates moving to cellulosic ethanol, for which corn stover would be an ideal feedstock. Cellulosic ethanol is much less energy-intensive to produce, and has long-term potential for producing economic biofuels from a wide variety of feedstocks, including wood, switchgrass and other perennial grasses as well as stover. Currently the technology is still in the demonstration stage, and the few plants that are operating in the world have very high production costs. The federal RFS requires that cellulosic ethanol provide 250 million gallons, or 3 percent of the total mandate, by 2013. In addition, one gallon of cellulosic ethanol counts for 2.5 gallons towards the RFS.

If Minnesota's entire ethanol capacity in 2010 of one billion gallons were retooled to use corn stover, it would create a demand for about 11 million tons of corn stover.[57] At this level, it would consume practically all of the available stover in Minnesota, even assuming a higher collection efficiency. This is probably a very optimistic goal for cellulosic ethanol to achieve within the next ten years. Some fairly significant technical barriers will have to be overcome before cellulosic ethanol is commercially viable. The generally conservative Energy Information Administration predicts that total U.S. cellulosic ethanol production will barely climb above federally mandated levels of 250 million gallons/year by 2020.[58] Others are more bullish, and over the next 25 years it is highly likely that many of the current technical barriers for cost-effective production of cellulosic ethanol will be overcome, but exactly when that will happen is anyone's guess. Additionally, corn stover is not the only feedstock being considered for cellulosic ethanol conversion.

Although this demand for corn stover represents a potential threat to a feedstock supply for Rock-Tenn, the advantages of fuel diversity at the plant may outweigh these risks. The closest ethanol plant to Rock-Tenn is about 75 miles to the south (Al-Corn Clean Fuel in Claremont), and none of the proposed ethanol plants are any closer to Rock-Tenn. Thus, in the mid term, competition for nearby stover (25-40 miles from Rock-Tenn) will likely be small.

Even should competition increase near Rock-Tenn, there is a high availability of stover relative to Rock-Tenn's needs. Depending on the conversion technology, it is likely that Rock-Tenn's boiler would be restricted to 10 to 30 percent agricultural residues, or about 20,000-60,000 wet tons/year of corn stover. Compared to statewide totals and even local availability, this is a relatively small portion. Thus it is not likely that increased demand would threaten the availability of stover fuel, but increased competition could drive up the premium paid to farmers for removal of the stover. If corn stover were more widely used in the state, however, efficiencies in collection and handling could drive down collection costs, which could work to offset increases in farmer payments. Finally, it may be possible to reduce fuel risk by entering into long-term contracts with agricultural providers for the corn stover.

We estimate that a farmer participation rate of 25 percent would be possible, resulting in near-term availability of corn stover of 490,000 tons/year. Long term, increasing demand would give more farmers incentive to

56 Around 35,000 Btu/gallon of ethanol. Other assumptions for the calculation are 15 percent stover moisture content, 85 percent efficient conversion, and stover energy content of 8191 Btu/lb.

57 Assuming 87.9 gallons per dry ton, per NREL estimates.

58 U.S. Department of Energy, Energy Information Administration, "Annual Energy Outlook 2006," Appendix.

participate in the market, but would also reduce demand. A 75 percent farmer participation rate would be reasonable in a market with increased demand. Assuming that Rock-Tenn would be able to capture only a relatively conservative 5 percent of this market, 73,500 wet tons/year would be available long term.

3.4. Dedicated energy crops: grasses

Before the introduction of agriculture, most of Minnesota was covered with a diverse mix of grass species. The deep root structure of prairie grasses (most of the mass of grasses is below ground) provided a buildup of soil carbon and organic matter that resulted in the fertile soils that farmers enjoy today. This ability of grasses to remove carbon dioxide from the air and sequester the carbon in soil has captured the interest of researchers and policymakers concerned about climate change and the buildup of greenhouse gases.

In addition, research has focused on grasses as a potential source of renewable energy, for both direct combustion and production of synthetic gas and biofuels. This is due to perceived advantages of grasses over other crops for non-food biomass production. Although initial establishment costs are higher than conventional crops, once established, they require less inputs (fertilizer and chemicals) and less mechanical cultivation. The stands may need to be re-established at some interval, or they may prove to be self-sustaining. Many researchers are optimistic that current grass yields can be doubled with appropriate investment in research and development, which could offer significant quantities of biomass compared to agricultural residues. Grasses can also provide ecological benefits through increased habitat and carbon sequestration and improvement of water quality, compared to conventional crops. Limiting harvesting to certain times of the year or every other year can provide increased wildlife habitat while also allowing harvesting of biomass. If planted in riparian areas near conventional crops, stands of grasses can absorb runoff of nitrogen and other pollutants before they reach rivers.

In addition to grasses, other dedicated energy crops have been considered for biomass production, including hybrid poplar trees and willow trees. The Laurentian Energy Authority has planted a plantation of hybrid poplar trees to grow fuel for their plant. For simplicity, we only consider grasses as representative of perennial energy crops, but other dedicated energy crops may be possible. Current reported costs of grasses are representative or lower than other dedicated energy crops.

Most academic research on grasses has focused on switchgrass, but multi-species crops that combine switchgrass with other native species such as Big Bluestem, Little Bluestem and Indian Grass are also being studied. The evidence shows that a more diverse species blend can increase biomass yields compared to grass monocultures on degraded lands.[59] However, this comes at higher establishment costs and may not apply to more fertile soil types.

3.4.1. Potentially available quantities of grasses

Very few acres of grasses are currently available for biomass harvesting. Thus current availability is assumed to be zero. Acres currently planted in hay are used for animal feed. Thus production of grasses in sufficient quantities to supply biomass to Rock-Tenn would have to come from converting current land uses to grass production. We assume that with sufficient market opportunities, up to 25 percent of acres currently planted and harvested for corn could be converted to grasses, 25 percent of which would flow to the Rock-Tenn facility. (This number considers only acres actually planted to corn, as part of a corn-bean rotation, in any given year.) A recent literature review found yields of 3 tons/acre on marginal lands in the Upper Midwest.[60] We assume a 4 tons/acre for land converted from corn. This would result in more than 1.5 million wet tons in grass that could be available in counties within 75 miles of the plant (Table 9). Realistically, perhaps 25 percent of this amount would be available to Rock-Tenn (390,000 tons).

59 Tilman, 2006 (see bibliography).
60 Tiffany et al., 2006 (see bibliography).

Table 9: Potential volumes of grasses available in counties within 75 miles of Rock-Tenn

County	Acres Currently in Corn	Acres Potentially Converted to Grass	Wet Tons Harvested
Anoka	7,400	1,850	7,400
Benton	47,460	11,865	47,460
Carver	54,780	13,695	54,780
Chisago	21,120	5,280	21,120
Dakota	86,060	21,515	86,060
Dodge	102,660	25,665	102,660
Goodhue	124,220	31,055	124,220
Hennepin	14,620	3,655	14,620
Isanti	31,760	7,940	31,760
Kanabec	12,480	3,120	12,480
Le Sueur	87,020	21,755	87,020
McLeod	96,900	24,225	96,900
Meeker	105,440	26,360	105,440
Mille Lacs	18,280	4,570	18,280
Nicollet	110,660	27,665	110,660
Rice	75,660	18,915	75,660
Scott	36,400	9,100	36,400
Sherburne	25,860	6,465	25,860
Sibley	127,660	31,915	127,660
Steele	99,820	24,955	99,820
Wabasha	72,980	18,245	72,980
Waseca	112,500	28,125	112,500
Washington	20,460	5,115	20,460
Wright	67,520	16,880	67,520
Total	**1,559,720**	**389,930**	**1,559,720**

In addition to land currently in agricultural production, there is some potential for grasses to be planted on lands not currently being used for production. Some of these are enrolled in the federal Conservation Reserve Program (CRP), which, under current rules, permits biomass harvesting only on a limited demonstration basis. Even then, harvesting must meet ecological criteria set by the U.S. Department of Agriculture, such as harvesting only every other year. Several groups are proposing that the rules be changed to expand the amount of CRP land allowed to be harvested for biomass energy. In addition to CRP, state changes are being proposed to create new acres of Reinvest in Minnesota (RIM) land for planting biomass crops. This could increase the potentially available volumes from those reported above.

Nationally, the billion-ton study estimated that growing perennial crops on about 13 percent of agricultural land would provide about 29 percent of the total biomass the U.S. is capable of harvesting (1.3 billion dry tons/year). This amount would be sufficient to supply more than one-third of current U.S. petroleum demand.[61]

[61] U.S. Department of Energy, 2005 (see bibliography).

3.4.2. Market dynamics and competing markets for grasses

In order to persuade farmers to produce grasses, the economic returns from grasses must be at least comparable to conventional crops. An additional hurdle is that although maintenance costs are lower, initial establishment costs are relatively high. Because land cannot be readily converted back and forth from grasses to other crops as it can with most conventional crops, farmers must also be convinced that there is a long-term market in place that will justify the initial investment to convert land to grasses.

Just as for corn stover, future demand for biomass from grasses is likely to come from ethanol plants, and the same considerations apply to grasses. Thus, we estimate the same amount of wet tons as for corn stover would be available long-term, representing roughly 5 percent of the total market. As we assume that some land currently planted in corn would be converted to grasses, increasing grass acreage would reduce the amount of corn acreage, and thus the total availability of corn stover. To avoid double-counting between grasses and corn stover in our summary of total long-term biomass availability, we assume that up to 50 percent of corn acres could be converted to grasses.

3.5. Forest residues

Although Minnesota's forested areas are a greater distance from Rock-Tenn than the other sources considered here, there is still potential for forest residues to provide a significant portion of Rock-Tenn's fuel needs. According to statistics compiled by the Minnesota Department of Natural Resources (DNR),[62] the forest products industry employs 22,400 Minnesotans in primary processing (including logging), 18,860 in secondary manufacturing, and had total manufacturing shipments of $6.9 billion in 2004. The forest products industrial base includes five virgin pulp and paper mills, three recycled pulp and paper mills (including Rock-Tenn), three hardboard and specialty mills, six oriented strand/structural board mills, more than 500 sawmills, 150 associated industries, 300 logging companies and more than 800 secondary manufacturers such as Andersen and Marvin Windows. Approximately 29 percent of the land in Minnesota, 15 million acres, is harvestable timberland. In 2004, approximately 8.6 million wet tons[63] of wood were harvested for industrial pulpwood (81 percent), sawlogs (15 percent) and residential fuel wood use (4 percent). Total timber harvested on private lands is slightly higher than that harvested on public lands. Most of the harvested timber and the industry using this timber are centered around the northeast part of the state in St. Louis and Koochiching counties.

Specialized equipment is used to harvest trees (IATP)

[62] Minnesota Department of Natural Resources, "Minnesota's Forest Resources," November 2006.

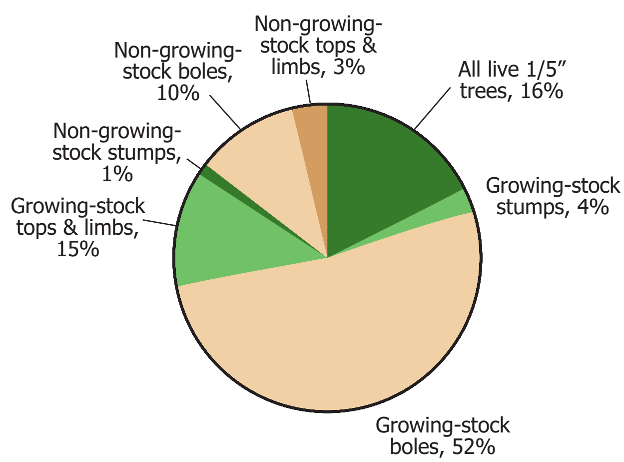
[63] Reported as 3.6 million cords, conversion factor of 2.4 tons/cord used. Actual conversion can vary depending on moisture content of wood. U.S. Dept. of Energy reports 1.2 dry tons/cord; at 50 percent moisture that would be 2.4 wet tons/cord.

The forest products industry in Minnesota already consumes a considerable amount of wood residues. Most of this residue is generated at primary mills. In 1997, Minnesota primary wood-using mills generated a total of 2.9 million tons of mill residues. More than 90 percent of these residues were used, mostly for fiber products or boiler fuel.[64] Most of the virgin pulp and paper mills have wood boilers constructed to use mill residues generated on-site for their own thermal needs. Because primary mill residues are already highly utilized, they are not further considered here.

3.5.1. Logging residues

Logging residue refers to the unused portion of trees cut or left after logging. Present logging practices for pulpwood harvest trees greater than six inches diameter and use the portion of the trunk that is four inches or greater in diameter. This merchantable portion of the tree trunk, from one foot above the ground to a four-inch top, is called the "bole." The remaining woody material, tops and limbs, is a potentially available source for boiler fuels. Industry practice is moving toward using the trunk down to three inches, and in some cases two inches, although this would only minimally reduce the total residues available.[65] In addition to harvested trees, non-merchantable tree species are in some cases considered for boiler fuel. As can be seen in Figure 7, merchantable biomass (i.e., growing-stock boles) is about 52 percent of total forest biomass, while the tops and limbs of the merchantable biomass are about 15 percent of total forest biomass. As Table 10 shows, tops and limbs are a slightly lower percentage of total forest biomass for softwoods (12 percent) than for hardwoods (16 percent). Thus, according to this study, the portion of harvested tree biomass left as residue varies from about 19 to 24 percent. This is consistent with, and perhaps on the low side of, the conclusions of other studies and estimates by logging industry professionals (18 to 30 percent).[66]

Figure 7: Components of forest biomass on Minnesota timberland[67]



[64] William Reading IV and John Krantz. "Minnesota Timber Industry – An Assessment of Timber Product Output and Use, 1997." USDA Forest Service, North Central Research Station, 2002.

[65] Berguson, 2005 (see bibliography) does a detailed analysis of reducing the tops from four inches to two inches, and concludes that it would increase merchantable biomass by less than 3 percent.

[66] Berguson, 2005 (see bibliography).

[67] Miles, Chen, and Leatherberry, 1992, "Minnesota Forest Statistics, 1990, Revised" North Central Forest Experiment Station, totals for all ownership classes and all species types.

Table 10: Total biomass on Minnesota timberland (million wet tons) by component and species[68]

Components of Forest Biomass	All Hardwoods		All Softwoods		All Species	
All Live 1”-5” Trees	77	(12%)	61	(26%)	138	(16%)
Growing-stock Stumps	26	(4%)	11	(5%)	37	(4%)
Growing-stock Boles	340	(52%)	123	(52%)	462	(52%)
Growing-stock Tops & Limbs	102	(16%)	28	(12%)	130	(15%)
Non-growing-stock Stumps	6	(1%)	1	(0%)	7	(1%)
Non-growing-stock Boles	79	(12%)	9	(4%)	88	(10%)
Non-growing-stock Tops & Limbs	22	(3%)	2	(1%)	24	(3%)
Total:	**651**	**(100%)**	**235**	**(100%)**	**885**	**(100%)**

Although it may be technically possible to use nearly all of the available tops and limbs, environmental reasons require leaving a portion of the residue in the forest. These reasons include soil nutrient preservation and impacts on wildlife. The impact of forest residue removal on soil nutrient balances is heavily dependent upon soil types. A recent review of the literature and analysis of the science indicates that the impact of forest residue removal for most mineral soils in Minnesota would likely have a minimal effect on soil nutrient balance, while organic soils could experience a much greater impact.[69] Most of the peatlands (the main category of organic soils) in Minnesota are in northern and central Minnesota. Forests between the Twin Cities and Duluth do not have a high percentage of organic soils.

In late 2006 the cities of Virginia and Hibbing completed construction of new biomass boilers for their district heating systems. The joint project, called the Laurentian Energy Authority, will also produce power for sale to Xcel Energy as part of meeting its biomass mandate, and will run entirely on forest residues in its initial years. Hybrid poplar plantations are being planted to fuel a portion of the plants’ needs in later years. A study conducted by Bill Berguson at the University of Minnesota’s Natural Resources Research Institute in Duluth estimated 730,000 green tons of forestry residues are potentially available within 100 miles of the Laurentian woodyard.

As part of an effort to ensure that the project would have a positive environmental impact, a process was created to develop guidelines for removing logging residues from forests. This process is led by the Minnesota Forest Resources Council, with participation from the University of Minnesota Department of Forest Resources, the Minnesota DNR, and other stakeholders. The guidelines are expected to be completed by summer 2007, and are currently undergoing peer review. A draft of the guidelines made available to the project team states that the goal is to retain about a third of the forest woody debris on a logging site.[70]

In the summer of 2006, the Minnesota DNR completed a survey of quantities of logging residue left from timber harvests.[71] A total of 124 sites were surveyed in 2003-2004, representing 2.5 percent of all acreage harvested during that time. The data were collected by cover type, harvest type and logging method. Piles of woody debris left on landings and scattered on the site were tallied. Based on the results of this study

[68] Ibid.

[69] David Grigal. “An Update of Forest Soils. A Technical Paper for a Generic Environmental Impact Statement on Timber Harvesting and Forest Management in Minnesota.” December 28, 2004.

[70] “DRAFT Biomass Harvesting on Forest Management Sites in Minnesota,” prepared by the Minnesota Forest Resources Council Biomass Harvesting Guideline Development Committee, January 12, 2007.

[71] Sorenson, 2006 (see bibliography).

and given average harvested acres, logging residues can be estimated by county. This analysis was performed for counties within 100 miles and 150 miles of Rock-Tenn (Table 11). Accounting for leaving one-third of the residue on-site for environmental reasons, nearly 47,000 wet tons are estimated to be available in counties located within 100 miles, two-thirds of which is in Pine County. Extending the reach to counties within 150 miles increases the availability of logging residues to 172,000 wet tons.

Table 11: Estimated logging residue available from Minnesota counties within 150 miles of Rock-Tenn[72]

	Average Annual Logged Acres	**Total Logging Residue** (wet tons)	**Residue Available for Removal** (wet tons)
Minnesota Counties w/in 100 miles			
Chisago	86	1,309	877
Isanti	123	1,538	1,030
Kanabec	312	4,302	2,882
Mille Lacs	174	2,556	1,713
Morrison	437	5,803	3,888
Pine	3,6770	46,707	31,294
Wabasha	61	1,159	777
Winona	355	6,745	4,519
Subtotal:	***5,222***	***70,120***	***46,980***
Minnesota Counties w/in 150 miles			
Aitkin	6,718	88,167	59,072
Carlton	2,822	35,438	23,743
Crow Wing	2,473	32,531	21,796
Wadena	2,461	27,356	18,329
Todd	188	2,936	1,967
Cumulative Total	**19,884**	**256,547**	**171,887**

[72] Estimates calculated following the methodology outlined in Sorensen 2006 (see bibliography), and assuming 33 percent of logging residue is left on-site, consistent with the draft biomass harvesting guidelines (see footnote 71).

Wisconsin also has significant forested areas within 100 and 150 miles of Rock-Tenn. Because the same data set is not available for Wisconsin counties, a different methodology was employed to estimate logging residues there. The amount of total residue was estimated from USDA Forest Service data.[73] From the data presented in Figure 7 above for total forest biomass, a factor of 28.8 percent was applied to the harvested quantities, which represents the ratio of tops and limbs to harvested wood (i.e., 15 percent divided by 52 percent = 28.8 percent). Thirty-three percent, representing the volume of logged residue to be left in the forest, was deducted as above. This methodology is similar to those of two recent studies.[74] Results are presented in Table 12. Approximately 160,000 wet tons is available from counties within 100 miles, and over 400,000 wet tons is available in counties within 150 miles. Minnesota and Wisconsin availability is presented graphically in Figure 8.

Table 12: Estimated logging residue available from Wisconsin counties within 150 miles of Rock-Tenn

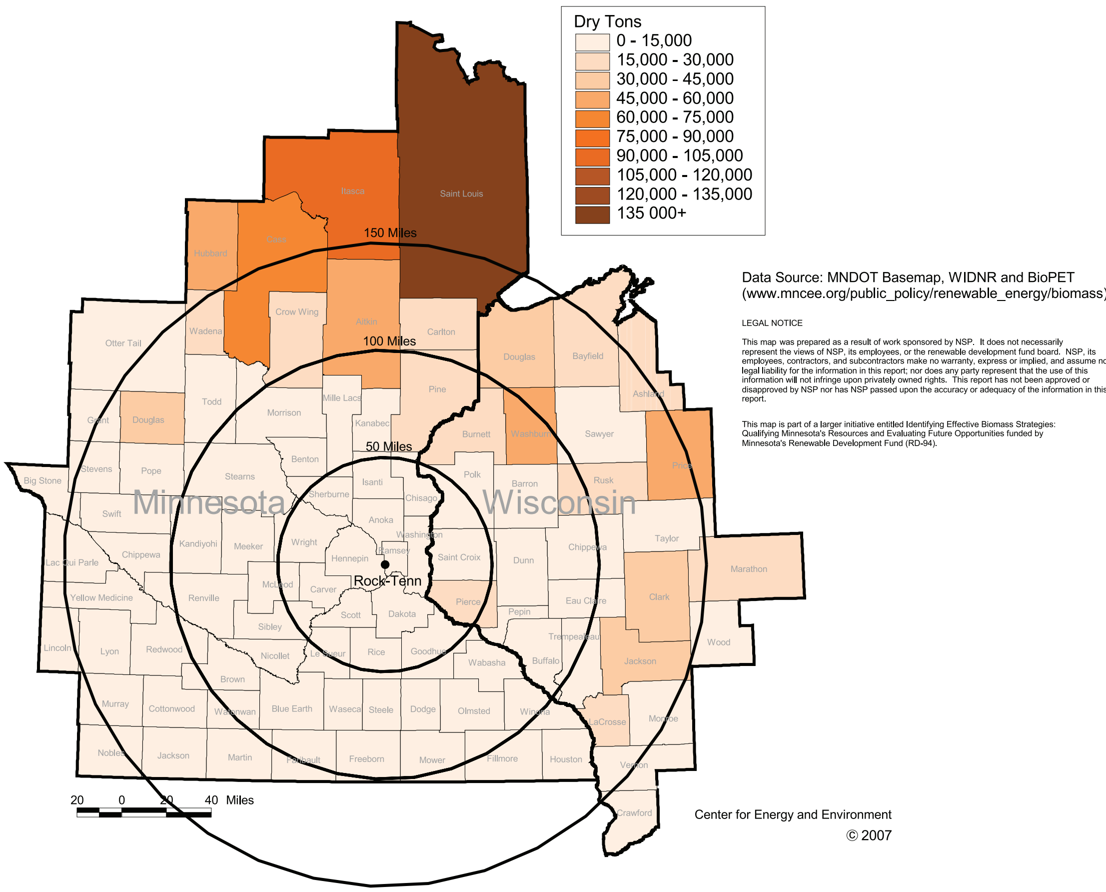
	Average Annual Harvest (Wet Tons)	**Total Logging Residue** (Wet Tons)	**Residue Available for Removal** (Wet Tons)
Wisconsin Counties w/in 100 miles			
Barron	26,100	11,042	7,398
Burnett	102,950	43,556	29,182
Chippewa	31,682	13,404	8,981
Dunn	52,896	22,379	14,994
Pierce	82,101	34,735	23,272
Polk	20,432	8,644	5,792
St. Croix	13,762	5,822	3,901
Washburn	234,225	99,095	66,394
Subtotal:	***564,148***	***238,678***	***159,914***
Wisconsin Counties w/in 150 miles			
Clark	199,760	84,514	56,624
Douglas	152,299	64,434	43,171
Jackson	169,521	71,720	48,053
La Crosse	74,362	31,461	21,079
Monroe	55,168	23,340	15,638
Rusk	134,986	57,109	38,263
Sawyer	48,937	20,704	13,872
Taylor	36,201	15,316	10,262
Vernon	55,628	23,535	15,768
Cumulative Total:	**1,491,010**	**630,812**	**422,644**

[73] Average annual removals of growing stock on timberland by county and major species group, Wisconsin, 2000-2005, U.S. Department of Agriculture, Forest Service, Forest Inventory Assessment. Thousand cubic feet was converted to green tons using 20 lbs/cubic foot. Reported sampling errors vary from about 50 to 100 percent, so the data are not very precise.

[74] Berguson, 2005 and Petrolia, 2006b (see bibliography).

In addition to the Laurentian project, at least four other facilities in Minnesota meet a portion of their fuel needs with logging residues: the SAPPI paper mill in Cloquet, Rapids Energy Center (serving UPM-Kymenne paper mill) in Grand Rapids, Minnesota Power's Hibbard power plant in Duluth, and District Energy in St. Paul. In addition, the gasifier unit recently installed at the Central Minnesota Ethanol Cooperative (CMEC) plant in Little Falls may use logging residues. They are currently using sawmill residues, a good fit for their boiler fuel specifications of 30 percent moisture content fuel sized to less than a quarter inch. Future use of logging residues may require CMEC to overcome fuel processing requirements.

Figure 8: Estimated quantities of logging residue with 50 to 150 miles of Rock-Tenn (dry tons by county)



Recent delivered prices for the four projects currently using logging residues vary between $17 and $27 per wet ton. Discussion with logging industry professionals suggests that the lower end of this range may not allow loggers a sufficient profit margin to be economically sustainable. For comparison, market data from 2005 indicates the average delivered cost of hardwood pulpwood chips at that time was around $40/wet ton.[75] The slowdown in the construction industry and demand for saw wood and composite wood products since 2005 is likely to have reduced prices, and prices fluctuate widely depending on market conditions. In addition, although the availability data extend to 150 miles, discussion with current buyers of forest residues indicates that pricing and reliability of fuel supply beyond 75 miles is considered difficult to

[75] Petrolia, 2006 (see bibliography) reports the delivered price of U.S. market hardwood roundwood pulpwood during the first half of 2005 to be $74/dry ton according to the 2005 Pulp & Paper Global Fact & Price Book, and estimates grinding costs to be $7/dry ton, for a total cost of $81/dry ton. Assuming 50 percent moisture content, this would be $40/wet ton.

quantify. In the cost chapter, it is assumed that delivery to Rock-Tenn will involve higher transportation costs than for plants within 75 miles of forest residue sources.

The project team discussed delivering forest residues to Rock-Tenn with one logging company in Pine County that also has considerable capacity for grinding. They indicated that additional contracted quantities of around 50,000 wet tons/year were available and that contracts for under $40/ton delivered were reasonable. Seasonal variation might be an issue, as logging activity is much greater in winter, when the ground is frozen. However, this would complement urban waste wood supplies, which are greater in summer than winter. Also, logging operations might be willing to store wood, which would be much cheaper in rural areas than in metro areas.

Some environmental groups have expressed concern that if insufficient logging residues were available at a future date, biomass plants might need to use merchantable timber. This would increase the number of acres logged and could increase pressure on sustainable management of forests. However, at current levels of usage, including by Rock-Tenn, supplies of logging residues far surpass demand.

Current availability of logging residues within 100 miles of Rock-Tenn is estimated at about 90 percent of the total potentially generated, or 180,000 wet tons/year. Long-term, we apply a fuels multiple of 3X, given other competing sources, and estimate availability at 60,000 wet tons. Annual shortfalls of this amount could be supplemented by extending the supply shed to 150 miles, although this is not a recommended long-term strategy.

3.5.2. Forest thinnings and ecological restoration

Forest thinning is the selective removal of trees. In a commercially managed forest, thinning is undertaken primarily for timber stand improvement (i.e. to improve the growth rate or health of the remaining trees). Thinning can improve the long-term harvest potential of a forest. Overcrowded trees experience stress and competition from neighbors. Thinning can increase the resistance of the stand to environmental stresses such as drought, insect infestation or extreme temperature. Non-merchantable tree species may also be removed. Thinning that results in very little harvest of merchantable wood is referred to as pre-commercial thinning.

Thinning may also be performed for ecological reasons (“ecological thinning”). Here the primary aim is to increase growth of select trees, favoring the development of wildlife habitat, water quality improvement, and increased species diversity. Ecological thinning may accomplish many of the same objectives as pre-commercial thinning, such as removal of invasive species and stand improvement for merchantable species.

Finally, forest thinning may be performed to reduce fire hazard. In pre-settlement times, more frequent natural fires reduced the fuel loading of forests to limit the spread and impact of individual fires. However, human suppression of fires has resulted in a build-up of fuel in forests that can be vastly destructive when a fire does happen. Many large and destructive fires in recent years have highlighted the need for proactive steps to reduce fuel loading. Although controlled burns have been used successfully to reduce fire risk, this method is not practical near populated areas, where the need is greatest, and increasingly mechanical thinning methods are being examined. Federal fuel reduction efforts have focused more on western states with generally drier conditions than Minnesota, but there is a need for fuel reduction in Minnesota as well.

Limited experience with using forest thinnings as biomass fuel makes it difficult to estimate the proportion of total biomass removed from forest thinnings that would be available for Rock-Tenn. Some forest thinnings are likely to be merchantable pulpwood. A USDA Forest Service assessment of fuel reduction treatments in western states estimated availability of biomass using mechanical thinning. Estimated merchantable biomass represents about 70 percent of total volume of the thinnings, with non-merchantable, boiler fuel biomass representing about 30 percent.[76] Another USDA Forest Service study found non-merchantable wood to be 33 percent to 50 percent of total biomass removed.[77] This finding may not apply to Minnesota forests and for forest thinning objectives other than fire hazard reduction, but provides a general indication of what might be expected in Minnesota.

Another difficulty in assessing the potential of this biomass source is that it is not known how many acres are viable candidates for forest thinnings, and how much biomass could be removed from those acres. Anecdotal evidence suggests that a large percentage of the forests in and around Pine County, both public and private, are candidates for thinning to improve forest health. The Minnesota DNR is assessing the biomass potential from forest thinnings in counties between the Twin Cities and Duluth. Results are expected in late March 2007.

Limited data exist on the economics of using forest thinning residue as boiler fuel. Forest thinning for all three of the purposes outlined above is still emerging as an area of interest, and not much data on cost of removal are available. In addition, thinning costs can vary by a factor of 3 or more depending on the purpose of the thinning and the specific characteristics of the forest. One USDA Forest Service study of western forests estimated the cost to cut and move woody biomass from fuel treatments to the roadside varied from about $700 to just under $1000 per acre for low-slope areas.[78] When combined with the study estimates of biomass removed for each scenario, costs are about $55 to $210 per green ton for the low-slope areas. The cost of chipping and delivery would add to this cost.

A study is currently under way in Minnesota to estimate the costs and characterize the biomass produced from forest thinnings using state-of-the-art harvesting equipment. The project is led by the Institute for Agriculture and Trade Policy, along with the Laurentian Energy Authority and a cooperative logging business, Forest Management Systems (FMS). Test biomass harvests have been conducted at nine sites comprising approximately 180 acres in the Superior National Forest in areas identified as high-priority fuel treatment areas for fire hazard reduction. All sites have little potential for commercial timber harvest. Full project results are expected to be available in summer 2007. It is likely that reported removal costs will be an upper limit of what costs could be for a commercial operation removing thinnings. However, federal money available for fuel reduction can significantly reduce these costs.

Another source of forest thinnings that offers much potential is ecological restoration of public and private forested land in and near the metro area. In particular, oak savanna has been identified as an opportunity for improvement. A recent meeting of an ad-hoc "Quality Forest Management" group of nonprofit and government stakeholders estimated that a minimum of 50,000 tons per year for at least five years would be available if existing plans for ecological restoration were implemented at state and regional parks near the metro area. It is likely that additional quantities would be available as an ongoing source of fuel for Rock-Tenn. However, insufficient information was available to the project team to fully evaluate this source. Additional assessment is necessary to evaluate annual quantities, the extent to which they could be relied upon, costs of removal, and other potential markets for the wood removed from such thinnings.

76 USDA Forest Service, Research and Development. "A Strategic Assessment of Forest Biomass and Fuel Reduction Treatments in Western States," Rocky Mountain Research Station. March 2005.

77 See footnote 79.

78 Kenneth Skog, et al., "Evaluation of Silvicultural Treatments and Biomass Use for Reducing Fire Hazard in Western States," U.S. Department of Agriculture Forest Service, Forest Products Laboratory, May 2006.

Because of the limited information currently available, and because additional research will be completed soon, potential forest thinning quantities were not included in the estimates in this study.

3.5.3. Brushland

Biomass from brushland harvesting is another emerging source of biomass that may present an opportunity for Rock-Tenn. Brushland and open lands are predominantly non-forested habitats dominated by shrubs such as alder and willow, grasses, sedges and herbs. In recent years there has been much interest in removing woody material from brushland areas to convert them to open lands and thus improve habitat, particularly for the sharp-tailed grouse. The sharp-tailed grouse, along with 17 other species of vertebrate wildlife, are considered dependent specifically on Minnesota open lands. The Laurentian project has identified wood from brushland as a potential biomass source, and this in part has increased interest in examining the biomass fuels potential of brushland. Removal for a biomass fuels market could create an economically viable way to clear brushland for habitat improvement. Guidelines similar to those being developed for logging residue removal are being developed for brushland harvesting by the Minnesota Forest Resources Council in cooperation with the DNR and a variety of technical specialists and stakeholders.

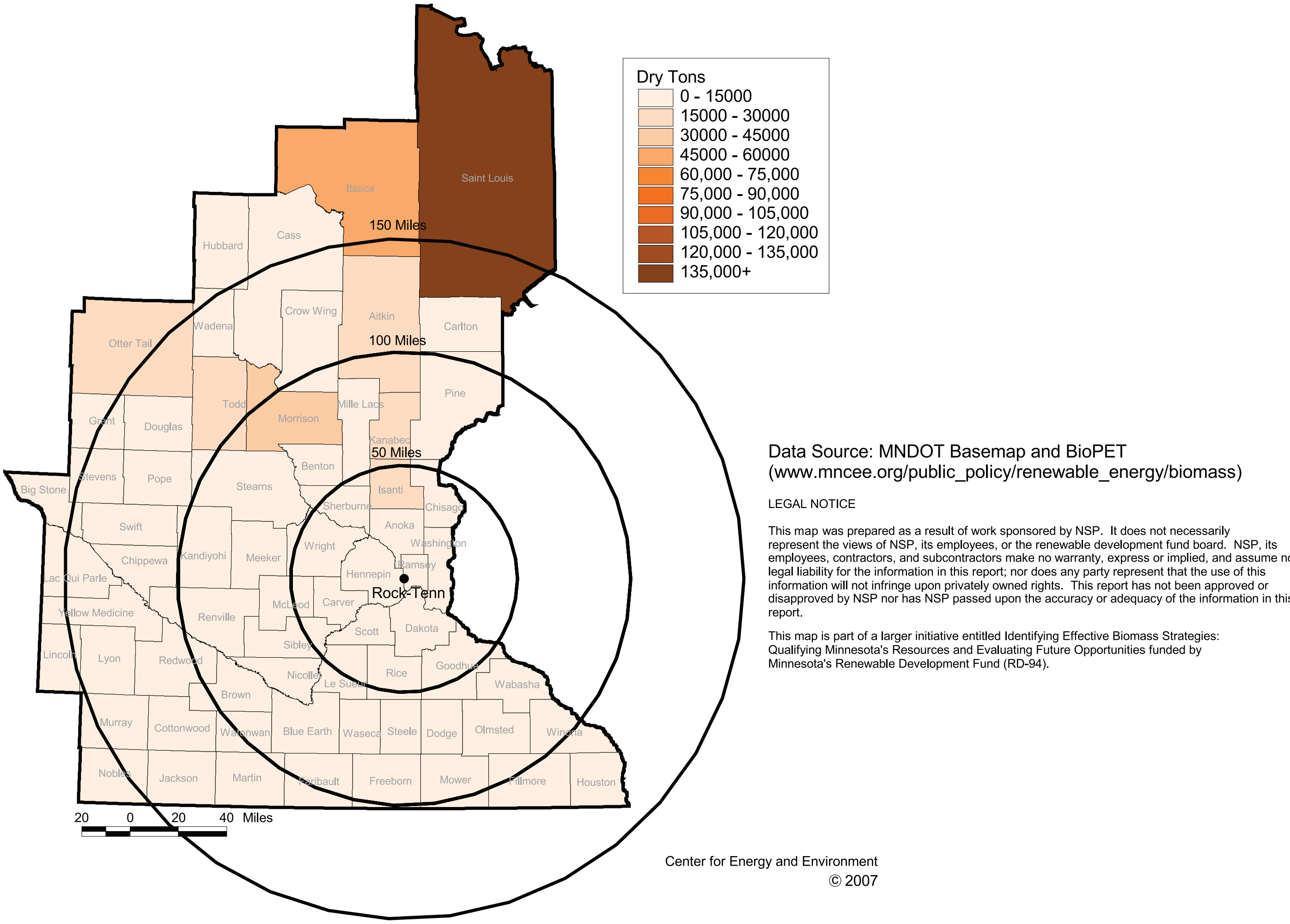
Total quantities of brush within 150 miles of Rock-Tenn are estimated at 195,000 wet tons, as presented in Table 13. Data are from Center for Energy and Environment, for counties with more than 1,000 tons available. Center for Energy and Environment estimates the recoverable portion at 80 percent.[79] The same data set, in dry tons (assuming 50 percent moisture), is used for Figure 9.

Table 13: Estimated potentially available quantities of wood from brushland in counties within 150 miles of Rock-Tenn (wet tons)

County	Total on Land	Recoverable Portion
Counties w/in 100 miles		
Chisago	13,089	10,471
Isanti	32,597	26,077
Wright	4,883	3,906
Sherburne	13,809	11,047
Benton	15,066	12,053
Kanabec	39,845	31,876
Subtotal	***119,288***	***95,430***
Counties w/in 150 miles		
Olmsted	23,334	18,667
Stearns	27,998	22,398
Morrison	73,493	58,794
Cumulative Total	**244,112**	**195,289**

[79] Butcher, 2006 (see bibliography) and accompanying software, "Biopower Evaluation Tool," available at www.mncee.org/public_policy/renewable_energy/biomass/index.php.

Figure 9: Estimated quantities of wood from brushland with 50 to 150 miles of Rock-Tenn (dry tons by county)



Current methods for clearing brushland areas involve shearing, mowing or burning. Unburned biomass is left on the land, and could be put into windrows and collected. Little information is available on the costs of shearing, collecting, forwarding and processing the woody biomass. Researchers at the University of Minnesota Department of Forest Resources are currently conducting a project to assess the availability and economics of harvesting brushland. The data presented above are gross availability. It is not known how much of this quantity is economically recoverable; it might be only a fraction of the total presented above. Because of the relatively limited data on removal, this biomass source is not considered further here. It could represent a future biomass source for Rock-Tenn, however, and can add to the reserve quantities of biomass for the project to ensure adequate supplies over a long time horizon.

3.6. Paper recycling residues

Waste residue produced at the plant is a primary candidate for consideration as a biomass source. Rock-Tenn produces about 30 tons per day (about 11,000 tons/year) of waste residue that is not suitable for use in its mill. The residue is about 50 percent moisture content which is near or above the moisture content generally acceptable for combustion in a boiler. However, blending with lower-moisture-content fuels might be a way to use this potential fuel. The level of non-fiber contaminants, Btu value and other characteristics that would determine its suitability as a boiler fuel are unknown but worth investigating.

3.7. Summary of available biomass quantities

Table 14 presents a summary of the estimated quantities of non-RDF biomass available to Rock-Tenn. The derivation of these estimates is described in detail in the previous sections. A subjective estimate of uncertainty associated with each source is also included (columns with "+/-"). Some of the uncertainty is based on annual variations (such as land clearing), and on the limitations of the data employed to derive the estimates. A conversion from wet tons to dry tons is calculated based on fuel-specific moisture content as reported in Appendix D. The final column of the table is the proportion of Rock-Tenn's total energy demand that could be met by the estimate of long-term availability. Rock-Tenn's energy demand is assumed to be their current demand provided by an 85 percent efficient boiler with a 95 percent capacity factor (i.e. an average of 226,000 lbs/hour of steam delivered 95 percent of the hours of the year, or 2.6 million MMBtu/year). As discussed more fully in section 4.2, this assumption of plant demand is simplistic, and may not represent the energy demand of the final plant design.

Table 14: Summary of estimated quantities of non-RDF biomass available to Rock-Tenn

	Mean Quantity Generated			Current Availability	Long-term Availability		
Biomass Source	**Wet Tons**	**Dry Tons**	**+/-**	**Dry Tons**	**Dry Tons**	**+/-**	**Proportion of Plant Demand**
Urban waste wood							
Urban tree residue							
Tree trimming and removal	300,000	195,000	25%	--	--		
Land clearing	150,000	97,500	100%	--	--		
Subtotal Urban Tree Residue	*450,000*	*292,500*	*40%*	*26,000*	*5,000*	*200%*	*3%*
Secondary wood sources	132,000	118,800	30%	9,000	3,000	200%	2%
C&D wood							
Clean wood	77,500	69,750	25%	12,000	5,000	100%	3%
Other wood (composites/painted/treated)	313,000	281,700	25%	140,000	70,000	50%	45%
Subtotal, C&D wood	*390,500*	*351,450*	*25%*	*152,000*	*75,000*	*60%*	*48%*
Clean wood in the MSW stream	84,000	67,200	20%	0	0		0%
Other wood in the MSW stream	48,000	40,800	20%	0	0		0%
Subtotal all urban wood sources	*1,104,500*	*870,750*	*30%*	*187,000*	*83,000*	*60%*	*53%*
Milling residues: oat hulls							
Twin Cities	80,000	72,000	10%	9,000	4,500	200%	3%
Imported from Canada	25,000	22,500	20%	22,500	11,000	200%	6%
Subtotal	*105,000*	*94,500*	*15%*	*31,500*	*15,500*	*200%*	*9%*
Agricultural residues: corn stover	6,000,000	4,900,000	30%	400,000	60,000	50%	38%
Dedicated energy crops: grasses (assuming corn conversion)	0	0		0	60,000	50%	37%
Subtotal[80]	*6,000,000*	*4,900,000*	*30%*	*400,000*	*90,000*	*50%*	*56%*
Forest residues							
Logging residues	207,000	103,500	50%	90,000	30,000	75%	20%
Forest thinning/ecological restoration	n/a	n/a		n/a	n/a	--	--
Brushlands	95,000	47,500	100%	n/a	n/a	--	--
Subtotal forest residues	*302,000*	*151,000*	*75%*	*0*	*30,000*	*150%*	*20%*
Total, all sources	**7,511,500**	**6,016,250**	**40%**	**618,500**	**218,500**	**50%**	**138%**

[80] Subtotals of corn stover and grasses are not the total of their individual estimates, because some corn land is assumed to be converted for grass production, thus limiting the amount of corn stover available when totaled with grasses.

4. Costs and Procurement of Biomass Fuels

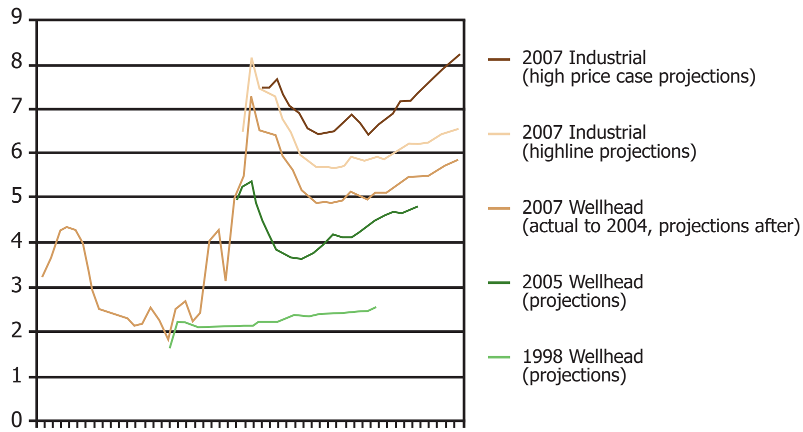
4.1. Benchmark costs of energy generation

Rock-Tenn plans to use natural gas and fuel oil as an interim fuel source, but believes that a plant operation based on natural gas alone is not economically viable for the company. We use natural gas economics as a reference point for determining the economic viability of a biomass plant. This section compares total costs of energy production from these two sources, including non-fuel operating costs. With actual capital costs and financing parameters still unknown, estimating non-fuel costs for biomass is difficult. Refused-derived fuel (RDF) is also considered.

4.1.1. Natural gas cost trends

As Figure 10 shows, the U.S. Department of Energy (DOE) Energy Information Administration (EIA) estimates industrial natural gas prices will level out from current peaks by 2010 to $7-$8/MMBtu. There is considerable uncertainty in these projections, as in all predictions of long-term future energy prices, and EIA's forecasts have tended to significantly under-predict actual gas prices over the last decade as Figure 8 demonstrates. Thus, sustained prices of $8-$9/MMBtu or higher would not be an unreasonable expectation. In a review of five other private-sector projections, the EIA reports that the highest projected industrial prices are about $9/MMBtu by 2030.

Figure 10: Natural gas prices: historical data compared with projections from 1998, 2005 and 2007[81]



4.1.2. Non-fuel operating costs

It is important to consider the non-fuel costs of owning and operating a biomass plant versus a natural gas plant. A biomass plant will have significantly higher capital and operating and maintenance (O&M) costs than a natural gas plant. Thus the project team found it necessary to estimate non-fuel costs for a biomass plant compared to a natural gas plant (Figure 11 and Table 15).

To estimate biomass non-fuel costs, three scenarios were constructed, to establish a lower and upper bound of what potential costs might be. This is intended to be a screening analysis of the range of costs, and not a detailed financial cost analysis. The main variables in the scenarios are:

- **Initial capital costs.** Capital costs are dependant upon the conversion technology selected, as well as pollution control equipment. The pollution control equipment will be dependant upon the fuels that are used by the facility. Environmental review will determine the pollution control equipment required.

[81] U.S. Department of Energy, Energy Information Administration (U.S. DOE, EIA), "Annual Energy Outlook 1998," "Annual Energy Outlook 2005," and "Annual Energy Outlook 2007."

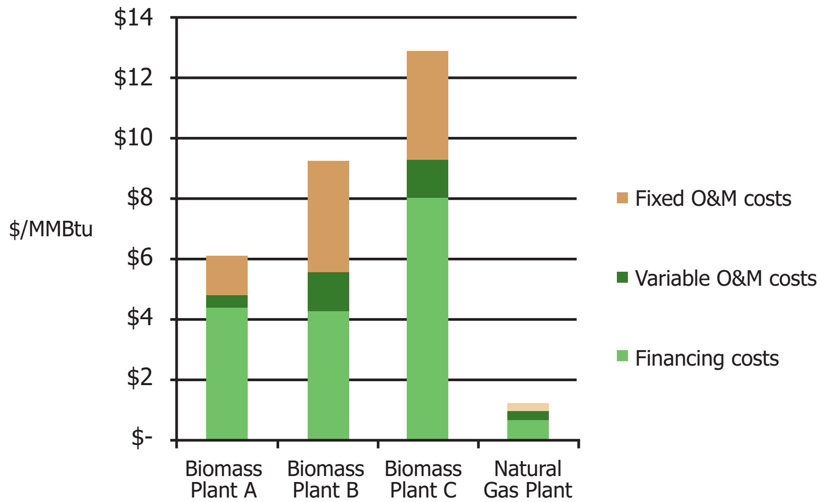
- **Cost of financing.** There are a great many variables that can influence the debt and equity financing costs of the plant. A key factor is the level of project risk. The three most important issues in determining risk are: 1) the strength of the steam and power purchase agreements (determined by the length of the agreement, creditworthiness of the purchaser, and provisions for cost-of-fuel increases); 2) the degree to which there is long-term assurance of biomass fuel supply (determined by the assessed availability of fuel during the entire duration of the financing term, duration of supply contracts and creditworthiness of fuel suppliers); and 3) the experience and financial strength of the operator. Projects with long-term energy purchase agreements and long-term fuel supply contracts with financially solid companies, and an experienced operator with skilled staff, will have lower risk and be able to obtain lower-cost financing than projects without these characteristics. Loan guarantees or other assurances by government entities can considerably reduce risk, and thus financing costs. Another factor determining financing costs is ability of the project to qualify for tax-exempt bond status, which is subject to a range of complicated federal laws. For example, generally an RDF plant can qualify for tax-exempt bonds, while a plant-based biomass plant does not, unless it is part of a district heating system that serves a nonprofit entity.
- **Operating costs.** To some extent, the operating costs also depend upon the fuels and the pollution control equipment used. A higher level of pollution control equipment is more expensive to maintain. Some fuels, such as RDF, may incur higher costs for ash disposal, due to levels of hazardous materials in the ash.

Scenario A is the lower-cost estimate, and assumes a lower initial capital cost and lower operating costs. The biomass O&M costs are for a bubbling fluidized bed boiler. These are estimated from work the Green Institute commissioned from an engineering firm, Black and Veatch, in 2004 for a slightly smaller project proposed for South Minneapolis, now called the Midtown Eco Energy Project. Capital costs are based on a 2006 estimate from this project including all financial closing costs as well as electric generating equipment that Rock-Tenn may not need, and thus may overestimate actual costs for this project. However, the total capital costs for Scenario A are slightly higher than a recent capital cost estimate for a 300,000 pound/hour bubbling fluidized bed boiler project in southern Minnesota, not including electric generating equipment. Scenario A assumes pollution control equipment for wood and some agricultural biomass, but not for burning RDF and perhaps other contaminated fuels. Ash disposal costs are assumed to be beneficially land applied at zero cost, which may not be realistic. However, the total variable and fixed O&M costs for Scenario A ($1.67/MMBtu) are within the range of what has been reported for other operating non-RDF biomass plants in the same or larger size range ($1.24-$2/MMBtu).[82] Including ash disposal at the level included in Scenario B and C would raise O&M costs by about $1/MMBtu (for a total operating cost of $7/MMBtu). Similarly, decreasing debt interest rates for Scenario A to the level in Scenarios B and C would decrease financing costs by about $1/MMBtu (for a total operating cost of $5/MMBtu).

82 Bain, et al., 2002 (see bibliography) and Gregory Morris, "Biomass Energy Production in California: The Case for a Biomass Policy Initiative," National Renewable Energy Laboratory, 2000, converted from kWh estimates to MMBtu equivalent.

For Scenarios B and C, we use capital and operating estimates from the Foth study for an RDF/biomass plant, which included the costs for a 40-megawatt steam turbine/generator.[83] Rock-Tenn biomass plant capital costs were estimated by Foth to be $141 million. Similarly, operating costs are higher than in Scenario A. These higher capital and operating costs are consistent with additional pollution control and maintenance requirements of an RDF facility. Scenario B presents lower-cost financing assumptions, while Scenario C represents higher-cost financing. Scenario B's debt costs are consistent with achieving 100 percent tax-exempt debt financing. Scenario C's higher financing costs assume that a high proportion of at-risk equity investment will be needed to compensate for the higher risk in the project. Scenario C also assumes taxable debt financing. The actual capital and operating costs could be higher or lower than this. Discussions with Market Street Energy suggest that actual capital costs could be significantly higher. However, Market Street is believed to be including costs related to incorporating a district heating system into the project.

Figure 11: Comparison of estimated biomass and natural gas non-fuel operating and maintenance costs



The natural gas assumptions are from an analysis that Rock-Tenn commissioned from Utility Engineering when it was considering installing new natural gas/fuel oil boilers. All construction and operating costs are from Utility Engineering's estimates.

83 Foth, 2006 (see bibliography). Foth assumes the plant will produce significantly more energy than needed by the plant, the majority of which would be converted to electricity and sold. To compare the scenarios on an equal basis, we assume the plant will only meet plant load, and adjust variable operating costs downward accordingly from that reported in Foth. However, should more energy be produced as in the Foth report, this would decrease the cost per MMBtu for the fixed costs, as more energy would be produced for the same cost, but a factor would need to be used to consider that the project is producing generally less valuable electricity for sale and not offsetting natural gas purchases.

Table 15: Assumptions for estimating non-fuel operating costs for biomass and natural gas plants[84]

	Biomass Plant A	Biomass Plant B	Biomass Plant C	Natural Gas Plant
General Assumptions				
Average boiler output (lb/hr steam)	225,000	225,000	225,000	225,000
Capacity factor	85%	95%	95%	95%
Annual energy output (MMBtu)	2,010,420	2,246,940	2,246,940	2,246,940
Fixed Capital Costs (Financing Costs)				
Capital cost	$98,000,000	$141,000,000	$141,000,000	$11,200,000
Debt/equity ratio	100%	100%	60%	60%
Debt interest rate	7.75%	4.75%	7.75%	8.5%
Equity rate of return	--	--	17%	17%
Debt term (years)	25	25	20	20
Annual debt payment	$8,985,270	$9,755,103	$8,457,016	$710,109
Annual equity payment	$0	$0	$9,588,000	$761,600
Subtotal, annual financing cost	$8,985,270	$9,755,103	$18,045,016	$1,471,709
Subtotal, annual financing costs ($/MMBtu)	$4.47	$4.34	$8.03	$0.65
Non-fuel variable O & M costs				
Urea Costs	$133,272			--
Scrubber reagent (lime)	--	$333,424	$333,424	--
Ash disposal	$0	$2,294,350	$2,294,350	--
Water treatment	$22,186	$0	$0	--
Raw water	$423,649	$120,562	$120,562	--
Boiler chemicals	$66,469	$0	$0	--
Electrical costs (FD/ID fan, boiler feed pump, etc)	$83,898	$83,898	$83,898	$400,000
Natural gas for start-up	$29,548	$29,548	$29,548	--
Water treatment	--	--	--	$225,000
Miscellaneous supplies	--	$15,921	$15,921	$60,000
Subtotal, annual non-fuel variable costs:	$759,022	$2,877,703	$2,877,703	$685,000
Subtotal, annual non-fuel variable costs ($/MMBtu)	$0.38	$1.28	$1.28	$0.30
Non-fuel fixed O & M costs				
Labor costs ($/year)	$1,377,500	$1,626,768	$1,626,768	$204,000
Property tax, insurance, admin. and general ($/year)	$400,000	$563,600	$563,600	$200,000
Repair and maintenance	$811,628	$3,522,500	$3,522,500	$100,000
Overhead, supervision and indirect		$2,283,608	$2,283,608	
Vehicles and equipment		$140,900	$140,900	
Subtotal, non-fuel fixed costs	$2,589,128	$8,137,376	$8,137,376	$504,000
Subtotal, annual fixed costs ($/MMBtu)	$1.29	$3.62	$3.62	$0.22
Subtotal, annual fixed and variable O&M costs	$1.67	$4.90	$4.90	$0.53
Total Annual Non-fuel Operating Costs:	**$12,333,420**	**$20,770,182**	**$29,060,095**	**$2,660,709**
Total Annual Non-fuel Operating Costs ($/MMBtu)	**$6.13**	**$9.24**	**$12.93**	**$1.18**

As shown above, non-fuel expenses for natural gas are estimated to be around $1/MMBtu. Thus, the reference price for a biomass plant will have to be less than $6.50-$10/MMBtu (non-fuel costs + estimated fuel costs).

Based on the three scenarios above, non-fuel costs for a biomass plant are estimated to range from $6 to $13/MMBtu. The difference between Scenario B and Scenario C of nearly $4/MMBtu is particularly striking, and due entirely to different costs of financing. Additional low-cost financing tools could allow these costs to come down further.

Based on these scenarios, to beat natural gas generation cost, biomass fuel costs must range from a negative fuel cost to $3.50/MMBtu. This range varies depending on assumptions of natural gas costs and biomass non-fuel costs.[85] The scenarios suggest that a biomass plant with high-cost financing is not viable, and that a biomass plant which includes advanced pollution control equipment is marginally viable and would require very low-cost biomass fuels. Even the low-cost biomass plant estimate would require fuel costs to be a fraction of natural gas fuel costs. More detailed analysis is necessary before coming to any final conclusions.

4.1.3. Refuse-derived fuel economics

Although this study does not consider RDF in detail, it is important to understand RDF economics for comparing to other biomass fuels. Here we report benchmark economics at one RDF facility, the Newport Resource Recovery Facility in Washington County, which is a candidate for supplying fuel to Rock-Tenn. These economics are difficult to precisely identify because much information is not publicly available and key transactions are governed by complicated contracts.

More than 400,000 tons/year of municipal solid waste is received at Newport for processing into RDF. An average of about 320,000 tons/year is actually processed into RDF. The facility is now owned and operated by Resource Recovery Technologies (RRT) under an agreement effective January 1, 2007. Historically, revenue from operations has not been enough to support total processing costs, including capital financing costs. Thus, Ramsey and Washington Counties have provided a processing payment to Newport to support continued operations. In recent years this has totaled about $14 million a year. Under a new contract with RRT, these payments are split between direct payments to RRT and "hauler rebates" to waste haulers that deliver to Newport. The total cost of these payments will diminish to the contractual maximum of $8.4 million a year by 2012.[86] The counties would like to reduce the payment further after 2012.

Although actual costs are not available, Foth estimates that the current processing costs are about $22 million, not including debt costs of owning the facility. RDF is currently being delivered to two Xcel Energy plants, one in Red Wing (Red Wing plant) and one in Mankato (Wilmarth plant). RRT pays for all transport costs to the plants. In addition, based on previous contracts, Xcel must be paid a "burn incentive" to take the RDF, as well as a penalty payment if minimum deliveries are not made, which has been the case in recent years. Ramsey and Washington Counties also receive a fuel credit from Xcel Energy dependent upon the heating value of the RDF. Thus, total net payment to Xcel is about $6/ton, not including the transportation costs ($14/ton) incurred to bring the fuel to the plants. These costs are summarized in Table 16.

[84] For Scenario A, Black & Veatch did not include cost for natural gas start-up or electrical costs (which were assumed to be deducted from net plant output). For consistency, Scenario A includes these costs per the Foth estimates. Black and Veatch also assumed that the ash from wood biomass sources could be beneficially applied on agricultural lands at zero cost, an assumption which may not be accurate. Debt interest rates are assumed to be 4.75 percent for tax-exempt bonds, and 7.75 percent for taxable bonds. Equity rate of return is assumed at 17 percent.

[85] "Beating" natural gas pricing is assumed here to be a minimum of $0.50/MMBtu under natural gas prices.

[86] Correspondence with Zack Hansen, Ramsey County, March 6, 2007.

Table 16: Estimated annual costs and revenues, Newport RDF facility[87]

Estimated revenues to Newport operator	
Projected tipping fee revenue ($55/ton)	$23,650,000
Citizen area tip fees	$50,000
Ferrous recovery revenues	$320,000
Aluminum recovery revenues	$600,000
Subtotal	***$24,620,000***
Estimated operating and maintenance costs to Newport operator	
RDF processing O&M costs, including taxes	$10,333,840
RDF transport	$4,772,230
Residue and hazardous waste disposal	$3,554,230
Xcel burn incentive (payment to Xcel)	$3,226,540
Penalty payment (payment to Xcel)	$203,860
Subtotal:	***$22,090,700***
Fuel credit to Ramsey/Washinton Counties (payment from Xcel)	**$1,375,500**
Net payment to Xcel to accept RDF	**$2,054,900**
Payment per ton	***$6.23***

Based on the current economics of the Newport facility, RDF would have a zero or negative fuel cost delivered to a Rock-Tenn biomass plant. This is typical of RDF facilities, as high financing and operating costs limit the amount that can be paid for fuels. Whether Rock-Tenn would be able to negotiate a contract to get paid to take RDF is unknown, as the counties are interested in reducing their current subsidy for RDF processing and there may be other competitors for the RDF. Nonetheless, RDF fuel cost can be expected to be quite low for a Rock-Tenn facility, assuming uncommitted RDF would be available. Compared to delivering to Red Wing (80 miles round-trip from Newport) or Mankato (200 miles round-trip from Newport), transport costs would be lower to deliver to Rock-Tenn (30 miles round-trip from Newport).

4.1.4. Other financing tools

The scenarios above do not consider other financing tools that may be available to reduce the total financing cost of the project. Grants or other zero-cost capital reductions may be available to the project. The St. Paul Port Authority is currently asking the Minnesota Legislature to approve a $20 million "renewable energy transition charge" to Xcel Energy ratepayers for developing and constructing the project, which could help improve project financing.[88]

In addition, the federal government offers several grant and loan guarantee programs for which the project might be eligible. The Department of Energy can issue up to $4 billion in loan guarantees for innovative technologies.[89] To qualify for this, the project would have to install technology considered innovative, such as an advanced gasification system.

[87] Calculated from figures reported in Foth, 2006 (see bibliography).
[88] Minnesota House File No. 1624, wdoc.house.leg.state.mn.us/leg/LS85/HF1624.0.pdf.
[89] Minnesota House File No. 1624, wdoc.house.leg.state.mn.us/leg/LS85/HF1624.0.pdf.

The renewable energy designation of the project could also benefit project financing. Minnesota's newly enacted renewable energy mandate requires utilities to generate 25 percent of their power from renewable energy by 2025 (and Xcel Energy to generate 30 percent by 2020). Thus, it might be possible to reach an agreement with a utility to have an option to buy power after, say, ten years, if Rock-Tenn is not willing to commit to a long-term energy purchase agreement. This would create long-term assurance that the project could generate revenues beyond the time frame that Rock-Tenn can commit to, reduce the risk profile of the project, and benefit the financing package.

The federal production tax credit (PTC) is another financing tool available to renewable energy projects that sell electricity. A ten-year tax credit on passive income of 1.9 cents/kilowatt-hour is available for electricity sold from dedicated energy crops, and 1.0 cents/kilowatt-hour is available for the other sources considered here, as well as RDF.[90] However, the PTC does not apply to thermal energy, and non-taxable entities such as governmental units cannot apply the PTC's to the portion of the plant that they own.

Clean renewable energy bonds (CREB's) were created for non-taxable entities that could not take advantage of the PTC. CREB's are bonds where interest is paid in the form of federal tax credits that can result in an effective project interest rate cost of between 1 and 2 percent for qualified projects. In 2006 the St. Paul Port Authority applied for CREB's for the Rock-Tenn project. However, the current allocation system used for CREB's gives priority to smaller projects and is likely to result in CREB's being allocated for only a small portion of total project system costs, if at all.

In addition, federal greenhouse gas legislation could create a market for carbon dioxide (CO_2) reductions that could potentially benefit a Rock-Tenn project. An EIA analysis suggested that the impact of one congressional proposal would result in CO_2 prices of $25 per ton CO_2 in 2010, $36 in 2015, $55 in 2020, and $67 in 2025.[91] This would increase the cost of fossil-based energy generation and make purchased energy from a Rock-Tenn project more attractive in the future. If a coal-fired source had to pay $25/ton CO_2 emitted, it would cost about $2.60/MMBtu.[92]

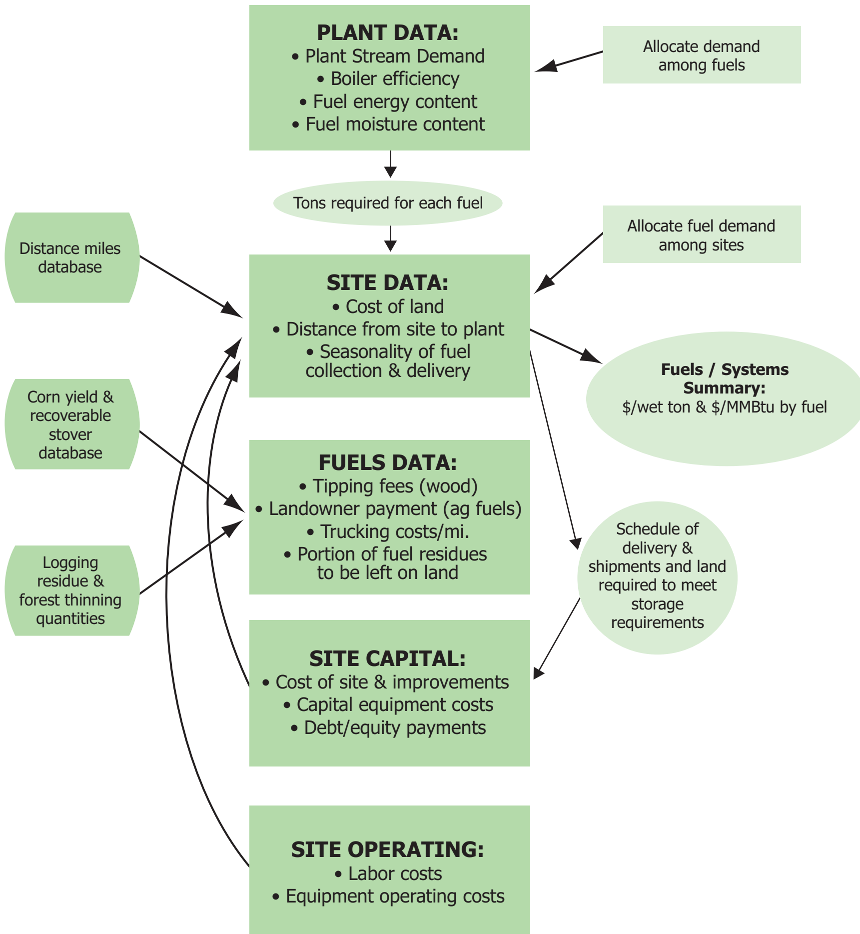
Although it is beyond the scope of this study to conduct a full financial analysis of a biomass plant, this cursory analysis suggests that low-cost financing will be critical to the plant's success, including securing a long-term energy purchase agreement, reaching agreements with fuel providers with solid financial backing, and identifying an experienced operator for the facility. Low-cost financing would likely need the full faith and credit of an entity able to issue general obligation bonds, such as the City of St. Paul, Ramsey County or the State of Minnesota. Obtaining tax-exempt bond status or similar financing would also be crucial for low-cost financing.

4.2. Fuels cost model

In order to estimate biomass fuels cost, the project team developed a fuels cost model to evaluate different combinations of biomass fuels, and create potential scenarios for use of biomass fuel at Rock-Tenn. The model estimates the costs of collection, off-site storage (if necessary), processing, transport to Rock-Tenn and additional on-site processing for biomass fuels. The model permits collection and some processing to be done at a number of remote sites. If necessary, the biomass fuel is stored at these sites until ready for use. It is then transported to Rock-Tenn, where it undergoes further processing so that it is completely ready for use by Rock-Tenn's boiler. Figure 12 summarizes the model structure and key data inputs for the model. A full list of assumptions is contained in Appendix D, and briefly described below.

[90] IRS form 8835, "Renewable Electricity Production Credit," www.irs.gov/pub/irs-pdf/f8835.pdf.
[91] 2006 dollars. EIA, Office of Integrated Analysis and Forecasting, U.S. DOE, "Analysis of S.139, Climate Stewardship Act of Highlights and Summary." June 2003. Available at www.eia.doe.gov/oiaf/servicerpt/ml/pdf/summary.pdf.
[92] At a carbon content of 210 lbs CO_2/MMBtu, which is typical for coal.

Figure 12: Model structure and key data inputs of Rock-Tenn fuels model



The starting point for the model is plant steam demand. For each of the scenarios, a simplifying assumption was made that the biomass plant would only produce enough energy to serve Rock-Tenn's current average steam load of 226,000 lbs/hour.[93] This may not be an accurate assumption for project developers. Some of the factors that impact fuel needs as well as overall biomass facility design, and not included in our calculation of plant demand, include:

- efficiency improvements at Rock-Tenn that may reduce future energy demand at the plant;
- internal demands for steam by the biomass plant (parasitic load), estimated by Foth to be 9 percent of total steam production for an RDF facility;
- optimal operating strategy to effectively and reliably handle load fluctuation and peaks, such as when steam needs drop precipitously due to equipment suddenly going off-line;
- the minimum operating needs of the boiler(s) and steam turbine;
- how to provide for redundant energy needs to ensure reliability of energy supply, such as when one boiler is down for repair;
- the opportunity to utilize more biomass than is needed for plant operations due to seasonal variability in fuel supplies, such as is true with urban tree residues and RDF; and

[93] This is roughly equivalent to needed fuel input of 2.6 million MMBtu/year, assuming 1175 Btu/lb steam, 95 percent capacity factor, and an 85 percent efficient boiler.

- other steam loads other than Rock-Tenn that could factor into plant development, such as a district heating system or additional power for use by others.

Thus further investigation is necessary by the development team to identify the optimal energy production of a biomass facility compared to the simplifyied assumptions here. For example, for the reasons listed above, Foth recommends two biomass boilers and a resulting fuel input (394,000 tons RDF) that is nearly twice what is necessary to meet plant energy demand.[94] The model could handle expanded design specifications such as this.

The steam demand is then allocated by the user among various biomass fuels, limited by the total availability of each fuel as set out in the previous chapter. Based on assumptions of moisture content and fuel heat content, the total volume of biomass required from each fuel is calculated. For fuel heat content (Btu/lb), we use values from a Center for Energy and Environment (CEE) biomass study, except for grasses.[95] One reviewer considered these to be low, so we instead use an average of 33 reported heating values for switchgrass,[96] which is almost 10 percent higher than reported by CEE. The user can then choose which sites to use for each fuel, and what proportion of the total fuel will come from each site. Since the sites are hypothetical for purposes of the model, they are assumed to be at the center of the county in which they are located.

For each site, land requirements are estimated based on the volumes that are required to process and store fuel at the site. It is assumed that the price paid to the site for of the biomass fuel will need to reimburse all capital and operating costs associated with a site, including a return on equity. This includes equipment necessary for processing, storing and transport of the fuel.

The cost of transporting the fuel to the site varies with the fuel. Some fuels, for example tree branches, can have a negative cost, i.e., generators pay a tipping fee to have the site take their waste wood. For agriculture and forest fuels, direct and overhead costs of collecting the biomass are entered into the model, as well as any landowner payment for allowing biomass to be collected. For agricultural and forest fuels, the model accounts for delivery to the site based on county-level availability. If insufficient biomass is available within a county, the model calculates the distance from the site to the source, and accounts for transportation costs to the site.

Capital costs of the site are estimated and a yearly payment assessed, based on assumptions of debt and equity payments. Purchase or rental of equipment necessary for processing is assessed to the fuel cost. Storage costs are also included where appropriate, as well as losses during storage. The fuel drying that occurs during storage is accounted for as well.

Although it would be possible for Rock-Tenn to own all these remote sites, the model also works for third-party ownership. If the sites are also processing and delivering product to sources other than Rock-Tenn, for example the mulch market, only the volume that is delivered to Rock-Tenn is added to the fuel cost. This is a realistic representation of market conditions for wood, where wood consolidators will send their product into multiple markets. However, the model does not predict the implications of any supply and demand imbalances that could result in collection sites charging a significant premium over cost to Rock-Tenn.

For short hauls from field to assembly point within the county, we assume a constant 20 miles. Transport from each county assembly site to the remote sites is costed at the same rate as transport from the remote site to Rock-Tenn. These costs vary by distance: 0-25 miles ($5.00/mile), 25-100 miles ($3.60/mile), 100-200 miles ($2.35/mile), and more than 200 miles ($1.90/mile). These are based on the most recent USDA grain

[94] Foth assumes a fuel input of 5.0 million MMBtu/year (394,000 tons RDF at 6300 Btu/lb, as reported by Foth).

[95] Center for Energy and Environment, "Identifying Effective Biomass Strategies: Quantifying Minnesota's Resources and Evaluating Future Opportunities," www.mncee.org/public_policy/renewable_energy/biomass/index.php.

[96] As reported in the Appendix of Bain, et al., 2003 (see bibliography).

shipping costs per mile for a 23-ton load of grain, charged for one-way but including return charges. We assume that these costs include loading and unloading at the appropriate location. A curve is estimated for values between these three points. We also received a quote for short-line rail transportation of forest residues (chipped) from Pine County to Rock-Tenn. However, the quote was higher than the trucking option, and the rail option was not further considered.

Once the fuel arrives at Rock-Tenn, it must be processed. Based on the experience of District Energy St. Paul/St. Paul Cogeneration, it is assumed that additional screening of wood fuels will be required to maintain quality control, and that 10 to 20 percent of the fuel will need to be reground on site. We assume that agricultural fuels (corn stover and grass) will be delivered in bales, which will need to be ground on-site before delivery to the boiler. We assume an additional processing line for agricultural fuels, although further investigation is recommended to confirm this assumption, as there would be cost savings to combine the processing lines. The model accounts for the additional equipment and labor necessary to achieve these on-site processing functions, but not the additional storage, land and building requirements of this operation. These costs are to some extent independent of fuel choice, and thus assumed to be part of the capital costs associated with building a solid fuel plant.

It should be emphasized that the model does not account for dynamic market conditions, such as balancing supply and demand. Further, it does not optimize among all the various site and fuel combination possibilities to find the lowest cost fuel mix at any given demand level. It is meant to generally suggest a range of fuel costs that Rock-Tenn could expect for a given scenario, but not find the optimum solution. In general, the approach taken for the model was to be as realistic as possible with a slight bias towards conservative assumptions.

4.3. Scenarios for biomass fuel use at Rock-Tenn

Four scenarios were developed for biomass fuel use at Rock-Tenn including 15 percent, 30 percent, 60 percent and 100 percent of Rock-Tenn's current energy demand, as described above. Each scenario has a different mixture of fuels. The cost figures should not be interpreted as the final word on fuel costs. There are opportunities for optimizing and cost reduction that are not captured by the model. On the other hand, changing market conditions could increase costs. The cost figures presented here are intended to give a general indication of costs for planning purposes.

4.3.1. Scenario A (15 percent): urban wood waste (tree residues only)

At the relatively modest level of providing 15 percent of Rock-Tenn's fuel needs, 36,000 wet tons of urban tree residues would consume virtually all of the estimated currently uncommitted sources of urban tree residues. This may not be a viable long-term solution unless it is part of a broader portfolio of fuel sources.

We assume that the wood waste will be collected from four collection sites, located in Hennepin, Anoka, Washington and Scott Counties. Each of these sites will process and deliver equal amounts (25 percent each) of the total required by Rock-Tenn. We assume that each site will also collect and process wood for other markets, such as for the higher-end mulch market or for boiler fuel for District Energy St. Paul/St. Paul Cogeneration. This is consistent with current market conditions, where wood processors have several markets for their wood products. The capital costs of the sites are allocated to the Rock-Tenn wood fuels as the proportion of total fuel processed at the site.

Tipping fees vary by type of wood, and average about $18/ton. However, as this scenario would require all of the uncommitted urban tree residues, our model assumes a zero tipping fee, which adds considerably to total fuel costs, but offers generators an incentive to drop off sufficient wood at the modeled sites.

The sites are assumed to operate for collection of wood wastes eight months a year, staffed by two site workers. Wood processing is contracted with third parties with mobile grinders for processing, so the sites do not have to own the grinding equipment. All other equipment is rented.

A summary of the results is presented below (Figure 13 and Figure 14). Total costs/ton for supplying 15 percent of Rock-Tenn's annual energy needs are estimated to be just over $40/wet ton or nearly $4/MMBtu.

Figure 13: Estimated fuel costs ($/wet ton) for Scenario A, 15 percent urban wood waste

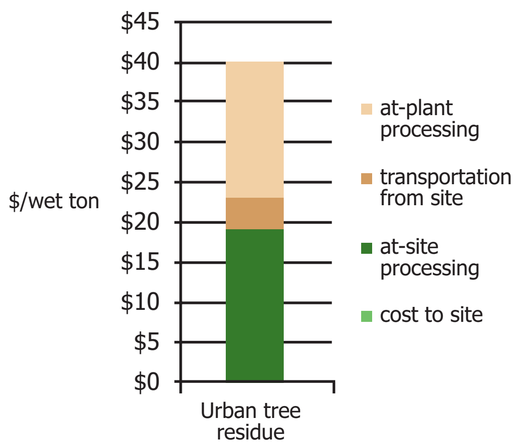
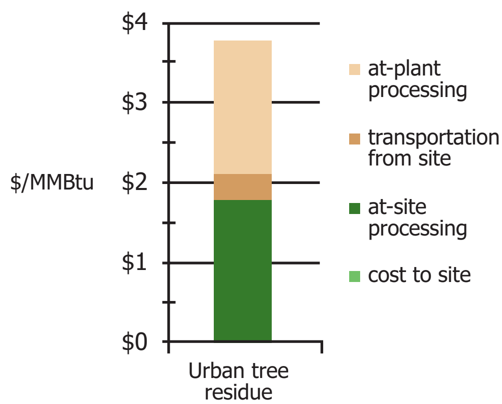


Figure 14: Estimated fuel costs ($/MMBtu) for Scenario A, 15 percent urban wood waste



Because fixed at-site processing costs are high, at-plant processing costs are the highest portion of the costs. Some efficiencies could undoubtedly be achieved at these low levels of use. If the plant had sufficient assurance of fuel quality for fuel delivered from the remote sites, it would not need to re-process the wood again at the site, and could save perhaps $25/wet ton and cut costs by more than one-third.

4.3.2. Scenario B (30 percent): more urban wood waste (tree waste + C&D wood)

Scenario B is the same as Scenario A, except that C&D wood contributes an additional 15 percent (26,000 wet tons). It is assumed that the C&D wood is procured from a C&D landfill or transfer station that sorts out the wood. Because the quantities of clean C&D wood are limited and would command a significant price premium, this C&D would likely be composite or other contaminated wood. It is assumed that Rock-Tenn's boiler would have sufficient pollution control equipment, and that burning these types of woods would be permitted. Discussions with industry insiders indicate that processing costs for sorting C&D wood are roughly equal to tipping fees received by C&D transfer stations. Here we assume $10/ton is paid to a C&D facility for the wood, which is then processed and stored at a site in Hennepin County for delivery to the plant at additional cost.

As shown by Figure 15 and Figure 16, C&D wood costs total nearly $30/wet ton delivered to the plant, with an additional charge for processing at the plant. This is probably on the low side for costs to have processed C&D wood delivered to the plant under current market conditions. Several existing facilities would be able to sort and process wood for the plant.

Figure 15: Estimated fuel costs ($/wet ton) for Scenario B, 30 percent urban wood waste

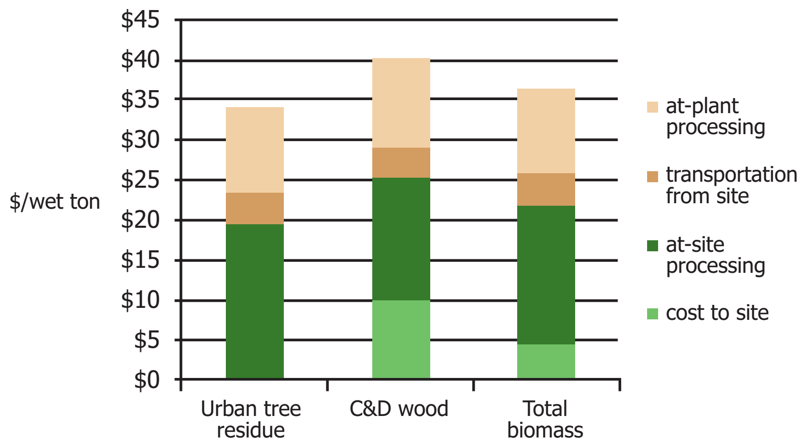
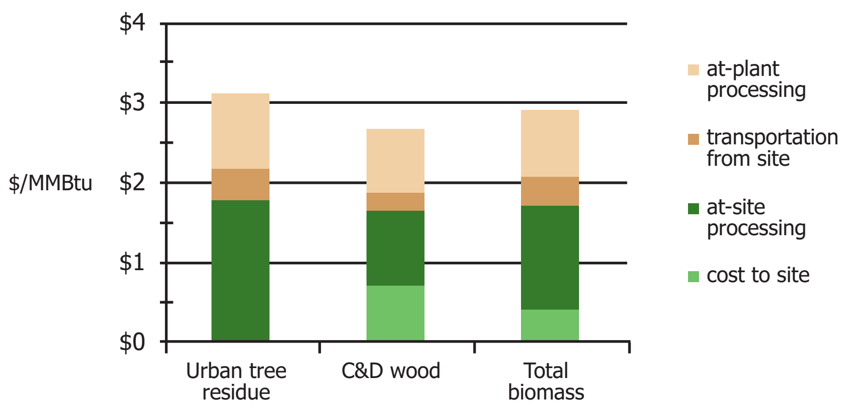


Figure 16: Estimated fuel costs ($/MMBtu) for Scenario B, 30 percent urban wood waste



Total biomass costs are about $2.90/MMBtu or $37/wet ton for Scenario B. At-plant processing costs are lower per ton than in Scenario A, as the fixed costs of processing are spread out over greater volumes. Note that although the total cost/wet ton is higher for C&D wood than for urban tree residues, the cost per MMBtu is lower. This is because C&D wood has lower moisture content.

4.3.3. Scenario C (60 percent): urban wood waste + agricultural sources (corn stover + grasses)

Scenario C assumes the same urban wood waste blend as above, with the addition of 15 percent corn stover (29,000 wet tons) and 15 percent grasses (31,000 wet tons).

A collection and storage site in Wright County is assumed for collecting the corn stover. Collection volumes are as estimated in the previous chapter, and assuming that 25 percent of farmers growing grass will sell to Rock-Tenn. The farmer is paid $5/wet ton for allowing the removal of stover. Direct and overhead costs of removal are estimated at $24/wet ton to gather the stover into rectangular bales, which are easier to transport via semi-truck to urban areas.[97] As there is a short harvest season for stover, significant storage is involved. The stover is not covered in storage, either by a roof or by plastic, so some losses are expected. We model this as 2 percent loss for every three months that the stover is stored.

The model assumes a site in Dakota County for the grass. Grass is not a residue like corn stover where the sales of the crop (corn) can cover land rental and planting costs. All direct and overhead costs of producing a dedicated energy crop like grasses must be covered by sales of the biomass. In the model, we estimate that the per-ton cost of biomass grass production, harvesting, and storage is $20/ton; land rental $120/acre; and yield 4 tons/acre. This price covers direct costs of machinery and fuels, the opportunity cost of the land, and overhead expenses.[98] Grass is baled and stored similarly to corn stover.

Results for Scenario C are presented in Figure 17 and Figure 18. Total biomass fuel costs are $51/wet ton, or $3.90/MMBtu.

Figure 17: Estimated fuel costs ($/wet ton) for Scenario C, 60 percent urban wood waste and agricultural sources

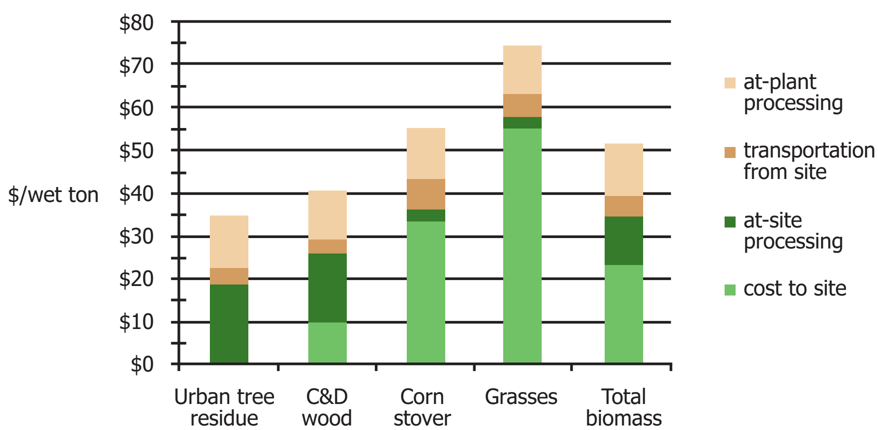
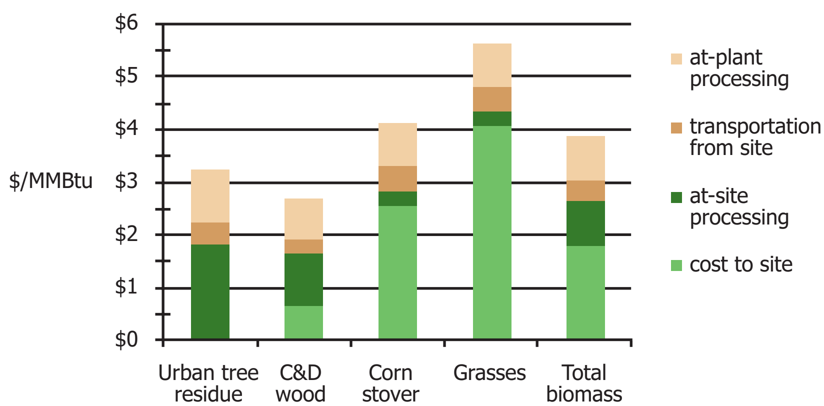


Figure 18: Estimated fuel costs ($/MMBtu) for Scenario C, 60 percent urban wood waste and agricultural sources



97 Petrolia 2006 (see bibliography).
98 Tiffany, et al., 2006 (see bibliography).

A sensitivity analysis assuming grass yields of 6 tons/acre, which the project team considered an upper limit, resulted in reducing fuel costs for grasses from $75/wet ton to $61/wet ton, or $4.60/MMBtu. Conversely, reducing yield to 3 tons/acre results in fuel costs of $86/acre or $6.40/MMBtu.

Uncovered storage is a major untested assumption in the model's treatment of corn stover and grasses. If covered storage were necessary, it could increase costs significantly.

For grasses, a co-benefit payment as discussed in the previous chapter may help to improve the economic viability for Rock-Tenn. We calculated the necessary co-benefit payment that would be necessary to reduce the delivered fuel cost to $5/MMBtu, $4/MMBtu and $3/MMBtu. The required co-payment varies from $35/acre to $141/acre as shown by Table 17.

Table 17: Necessary co-benefit payment for grasses to reduce delivered fuel costs to $5, $4 and $3/MMBtu

Target delivered fuel price, $/MMBtu	Necessary co-benefit payment per acre
$5	$35
$4	$88
$3	$141

4.3.4. Scenario D (100 percent): urban wood waste + agricultural sources + forestry residues (logging residues + thinnings)

Scenario D is the same as Scenario C with the addition of 35 percent logging residues (87,000 wet tons) and 5 percent forest thinnings (12,000 wet tons). This is near the limit of estimated current availability within 100 miles. Use of logging residues at this level may necessitate extending the supply shed further than 100 miles, and may not be viable long term should demand logging residues increase. We use a relatively small proportion of forest thinnings because the project team was unable to obtain good data on potential available quantities and removal costs, so the assumption that 12,000 wet tons/year would be available at the price suggested here is untested. This will require further analysis by Rock-Tenn.

A site in Pine County is assumed for obtaining logging residues, and a site in Aitkin County is assumed for collecting and storing forest thinnings. For logging residues, costs were estimated to be $5/ton payment for access, $8/ton for hauling, and $8/ton for wood chipping at the landing.

The federal government can pay up to $575/acre to the landowner for forest thinning that accomplishes forest fuel reduction goals, which the model assumes for this scenario. Taking account of the expected wood yield from this activity (10 ton/acre) and the actual removal rate (60 percent), this is $96/ton for wood removed. This is treated as a negative cost in the model. Actual harvest costs of $90/ton are from a recent project in Northern Minnesota.[99] These costs likely overestimate long-term removal costs, as the project was a pilot project using equipment unfamiliar to the operators. Transport costs to the remote site and then to Rock-Tenn are calculated at the same rate as for corn stover and grass.

[99] Abbas, D., D. Current, M. Ryans, S. J. Taff, H. Hoganson, K. N. Brooks, "Harvesting biomass energy to reduce the costs of mechanical fuel reduction: Trials in the Superior National Forest, U.S.A.," submitted to Biomass and Bioenergy, 2007.

Figure 19: Estimated fuel costs ($/wet ton) for Scenario D, 100 percent urban wood waste, agricultural fuels and forest residues

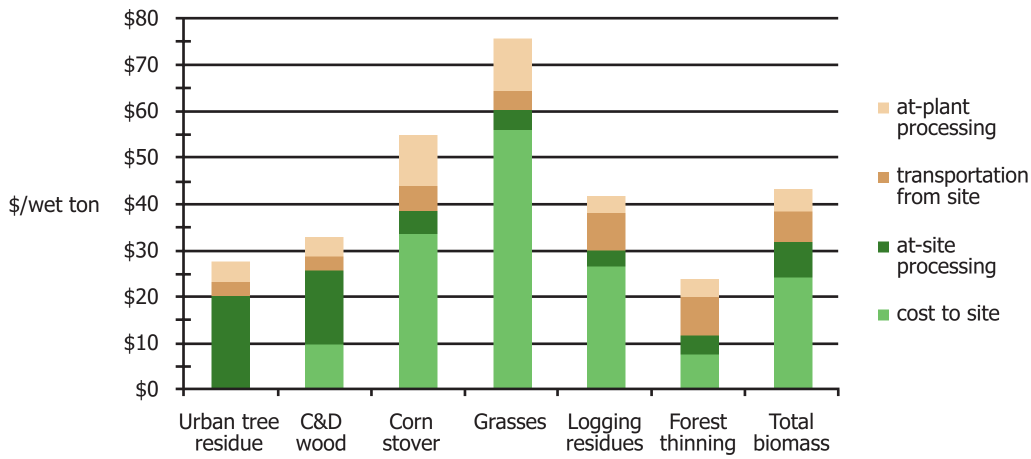
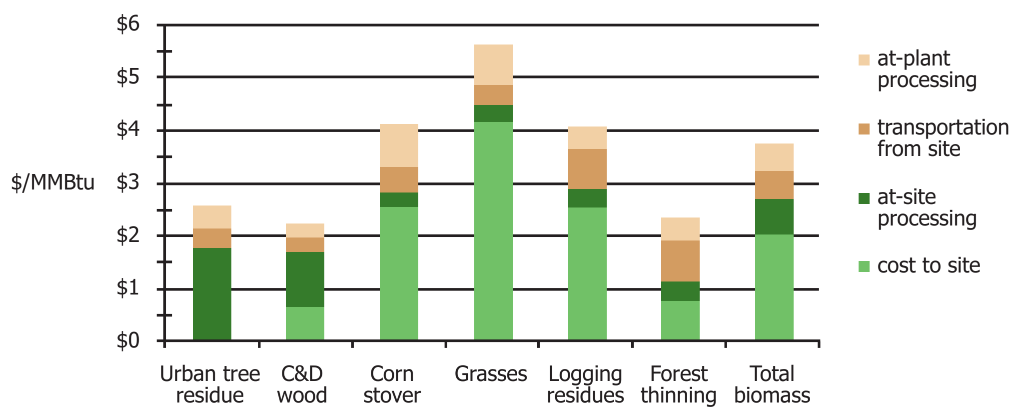
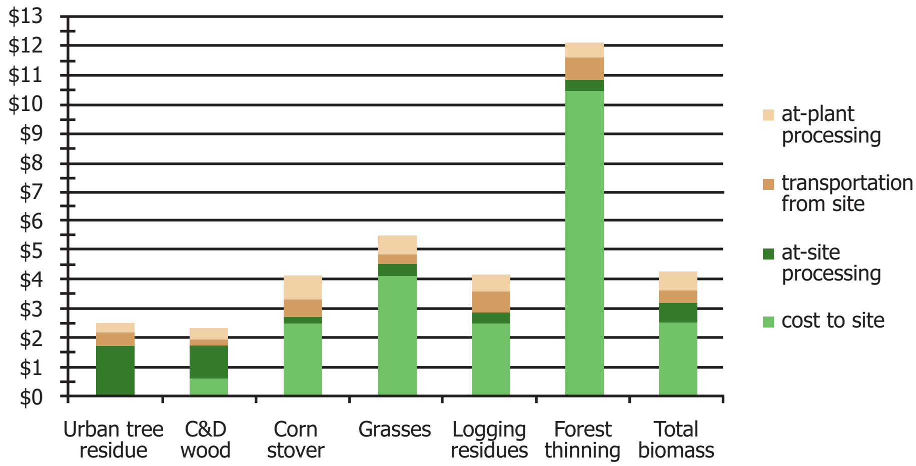


Figure 20: Estimated fuel costs ($/MMBtu) for Scenario D, 100 percent urban wood waste, agricultural fuels and forest residues



Total biomass costs for Scenario D are $44/wet ton or about $3.80/MMBtu as shown by Figure 19 and Figure 20. This total cost assumes a fuel reduction payment received for the forest thinning. Without that payment, forest-thinning cost rises to $127/wet ton ($12/MMBtu), and total biomass costs to $4.20/ MMBtu (Figure 21).

Figure 21: Sensitivity analysis of Scenario D without forest thinning subsidy ($/MMBtu)



With a larger processing capacity, the fixed costs of processing at the plant are spread over larger volumes, and cost for at-plant wood processing is lower than in the other scenarios. However, there is still probably room for cost reductions with the wood processing costs if quality assurance could be achieved before the fuel reaches the plant. For the agricultural fuels, processing at-site is necessary, and such efficiencies are not possible.

Again, it must be emphasized that the scenarios above are not the project team's recommendation of the ideal fuel mix, but presented to give a general idea of what costs of fuel procurement could be under a given set of assumptions.

4.4. Procurement strategy

Ensuring a reliable fuel supply for the financing period will be critical to the success of a Rock-Tenn biomass plant. The financing period is typically at least 20 years for such capital-intensive projects. Changes in supply and demand for biomass can be predicted with some certainty in the short term as was done in the previous chapter, but as the time horizon increases, the validity of prediction decreases. Over this long of a period, the only thing that can be said with certainty is that there will be changes in the market conditions and availability of biomass. There are several strategies for reducing long-term fuel supply risk: 1) asserting control over the supply chain; and 2) designing for fuel flexibility in order to use sources not easily used by others and to adapt to changes in fuel supply and demand. Both of these strategies have cost-benefit trade-offs.

The plant's ability to assert control over the supply chain depends to a large extent on the source of fuel and proximity to the plant. Total vertical integration – ownership of the biomass collection infrastructure – would provide the most security of fuel supply, but in most cases is not practical. Long-term contracts are another way to achieve supply-chain security. However, contracts are only as good as the contracting business, and in many biomass markets there are few businesses with a long-term track record and significant assets to ensure they will be in business for the long term. Providing for liquidated damages if supply goals are not met, backed by a bond, is one way to increase the security of a contract.

For plants that do not generate their fuel on-site, fuel flexibility is a key factor in the plant's success in having a secure fuel supply. Sources that don't exist today, such as harvest of brushland, may be practical in the future. Moisture content is one of the key variables. The research here has shown that low-moisture-content fuels are already in high demand, so ability to handle high-moisture fuels may be necessary to secure significant quantities of biomass. Ability to handle contaminants in an environmentally safe manner is another method of increasing fuel flexibility. This comes at higher capital cost to the project, however.

Designing a portfolio of biomass sources, each with different risk characteristics, is one way to manage risk. Under this strategy, a portion of the portfolio would be the "blue chip" sources, with high supply-chain security achieved through a long-term contract or ownership of biomass collection assets. Rock-Tenn would likely pay a premium for the guarantee of delivery for this portion of the fuel. Another portion could be under short-term contract of two years or less, which ensures some reliability from short-term market fluctuations. The rest of the supply could be more flexible, purchased on the spot market or purchase order, and adapting to changing market conditions and availability of different sources. This approach is similar to how the Laurentian Energy Authority manages its fuel procurement.

A procurement plan will also need to address the scheduling of storage and delivery for biomass fuels. Most biomass fuel sources have seasonal fluctuations. This requires storage, which given limited storage space at Rock-Tenn, is probably best done by the fuel supplier off-site.

4.4.1. Urban waste wood – urban tree residues

The experience of District Energy, as described in the previous chapter, is illuminating in designing a procurement strategy for urban tree residues. Its approach is now a combination of ownership of collection assets and contracting. District Energy's for-profit subsidiary, Market Street Energy, has exclusive development rights to co-develop a plant with Rock-Tenn. Having a partner that has some significant supply-chain control would benefit the fuel reliability of a Rock-Tenn project. The project would be developed under a separate business entity, of which Market Street would be part owner. One issue with this arrangement is competition from District Energy's own current facility, and how to ensure that the arrangement with a Rock-Tenn plant would deal with this potential internal conflict of interest.

There are several other options for procuring urban tree residues. One is contracting with another entity with significant assets in the collection of urban tree residues. There are only several such entities, and some may not be interested in or suitable for such an arrangement. It may be possible to directly purchase one of these businesses in order to achieve some level of vertical integration.

Short-term contracting with third parties could make use of existing infrastructure to deliver urban tree wood to Rock-Tenn. Market conditions would set the price of the delivered fuel, and could be higher during winter months to encourage suppliers to store wood on their sites for delivery during these scarcer times.

4.4.2. Urban waste wood – construction and demolition

The C&D procurement options available to Rock-Tenn are highly dependent upon whether the project will procure contaminated wood. Clean wood from the C&D market is highly desirable for other markets, so although it would be possible to cull this wood, very little could be reliably secured, and it would probably not be worth the effort. This premise is supported by the fact that relatively small quantities of clean wood waste are currently found in the C&D landfill stream.

On the other hand, there are large quantities of contaminated wood in the C&D waste stream, and there are several procurement strategies for accessing this wood. These are again dependent to some extent on how much contamination the facility can accept.

Source separation would provide the greatest control over contaminants. Rock-Tenn could contract for source-separated wood, either clean or contaminated, although a significant premium would have to be paid for clean wood. Source separation at construction sites is growing in popularity, but is still not widely done. There is at least one business that will pick up source-separated materials, but it is not a very developed market. A customer such as Rock-Tenn could help provide a business entity with a stable sales outlet to grow significant market share.

Several landfills and transfer stations currently sort wood and other materials out of the waste stream prior to landfilling, as outlined in the previous chapter. These entities could be contracted with to provide boiler fuel to Rock-Tenn. This would be a reliable source for short- to medium-term contracting for supplies. The waste business is highly competitive and short-term in their profit horizon, so it is likely that a significant premium would have to be paid for long-term contracts.

Finally, a centralized, highly mechanized C&D processing facility could be developed as outlined by Foth.[100] This could supply 125,000 tons, or perhaps half of the plant demand, depending on the heat content of the fuel. Composite and painted wood would be roughly half of the fuel delivered to the facility, but there would also be other materials, such as carpet, plastics and green treated wood. The security of fuel supply would be relatively high, as Rock-Tenn could enter into a long-term contract with the owner of the C&D facility. A potential financial risk would be the long-term composition of materials delivered to the C&D facility. Should a higher-value use be found for composite woods or other contaminated woods, these materials could be pulled out of the C&D supply prior to reaching the processing facility, and reduce fuel supply to Rock-Tenn. This is the fate of most clean wood generated as C&D, and the C&D processing facility would have little control in preventing the customers of its facilities from pulling this material out. However, in more than two decades of existence of composite materials, no significant markets have emerged other than as boiler fuels. One area of concern is on-site grinding and use of wood at construction sites; in some cases, composite wood as well as clean wood is used for this purpose.

4.4.3. Agricultural sources

Corn stover and grasses involve a large number of small farmer-producers that need to be organized to coordinate the harvest, storage, and potentially delivery of the biomass fuels. Although Rock-Tenn could contract directly with individual producers to accomplish this, it is probably better to contract with a third party.

An obvious choice for this function is an agricultural cooperative. Minnesota has a long-standing tradition of farmers forming agricultural cooperatives to jointly purchase fuels and other agricultural inputs, market products, and even develop energy projects. Farmers would probably respond well to a new initiative coming from an established entity in the community. Rock-Tenn could contract for long-term supply of agricultural sources in this manner. The coop would be responsible for signing people up for the program, making sure the biomass is harvested (this would involve hiring outside custom harvesters in the case of corn stover), and storage and transport of the biomass to Rock-Tenn. A long-term contract would ensure that the coop would be able to invest the money necessary to make this happen. If another source was interested in delivery of biomass as well (such as Koda Power), Rock-Tenn might be able to achieve economies of scale if it is only to use 10 to 30 percent agricultural fuels. A long-term contract backed by a coop with significant assets would also enable higher fuel security, to provide higher levels of fuel supply for Rock-Tenn.

4.4.4. Forestry sources

Current biomass plants that use logging residues contract directly with loggers for both short-term (six months or less) and long-term supply. There are about 300 loggers in Minnesota, but only a small number of them have the ability to process wood on-site or nearby, where it would be most economical to do so. This is expected to grow as the demand grows for logging residue boiler fuel.

[100] Foth, 2006 (see bibliography).

Another option is to contract with groups of landowners. Similar to agriculture organizing, forest landowners have formed cooperatives to help them manage their assets. This is more established in Wisconsin, but is developing in Minnesota as well, and currently 6 to 8 forestry cooperatives exist in Minnesota and western Wisconsin. A forestry cooperative typically has about 1,000 members. The aggregation of many acres of land under a single entity can provide adequate access to forest biomass sources for Rock-Tenn. A biomass plant in northern Minnesota has reportedly contracted with a western Wisconsin forestry cooperative for delivery of logging residues, but the project team did not confirm this.

A relatively safe level of procurement for logging residues would be 20 percent, which would provide a fuels multiple of about 4x within 100 miles. At a level of 40 percent of plant fuel needs, the fuels multiple within a 100-mile radius would be 2x, while a 150 mile radius would provide 6x. Depending upon the mix of other fuels used at the plant, a level of beyond 40 percent is probably not advisable.

Our research suggests that at current levels of experience, procurement of forest thinnings are not economically viable without co-benefits payments. That is, it is necessary to have someone willing to pay the additional cost of procuring this source in return for the benefit of reduced fire hazard or ecological benefits. The future of these payments is uncertain, so it is difficult to develop a fuels business plan around this biomass source. However, a long-term program would allow Rock-Tenn to potentially incorporate this source into a fuels plan.

5. Environmental and Permitting Considerations

This section outlines some of the major environmental impacts associated with biomass plants and the steps Rock-Tenn would have to take for permitting a biomass or RDF plant. This is not intended to be comprehensive in its treatment of impacts, but rather to provide an overview.

A biomass plant has impacts both "upstream" and "downstream" of the plant. Upstream impacts include the impacts of growing, harvesting, processing and transporting the biomass. This could include runoff of nitrogen into rivers from fertilizers used for crop production or land use changes from converting unmanaged ecosystems to crop production, for example. Increased traffic may also result from transporting biomass to the plant. Downstream impacts include noise and health impacts from air and water emissions and ash disposal.

Air emissions have the most significant downstream impacts. Several emissions of concern are relatively independent of fuel used in the biomass plant. These include particulate matter (soot) and other substances which are the product of combustion, e.g., nitrogen oxides, volatile oganic compounds (VOCs), and carbon monoxide. Direct particulate matter and secondary particulates formed from nitrogen oxides have been shown to be responsible for many of the health impacts of combustion. These emissions are largely a factor of the boiler type, efficiency of combustion, and pollution control equipment employed.

Pollutants that are fuel dependent include toxic metals (e.g., mercury, lead, cadmium), sulfur dioxide, and a broad category referred to as hazardous air pollutants (HAPs). HAPs include 188 air pollutants named in the Clean Air Act, and others that have been determined to cause health problems but are not specified in the Clean Air Act.[101] Biomass is a very broad term and could include materials that are considered municipal or industrial waste under state or federal rules. This distinction is important because it determines the type of regulations that apply to a facility that combusts these materials.

Chlorine has been identified in recent Minnesota permit applications as a potential concern for agricultural fuels. Chlorine is found in agricultural fuels and forms HCl, which is one of the listed HAPs, when combusted. The combustion of agricultural fuels would have to be done in a way that would address this HAP.

Composite woods, including oriented strand board (OSB), medium-density fiberboard (MDF) and plywood present a different problem. The adhesive binding materials in these woods contain resins made of polymeric organic compounds. There are four basic kinds of adhesives typically used in composite wood: 1) Phenol-formaldehyde; 2) Urea-formaldehyde; 3) Melamine-formaldehyde; and 4) Diphenylmethane di-isocyanate.[102] Appropriate combustion and pollution control equipment is required to destroy these compounds.

Pressure-treated wood can also create emissions of concern. Chromated copper arsenate (CCA) and pentachlorophenol ("penta") treated wood are of primary concern. These treatments were recently banned for residential use, but are still used by industry and are likely to be found in the construction and demolition (C&D) stream for many years to come. This wood source is identified as one of the primary concerns with combustion of C&D wood in a recent study sponsored by a consortium of Northeast states' government agencies (referenced in the previous chapter).[103] Advanced pollution control equipment is required to reduce emissions coming from the combustion of these substances.

[101] Pratt, Gregory, Kari Palmer, Chun Yi Wu, Fardin Oliaei, Cynthia Hollerbach, and Mary Jean Fenske, "An Assessment of Air Toxics in Minnesota," Environmental Health Perspectives, Vol. 108, No. 9, September 2000.

[102] USDA Forest Service, Forest Products Laboratory, Wood Handbook: Wood as an engineering material, General Technical Report 113, Madison, WI, 1999.

[103] Northeast States for Coordinated Air Use Management (NSCAUM), "Emissions from Burning Wood Fuels Derived from Construction and Demolition Debris," May 2006. Available at www.nescaum.org/activities/major-reports.

Since biomass is a renewable energy source, the increased use of biomass reduces fossil use, and results in a net reduction in the greenhouse gases that cause global warming. The extent to which greenhouse gases are reduced is dependent upon choice of biomass fuels, but the majority of the reduction occurs from displacing fossil sources of fuels. Greenhouse gases can be further decreased by soil carbon sequestration by some crops, such as prairie grasses. The extent to which biomass combustion reduces greenhouse gas emissions is affected by the fossil energy expended in planting, harvesting, processing and transporting the biomass to the boiler.

Studies by the U.S. Department of Energy of the life-cycle costs of biomass power plants estimate the net energy balance of of these systems to be between 15 and 30.[104] That is, the energy produced is 15 to 30 times greater than the energy used in growing, harvesting, transporting and processing the biomass. The lower range is a biomass system using dedicated energy crops, while the higher range represent a system using biomass residues, mostly urban wood waste. Dedicated energy crops can have lower net energy balances because of the additional energy required for establishment, harvesting and fertilization that are not all required for biomass residues. Since a Combined Heat and Power facility such as Rock-Tenn's is two to three times more efficient than a power-only facility, the net energy balance for a Rock-Tenn facility would be even higher than for a biomass power-only facility as projected by the study above. The estimates for the net energy balance of biomass power plants is considerably higher than for corn ethanol, which has a net energy balance between 1 and 2. It is also higher than projections for cellulosic ethanol, which a recent literature showed to vary widely, with a net energy balance of about 6 as an upper estimate.[105]

The Environmental Assessment and Permit Process

The environmental assessment and permitting process considers all of the above impacts before a permit is issued. The first step in the permitting process could be the preparation of an Environmental Assessment Worksheet (EAW), which outlines all of the major impacts of the facility. The Minnesota Pollution Control Agency (MPCA) is the governmental unit responsible for overseeing the permitting process, and in many cases would approve the EAW prepared by Rock-Tenn developers. As part of the EAW, an Air Emissions Risk Analysis (AERA) would be conducted. The AERA is a screening process used to identify the potential emission of air toxics. It assesses risk based on the potential impact on the human population, with the input of the Minnesota Department of Health.

Depending on the fuels used and size of the plant, a more complex and comprehensive Environmental Impact Statement (EIS) could be required instead of the environmental assessment conducted through the EAW process. If Rock-Tenn were to burn RDF and/or other material considered municipal or industrial waste, an EIS could be mandatory under Minnesota's Environmental Quality Board rules. An all wood and plant based facility might not require an EAW or EIS, unless potentially contaminated wood were to be combusted. The Foth study gives a good overview of what the EIS will need to contain.[106]

The permitting process may be subject to federal regulations for a Prevention of Significant Deterioration (PSD) permit, which is a federal permit for new and modified major sources. It is a fairly complicated site-specific permit approval process designed to ensure that the increase in emissions from a new facility will not have negative impacts on human health and the environment. It involves a site-specific determination of what is the best available control technology (BACT) for any pollutants emitted at levels significantly greater than

[104] Margaret Mann and Pamela Spath, U.S. DOE, National Renewable Energy Laboratory, "Life Cycle Assessment Comparisons of Electricity from Biomass, Coal and Natural Gas," Prepared for presentation at the 2002 Annual Meeting of the American Institute of Chemical Engineers, November 2002.

[105] Roel Hammerschlag, "Ethanol's Energy Return on Investment: A Survey of the Literature 1990-Present," Environmental Science and Technology, Vol. 40 No. 6, 2006.

[106] Foth, 2006 (see bibliography).

what is emitted by the current operation. Modeling of air emissions is required in PSD permits to determine the potential increase in concentrations of pollutants in the areas surrounding a permitted facility and to define the restrictions that ensure that the increase of emissions does not significantly degrade the ambient air quality.

The facility could also be subject to federal standards of performance such as the New Source Performance Standards (NSPS) and National Emission Standards for Hazardous Air Pollutants (NESHAP). These technology-based standards apply to defined categories of emission sources, regardless of their location and site-specific conditions.

Should the facility be determined to be a waste combustor because of its choice to burn enough RDF or C&D waste that is considered municipal or industrial waste, then the facility could be subject to state and/or federal waste combustor rules. In most cases, this would result in more stringent requirements than the federal NSPS standards for boilers that are not considered waste combustors.

The permit, when issued, would specify control technologies, emission limits and other operational restrictions the plant would need to achieve, as well as reporting requirements to demonstrate compliance. In some cases, restrictions may be put on the use of certain fuels. The MPCA has a very detailed manual describing the environmental review and Title V permitting process on its Web site.[107] Minnesota Planning has also prepared a guide describing the environmental review process.[108]

[107] Minnesota Pollution Control Agency, Major Source Modification and New Source Review Reform: Volume 1- Training Manual, produced by Barr Engineering, June 2004. Available at www.pca.state.mn.us/air/permits/nsr/trainingmanual.html.

[108] Minnesota Planning, Environmental Quality Board, Guide to Minnesota Environmental Review Rules, Revised 2003. Available at www.eqb.state.mn.us/pdf/rulguid3.pdf.

6. Conclusions and Recommendations

The project team, in collaboration with the technical advisory committee (see Appendices A and B), developed the following conclusions and recommendations.

Availability of Biomass

1. **There are sufficient quantities of biomass fuel sources within 75 to 100 miles of Rock-Tenn to provide all of Rock-Tenn's energy needs.** However, considering current and projected future demand for these sources, no single source of biomass considered in this study could supply all of Rock-Tenn's long-term fuel needs. The one possible exception is agricultural sources, which could be sufficient if a long-term fuel contract was signed with an entity (or entities) with the necessary capabilities and assets to securely back up a 20-year contract.

2. **Uncommitted urban tree residues are extremely limited, and in some years may be able to provide only about 15 percent of Rock-Tenn's fuel needs, but annual availability fluctuates considerably and supplies cannot be relied upon.** Tree waste availability varies considerably from year to year depending on the amount of land clearing from development activities, storm events, residential tree trimming activity and tree removals due to disease. While in some years there may be significant excess wood available, in others availability can be scarce. Because other markets exist for tree waste (mainly mulch), during times of scarcity it is possible to pull some of the quantities from those markets, but only by increasing the price significantly over current boiler fuel prices. A procurement strategy that requires diverting wood from the mulch market is not recommended. Two planned projects have the potential to further decrease available quantities, Koda Power and the Midtown Eco Energy Project. Of these, Koda Power is not expected to use any tree residues, but if Midtown Eco Energy were to come on-line, it would completely consume the uncommitted sources of urban tree residues, and possibly divert supplies from the mulch market. Another existing project, the University of Minnesota Twin Cities steam plant, has the capability to use more urban tree residues as well.

3. **All biomass options will necessitate highly controlled combustion practices and appropriate pollution control technology.** Solid fuel combustion results in the formation of air pollutants. This is true whether the fuel is urban tree waste, annual or perennial energy crops, construction and demolition wood, or other biomass sources. The air pollution concerns are heightened for some waste streams, especially those containing metals or industrial compounds. Use of C&D wood may necessitate installing additional pollution control equipment above what would be typically required for the other sources considered here.

4. **There is enough C&D wood to supply a significant portion of Rock-Tenn's fuel needs, but use of some of these sources will trigger a higher threshold of environmental review and the possible need for additional pollution control equipment.** Clean C&D wood is a highly desirable feedstock for other markets, primarily mulch and animal bedding, where it can fetch prices over $80 per ton. On the other hand, no significant markets currently exist for painted or engineered wood products, found in large quantities in the C&D waste stream. This report does not include a detailed study of the issues involved with using contaminated wood, but a limited review suggests that with proper combustion and pollution control equipment, use of C&D wood may be practical, and with proper sorting of the wood, pollution control costs may be lower than for RDF. Further analysis is necessary.

5. **Agricultural sources could provide at least one-third of Rock-Tenn's fuel needs (potentially more if long-term contracts were in place to offset the risk of increasing demand for biofuel production).** Sufficient quantities of corn stover now exist (and sufficient quantities of grasses or other perennial crops could exist) within 50 miles of Rock-Tenn to provide all of Rock-Tenn's fuel needs. Larger quantities are available within 75 miles. At some point in the next 20 years, these sources will probably begin to be used in significant quantities by liquid biofuel plants. However, using these sources to provide up to 30 percent of Rock-Tenn's fuel needs would be reasonable, as this would be a very small fraction of the total resource available. This is also the proportion that some consider the practical maximum for some common boiler types. Long-term contracts would reduce the risk that available quantities could be diverted from Rock-Tenn to other uses. However, these contracts must be with an entity with the assets to back up a long-term contract and that can provide sufficient assurance of the long-term reliability of the fuel supply. Very limited quantities of perennial crops are currently being planted, so although grasses might not be able to supply a large proportion in the time frame necessary for making plant fuel decisions, they could offer potential long term.

6. **There is increasing demand and pricing pressure for agricultural milling residues such as oat hulls, so this should not be considered a significant fuel source for Rock-Tenn.** However, if the material handling system selected at Rock-Tenn can also handle oat hulls and other residues, this could provide a portion of Rock-Tenn's fuel needs. Significant quantities of agricultural milling biomass outside of the metro area might be available for import at a price premium to meet fuel shortages.

7. **There is sufficient wood from logging residues and other forest sources within 100 miles to provide a significant portion of Rock-Tenn's fuel needs; but because of the distance only a portion of this resource should be used.** Guidelines can provide for the sustainable harvest of logging residues, which are currently used at low levels compared to what is available. Logging residues appear to offer opportunity as a Rock-Tenn fuel source. However, future demand for this resource may come from plants closer to the forests than Rock-Tenn. Forests are generally further out from the metro area than the other sources considered here, and necessitate a larger supply shed, which involves more risk. We recommend that Rock-Tenn consider supplying a maximum of 30 to 40 percent of its energy demand with this source. At a more conservative 20 percent of its energy demand, Rock-Tenn would have approximately four times as much logging residues as it needs within 100 miles. Any increase in demand for logging residues may be offset by the potential to use residues from ecological restoration, forest thinning, and brushland clearing to provide additional sources of biomass for Rock-Tenn. There is currently limited information available on the long-term availability and cost of these sources, but efforts under way may provide more information in the next 6 to 12 months.

Costs and Procurement Strategy

1. **Obtaining low-cost financing will be critical to the success of the project.** Financing costs associated with the high capital costs of a biomass project are a large portion of non-fuel operating costs. In order for the total cost of energy generation to remain competitive with natural gas, low-cost financing is essential. Reducing project risk is important to reduce financing costs. Key areas of project risk include the energy purchase agreement, fuel supply agreements, and operator agreement. Obtaining tax-exempt bond status for the project can also reduce financing costs. A screening analysis of total generation costs of natural gas and biomass suggest that, even assuming a high reference cost for natural gas, fuel costs of biomass must be less than $3.50/MMBtu for a low capital and operating cost biomass scenario. Increasing need for pollution control, such as would be expected for C&D wood, increases capital and operating costs, and lowers the threshold level of fuel costs that the project is able to bear.

2. **Maintaining supply-chain control over a significant portion of the plant's biomass fuel requirement will be essential.** Long-term security of fuel supply is essential for the success of a biomass energy project. This cannot be accomplished without direct control over at least part of the project's fuel sources. This supply-chain control can be accomplished through direct ownership of sites where the biomass is collected and processed. A firm contract with an entity with supply chain control is also possible. Although some percentage of biomass resources can be contracted for on a short-term basis, for this portion of the fuel supply there should be at least two to four times more volume than the project will need to ensure adequate quantities are available in the future.

3. **Conversion technology alternatives should be evaluated in part for their ability to able to use a wide range of biomass sources.** Our research suggests that there is no single source of non-RDF biomass near enough to the plant to securely provide all of Rock-Tenn's energy needs. In addition, many or all of the sources have significant annual variation. For example, a slowdown in the housing market would reduce the supply of wood from tree removals, or a significant storm event might dramatically increase the wood supply for several years. If the project is able to use a variety of fuel sources, the financial viability of the project improves.

4. **Our modeling suggests that a 100 percent biomass option using a blend of the fuel sources considered in this study might cost approximately $4/MMBtu under a given set of assumptions.** Individual sources range in cost from just over $2/MMBtu to nearly $6/MMBtu. The fuels model developed for this study represents the best collective judgment of the project team, but does not consider dynamic market conditions, and has a limiting set of assumptions that may not match well with future market conditions. However, it is considered generally indicative of what the costs to Rock-Tenn would be for procuring the biomass sources considered here. The average cost of $4/MMBtu for the 100 percent biomass option may be above what our screening analysis of non-fuel costs of biomass would suggest the project could bear for total fuel costs, even for our low-cost scenario of biomass non-fuel costs. This suggests that further work is necessary to find the ideal fuel mix and technology choice combination for a financeable project. In addition, some fuel sources, such as C&D wood, may incur other costs such as additional pollution control upgrades.

Recommendations

Ultimately, the development team will need to decide on a fuel mix and conversion technology that will result in a plant that can be financed and built. The information provided here is expected to help with that decision, but a broader consideration of issues as well as a comparison with the previous RDF study will be necessary. The following are recommended next steps for the development team.

1. **Conduct further analysis of C&D sources, including an assessment of pollution controls required and discussions with policymakers on future C&D policy changes.** Mixed C&D wood has the potential to provide large quantities of fuel to Rock-Tenn, if environmental questions about usage of composite and other contaminated wood can be addressed (an exercise that was beyond the scope of this study). Addressing these environmental concerns may have additional capital and operating cost implications compared to other sources considered here, although perhaps not as much as for RDF. The completion this summer of a major C&D and industrial waste study will give further information on the best way to proceed with policy changes. Rock-Tenn has the potential to develop a large market for C&D, which suggests a potential partnership with those interested in reducing C&D wastes currently being landfilled, such as environmental groups and county and state policymakers.

2. **Consider the viability of a C&D source separation program.** It may be worthwhile to work with construction industry associations such as the Builders Association of the Twin Cities (BATC) and other stakeholders to set up a C&D source separation program. BATC is interested in green building practices, such as finding alternatives to landfilling C&D waste. BATC is currently working with the Green Institute to develop a green homebuilding certification program, and may be willing to work with the development team to help set up a pilot source separation program. Such a program could potentially be a part of the business operations of a Rock-Tenn biomass plant.

3. **Work with other stakeholders who are convening a forest-thinning task force to develop a framework for capturing benefits of forest thinning while providing an additional biomass source for Rock-Tenn.** Advisory committee members from this project have initiated discussions that could result in the opportunity to access significant forest biomass resources. These conversations stem from the fact that in addition to producing waste biomass, forest thinning can help improve forest productivity as well as achieve ecological goals. State, county and regional park managers and private landholders are all interested in forest thinning to improve forest health. These conversations should be expanded to estimate costs, identify funding sources that could pay for the ecological benefits, and determine if this is a viable source for Rock-Tenn. Also, given that significant quantities of forest biomass are available across the border in Wisconsin, the development team is encouraged to engage stakeholders in Wisconsin in discussions as well.

4. **Work with policy makers, environmental and conservation groups, and other stakeholders to further evaluate perennial grasses and other potential perennial crops and the potential for state or federal dollars providing a co-benefit payment to improve the economic viability of this source.** Herbaceous and woody perennials can provide significant environmental benefits compared to conventional row crops, as well as provide a source of biomass for Rock-Tenn. Policy that provides incentives for these environmental benefits can help improve the economic viability of this biomass source. In order to achieve the maximum environmental benefits, standards are likely to be required.

5. **Consider financing energy-efficiency upgrades at Rock-Tenn as part of the plant financing package.** Investments in energy efficiency typically have a higher rate of return and shorter payback than investments in new energy production capacity. This could decrease the amount of fuel required to provide for Rock-Tenn's energy needs by 20 percent or more from the demand assumed for this report, as well as make Rock-Tenn more competitive for the long term no matter what the cost of energy generation. If bonds are issued as part of a plant financing package, Rock-Tenn could make significant investments in efficiency upgrades that it would then pay back over time, like a traditional energy plant investment. However, this commitment might be justified by a positive impact on profits if the projected annual energy savings were higher than the projected annual payment to the bond issuer for the efficiency investments. As some efficiency investments are now being implemented, this proposal could cover additional efficiency investments with longer payback periods. Further analysis is required to fully investigate this option.

6. **Begin discussions with farm organizations that might be able to contract for agricultural biomass fuels.** For both dedicated energy crops and corn stover, it would be important to have an "aggregator" active in the agricultural community to organize the contracting, production, storage and delivery of agricultural biomass. Working with those familiar with agricultural products will help to overcome the logistical issues, such as contracting with multiple producers and significant storage that will be required. Our research indicates that storage could be more expensive than we assumed for our model. There may also be opportunities to work with farm groups that act as aggregators for carbon credits, as they have established structures to deal with aggregation issues.

7. **Continue to refine urban tree availability estimates.** Our research has shown the limitations of surveying existing generators to estimate available quantities of urban tree residues, particularly for predicting future availability. A thorough characterization of Twin Cities tree resources, using forestry science techniques, could allow the prediction of tree residues generated from future land clearing activities, normal generation rates, and the potential impact of storms and disease.

8. **Consider using innovative conversion technology such as gasification for meeting all or a portion of Rock-Tenn's thermal needs.** No single biomass source considered here can provide all of Rock-Tenn's fuel needs. One possible strategy is to use biomass for meeting a portion of Rock-Tenn's fuel needs, and conventional natural gas/fuel oil based system for the rest. This would hedge against both high natural gas costs as well as concerns about future biomass availability. Gasifiers are suitable for smaller-scale projects and could be appropriate for this type of strategy. It may be possible to receive demonstration project funding for this type of strategy.

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Appendix A:
Recruitment letter and job description for Technical Advisory Committee members, July 31, 2006

July 31, 2006

Dear Community Member,

The Rock-Tenn paper recycling facility, formerly known as Waldorf paper, has been a fixture in the Midway area of Saint Paul for over 100 years. This facility is the largest paper recycler in Minnesota, is a significant factor in the local economy, and employees about 500 people. Making paper requires a lot of energy, and Rock-Tenn will soon lose its major source of energy (when Xcel Energy converts the High Bridge power plant from using coal to natural gas, resulting in the inability to produce the steam Rock-Tenn needs). Rock-Tenn is, essentially, a victim of good environmental policy. Rock-Tenn needs to find an affordable energy source to stay in business in Saint Paul.

As a result of this, Rock-Tenn has been looking for other ways to provide energy to its plant. The situation that Rock-Tenn is in provides our community with the opportunity to identify a clean, economically viable energy source for Rock-Tenn (and potentially the Midway area) so we can keep these jobs in Saint Paul and protect our environment.

Several of the stakeholders in this project, including the City of Saint Paul, Eureka Recycling, the Green Institute, the Saint Paul Port Authority, the Ramsey/Washington County Resource Recovery Project, Ramsey County, and Rock-Tenn, have agreed to fund a study of biomass alternatives. The study will look at the availability, logistical issues, and costs of using biomass material derived from a variety of sources, such as urban wood waste, demolition and construction waste, and agricultural by-products. We expect the study to be substantially completed by the end of the year but we also expect periodic updates on information as the study progresses that we will make available as we are able.

An important feature of the study calls for a Technical Advisory Committee* to provide feedback on the results of the study. **We are currently seeking members for the committee with technical expertise on clean biomass.** See attached description of the Technical Advisory Committee for more details on qualifications desired for committee members.

If you are aware of anyone who meets these qualifications, or have any questions, please contact Carl Nelson at the Green Institute at 612-278-7117 or cnelson@greeninstitute.org.

Thank you for your attention to this important community matter.

Sincerely,

Jack Greenshields
Rock-Tenn Company

Anne Hunt
City of St. Paul

Susan Hubbard
Eureka Recycling

Lorrie Louder
St. Paul Port Authority

Carl Nelson
Green Institute

Zack Hansen
Ramsey County and
Ramsey/Washington County
Resource Recovery Project

** NOTE: The technical advisory committee is not the "citizen's advisory committee" that Rock-Tenn mentioned in the community meetings. The citizen's group will very likely meet once in conjunction with the permitting process for a facility, before a facility would begin operation. Rock-Tenn will be in contact with community councils about this process.*

Technical Advisory Committee for Rock-Tenn Biomass Fuels Study

July 31, 2006

Purpose

The Green Institute is leading a team to conduct a feasibility assessment of using clean biomass sources for providing energy to the Rock-Tenn facility. The report will:

1) Assess the availability of clean biomass fuel for use at the Rock-Tenn site;
2) Estimate costs at various annual usage quantities; and
3) Develop the building blocks for a supply-chain procurement plan.

The role of the advisory committee is to provide input and guidance to the project team, including reviewing and providing comments on drafts of the project report. In addition, advisory committee members will provide input on report recommendations, and provide their assessment of proposed recommendations. We expect the advisory committee to be composed of 12-15 members.

Scope of Technical Review

Advisory committee members will be chosen for their expertise in the following issue areas:

1) Urban and construction/demolition wood waste collection, procurement, transportation and utilization
2) Agricultural residue collection, procurement, transportation and utilization
3) Generation of heat and power from biomass
4) Finance and economics of biomass
5) Regulation and policy issues associated with solid waste, biomass and energy

Selection

Advisory committee members will be chosen by a project management committee composed of representatives from the City of St. Paul, Ramsey/Washington County Resource Recovery Project, St. Paul Port Authority, Rock-Tenn and Eureka Recycling.

Criteria for selection include:

1) Technical knowledge and experience in one or more issue areas
2) Availability for attending meetings
3) Independence from potential conflicts of interest
4) A balance of expertise such that the committee has expertise in all issue areas

Expectations and Responsibilities of Committee Members

1) Attend 3 advisory committee meetings
2) Review draft reports and provide feedback, either verbal or written
3) Participate in evaluating report recommendations

Committee members will be rewarded through public recognition and the gratification of contributing to the public benefit.

Schedule

Aug. 16	Applications due
Aug. 21	Final committee membership determined
Sept. 28, 1pm	1st Advisory Committee meeting
Dec. 7, 1pm	2nd Advisory Committee meeting
Jan. 18, 1pm	3rd Advisory Committee meeting

Contact information

To apply, please send your qualifications to the address or (preferably) email below. Please cite any potential conflicts of interest.

Carl Nelson
Director of Community Energy
Green Institute
2801 21st Avenue South
Minneapolis, MN 55407
cnelson@greeninstitute.org
612-278-7117

Appendix B: Technical Advisory Committee members

Rock-Tenn Biomass Fuels Study
Technical Advisory Committee Members

Name	Title	Affiliation
Don Arnosti	Forestry Program Director	Institute for Agriculture and Trade Policy
Dean Current	Director, Center for Integrated Natural Resource and Agricultural Management	U of MN, Dept of Forest Resources
Alan Doering	Associate Scientist – Co-Products	Agricultural Utilization and Research Institute
Jerry Fruin	Associate Professor	U of MN, Dept. of Applied Economics
Shalini Gupta	Senior Energy Associate	Izaak Walton League of America - Midwest Office
Dentley Haugesag	Economic Development Specialist	MN Dept. of Employment and Economic Development
David Morris	Vice President	Institute for Local Self Reliance
Steve Morse	Executive Director	MN Environmental Partnership
Daniel O'Neill	Vice President	Northland Securities
Gregory Pratt	Research Scientist	MPCA
Richard Sandberg	Manager, Air Quality Permits Section, Industrial Division	MPCA
Matthew Schuerger	President	Energy Systems Consulting
Lance Sorensen	Utilization and Marketing Forester, Southern Region	DNR, Lake City office
Carlyle Sulzer	Manager, Generation Services	Great River Energy
Lise Trudeau	Renewable Energy Engineer	MN Department of Commerce
D. Scott Vandenheuvel	President	Vandenheuvel Consulting
David Zumeta	Executive Director	MN Forest Resource Council
ALTERNATES:		
Michael Bull	Assistant Commissioner for Renewable Energy and Advanced Technologies	MN Department of Commerce
Jim Kleinschmit	Director, Rural Communities Program	Institute for Agriculture and Trade Policy

Appendix C:
Assessing Urban Tree Residues and Secondary Wood Sources in the Twin Cities Metro Area

Urban Tree Residues

The source of wood residues from trees in the urban landscape can be divided into two broad categories: 1) tree trimming and removal; and 2) land clearing activities. Tree trimming and removal is a highly fragmented industry as described in more depth below. Most tree trimming/removal companies deliver their wood residues to wood processing sites, where the wood is ground and resold into other markets. Land clearing activities are driven by the continued expansion of the metro area into exurban areas and is highly dependant upon the housing market.

Private Tree Service Companies and Municipalities

The Minnesota DNR commissioned an analysis, conducted in 1991 and 1992, of urban tree residues in Minnesota. The project team was unable to obtain a detailed explanation of survey methods, but the results are reported in the DNR's Wood Waste Study. The DNR's estimate of the tree waste generated in the Twin Cities was 326,000 wet tons, split into the following categories: Public Agencies (15.1 percent), Private (46.2 percent), Utilities (31.3 percent) and Land Clearing (7.4 percent). This estimate was derived from surveying municipal tree departments, utility companies, land clearing companies and consolidators operating wood processing sites for private tree trimming companies. However, the survey has been criticized for overestimating available quantities because some municipalities deliver wood waste to processors, and thus a portion of the wood is double-counted in the survey. Adjusting for this flaw by conservatively assuming 75 percent of municipality wood was double-counted, and subtracting out the land clearing, results in an adjusted estimate of 207,000 wet tons.

In 1998, the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) collected data from 30 metropolitan areas around the country. The study included statistical analysis of the data designed to estimate urban wood waste resources using demographic and economic variables. We used the NREL's weighted average of per capita municipal solid waste wood resources (0.20) to estimate the MSW wood waste for the Twin Cities population (2,810,000) at 562,000 wet tons of tree waste. This estimate includes the following categories: tree waste wood hauled with trash, municipal yard waste recycling, utility tree trimming, and private tree service companies. Thus, in order to compare this number to our other urban tree waste estimates, we had to subtract the amount of wood hauled with trash because this category is not included in our other urban tree waste calculations. The NREL study estimates this as 4 percent of total MSW. As total MSW in the Twin Cities was 2.1 million tons, the final estimate for urban wood waste not including wood waste in the MSW stream is 478,000 wet tons.

Another national study was conducted by NOES Associates in 1994 specifically of urban tree residues, and is the most comprehensive study that focuses only on urban trees sources. An effort was made to carefully assess the total population and randomly select a representative sample of organizations across all regions of the country. NOES mailed 3,878 surveys, and the response rate was 44 percent. According to the results, per capita annual wood generation is about 0.24 tons per person, or 549,500 tons for the metro area.[109] Note that

[109] Jack Whittier, Denise Rue, and Scott Haase, "Urban Tree Residues: Results of the First National Inventory," Journal of Arboriculture 21(2): March 1995. Estimate is reported in cubic yards, converted to wet tons per Jeffrey E. Fehrs, "Secondary Mill Residues and Urban Wood Waste Quantities in the United States," Prepared for Northeast Regional Biomass Program Washington, D.C., 1999. Per capita urban tree waste estimates based on total 1994 population (263,126,000).

land-clearing is included in this estimate. If one were to subtract our estimate of Twin Cities wood waste from land clearing activities (125,000 tons, from the next section below), an estimate of 424,500 tons would be due to just tree trimming activities.

Green Institute staff carried out its own extensive survey in 2005 specifically of generators of wood waste. For this survey, a contact list of 101 tree service companies and 32 municipalities within 50 miles of St. Paul was generated from old studies and current phone directories. Phone calls were made to each of the companies on the contact list. Respondents either answered the survey questions over the phone, or the survey was then emailed or faxed to have another member of the company provide the information. Fifteen of the private tree service companies were removed from the data set because they did not generate any wood waste or were no longer in business. Responses were received from 26 of the private tree service companies and 16 of the municipalities. This data was then used to calculate a non-response estimate for the remaining companies on the contact list. For these companies that did not provide information regarding their yearly wood waste generation, the non-response estimate was used in order to extrapolate their potential generation. This estimate was based on the median of all companies actually surveyed. The median was used rather than the mean for this estimate because there were several outliers that skewed the mean making it an unacceptable estimate for yearly generation quantities. The median provided a more conservative estimate of a company's generation.

From this survey, it was estimated that there were 310,200 wet tons of tree waste in the area. Approximately 228,700 tons of this was generated by private tree service companies (including utilities), and the other 81,500 tons was generated by municipal departments. The results of the local and national studies are summarized in Table 18.

Table 18: Estimates of wood waste generated from urban tree trimming

Study	Generator	**Tree Waste** (Wet Tons)
Minnesota DNR, 1992	Private tree service companies, electric utilities	207,000
NREL, 1998	Private tree service companies, electric utilities, municipalities (national)	478,000 (not including MSW waste)
NEOS Corporation, 1994	Private and municipal tree service companies, land clearing, electric utilities (national)	424,500 (not including land clearing)
Green Institute, 2005	Private tree service/municipalities/utilities	310,000
	Private tree service companies inc. utilities	228,700
	Municipalities	81,500
	Total Estimated Tree Trimming:	**207,000 – 478,000**

It is not clear why the national studies indicate that tree waste is higher than that found by the local studies. It could be due to annual variability in the tree waste generated, or the larger size of the Twin Cities nearly 15 years later. From 1990 to 2005, the Twin Cities population grew by 23 percent in the seven county metro area. For a mean estimate, we gave heavier weighting to the local studies. Assuming tree waste is proportional to population (as assumed by the NREL study) and adjusting the DNR study accordingly results in an estimate of about 255,000 tons annually. For our central estimate, we adjust our recent survey downward slightly to 300,000 tons/year, recognizing the lower value of the DNR study, but also that the national studies predict much higher results.

Land Clearing Firms

Land clearing companies are hired by land developers to remove trees from sites to be developed. These sites are eventually developed into new residential and commercial areas. Thousands of acres of trees are cut in the Twin Cities metropolitan area in preparation for urban expansion. Typically the costs of clear-cutting trees in the metro area vary from $2,000 to $3,000 per acre, although it can be as low as $1,500 per acre for land with smaller trees. Until the opening of District Energy St. Paul's wood burning facility, most of this tree waste was burned or buried on site. Some percentage was also recovered for the mulch market. Since 2003, companies have begun to haul this material to District Energy St. Paul's wood processing site in St. Paul. Clear-cut wood from land clearing jobs contains very few impurities and is usually chipped rather than ground, resulting in uniformly sized pieces that are better handled by the equipment used with boilers. Also, a good percentage of all wood that is chipped by land clearing companies is blown directly into semi-trailers, which reduces the content of sand, gravel, and other debris in the fuel. As a result, land clearing wood waste is considered a high-quality wood fuel.

The DNR study referenced above estimated that 24,000 tons are generated from land clearing activities. This is nearly an order of magnitude difference from what the project team found. Without access to the original study, the reason for this anomaly is not clear. Review of regional housing start statistics indicate a slightly slower level of housing development during 1991-1992, which could explain some of the difference.

According to research done for the Green Institute by Trillium Planning and Development, large land clearing firms reported generating 160,000 to 180,000 wet tons in 2003. Project team members re-contacted land clearing firms in 2006, and four land clearing companies reported generating approximately 72,000 wet tons of wood waste. In addition, two other land clearing companies recently began to function as wood consolidators/processors, and did not report land clearing activities separately from other sources of wood. One of them, Central Wood Products, was estimated to be responsible for a significant portion of all land clearing. Their totals were not available, but we believe figures from these two companies could be more than double what is reported in Table 19.

Table 19: Wood waste generated by land clearing firms in 2006

Company	Wet Tons of Wood Waste
Thomas & Thomas	10,000
Tree Technology and S & A Land Clearing	28,000
Tree Top	25,000
Silva Corporation	8,800
Central Wood Products	n/a
All-wood Products	n/a
Total	**71,800**

Based on this survey work, we estimate the annual mean quantity of land clearing activities to generate 150,000 tons/year. As noted above, this is highly variable and dependant upon development activities. Many land clearing companies reported a significant decrease in land clearing in the latter half of 2006, and expected much less activity in 2007 than in recent years.

Wood Processors/Consolidators

Wood processors process wood from tree trimming sources with high through-put grinders primarily into mulch, boiler fuel and compost. Environmental Wood Supply also accepts wood from land clearing operations. Processors are also referred to as consolidators because primary generators drop off wood at their sites. Wood processors generally charge a tipping fee of $10-$30/cubic yard depending on the quality of the wood being delivered. Chipped wood is generally taken for free, and recently one of the processors has started to pay tree companies for whole logs. As demand grows for mulch and boiler fuel, the processors are starting to respond by reducing tipping fees.

In addition to processing wood generated by others, some processors also generate their own wood. Processors are starting to enter into the land clearing market to increase their supply of wood as markets grow. They also are one of the few entities that can handle storm events, and will respond to requests from municipalities and others to remove downed trees. Processors are increasingly regional in their reach, so it is difficult to attribute their sources to the metro area, as they may run crews to collect and process wood from over 100 miles outside of the metro area. This results in some wood being essentially imported into the metro area.

In 2006 and early 2007, the principal processors in the Twin Cities area were interviewed by the project team to estimate how much wood they take in each year. Many large wood processors and land clearing firms were left out of this estimate in order to avoid double-counting the material they provide because their wood waste goes to either the mulch market or District Energy. In addition, because this information is based on personal interviews, it is only as accurate as the numbers provided by each firm.

Table 20: Wood waste generated by principal wood waste processors, project team survey, 2006/2007

Company	Wet tons
Rumpka Company	35,200
All-Wood Products	79,200
Central Wood Products	93,500
Buberl Recycling and Compost	18,800
NRG Processing Solutions	6,500
Environmental Wood Supply (additional)	190,000
Total	**423,200**

As the tree residue and land clearing estimates overlap with the consolidators, these numbers are presented as a check on the total amount of wood waste available in the Twin Cities. Total wood handled by processors is estimated at 423,000 (Table 20). The numbers reported for District Energy account for wood received from the other processors. When combined with the other land clearing number from above (72,000 wet tons), the total tree residues would be 495,000 tons. This is 10 percent above our estimate of 450,000 tons (300,000 tree trimming + 150,000 land clearing), but given the general lack of precision, we believe this confirms our estimate. Also, our generator survey was conducted in 2005 and the consolidator survey in 2006, so some of the variation could be from annual supply fluctuation.

Difficulties in Estimating Urban Tree Residues

Estimating with a high degree of precision the annual generation of wood waste in the metropolitan area is not possible for several reasons. The two largest factors affecting wood waste generation are weather and tree diseases, both highly variable by nature. The last significant storms in the region occurred in Ramsey County in 1998. Large storms create additional business for tree services for up to four years. Some logs from the 1998 storm were still unprocessed in 2003 when Environmental Wood Supply took custody of the St. Paul Wood Processing site on Pig's Eye Lake Road. It is estimated that a large storm hitting mature tree regions of the metropolitan area could generate more than a million tons in a single year. The Dutch elm epidemic of the late 1970s and early 1980s also generated more than a million tons of tree waste per year. The emerald ash borer will likely increase the amount of wood waste generated in upcoming years (see emerald ash borer section below). Oak wilt and Dutch elm disease continue to attack remaining stands of trees in the area. In addition, forestry experts at the University of Minnesota predict that more diseases will hit the region's trees as a result of global warming, which will eliminate the extremely cold winters that normally keep many diseases away. It is not yet known how these epidemics will compare with Dutch elm disease.

Data reporting difficulty

Data are often not recorded accurately by generators, or are reported in inconsistent units. For wood entering sites, volumes are often "eyeballed" to estimate cubic yards. The number of cubic yards per ton can also vary considerably depending on the material. Just branches and brush are closer to 8 cubic yards/ton, while logs can be less than 3 cubic yards/ton. Even once it is ground or chipped, density can vary considerably. Thus, reported data are typically not considered very accurate.

Survey Bias

An additional problem with the data is that all of the numbers are self-reported by the generators and processors. They are not required to report this information, so it is based on voluntary responses. The project team found that many companies did not keep good records on wood waste generated or collected or were not willing to share the information because of the industry's competitiveness. In some cases, companies might over-report their quantities in order to give the appearance of doing more business than they actually are.

External Factors Affecting Quantities of Urban Tree Residues

Emerald Ash Borer

The emerald ash borer (EAB), a shiny green beetle first identified in the United States in 2002, is believed to have entered Detroit by ship from Asia. Since then, the EAB has been responsible for the death of approximately 15 million of Michigan's 700 million ash trees. The EAB has spread to forests in parts of Indiana, Ohio, Illinois, and Ontario, and Minnesota may be next. The adult beetles nibble on ash foliage but cause little damage; the larvae, on the other hand, feed on the inner bark of ash trees, disrupting the tree's ability to transport water and nutrients. Trees with EAB usually die in three years but have been seen to die in one to two years when EAB populations are high.[110]

Ash trees have been a popular street tree for decades because they are drought and salt tolerant; they were widely planted in urban areas around the country to replace elms killed by Dutch elm disease. In order to prepare for this urban forestry threat, the Minnesota DNR conducted a preliminary inventory to assess the size and distribution of the populations at risk. In 2006 the DNR undertook a project designed to characterize the abundance, size, and condition of the ash and elm trees in residential and commercial areas of Minnesota municipalities. It conducted on-the-ground sample surveys of more than 750 communities across the state to gather this information.[111]

110 www.emeraldashborer.info.

111 Minnesota Dept. of Natural Resources, Resource Assessment Unit, Forestry Division. Rapid Assessment of Ash and Elm Resources in Minnesota Communities.

Statewide, the DNR found that ashes represent 6.4 percent of total urban trees. They found urban ash populations to range from 3.8 percent of the tree population in Washington County to 18.9 percent in Carver County. (See Table 21 for county data.) Ashes make up an average of 9.5 percent of trees in the seven-county metropolitan area.[112] The primary interest of the study was in the main street and residential yard areas of each municipality, so the survey was confined to residential neighborhoods and main business corridors within each city. In addition, the study targeted smaller communities that do not have inventories of their own, so some of the bigger cities in the area are not included (e.g., Minneapolis and St. Paul). Also, field checks conducted after the initial survey was completed indicated that ash trees were undercounted by approximately 14 percent statewide. These estimates might therefore be low, but they provide a good overall county and statewide assessment. Although ashes make up a small percentage of urban trees, they might contribute a large quantity of tree waste if the emerald ash borer arrives.

Table 21: Ash populations and percentages by county in Twin Cities metropolitan area

County	Ash Population	Trees per Acre	Percentage Ash
Anoka	175,150	1.4	5.3 %
Carver	129,186	6.6	18.9 %
Dakota	296,946	3.0	15.3 %
Hennepin	324,210	5.2	7.7 %
Ramsey	213,524	4.2	4.9 %
Scott	107,792	3.8	10.5 %
Washington	368,216	4.0	3.8 %
Average (7 Counties)	***230,718***	***4.0***	***9.5 %***
State	**2,968,513**	**3.2**	**6.4 %**

In addition to this statewide data, some inventories have been conducted for individual cities as well. In Minneapolis, for example, an inventory was conducted to determine whether the benefits from the city's urban forests outweigh the city's annual costs. This study provides a more in-depth analysis of urban forest composition, including species, diversity, age distribution, size, and condition, along with maintenance needs and benefits provided. According to this inventory, 16.1 percent of the actively managed urban trees, or approximately 32,050 trees, are green or white ash. This citywide data can be used to estimate how much biomass might be generated in Minneapolis as a result of the emerald ash borer.[113] Although it is impossible to predict when or even if it will arrive, given the history of disease migration, it is more likely than not that the emerald ash borer will arrive in Minnesota within 15 years. The resulting surge of ash trees in the wood waste supply could last for ten years or more.

Michigan's Experience with Emerald Ash Borer

In Michigan, approximately 15 million ash trees are dead or dying as a result of EAB, and a huge number of trees are awaiting disposal. The Michigan Department of Agriculture established a quarantine and set up eight yards in the southeast part of the state for disposal of the affected trees; the state initially paid for the grinding of the wood waste, and much of it went to a nearby power plant. From June of 2004 to June of 2005, more

[112] Ibid.

[113] McPherson, E. Gregory et al., City of Minneapolis, Minnesota Municipal Tree Resource Analysis. Center for Urban Forest Resource, USDA Forest Service, Pacific Southwest Research Station. June 2005.

than 300,000 tons of wood were processed as a result of the EAB. Michigan did not have a viable urban wood industry, and took advantage of the insect outbreak to build large-scale urban wood programs. The state contracted researchers to conduct a two-part analysis of the green side (a living tree inventory) and the brown side (mostly tree residue, pallets, construction waste, and mill residues) of urban wood waste. [114]

David MacFarlane used forest-based inventory techniques and applied them to an urban setting to get at the larger questions of how many trees are in urban areas, how much they might be worth, and whether it would be feasible for them to make any contribution to biomass fuel or wood product manufacturing if the trees that become available were harvested. To do this, MacFarlane used a stratified sampling methodology and a land-use land cover map in order to select high- and low-density urban areas, parks and golf courses, and roads and other paved areas. The field crew then drove to those neighborhoods and went door to door to get permission from the landowner, measure the dimensions of the property, and take measurements of the trees. This allowed MacFarlane to extrapolate total quantities based on the proportion of different land use types, and the amount that certain species contribute to each land use type. Using published biomass equations, he was then able to estimate the amount of standing biomass in live and dead trees in urban areas in southeast Michigan. This report is not yet finished, but is slated for publication in the July 2007 issue of Aboriculture and Urban Forestry.[115]

In order to estimate the brown side of urban wood waste, Sam Sherrill conducted a thorough analysis of five categories of wood waste: pallets, edgings and cutoffs, chips and shavings, tree trunks and limbs, and construction debris. Sherrill used SIC codes to generate a contact list of 20,000 companies that were used as the total population, and then selected one out of three for his sample. Surveyors then telephoned 1,500 of these companies and conducted a 70-question survey in order to understand the wood waste that was being generated and where it was going. Although this report is not yet finished, the data have been collected and Dr. Sherrill expects the report to be finished within the year. This in-depth analysis could be replicated for the Twin Cities area if a thorough analysis of wood waste is deemed necessary.[116]

In addition to the two studies, the Michigan Department of Agriculture also began to conduct outreach efforts in biomass research and demonstrations, implementation projects, and community demonstration grants to promote the use of urban wood waste. Although Minnesota's course of action is unclear if the EAB arrives, lessons can be learned from Michigan's experience, and urban wood programs will benefit from the wood waste caused by this invasive species.

Housing Market Trends Affect Urban Wood Waste

The housing market can alter wood waste generation rates by tens of thousands of tons per year. When the housing market declines, as it did in late 2006, the generation of wood waste that results from clearing land to prepare for new housing decreases. In November the State Economics Office announced that housing starts for 2006 were down by 37 percent, and much of this decline occurred in the second half of the year. Interviews with land clearing companies confirmed that land clearing has declined considerably during the fall of 2006 and is expected to be at record low levels for the spring of 2007.

The availability of land clearing residues in the future will roughly mirror residential development trends in the region's suburbs and exurbs. The region's planning authority, the Metropolitan Council, estimates that the

[114] Weatherspoon, Anthony and Jessica Simons. May 17, 2006. Urban Wood Utilization and the Emerald Ash Borer: Increasing the Viability of Wood-Based Industry in Southeast Michigan. MI DNR and Southeast Michigan Resource Conservation and Development Council.
[115] Personal communication, Dr. David MacFarlane, Professor in Forest Measurements and Modeling, Michigan State University, February 14, 2007.
[116] Personal communication, Dr. Sam Sherrill, Professor in School of Planning, University of Cincinnati, February 7, 2007.

Twin Cities metro area will add nearly 1,000,000 new residents and 500,000 new households over the next 25 years. This anticipated growth rate is roughly similar to the growth experienced over the past decade. Table 22 provides growth projections for the metro region by county for 2010, 2020, and 2030.

Table 22: Twin Cities metropolitan area projected population growth 2000-2030[117]

County	2000 (actual)	2010	2020	2030	2010	2020	2030
	Projections for Population Growth				*Projected population growth from previous period as a % of total growth*		
Anoka	298,084	358,270	399,810	413,260	15%	11%	5%
Carver	70,205	107,910	159,300	191,380	9%	14%	12%
Dakota	355,904	421,960	480,150	517,010	16%	16%	14%
Hennepin	1,116,206	1,213,950	1,310,030	1,384,800	24%	26%	28%
Ramsey	511,035	547,700	570,860	598,900	9%	6%	11%
Scott	89,498	147,840	193,900	221,670	14%	12%	11%
Washington	201,130	258,502	316,043	365,570	14%	15%	19%
Twin Cities Total	**2,642,062**	**3,005,000**	**3,334,000**	**3,608,000**	--	--	--

Secondary Wood Processing

A Minnesota DNR study conducted in 1994 estimated 200,000 dry tons of wood waste was generated by secondary wood processing companies, such as cabinetry, furniture, and window manufacturers.

Because the DNR study is more than ten years old, the project team decided to conduct a limited follow-up survey to test whether it was still valid. Surveys were mailed to a sample of 60 of the 256 secondary wood processors in the seven-county metropolitan area. Responses were received by mail or by telephone. Twenty-two responses were received, and six of the addresses used were no longer valid, giving the survey a response rate of 41 percent.

Survey Results

The total number of secondary wood processors has decreased from 300 in the seven-county area in 1994 to 256, according to the most recent update of the DNR's database in 2004. The wood waste generated seems to be decreasing as well. The sample survey and discussions with survey respondents indicate that the trend in recent years has been toward minimizing production waste and finding recycling alternatives. Most clean wood waste goes to animal bedding, whether directly to farmers or via trucking companies or animal bedding companies that then sell it to farmers. In addition, some of this waste still goes to the mulch market and wood processors. Waste management companies are also taking advantage of this market by collecting wood waste from secondary processors and selling it to District Energy St. Paul for fuel. One company conjectured that no secondary wood waste was going to landfills because it is too expensive; very few companies are unable to sell their clean wood waste.

[117] Source: Metropolitan Council 2030 Regional Development Framework, Revised Forecasts (3/8/06).

The survey also indicated that composite wood (plywood, OSB, etc.) makes up a higher proportion of the wood waste generated by these companies than was estimated by the DNR in 1994. Although there seemed to be less of a market for this than for the clean wood waste, there appear to be some markets for this wood waste as well. A few respondents still paid to dispose of particle board, painted or treated wood, and other wood waste with residues, but most reported getting paid for it or had it taken away for free. One respondent used clean wood cuts for boiler fuel in the winter, but then paid to dispose of nearly 1,000 tons/year during non-heating months.

Based on our limited study, we estimate that perhaps two-thirds of the original DNR estimate is still generated in the Twin Cities (134,000 dry tons). However, because of the low moisture content and high quality of the wood waste generated by secondary wood processors, it is unlikely that much of this wood would be available for fuel. The animal bedding market, which currently captures much of this wood, has low processing costs and a high resale value. In addition, the clean, dry wood, such as dimensional lumber and pallet wood waste, is also a good source of wood for manufacturing dyed mulch. Rock-Tenn would have to compete with both of these high-priced end markets for clean dry wood waste. We estimate that perhaps 10,000 tons of clean wood could be collected.

Market Cost Structure and Competing Markets

Mulch Market

Demand for bagged mulch has increased in recent years and is expected to continue to grow over the next decade based on product innovations, growing consumer interest in landscaping, and the increasing availability of plants, flowers, and shrubs in the retail market. The market for value-added mulches, such as colored and treated mulch, is expected to grow even faster. According to the Freedonia Group, the national mulch and chips market was $440 million in 2006 and is projected to increase to $570 million by 2011. Mulch prices have also increased in recent years and are projected to continue to rise as clean wood waste becomes more scarce, especially in urban areas. The table below breaks down the mulch market, providing sales, pricing, and quantities of mulch sold nationally along with predictions regarding the future of the market.[118] Extrapolating Twin Cities mulch sales from these national projections results in a sales estimate of about 40,000 wet tons in the seven-county metro area. This number is likely a lower limit; our research shows a much higher figure.

[118] Schmidt, Darren D., Sheila K. Hanson, and Kyle E. Martin, Energy & Environmental Research Center, University of North Dakota. Identifying Resources and Options to Mitigate the Risk of Wildland Fires in North Dakota, June 2003.

Table 23: Past and projected U.S. mulch sales in lawn and garden applications (1992 – 2011)

Item	1992	1996	2001	2006	2011
Total Lawn and Garden Mulch Sales	**550**	**630**	**850**	**1080**	**1350**
% Bagged	40.9	41.3	42.9	44.9	48.1
Lawn and Garden Mulch Sales	225	260	365	485	650
By Type:					
Wood and Mulch Chips	215	245	340	440	570
Conventional	213	240	290	340	390
Colored	2	5	50	100	180
Other	10	15	25	45	80
By End User:					
Consumer	165	195	280	390	545
Professional	60	65	85	95	105
By Market:					
Residential	165	195	280	390	545
Commercial	21	23	30	33	37
Golf Courses	18	20	26	29	32
Government and Other	21	22	29	33	36
$/lb	.04	.04	.05	.06	.07
Lawn and Garden Mulch Sales (mil lb)	**5600**	**6100**	**7200**	**8300**	**9500**

Sales totals are listed in millions of dollars.

Source: The Freedonia Group as cited in *Identifying Resources and Options to Mitigate the Risk of Wildland Fires in North Dakota*.

Other mulch sold in the Twin Cities but not sourced locally includes red cedar from British Columbia, cypress from Georgia and the Carolinas, pine straw from Minnesota and Georgia, pine bark from South Dakota and Minnesota, and a variety of hardwood and softwood byproducts from the Minnesota Forestry industry. Silva Corporation, which imports cypress and red cedar, is the principal importer of various out-of-state mulches. Silva also uses byproducts from Weyerhaeuser and other forestry industrial operations in northern Minnesota.

Horticultural sales in general and mulch in particular have increased steadily over the past 25 years; however, recent data suggest that this trend has leveled off and sales over the past few years have been flat.[119] According to the three largest mulch sources in Minnesota, this national trend is moderated somewhat by the rapid growth of the Twin Cities metropolitan area. The largest driver of the mulch market is urban development. New residential areas need mulch to cover new trees and shrubs. New big-box commercial developments use mulch to beautify their grounds and make shopping more appealing. According to Gertens, mulch sales have continued to increase over the past few years. However, the three largest mulch players saw a decline in sales for residential users during the fall of 2006. All three firms agreed that this decrease in sales is due to the housing market decline. The mulch market can be expected to follow the housing market, and declines in quantities of land clearing wood during times of housing contraction may be moderated by a corresponding decline in demand for mulch.

119 Personal communication, Dr. Mary Meyer, professor of Horticultural Science, University of Minnesota, November 20, 2006.

Two other moderate trends in the mulch business relate to the creation of new markets for mulch in horticultural container mixes and as insulation by large builders. Container mixes are the material used to grow trees, shrubs, and many flowers. Most of these products are sold to customers in containers. Composted mulch is used in container mixes, because it is absorbent and because the particle size creates pore space, or air, in the soil structure. Because the mulch has been aged for a year, it will not rob the plant of nitrogen and cause yellowing. Bailey Nurseries, the largest wholesale nursery in Minnesota and one of the largest nurseries in the nation, cultivates several thousand acres in the metropolitan area. It is the largest user of container mixes and composted mulch for use in container mixes. A few years ago, one large firm processed all of the waste shrubs and wood waste from Bailey Nurseries into 30,000 yards of mulch, which was sold to retail customers. Today Bailey Nursery consumes this mulch internally, and acquires additional material to make container mixes. Although this is not a huge market expansion, it is a growing use that competes with wood used for fuel.

Many land clearing and wood processing companies have few customers for mulch in the fall, but the use of mulch by builders is also expanding. In the past three years, builders have been purchasing low-grade mulches to insulate the ground. If just over a foot of mulch is put in place on the footprint of a future building, the land will not freeze over the winter. When a builder is ready to begin, the mulch is easily removed with a front-end loader and the soil is ready for digging. Builders are also learning to use the compost in berms instead of using silt fencing. Several studies around the United States have shown that berms of mulch and compost are superior to silt fencing in preventing soil erosion. In some building projects, the year-old compost is reused for container mixes or other uses.

The use of mulch by the Minnesota Department of Transportation (MNDOT) has also been expanding. Current consumption is 12,000 to 20,000 tons per year. Interviews with MNDOT's soil science team indicate that up to a 10 percent increase in mulch use is expected over the next five to ten years. Approximately 25,000 tons per year will be used in the near future. To some degree, mulch is again tied to the growth of urban development.

Interviews conducted by the project team of wood processors, land clearing, and mulch retail firms universally suggested that three firms control about 80 percent of the metro mulch market. Numbers reported by these three firms and accounting for other companies suggest that about 125,000 wet tons are sourced from the metro area to the mulch market. Some of this might be exported to other Upper Midwest markets, but how much is exported is not known. The 20 percent of the mulch market not identified includes tree services and other firms that market mulch directly to consumers from their businesses.

Animal Bedding Market

The animal bedding industry uses a variety of materials, including wood waste, to manufacture its product. Sand, dried manure, finished compost, shredded newspaper and magazines, hay, corn stover and other crop residues, wood shavings, and sawdust are all source materials for animal bedding. Nearly all wood-based bedding comes from dried sources such as cabinet manufacturers, wood-working shops, and furniture manufacturers because it is necessary that the moisture content of the wood be extremely low in order to absorb manure.

Little is known about the animal bedding market. Farmers often contract directly with secondary wood processors for the wood waste they generate, thus eliminating the middleman. In addition, there are many companies that simply buy wood shavings and sawdust from these secondary wood generators and deliver it to farmers. A third group of animal bedding producers actually function more like wood processors. They provide semi-trucks to the secondary wood generators to fill up with their wood waste, collect the waste, grind it up, and sell it to farmers as animal bedding. Very few animal bedding companies in the Twin Cities operate at this level.

The market for animal bedding appears to be relatively stable, with higher demand in the winter when it's wetter and colder. Because the generation of wood waste is higher in the summer, some companies sell animal bedding only in the summer months when it's easy to get a hold of wood waste and transport it to farmers where they can sell it at relatively low prices. In the winter, however, when there is less wood waste available, the larger, more stable animal companies are the only ones who can provide bedding. Yearly, most of the variations in the animal bedding market depend on the weather and fluctuate depending mostly on how wet and cold the weather is.

One large animal bedding company indicated that it receives wood waste from 20 to 30 cabinet companies, truss manufacturers, and companies that generate pallet waste. The quality and moisture content of the wood are extremely important, so it has strict policies for the companies that provide wood. It must pre-approve any waste stream before it will take it, and if there are any contaminants in the wood waste supply, it will stop dealing with a company until the problems are resolved. This company usually charges a tipping fee of approximately $3.50 per cubic yard of wood waste, depending on how long it takes the generator to fill a semi-truckload of waste.

The animal bedding market is not known to use urban tree residues due to their high moisture content, but do use a high proportion of available secondary sources.

Compost Market

The compost market is another alternative for wood waste. Interviews with wood processors indicate that very little wood waste is composted. Composting wood is a low-value market given the processing costs involved, and wood is generally composted only if it cannot be sold into other markets. The composting organic matter must remain on the site for at least a year in order to be made into a marketable compost. However, shredded pallets, yard waste, manufacturing by-products, paper, chips, sawdust, ash, shredded lumber, and land clearing debris can be used in composting to improve air flow, allow excess heat to escape, and absorb moisture. It is often the wood waste that is mixed with yard waste and dirt that is turned into compost.

Table 24: End-market pricing for urban wood waste products

Market	Price/Cubic Yard	Price/Ton
Animal Bedding	$18.00 - $24.00	$60.00 - $ 80.00
Mulch		
Non-colorized low grade	$10.00 - $13.00	$33.00 - $43.00
Colorized & high grade	$16.00 - $43.00	$50.00 - $143.00
Fuel (District Energy)		$ 9.50 - $18.00
Compost	$12.00 - $15.00	$40.00 - $50.00

Tree Service Industry Profile

Size and Geographical Distribution of Generators

Tree service companies vary in size but most are small, family-owned operations. The smaller generators (who generate approximately 30-1,500 wet tons of tree waste per year) tend to focus on nearby residential areas while the larger ones (who generate 1,500 to 50,000 wet tons of tree waste per year) work all over the Twin Cities area and also have contracts to provide services for different cities. Many tree service companies also provide lawn care and landscaping services. In examining the geographical distribution of tree service companies in the Twin Cities area, there are five key areas where these generators are clustered: Minneapolis (includes Edina, St. Louis Park, Richfield, and others), the northwest suburbs of Minneapolis (includes Brooklyn Park, Maple Grove, Plymouth, Minnetonka, and others), the southwest suburbs of Minneapolis (includes Excelsior, Eden Prairie, Shakopee, Bloomington, and others), Mankato (includes Winthrop, New Ulm, Waterville, and others), and Rochester (includes Faribault, Northfield, Owatonna, Red Wing, and others).

Drivers for the Business and Market Entry Barriers

Weather, tree diseases, and pests play a big role because they increase the demand for tree services as trees need to be removed quickly. Labor is also a key issue because the industry often faces labor shortages and has to find new ways to attract workers to the business. In a booming economy, this issue is especially important due to the increased demand for landscaping services.[120]

The high cost of starting up a tree service company is one of the biggest barriers to entering the market. More education is necessary for working with trees and shrubs than other areas of landscaping, which is expensive for companies to provide. In addition, equipment, whether rented or purchased, is expensive. Insurance is another expense that can be costly due to the nature of the industry. As a result, there is a high failure rate and many companies don't survive their first few years in business.[121]

Another important barrier to entering this market is the necessary permits and licenses involved with tree trimming and removal. They vary in each city, so companies must seek out the necessary permits for every location in which they will be doing business. In Bloomington, for example, no permit is needed with the exception of the Minnesota River Bluff area, where residents must create a plan and agree on it with the city before any trees on city property can be trimmed or removed. In Burnsville, no permits are needed. Minneapolis, on the other hand, requires that companies obtain a Minneapolis Tree Servicing license to do any tree trimming, stump removal or tree removal within the city limits. This license runs from February 1 to February 1 and is renewable each year. The yearly license fee is $83 for one vehicle and $28 for each additional vehicle. Minneapolis also has a minimum general public liability and vehicle liability insurance.

[120] Pearce, Lynn (Ed.). (2005). Encyclopedia of American Industries (4th ed., 2 vols.). Detroit: Gale, p. 112-114 (SIC 0783: Ornamental Shrub and Tree Services).
[121] Ibid.

Equipment Inventory, Prices, and Information

Table 25: Tree trimming equipment pricing, throughput, and maintenance costs[122]

Equipment	Price Range	Time to Chip Wood	Maintenance Costs (per year)
Tree Pruner	$20 - $80	n/a	n/a
Chainsaw	$40 - $100	n/a	n/a
Small Tow-behind Chipper (6")	$12,500 - $17,000	20 yds/hr	$500-$700
Medium Tow-behind Chipper (12")	$26,000 - $31,000	33 yds/hr	$1,100-$3,000
Large Tow-behind Chipper (18")	$41,000 - $70,000	40 yds/hr	$1,500-$3,700
Small Tub Grinder (950)	$70,000 - $80,000	70 yds/hr	$18,000
Large Tub Grinder (1200XL)	$300,000 - $350,000	200 yds/hr	$51,000

Seasonal Variability and Synergistic Industries

Summer is the busiest time in the tree service industry, but most companies work year-round. In the fall and winter, they do more tree maintenance (trimming and pruning). During the spring and summer, companies are more focused on tree removal. In the fall and winter when tree service companies have less business, some also dedicate their time to other industries such as snow removal and logging. In addition, many tree service companies also provide lawn maintenance and landscaping services.

Options for the Fate of the Fuel

Tree service companies have many options for disposing of their tree waste. Some leave the tree waste on the resident's land or on city land rather than taking it anywhere to dispose of it. They can pay to dump it at a landfill, which is usually the most expensive option. There are also many companies that either pick up the tree waste or allow companies to drop it off for free and then recycle it into other products and sell it. Many tree service companies also chip the wood and give it away or sell it as mulch, animal bedding, or firewood. See Table 2 for revenues and costs associated with each of these options.

Conversions

Because some urban wood waste statistics are presented in cubic yards while others are stated in tons, the following table outlines the conversions used throughout this report to compare the different data available on wood waste. Although the actual yardage to weight conversions may vary somewhat from these formulas, they provide the best estimate possible in order to report consistent overall quantities of wood waste. In addition, depending on the source of the information, some statistics are expressed in terms of wet tons while others are reported in dry tons. For ease of comparison, the quantified wood waste used in this report was converted to wet tons. See table below for moisture content conversions as well.

[122] This table was compiled from information off various tree trimming equipment Web sites as well as various phone conversations and emails with Morbark representatives. See http://landscaping.about.com/od/helpforconsumers1/tp/tree_trimming.htm, www.morbark.com, and www.bearcat-products.com.

Table 26: Estimated wood waste volume and weight conversions[123]

Type of Wood Waste	In yards	Weight	In Tons
Wood Pallet	1 cu yd	300 lb	0.15 wet tons
Sawdust, loose	1 cu yd	375 lb	0.19 wet tons
Wood Chips, shredded	1 cu yd	600 lb	0.3 wet tons
Timber Industry Wood Waste	1 cu yd	1200 lb	0.6 wet tons
Brush/Limbs	1 cu yd	330 lb	0.17 wet tons
Logs/Stumps	1 cu yd	900 lb	0.45 wet tons
Mixed Urban Wood	1 cu yd	400 lb	0.2 wet tons
Residential Construction Waste	1 cu yd	300 lb	0.15 wet tons

Table 27: Estimated moisture content for select urban waste wood fuels[124]

Type of Wood Waste	Range (wt%)	
Bark	25	75
Sawdust	25	40
Baled Switchgrass	10	15
Pallet		15
Tree Waste	30	40
Demolition Waste		8
Secondary Wood Waste Processors		10

[123] Sources: Urban Wood Waste Resource Assessment, prepared by Appel Consultants Inc., 1998; Construction Waste Project, prepared by URS Corporation, 2002.

[124] Source: Biomass Feedstock Availability in the United States, Department of Energy, 1999.

Appendix D: Assumptions for Fuels Model Scenarios

Scenario A: 15% biomass

FUELS DATA: Assumptions for model (Scenario A)

	Fuel type						
	Urban tree residue	C&D wood	Corn stover	Grasses	Logging residues	Forest thinning	Total
Fuel Characteristics							
Fuel moisture at site	45%	10%	18%	16%	50%	50%	
Fuel moisture at plant	35%	10%	18%	16%	40%	40%	
Heat content (Btu/lb, dry basis)	8,361	8,361	8,191	7,936	8,669	8,669	
Proportion of energy needs	15%	0%	0%	0%	0%	0%	15%
Wet tons used	35,879	0	0	0	0	0	35,879
Dry tons used	23,322	0	0	0	0	0	23,322
Scheduling							
add to site (proportion)							
Winter	10%	0%	30%	20%	55%	40%	
Spring	20%	30%	0%	10%	0%	0%	
Summer	30%	30%	0%	10%	0%	20%	
Fall	40%	40%	70%	60%	45%	40%	
ship to plant (proportion)							
Winter	15%	40%	25%	25%	50%	25%	
Spring	40%	0%	30%	30%	25%	25%	
Summer	20%	35%	25%	25%	10%	25%	
Fall	25%	25%	20%	20%	15%	25%	
Miscellaneous							
storage loss (%/quarter)	2%	2%	2%	2%	2%	2%	
storage (tons/acre)	1,500	1,500	1,500	1,500	1,500	1,500	
participation rate			25%	25%	25%	25%	
percent taken from corn/beans			0%	25%	0%	0%	
typical yield (tons per acre at harvest)			4	4	15	10	
technologically feasible removal			40%	100%	60%	60%	
Costs to site ($/wet ton)							
fee unchipped mixed logs/branches	$-						
fee clean logs and materials	$-						
fee unchipped brush	$-						
fee chipped branches	$-						
percent chipped logs/branches of all branches/logs	$0.20						
percent branches and logs of total	$0.85						
percent mixed branches of unchipped branches/logs	$0.66						
typical rent per acre							
payment							
direct and overhead costs							
process at yard/landing							
miscellaneous costs							
yard/landing storage							
cost for rail shipment ($/ton)	$10						
lease cost for rail car ($/year)	$7,200						

SITE DATA: Assumptions for model (Scenario A)

	RockTenn wood	Hennepin	Anoka	Washington	Scott
General site information					
Site type	plantwood	wood	wood	wood	wood
Transport type	truck	truck	truck	truck	truck
Miles to plant	-	18	19	11	33
Annual throughput (tons)	36,000	50,000	25,000	25,000	25,000
Land costs ($/acre)	59,000	30,000	30,000	30,000	30,000
Proportion of total fuel needs by allocated to each site					
Urban tree residues		25%	25%	25%	25%
C&D wood		-	-	-	-
Corn stover		-	-	-	-
Grasses		-	-	-	-
Forest residues		-	-	-	-
Forest thinning		-	-	-	-
Site capital costs					
Pit	$50,000				
Temporary storage area for bales					
Walking floor (pit)	$95,000				
Conveyor pit to screen	$25,000				
Screen and magnet	$180,000				
Conveyor to grinder	$25,000				
Horizontal grinders	$278,000				
Conveyor to storage	$50,000				
Screen rejects conveyor	$25,000				
Grinder rejects conveyor	$25,000				
Conveyor to boiler	$75,000				
Screener	$200,000				
Feed hopper	$50,000				
Reversing cross conveyor	$0				
Skid loader	$90,000				
Front-end loader	$200,000				
Excavator with grapple					
Land acquisition		$750,000	$450,000	$450,000	$450,000
Site Preparation		$30,000	$30,000	$30,000	$30,000
Start-up costs		$15,000	$15,000	$15,000	$15,000
Total capital costs		$795,000	$495,000	$495,000	$495,000
Equity proportion	1%	1%	1%	1%	1%
Debt interest rate	0%	0%	0%	0%	0%
Equity return	0%	0%	0%	0%	0%
Site operating costs					
Lead operator(s)	$143,000				
Junior operator(s)	$130,000				
Receiving clerk(s)	$117,000				
Mechanic(s)	$32,500				
Miscellaneous Costs	$10,000				
Insurance	$40,000				
Diesel Fuel	$32,400				
Electricity	$14,316				
Site laborer(s)		$69,888	$52,416	$52,416	$52,416
Site manager/operator(s)		$40,499	$40,499	$40,499	$40,499
mobile grinder at site		$440,000	$220,000	$220,000	$220,000
Front-end loader		$48,000	$48,000	$48,000	$48,000
Cell phones		$1,760	$1,760	$1,760	$1,760
Office trailer		$2,800	$2,800	$2,800	$2,800
Portable toilet		$600	$600	$600	$600
Fuels, lubricants, etc.		$9,000	$9,000	$9,000	$9,000
Liability insurance		$8,000	$8,000	$8,000	$8,000
Administrative and general		$93,082	$57,461	$57,461	$57,461

Scenario B: 30% Biomass

FUELS DATA: Assumptions for model (Scenario B)

	Fuel type						
	Urban tree residue	C&D wood	Corn stover	Grasses	Logging residues	Forest thinning	Total
Fuel Characteristics							
Fuel moisture at site	45%	10%	18%	16%	50%	50%	
Fuel moisture at plant	35%	10%	18%	16%	40%	40%	
Heat content (Btu/lb, dry basis)	8,361	8,361	8,191	7,936	8,669	8,669	
Proportion of energy needs	15%	15%	0%	0%	0%	0%	30%
Wet tons used	35,879	25,913	-	-	-	-	61,792
Dry tons used	23,322	23,322	-	-	-	-	46,643
Scheduling							
add to site (proportion)							
Winter	10%	0%	30%	20%	55%	40%	
Spring	20%	30%	0%	10%	0%	0%	
Summer	30%	30%	0%	10%	0%	20%	
Fall	40%	40%	70%	60%	45%	40%	
ship to plant (proportion)							
Winter	15%	40%	25%	25%	50%	25%	
Spring	40%	0%	30%	30%	25%	25%	
Summer	20%	35%	25%	25%	10%	25%	
Fall	25%	25%	20%	20%	15%	25%	
Miscellaneous							
storage loss (%/quarter)	2%	2%	2%	2%	2%	2%	
storage (tons/acre)	1,500	1,500	1,500	1,500	1,500	1,500	
participation rate			25%	25%	25%	25%	
percent taken from corn/beans			0%	25%	-	-	
typical yield (tons per acre at harvest)			4	4	15	10	
technologically feasible removal			40%	100%	60%	60%	
Costs to site ($/wet ton)							
fee unchipped mixed logs/branches	-	-					
fee clean logs and materials	-	$10.00					
fee unchipped brush	-	-					
fee chipped branches	-	-					
percent chipped logs/branches of all branches/logs	$0.20	-					
percent branches and logs of total	$0.85	-					
percent mixed branches of unchipped branches/logs	$0.66	-					
typical rent per acre							
payment							
direct and overhead costs							
process at yard/landing							
miscellaneous costs							
yard/landing storage							
cost for rail shipment ($/ton)	$10						
lease cost for rail car ($/year)	$7,200						

SITE DATA: Assumptions for model (Scenario B)

	RockTenn wood	Hennepin	Anoka	Washington	Scott
General site information					
Site type	plantwood	wood	wood	wood	wood
Transport type	truck	truck	truck	truck	truck
Miles to plant	--	18	19	11	33
Annual throughput (tons)	62,000	50,000	25,000	25,000	25,000
Land costs ($/acre)	59,000	30,000	30,000	30,000	30,000
Proportion of total fuel needs by allocated to each site					
Urban tree residues		25%	25%	25%	25%
C&D wood		100%	-	-	-
Corn stover		-	-	-	-
Grasses		-	-	-	-
Forest residues		-	-	-	-
Forest thinning		-	-	-	-
Site capital costs					
Pit	$50,000				
Temporary storage area for bales					
Walking floor (pit)	$95,000				
Conveyor pit to screen	$25,000				
Screen and magnet	$180,000				
Conveyor to grinder	$25,000				
Horizontal grinders	$278,000				
Conveyor to storage	$50,000				
Screen rejects conveyor	$25,000				
Grinder rejects conveyor	$25,000				
Conveyor to boiler	$75,000				
Screener	$200,000				
Feed hopper	$50,000				
Reversing cross conveyor	$0				
Skid loader	$90,000				
Front-end loader	$200,000				
Excavator with grapple					
Land acquisition		$750,000	$450,000	$450,000	$450,000
Site Preparation		$30,000	$30,000	$30,000	$30,000
Start-up costs		$15,000	$15,000	$15,000	$15,000
Total capital costs	$1,368,000	$795,000	$495,000	$495,000	$495,000
Equity proportion	60%	60%	60%	60%	60%
Debt interest rate	8%	8%	8%	8%	8%
Equity return	12.5%	12.5%	12.5%	12.5%	12.5%
Site operating costs					
Lead operator(s)	$143,000				
Junior operator(s)	$130,000				
Receiving clerk(s)	$117,000				
Mechanic(s)	$32,500				
Miscellaneous Costs	$10,000				
Insurance	$40,000				
Diesel Fuel	$32,400				
Electricity	$24,316				
Site laborer(s)		$69,888	$52,416	$52,416	$52,416
Site manager/operator(s)		$40,499	$40,499	$40,499	$40,499
mobile grinder at site		$440,000	$220,000	$220,000	$220,000
Front-end loader		$48,000	$48,000	$48,000	$48,000
Cell phones		$1,760	$1,760	$1,760	$1,760
Office trailer		$2,800	$2,800	$2,800	$2,800
Portable toilet		$600	$600	$600	$600
Fuels, lubricants, etc.		$9,000	$9,000	$9,000	$9,000
Liability insurance		$8,000	$8,000	$8,000	$8,000
Administrative and general		$93,082	$57,461	$57,461	$57,461

Scenario C: 60% Biomass

FUELS DATA: Assumptions for model (Scenario C)

	Fuel type						
	Urban tree residue	C&D wood	Corn stover	Grasses	Logging residues	Forest thinning	Total
Fuel Characteristics							
Fuel moisture at site	45%	10%	18%	16%	50%	50%	
Fuel moisture at plant	35%	10%	18%	16%	40%	40%	
Heat content (Btu/lb, dry basis)	8,361	8,361	8,191	7,936	8,669	8,669	
Proportion of energy needs	15%	15%	15%	15%	0%	0%	60%
Wet tons used	35,879	25,913	29,031	29,251	-	-	120,074
Dry tons used	23,322	23,322	23,806	24,571	-	-	95,019
Scheduling							
add to site (proportion)							
Winter	10%	0%	30%	20%	55%	40%	
Spring	20%	30%	0%	10%	0%	0%	
Summer	30%	30%	0%	10%	0%	20%	
Fall	40%	40%	70%	60%	45%	40%	
ship to plant (proportion)							
Winter	15%	40%	25%	25%	50%	25%	
Spring	40%	0%	30%	30%	25%	25%	
Summer	20%	35%	25%	25%	10%	25%	
Fall	25%	25%	20%	20%	15%	25%	
Miscellaneous							
storage loss (%/quarter)	2%	2%	2%	2%	2%	2%	
storage (tons/acre)	1,500	1,500	1,500	1,500	1,500	1,500	
participation rate			25%	25%	25%	25%	
percent taken from corn/beans			-	25%	-	-	
typical yield (tons per acre at harvest)			4	4	15	10	
technologically feasible removal			40%	100%	60%	60%	
Costs to site ($/wet ton)							
fee unchipped mixed logs/branches	-	-					
fee clean logs and materials	-	$10.00					
fee unchipped brush	-	-					
fee chipped branches	-	-					
percent chipped logs/branches of all branches/logs	$0.20	-					
percent branches and logs of total	$0.85	-					
percent mixed branches of unchipped branches/logs	$0.66	-					
typical rent per acre			-	$120			
payment			$5	-			
direct and overhead costs			$24	$20			
process at yard/landing			-	-			
miscellaneous costs			-	-			
yard/landing storage			-	-			
cost for rail shipment ($/ton)	$10						
lease cost for rail car ($/year)	$7,200						

SITE DATA: Assumptions for model (Scenario C)

	RockTenn wood	RockTenn bale	Dakota	Wright	Hennepin	Anoka	Washington	Scott
General site information								
Site type	plantwood	plantbale	bale	bale	wood	wood	wood	wood
Transport type	truck	truck	truck	truck	truck	truck	truck	truck
Miles to plant	–	–	24	44	18	19	11	33
Annual throughput (tons)	62,000	59,000	75,000	75,000	50,000	25,000	25,000	25,000
Land costs ($/acre)	$59,000	–	$10,000	$10,000	$30,000	$30,000	$30,000	$30,000
Proportion of total fuel needs by allocated to each site								
Urban tree residues			-	-	25%	25%	25%	25%
C&D wood			-	-	100%	-	-	-
Corn stover			-	100%	-	-	-	-
Grasses			100%	-	-	-	-	-
Forest residues			-	-	-	-	-	-
Forest thinning			-		-	-	-	-
Site capital costs								
Pit	$50,000							
Temporary storage area for bales		$10,000						
Walking floor (pit)	$95,000	$95,000						
Conveyor pit to screen	$25,000	$0						
Screen and magnet	$180,000	$0						
Conveyor to grinder	$25,000	$25,000						
Horizontal grinders	$278,000	$278,000						
Conveyor to storage	$50,000	$50,000						
Screen rejects conveyor	$25,000	$0						
Grinder rejects conveyor	$25,000	$0						
Conveyor to boiler	$75,000	$75,000						
Screener	$200,000							
Feed hopper	$50,000	$50,000						
Reversing cross conveyor	$0	$75,000						
Skid loader	$90,000	$0						
Front-end loader	$200,000	$0						
Excavator with grapple		$100,000						
Land acquisition			$300,000	$300,000	$750,000	$450,000	$450,000	$450,000
Site Preparation			$30,000	$30,000	$30,000	$30,000	$30,000	$30,000
Start-up costs			$15,000	$15,000	$15,000	$15,000	$15,000	$15,000
Total capital costs	$1,368,000	$758,000	$345,000	$345,000	$795,000	$495,000	$495,000	$495,000
Equity proportion	60%	60%	60%	60%	60%	60%	60%	60%
Debt interest rate	8%	8%	8%	8%	8%	8%	8%	8%
Equity return	12.5%	12.5%	12.5%	12.5%	12.5%	12.5%	12.5%	12.5%
Site operating costs								
Lead operator(s)	$143,000	$71,500						
Junior operator(s)	$130,000	$260,000						
Receiving clerk(s)	$117,000	$58,500						
Mechanic(s)	$32,500	$65,000						
Miscellaneous Costs	$10,000	$10,000						
Insurance	$40,000	$40,000						
Diesel Fuel	$32,400	$6,480						
Electricity	$24,655	$4,488						
Site laborer(s)			$52,416	$52,416	$69,888	$52,416	$52,416	$52,416
Site manager/operator(s)			$60,749	$60,749	$40,499	$40,499	$40,499	$40,499
mobile grinder at site					$440,000	$220,000	$220,000	$220,000
Front-end loader			$72,000	$72,000	$48,000	$48,000	$48,000	$48,000
Cell phones			$2,640	$2,640	$1,760	$1,760	$1,760	$1,760
Office trailer			$4,200	$4,200	$2,800	$2,800	$2,800	$2,800
Portable toilet			$900	$900	$600	$600	$600	$600
Fuels, lubricants, etc.			$13,500	$13,500	$9,000	$9,000	$9,000	$9,000
Liability insurance			$12,000	$12,000	$8,000	$8,000	$8,000	$8,000
Administrative and general			$21,840	$21,840	$93,082	$57,461	$57,461	$57,461

Scenario D: 100% Biomass

FUELS DATA: Assumptions for model (Scenario D)

	Fuel type						
	Urban tree residue	C&D wood	Corn stover	Grasses	Logging residues	Forest thinning	Total
Fuel Characteristics							
Fuel moisture at site	45%	10%	18%	16%	50%	50%	
Fuel moisture at plant	35%	10%	18%	16%	40%	40%	
Heat content (Btu/lb, dry basis)	8,361	8,361	8,191	7,936	8,669	8,669	
Proportion of energy needs	15%	15%	15%	15%	35%	5%	100%
Wet tons used	35,879	25,913	29,031	29,251	87,473	12,496	220,043
Dry tons used	23,322	23,322	23,806	24,571	52,484	7,498	155,001
Scheduling							
add to site (proportion)							
Winter	10%	0%	30%	20%	55%	40%	
Spring	20%	30%	0%	10%	0%	0%	
Summer	30%	30%	0%	10%	0%	20%	
Fall	40%	40%	70%	60%	45%	40%	
ship to plant (proportion)							
Winter	15%	40%	25%	25%	50%	25%	
Spring	40%	0%	30%	30%	25%	25%	
Summer	20%	35%	25%	25%	10%	25%	
Fall	25%	25%	20%	20%	15%	25%	
Miscellaneous							
storage loss (%/quarter)	2%	2%	2%	2%	2%	2%	
storage (tons/acre)	1,500	1,500	1,500	1,500	1,500	1,500	
participation rate			25%	25%	25%	25%	
percent taken from corn/beans			-	25%	-	-	
typical yield (tons per acre at harvest)			4	4	15	10	
technologically feasible removal			40%	100%	60%	60%	
Costs to site ($/wet ton)							
fee unchipped mixed logs/branches	-	-					
fee clean logs and materials	-	$10.00					
fee unchipped brush	-	-					
fee chipped branches	-	-					
percent chipped logs/branches of all branches/logs	$0.20	-					
percent branches and logs of total	$0.85	-					
percent mixed branches of unchipped branches/logs	$0.66	-					
typical rent per acre			-	$120			
payment			$5	-	$5	$96	
direct and overhead costs			$24	$20	$8	$70	
process at yard/landing			-	-	$8	$10	
miscellaneous costs			-	-	-	$10	
yard/landing storage			-	-	-	-	
cost for rail shipment ($/ton)	$10						
lease cost for rail car ($/year)	$7,200						

SITE DATA: Assumptions for model (Scenario D)

	RockTenn wood	RockTenn bale	Dakota	Wright	Pine	Hennepin	Anoka
General site information							
Site type	plantwood	plantbale	bale	bale	timber	wood	wood
Transport type	truck	truck	truck	truck	truck	truck	truck
Miles to plant	–	–	24	44	78	18	19
Annual throughput (tons)	162,000	59,000	75,000	75,000	75,000	50,000	25,000
Land costs ($/acre)	$59,000	–	$10,000	$10,000	$3,000	$30,000	$30,000
Proportion of total fuel needs by allocated to each site							
Urban tree residues			-	-	-	25%	25%
C&D wood			-	-	-	100%	-
Corn stover			-	100%	-	-	-
Grasses			100%	-	-	-	-
Forest residues			-	-	100%	-	-
Forest thinning			-	-	-	-	-
Site capital costs							
Pit	$50,000						
Temporary storage area for bales		$10,000					
Walking floor (pit)	$95,000	$95,000					
Conveyor pit to screen	$25,000	$0					
Screen and magnet	$180,000	$0					
Conveyor to grinder	$25,000	$25,000					
Horizontal grinders	$278,000	$278,000					
Conveyor to storage	$50,000	$50,000					
Screen rejects conveyor	$25,000	$0					
Grinder rejects conveyor	$25,000	$0					
Conveyor to boiler	$75,000	$75,000					
Screener	$200,000						
Feed hopper	$50,000	$50,000					
Reversing cross conveyor	$0	$75,000					
Skid loader	$90,000	$0					
Front-end loader	$200,000	$0					
Excavator with grapple		$100,000					
Land acquisition			$300,000	$300,000	$750,000	$750,000	$450,000
Site Preparation			$30,000	$30,000	$30,000	$30,000	$30,000
Start-up costs			$15,000	$15,000	$15,000	$15,000	$15,000
Total capital costs	$1,826,000	$758,000	$345,000	$345,000	$195,000	$795,000	$495,000
Equity proportion	60%	60%	60%	60%	60%	60%	60%
Debt interest rate	8%	8%	8%	8%	8%	8%	8%
Equity return	12.5%	12.5%	12.5%	12.5%	12.5%	12.5%	12.5%
Site operating costs							
Lead operator(s)	$143,000	$71,500					
Junior operator(s)	$130,000	$260,000					
Receiving clerk(s)	$117,000	$58,500					
Mechanic(s)	$32,500	$65,000					
Miscellaneous Costs	$10,000	$10,000					
Insurance	$40,000	$40,000					
Diesel Fuel	$32,400	$6,480					
Electricity	$64,543	$4,488					
Site laborer(s)			$52,416	$52,416	$52,416	$69,888	$52,416
Site manager/operator(s)			$60,749	$60,749	$60,749	$40,499	$40,499
mobile grinder at site					$0	$440,000	$220,000
Front-end loader			$72,000	$72,000	$72,000	$48,000	$48,000
Cell phones			$2,640	$2,640	$2,640	$1,760	$1,760
Office trailer			$4,200	$4,200	$4,200	$2,800	$2,800
Portable toilet			$900	$900	$900	$600	$600
Fuels, lubricants, etc.			$13,500	$13,500	$13,500	$9,000	$9,000
Liability insurance			$12,000	$12,000	$12,000	$8,000	$8,000
Administrative and general			$21,840	$21,840	$21,840	$93,082	$57,461

SITE DATA: Assumptions for model (Scenario D) - continued

	Washington	Scott	Aitkin
General site information			
Site type	wood	wood	thinning
Transport type	truck	truck	truck
Miles to plant	11	33	111
Annual throughput (tons)	25,000	25,000	75,000
Land costs ($/acre)	$30,000	$30,000	$3,000
Proportion of total fuel needs by allocated to each site			
Urban tree residues	25%	25%	-
C&D wood	-	-	-
Corn stover	-	-	-
Grasses	-	-	-
Forest residues	-	-	-
Forest thinning	-	-	100%
Site capital costs			
Pit			
Temporary storage area for bales			
Walking floor (pit)			
Conveyor pit to screen			
Screen and magnet			
Conveyor to grinder			
Horizontal grinders			
Conveyor to storage			
Screen rejects conveyor			
Grinder rejects conveyor			
Conveyor to boiler			
Screener			
Feed hopper			
Reversing cross conveyor			
Skid loader			
Front-end loader			
Excavator with grapple			
Land acquisition	$450,000	$450,000	$150,000
Site Preparation	$30,000	$30,000	$30,000
Start-up costs	$15,000	$15,000	$15,000
Total capital costs	$495,000	$495,000	$195,000
Equity proportion	60%	60%	60%
Debt interest rate	8%	8%	8%
Equity return	12.5%	12.5	12.5
Site operating costs			
Lead operator(s)			
Junior operator(s)			
Receiving clerk(s)			
Mechanic(s)			
Miscellaneous Costs			
Insurance			
Diesel Fuel			
Electricity			
Site laborer(s)	$52,416	$52,416	$52,416
Site manager/operator(s)	$40,499	$40,499	$60,749
mobile grinder at site	$220,000	$220,000	$0
Front-end loader	$48,000	$48,000	$72,000
Cell phones	$1,760	$1,760	$2,640
Office trailer	$2,800	$2,800	$4,200
Portable toilet	$600	$600	$900
Fuels, lubricants, etc.	$9,000	$9,000	$13,500
Liability insurance	$8,000	$8,000	$12,000
Administrative and general	$57,461	$57,461	$32,761

Appendix E:
Letter from DNR on Forthcoming Forest Thinning Study

Minnesota Department of Natural Resources
Division of Forestry-Central Region
Regional Utilization and Marketing
1801 South Oak Street
Lake City, MN 55041
651-345-3216

March 6, 2007

TO: Rock Tenn Advisory Group
Subject: DNR – Division of Forestry Thinning Study for Pine County

As a part of the final report the Division of Forestry will produce an inventory study to determine the potential volume of pre-commercial thinning in conifer stands on Pine county on State Forest Lands. The Division does sell at auction stands with first thinning potential, which produce amounts of pulpwood as well as tops and branches. The market fluctuates for pine pulpwood. As of this writing the market is depressed. The tops and other residue from these operations currently are chipped into vans for transport to a paper mill in Cloquet. If pre-commercial thinning were to become a viable option some of this material would have to be diverted to other markets such as Rock Tenn.

Also a note: this study model will NOT include any lands in Wisconsin.

Our anticipated completion date is late March or early April. The report will be sent to The Green Institute for addition to the Final Report in the Addendum section.