THESIS

QUANTIFYING AND UTILIZING URBAN FOREST RESIDUES WITHIN FORT COLLINS, LOVELAND, AND GREELEY, COLORADO FOR 2008

Submitted by

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY KENDRA A. NASH ENTITLED “QUANTIFYING AND UTILIZING URBAN FOREST RESIDUES WITHIN FORT COLLINS, LOVELAND, AND GREELEY, COLORADO FOR 2008" BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

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ABSTRACT OF THESIS

QUANTIFYING AND UTILIZING URBAN FOREST RESIDUES WITHIN FORT COLLINS, LOVELAND, AND GREELEY, COLORADO, 2008

Throughout the United States large amounts of urban forest residues (UFRs) are generated by homeowners, landscape maintenance, and tree care companies as a result of managing urban forests. This study primarily focuses on urban forest residues generated by the cities of Fort Collins, Loveland, and Greeley, Colorado and the surrounding area. The amount of yard trimmings generated in the area was quantified. The study also identified where urban forest residues end up and assessed potential end uses for these residues. Based on findings from this study, the tree care industry in the Tri-City Area generates approximately 36,742 tons of UFRs annually. Two local landfills (Larimer and North Weld) collect about 50,941 tons annually and wood recyclers collect/utilize about 77,351 tons of UFRs annually, which includes UFRs produced by homeowners and landscape companies. Based on these findings, approximately 60 percent of UFRs produced in the Tri-City Area are utilized, with the majority being utilized as mulch. The remaining 40 percent are most likely deposited in landfills. Several alternative uses for UFRs currently exist in the Tri-City Area such as portable band-sawmills milling large

diameter wood and bio-energy applications, which are potential solutions for increasing the percentage of this resource that is utilized.

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CHAPTER 1: Introduction

Municipal Solid Waste (MSW) can be defined as the "materials disposed of by residential, commercial, industrial, and institutional facilities" (Ward et al. 2004: 2). The U.S. Environmental Protection Agency (EPA) categorized materials in MSW as glass, metal, plastic, food scraps, wood, yard trimmings, paper, rubber, leather, textiles, and "other" miscellaneous wastes (2003). In 2006, the American public produced just over 251 million tons of MSW, which is an average of about 4.6 pounds per person per day or just short of 1700 pounds per person per year (EPA 2006). Although approximately 82 million tons of MSW were recovered in 2006 (EPA 2006), a large amount continues to be disposed of in landfills.

As part of the MSW stream, yard trimmings consist of "leaves and grass clippings, brush, and tree trimmings and removals" (McKeever 2002). This study focuses on the "yard trimmings" category and will be referred to subsequently as urban forest residues (UFRs). UFRs can be defined as wood chips, brush, logs and some leaves and grass clippings. According to the EPA (2007), 32.4 million tons of yard trimmings were generated by the American public, which was approximately 12.9 percent of its MSW stream. Nationally, the U.S. produces approximately 217 pounds per person per year of UFRs (EPA 2006). Given that there were 3,970,831 people in Colorado during 2006 (U.S. Census Bureau), an estimated 588.12 pounds of UFRs were produced per capita per year. This is equivalent to 311 football fields filled to a depth of three feet.

UFRs are often disposed of in landfills. The wood being disposed of in landfills and some wood currently being processed into mulch could be recovered and utilized for higher, value-added products. Fehrs (1999: 45) reported that "At about 45,000,000 tons per year, UFRs represent the largest single source of available wood waste…exceeding other types of wood waste by at least a factor of 4." With a resource that is potentially 100 percent recoverable, the need for reducing the amount of UFRs going into landfills is important because utilizing a higher percentage of UFRs could extend the life of landfills. Encouraging residents and commercial entities to sort through their wastes will potentially lead to alternative uses for this biomass. It is also necessary that proper infrastructure such as biomass processing plants/facilities within the study area be developed to utilize this resource. Examples of utilization with respect to this resource include large diameter logs suitable for sawing, brush suitable for mulch (current method), and wood chips/stump grindings suitable for composting. Around the country, there are many successful programs utilizing UFRs that go beyond burying these residues in landfills or processing them into mulch. Potential uses for UFRs in the Tri-City Area include landscape material or firewood retailers, nurseries, sawmills and feedstock for bio-energy plants.

The area investigated in this study consisted of Fort Collins, Loveland, and Greeley, Colorado (the Tri-City Area). This project quantified and characterized the amount of UFRs produced within the Tri-City Area and determined which components can be utilized. In 2006, this area had a collective population of 279,635 people (Fort Collins with 129,467, Loveland at 61,122, and Greeley with 89,046) (U.S. Census Bureau 2006). The three cities are located in north-central Colorado and communally envelop about 100 square miles with Fort Collins covering about half of that area (46 square miles) (U.S. Census Bureau 2006). Figure 1.1 shows the Tri-City Area and the location within Colorado.

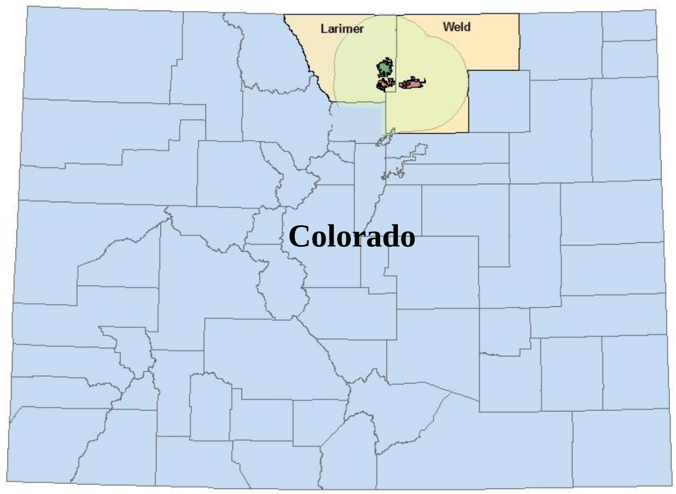


Figure 1.1: Tri-City Area, Colorado

Fort Collins, Loveland, and Greeley have large urban tree inventories that require a continual amount of arboriculture and landscape maintenance needs. Because of these needs, there are large amounts of UFRs produced daily by homeowners, landscaping maintenance companies, and the tree care industry. Within an urban setting, trees are susceptible to a variety of insect and disease infestations, damage from construction activities (i.e. root excavation), or natural mortality from other circumstances common in populated areas such as drought, lack of important nutrients and/or oxygen deprivation. Maintenance on urban trees is needed for increased aesthetics, increased health and vigor, and to remove hazardous, dead/dying branches, and/or whole trees.

Proper management of urban forests is important. Every day in an urban setting a tree may be pruned to rid the dead or diseased branches, raised up to see important street signs, thinned out to establish more filtered light, or possibly removed because the tree was unhealthy or unwanted. Because of these practices, there is an extraordinary amount of woody biomass that is generated. Where does all of this wood "waste" go? Throughout the Tri-City Area, the wood "waste" or UFRs end up in several different places. Quantifying and characterizing this resource is essential to using it sustainably.

A majority of UFRs are generated by the tree care industry. UFRs primarily consist of wood chips, brush, and logs of all diameters. Most of the tree care industry within the Tri-City Area process UFRs up to eighteen inches in diameter depending on the size of chipper they have. The chips produced are typically given away to homeowners or are hauled to the nearest recycling center to be reprocessed into mulch, which are dyed for colored mulch or sold as natural mulch. Wood chips are not usually taken to landfills as most recycle centers and nurseries accept them for free. Limbs or logs that are too large to be chipped are usually sold as firewood, hauled to a recycling center, or disposed of in the nearby landfill. Depending on the recycling center, diameters above the maximum chipping/grinding diameter are not accepted and as a result, these larger logs are often disposed of in landfills.

The purpose of this study was to collect data that would help quantify the amount of UFRs produced in the Tri-City Area, including how much UFRs were currently being utilized, and what opportunities existed to increase the percentage of utilization. Four objectives were constructed. The first objective was to quantify how many UFRs are produced in the Tri-City Area. The second objective assessed whether the tree care companies in the Tri-City Area were willing to dispose of their urban forest residues in places other than landfills. The third objective determined what percent of UFRs produced within the Tri-City Area can be considered as a potential renewable resource. The forth objective was to assess whether the amount of UFRs going into landfills will decrease significantly as urban residents and companies begin to sort and recycle their wastes in new ways such as in landscape material, firewood, compost, or bio-energy. The four objectives are listed in Figure 1.2.

1st Objective

- Estimate how many tons of UFRs were generated annually in the Tri-City Area?

2nd Objective

- Determine the percentage of tree care companies in the Tri-City Area that were willing to dispose of their urban forest residues in a reusable manner

3rd Objective

- Calculate the percentage of urban forest residues produced within the Tri-City Area that were currently utilized.

4th Objective

- Estimate the amount of urban forest residues going into landfills and whether this amount will decrease significantly (50 percent) as urban residents and tree care companies begin to sort and recycle/utilize their wastes in alternative ways such as landscape material or firewood retailers, composters, or bio-energy plants.

Figure 1.2: Objectives

The scope of this study primarily focused on estimates provided by responding tree care companies to quantify the amount of UFRs generated. Other data was provided by city recycling programs or other recycling companies that provided collection figures from 2007. Data from the two landfills located within the Tri-City Area were also collected in order to understand the amount of UFRs disposed of in landfills. Spatially, the study included all tree care companies located within a twenty-five mile radius around each city and lies in both Larimer and Weld counties. Economically, the scope of this study analyzes whether it is more feasible to direct UFRs towards alternative end uses. Figure 1.3 shows the Tri-City Area.

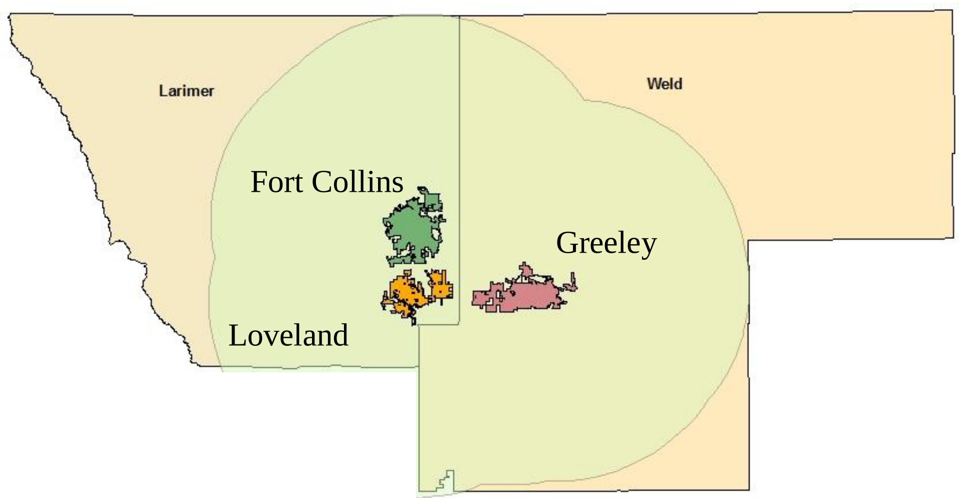


Figure 1.3: Tri-City Area with twenty-five mile radius around Study Area

Quantifying the current amount of UFRs currently generated by the tree care industry and assessing the total amounts of UFRs entering landfills provided a virtual snapshot of current industry practices. With this knowledge, potential opportunities for alternative uses of this resource were identified. Chapter 2 is a historical perspective of UFR generation and recoverability throughout the U.S., and Chapter 3 describes the methods used to conduct this research. Chapter 4 discusses the findings of UFR generation, disposal, and opportunities within the Tri-City Area. Finally, Chapter 5 covers the results and alternative uses for UFRs as well as recommendations for the future of biomass utilization.

CHAPTER 2: Literature Review

Previous studies evaluated urban forest residues (UFRs) on a national level, reporting the amount and distribution of UFRs generated within and around large metropolitan areas. Based on studies reviewed, only a handful of researchers have explored UFR generation with regards to utilization.

Bratkovich et al. (2008: 1) reported that urban forests "are rarely researched or discussed regarding their potential to provide wood-based products." Studies have shown that metropolitan areas throughout the United States have doubled in size since the late 1960s (Nowak et al. 2001). Because of the benefits of urban trees in these metropolitan areas, the inventories of urban trees increase as the size of urban areas increase: "It is estimated that today there are nearly 4 billion urban trees in the U.S., with another 70 billion trees growing in metropolitan areas" (Bratkovich et al. 2008: 1). Defined by the U.S. Census Bureau (2003), a metropolitan area is "a core area containing a substantial population nucleus, together with adjacent communities having a high degree of economic and social integration with that core."

2.1. National Information

Numerous studies across the United States assess the amount of municipal solid waste (MSW) produced by the American public. These studies typically separated MSW streams into categories such as "wood" and "yard trimmings" (McKeever 2002, NEOS

Corporation 1995). For instance, NEOS Corporation (1995: 45) identified residential yard waste "as the second largest component of municipal solid waste." Generators of UFRs for this study included commercial tree care firms, municipal/county park and recreation departments, municipal tree care divisions, county tree care divisions, electric utility power line maintenance, nurseries, landscapers and landscape maintenance, and excavators and land clearing entities (NEOS Corporation 1995). It was estimated that just over 200 million cubic yards of UFRs (including grass clippings and leaves) were generated annually in the continental U.S.

The NEOS Corp. study (1995) had a few limitations. One limitation was the choice of units: volume versus weight. Using units of volume, such as cubic yards, require the use of density factors. When quantifying UFRs, collecting data based on weight eliminates one's need to consider the many different shapes and forms of UFRs (i.e. wood chips, logs, brush, etc.) and associated weight/density factors. This is especially important when looking at wood source generation as a source of fuel. One concern that the authors had with their estimates was whether the generators were accurately able to estimate the production of UFRs. This may also be a constant threat to validity of many national assessments that surveyed individuals.

McKeever (1995) reported an estimated 27.8 million metric tons of yard trimmings generated in the U.S., which represents approximately 16 percent of the total MSW stream. The yard trimmings recovered for composting or recycling were estimated at 6.4 million metric tons while 21.4 million metric tons were discarded into landfills. McKeever (1995: 15) estimated that "after combustion and allowance for unrecoverable material as a result of contamination, size, commingling with other materials, and cost of collection, about 12.2 million metric tons were considered to be available for additional recovery (60% of the total amount discarded).” Shortly after, McKeever (1998) submitted a 1996 update where 29.3 million tons of yard trimmings were generated that represented 14 percent of the MSW stream. Approximately 8.6 million tons were composted or recovered and 20.7 million tons were discarded or burned.

NEOS Corp. (1994) estimated that 95 percent of urban tree and landscape residues were woody and the remaining 5 percent was grass and leaves. This is important because most studies do not categorize the yard trimmings further. If quantifying residues by tree and landscape maintenance companies, these percentages may be essential if the goal is to segregate the residue composition further. McKeever (1998: 65) used this distinction on his total yard trimmings estimates and found that “27.8 million tons of woody yard trimming residues were generated, with 12.8 million tons recovered or combusted: 5 million tons were unrecoverable.” Additionally, 10 million tons were available for recovery and the total discarded into landfills amounted to 56 percent.

In 1998, the Environmental Protection Agency (EPA) characterized the composition of the MSW generated in the U.S. in the following manner: the American public generated 210 million tons of MSW in 1997. Approximately 28 million tons (13.4 percent) of the MSW total were yard trimmings. It was estimated that 11 million tons (38.6 percent) of yard trimmings were recycled or recovered and 17 million tons (61.4 percent) were disposed of in landfills. One concern with this study was that the EPA considered “source reduction” before generation. The 1998 EPA report defined source reduction as “reuse of a material in its current form” (Fehrs 1999: 12). Although this consideration may seem trivial, it may have underestimated the total wood waste potentially available as a fuel. Assuming that the amount of wood waste managed by source reduction practices are conducted prior to generation indicates that these amounts were excluded from the generation and recycling estimates.

Another study submitted by Rooney (1998) assessed different cellulosic resources available to convert to ethanol for transportation fuel. Among the many resources addressed, urban tree residues (UTRs) were converted to green tons assuming a moisture content of 20 percent. UTR estimates were based on NEOS Corporation's (1995) estimates and reported that 39 percent of UTRs were used in "non-captive markets" or are unused and recoverable.

Wiltsee (1999) submitted an assessment on urban wood waste where data was extrapolated from 30 randomly selected metropolitan areas and eventually projected urban wood waste quantities for the 281 metropolitan areas defined by the U.S. Office of Management and Budget (OMB) in 1990. Through personal visits and telephone surveys, this assessment categorized wood within the MSW stream as industrial wood wastes, such as sawdust and wood scraps, construction and demolition (C&D debris), and land clearing debris. Wiltsee (1999) found that out of the projected total urban wood waste generated (64.3 million tons per year, including C&D debris, pallets, etc.), 39.2 million tons per year of MSW wood (i.e. yard trimmings) was estimated annually. Data for the 30 metropolitan areas were reported in tons of wood generated per year per person and supply curves were provided. The supply curves were based on quantity and cost of urban wood waste, which raises the concern of being interpreted incorrectly as wood waste availability. In other words, the supply curves were to show at what costs would UFRs be available (i.e. $5, $10, $15 per ton), not the quantity of UFRs that were available. There may also be some concern with such resource assessments being underestimated because of the difficulty of contacting all resource generators within certain time constraints.

The Antares Group, Inc. (1999) submitted an assessment to the U.S. Department of Energy and the National Renewable Energy Laboratory. This assessment used "state-level information on available wood waste quantities and projects the "delivered residue cost" (DRC) based on disposal (in landfills), collection and processing, and transportation costs" (Fehrs 1999: 27). An overall estimate of 111 million green tons (percent moisture content not specified) per year of all types of wood was available in the U.S. Approximately 10.1 million tons of that total were woody yard trimmings available for fuel. The "collection and processing cost" of yard waste was estimated at $12 per green ton.

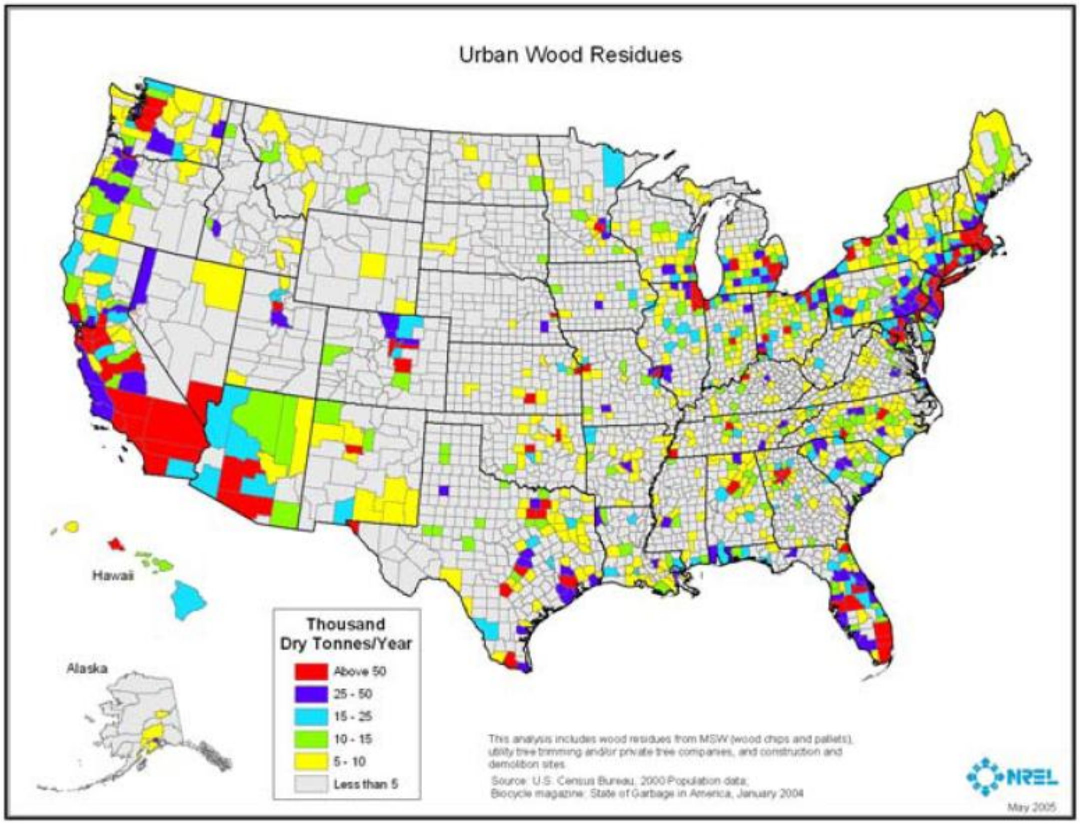
McKeever (1999) submitted an update of woody materials generated in the MSW stream during 1998. An estimated 25.2 million tons of yard trimmings were generated and of that total, 11.1 million tons was composted or recycled. The remainder (14.2 million tons) was broken down to 3.9 million tons combusted, 3.4 million tons deemed unusable and discarded, and 6.8 million tons were considered recoverable.

Fehrs (1999) quantified secondary mill residues and urban wood wastes. The estimates were based on methods from seven other biomass resource assessments and were evaluated in terms of quantity and price. Costs were reported as tons available up to $10 per ton, $20 per ton, and above $20 per ton. Total wood waste was estimated at 136 million tons per year prior to reuse, recycling, disposal, etc. Based on this total, an estimated 6.3 million tons per year of yard trimmings were generated. Approximately 1.2

million tons per year was available at up to $10 per ton, up to $20 per ton was 3,379,000 tons per year, and above $20 per ton was 5.5 million tons per year. Also estimated were urban tree residues at 51.5 million tons per year. These were available up to $10 per ton at 9.9 million tons per year, up to $20 per ton at 28.1 million tons per year, and above $20 per ton at 45.3 million tons per year. The study combined the yard trimmings estimate with the urban tree residues and an estimated 57.8 million tons were available annually in the U.S.

Another study conducted by McKeever (2002) included all wood waste generated in the U.S., including timber extracted from forestland, construction and demolition (C&D) debris, and municipal solid waste. It was also reported that UFRs categorized as yard trimmings comprised the second largest component of the United States' MSW stream. The estimates of this study were "based on published waste generation rates and recoverability, measures of economic activity, and trends in virgin wood use in specific markets" (McKeever 2002: 2). It was estimated that the yard trimmings component comprised approximately twelve percent (25.4 million metric tons) of the national MSW stream. Primarily used for compost and mulch, 8.5 million metric tons were recovered, and the remaining was either considered unusable or used in combustion facilities. McKeever (2002: 10) concluded that "nearly three-fourths of the recoverable wood was in woody forest residues."

Milbrandt (2005) estimated biomass resource availability in the U.S. The quantities were based on estimates from Wiltsee's (1999) study and other studies from the BioCycle Journal of Composting and Recycling. The total urban wood waste available in the U.S. is 30,902,000 tons per year (Milbrandt 2005). The urban wood waste for this study included MSW wood (i.e. wood chips, pallets, and yard waste), utility tree trimming and/or private tree care companies, and construction and demolition wood. A thorough break down of urban wood residues is shown in Figure 2.1.



(Source: Milbrandt, 2005)

Figure 2.1: National Break Down of Urban Forest Residues

A more recent study by the U.S. Department of Energy (DOE) and Department of Agriculture (USDA) (2005: i) jointly "determined whether the land resources of the United States are capable of producing a sustainable supply of biomass sufficient to displace 30 percent or more of the country's present petroleum consumption" by 2030. In order to meet this goal, an Advisory Committee established that 1 billion dry tons of biomass would be required annually. Biomass feedstocks researched and quantified were “forestry and agricultural resources, industrial processing residues, and municipal solid and urban wood residues” (DOE 2005: 4). The methodology used to quantify each specific feedstock was through assessing other studies as in McKeever (2004). The urban wood residue feedstock included the yard and tree trimmings category and was estimated at 9.8 million dry tons (without moisture) per year. The U.S. DOE (2005: 15) found that “only 1.7 million dry tons is considered potentially available for recovery after accounting for what is currently used and what is unusable.”

The EPA (2007) reported that yard trimmings in the MSW stream totaled 32 million tons in 2006. This estimate included grass clippings, leaves and other non-woody residues and “the urban tree and woody residue portion of the yard trimmings amount was estimated at nearly 19 million tons” (Bratkovich 2008: 2). In 2008, the American public generated approximately 32.5 million tons of yard trimmings; 12.8 percent of the national MSW stream (EPA 2008). Table 2.1 is a summary of UFRs quantified in the United States by author.

Table 2.1: Summary of National Urban Forest Residues, 1994-2008

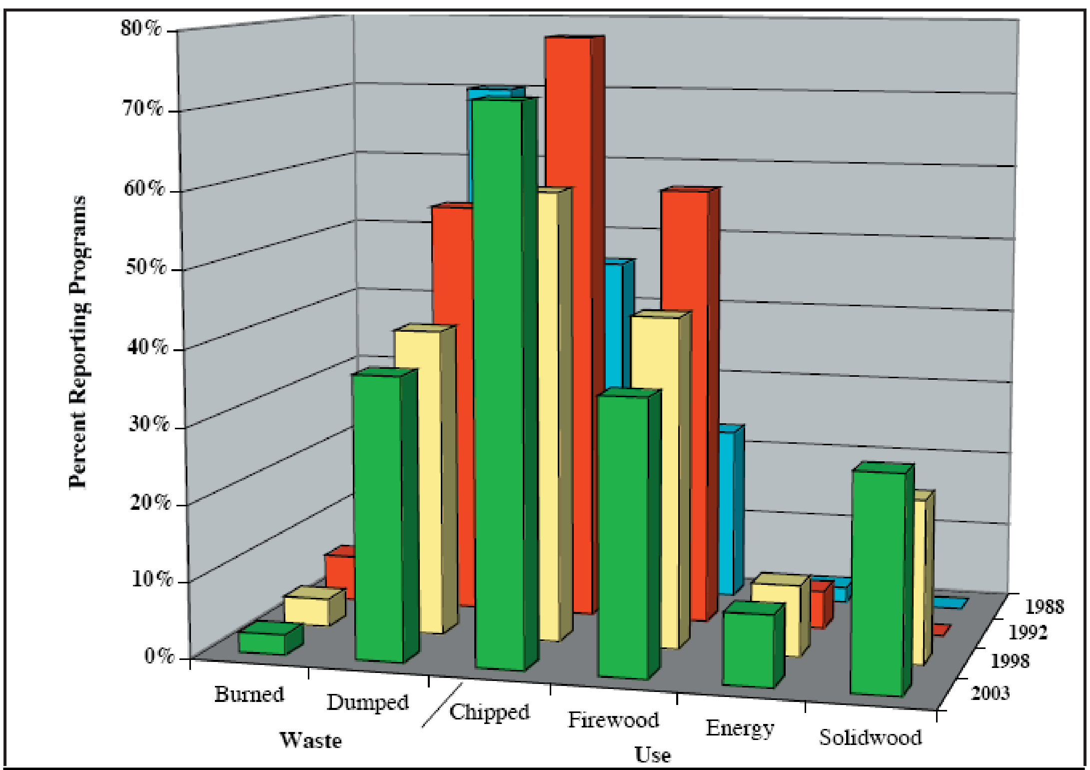
Author	Year	Urban Forest Residue Total (Million Tons)	Recovered (Million Tons)	Not Recovered (Million Tons)
NEOS Corporation	1994	50.2	N/A	N/A
McKeever	1995	27.8	6.4	21.4
McKeever	1996	29.3	8.6	20.7
EPA	1997	28	11	17
Rooney	1998	NEOS Corp. data		
Wiltsee	1999	39.2	N/A	N/A
Antares Group, Inc.	1999	10.1	N/A	N/A
McKeever	1999	25.2	11.1	14.2
Fehrs	1999	57.8	N/A	N/A
McKeever	2002	25.4	8.5	16.9
Milbrandt	2005	30.9	N/A	N/A
DOE/USDA	2005	9.8	1.7	8.1
EPA	2006	32	N/A	N/A
Bratkovich	2008	19	N/A	N/A
EPA	2008	32.5	N/A	N/A

2.2. State Information

Several studies were assessed for the states of Massachusetts, California, West Virginia and Washington. These studies were reviewed to obtain a better understanding of woody biomass availability, current end use, and alternative uses being researched or potentially practiced at the state level.

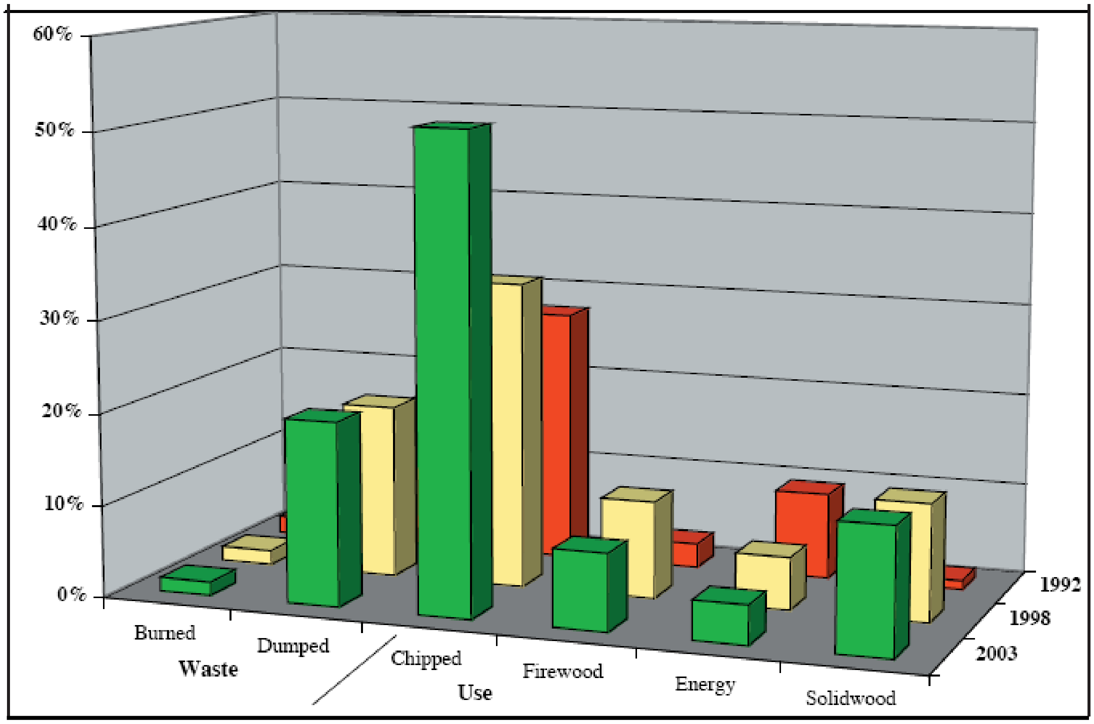
A study by Fallon and Breger (2002: 1) submitted to the State of Massachusetts was primarily "a literature-based estimate." The purpose of this study was to "build overall confidence in professionals making estimates of the statewide woody biomass supply, for the purpose of evaluating regional biomass energy potential or to serve the needs of early market assessment by project developers" in Massachusetts and its surrounding areas (Fallon and Breger 2002: 5). Urban woody residues were primarily generated through tree trimming and removal practices. Approximately 1,049,200 tons of urban woody residues were generated annually in Massachusetts, with 72 percent of this recovered and about 293,800 tons were discarded in landfills. It was estimated that 56 percent of urban woody residues were managed on-site, and "the other 44% were landfilled (17%), sold (12%), sent to recyclers (3%), burned for energy (3%), and open burned, stockpiled, incinerated, or managed in other ways (9%)" (Fallon and Breger 2002: 16). This study quantified a substantial amount of available woody residues and established that any sort of woody biomass program should look at available resources on a regional basis rather than state.

A study submitted by Thompson (2003) primarily focused on urban and community forestry including a resource estimate and disposal and utilization rates of tree trimmings and removals. Approximately 2 million tons of woody residues were generated annually in California. In 2000, the state of California passed a law requiring a 50 percent reduction in green wastes (i.e. woody debris, leaves, grass clippings, etc.) disposal. Thompson (2003: 24) reported that "prohibiting disposal of half of the woody material in landfills has created a serious problem for cities but also a growing perception of these materials as a potentially valuable resource." Below in Figure 2.2 and 2.3 are graphs from Thompson (2003) showing disposal and utilization rates of California. It is interesting to look at the decrease in waste of UFRs and the increase in use, particularly "solidwood" use. "Solidwood (i.e. larger diameter wood used as value-added products such as furniture) products utilization has increased significantly since 1992 to now over 20%" (Thompson 2003: 25) most likely from the use of small-scale portable band sawmills. As the tree inventory for the state of California has been estimated at 8 million trees, the planting and removal rates will also continue to grow and continuing with solidwood products will be a great way to utilize this source.



(Source: Richard P. Thompson, 2003)

Figure 2.2: Disposal and Utilization of UFRs in California



(Source: Richard P. Thompson, 2003)

Figure 2.3: Average Percent of UFRs Diposed or Utilized in California

Another study submitted by Wang et al. (2006) identified biomass resources, uses, and opportunities in West Virginia. Based on the 2.41 million tons of woody biomass available annually in West Virginia, urban tree residues comprised 118,590 dry tons of the total (3.6 percent). Commercial tree care firms generated 28,500 dry tons, utility line maintenance generated 87,500 tons and the municipal sector generated 2,590 dry tons of urban tree residues annually. Estimates were based from several studies previously mentioned, including Wiltsee (1998) and NEOS Corporation (1994). Wang et al. (2006: 2) stated that "with the biomass resource, West Virginia has the potential to produce 5.4 billion kWh of electricity from biomass, which is enough to supply power to 543,000 average homes, or 61% of the state's residential needs."

2.3. Costs and Benefits of Urban Trees

To effectively utilize UFRs, the costs and benefits of utilization must be fully understood. Costs include planting and maintaining (i.e. pruning, watering, fertilizing) the trees in order to avoid the hazardous and/or diseased; damage to sidewalks, roads, septic lines, and houses; or even the debris that some trees discard onto roads, sidewalks, and possibly cars (ISA 2008). The largest expense for planting or maintaining trees is “tree pruning, followed by tree removal/disposal, and tree planting” (McPherson et al. 2004: 14).

Conflict with urban infrastructures such as sidewalks and sewer lines are also an issue. Root-sidewalk conflicts have substantially impacted municipality budgets and have been known to cost certain regions over $100 million annually in repairs (McPherson et al. 2004). Additionally, older urban areas have older sewer lines and trees that typically cost more to maintain. Although issues with sewer lines do not normally occur with smaller trees, sewer repair companies have estimated repair costs ranging “from $100 to $1,000 or more…” (McPherson et al. 2004: 15). An assumption arises that these costs have increased significantly due to newer repair practices such as slip lining and/or pipe bursting.

Another cost associated with urban forests is seasonal shed of debris. Annually, leaves, flowers, fruits and branches drop from trees and become a nuisance along/within city streets and drains. Costs that occur are labor, time, and materials used to clean-up streets and unclog the drains. Costs of cleaning up debris usually “occur after windstorms… resulting in large expenditures” (McPherson et al. 2004: 15-16).

In addition, the most important cost to note within an urban forest is wood salvage, recycling, and disposal. In McPherson's survey (2004: 16), "most… cities are recycling green waste from urban trees as mulch, compost, and firewood. In some cases, the net costs of waste wood disposal are less than 1 percent of total tree care costs as cities and contractors strive to break-even." Because hauling and processing wood wastes can be expensive, the revenues generated from sales of mulch and firewood, and in some cases milled lumber (i.e. City of Colorado Springs) are much needed. Additionally, UFRs are potentially a renewable source of woody biomass. Utilizing UFRs in value-added ways such as sawn timber or tongue and groove flooring will provide a product to support the local economy.

Forests also provide many environmental, economic, psychological, and social benefits too (ISA 2008). They help improve air quality, conserve energy through shade and wind protection, reduce storm water runoff and erosion, sequester carbon, increase property values, and screen unwanted views and noise pollution (ISA 2008).

Urban trees improve air quality by capturing particulate matter and absorbing gaseous contaminants such as nitrogen oxide, ozone, etc. through the surface of the leaves (ISA 2008). Improved air quality is also achieved through the oxygen that is released through photosynthesis and reduced ozone levels by water transpiration and shaded surfaces (McPherson et al. 2003). Although some communities appear to have good air quality, most areas still exceed the EPA standards. McPherson et al. (2003: 10) reported that "tree planting is one practical strategy for communities in these areas to meet and sustain mandated air quality standards."

Larger mature trees help promote energy conservation, which results in saving money. McPherson (2003: 7) reported that “trees and other greenspace within individual building sites may lower air temperatures 5-degrees Fahrenheit (3-degrees Celsius) compared to outside the greenspace.” Planting trees strategically around structures will help conserve energy during the winter and summer months. A study done by McPherson et al. (1993) showed that the annual savings of an energy efficient home in a milder climate such as the Colorado Front Range (i.e. hot summers and cold winters) is approximately $45, equivalent to an annual reduction of nine percent. This could also be considered an economic benefit with savings that accrue during air conditioning and heating season.

Another environmental benefit is the reduction of stormwater runoff due to healthy root growth increasing soil infiltration and interception of rainfall by the leaves and branches (ISA 2008). McPherson et al. (2004: 11) stated that “studies that have simulated urban forest effects on stormwater report annual runoff reductions of 2 to 7 percent.” As stormwater runoff greatly affects riparian ecosystems through contamination, runoff and pollutants entering waterways is reduced by a healthy urban forest.

Carbon dioxide (CO_2) is sequestered by urban trees and removed from the atmosphere during the growing season. Very little CO_2 is released through respiration but as McPherson (2003: 8) reports, “all trees die and most of the CO_2 that has accumulated in their woody biomass is released into the atmosphere through decomposition.” Instead of woody biomass decomposing after removal, a source for wood-fired heating systems is provided. According to a study by McNeil Technologies (2006), gasification of wood waste greatly reduces emissions. Developing these systems will not only provide an alternative use for UFRs but will also help reduce CO_2 and other pollutants (i.e. methane) that may otherwise be released through wood decomposition. Additionally, studies have shown that methane is 25 times more potent than carbon dioxide (Lydersen 2009). Utilizing UFRs can reduce the impacts of more potent greenhouse gases.

Other benefits that shade trees provide include a prolonged life of roads and increased property values. Asphalt overtime becomes degraded by sunlight and with large shade trees protecting the road, the life of the asphalt is doubled from ten to twenty years (ISA 2008). This benefit in turn reduces the annual costs of repairing roads. Large urban trees have also been known to increase property values up to 20 percent (Kane 2006) because of increased "curb appeal." One study reported "that people are willing to pay three to seven percent more for properties with ample tree resources versus few or no trees" (McPherson et al. 2004: 12).

Psychological and social benefits include relieving mental stress and fatigue, enhancing community pride and sense of ownership, and mitigating psychological pressures and crime (ISA 2008). As McPherson (2004: 13) puts it, "Urban green also appears to have an 'immunization effect,' in that people show less stress response if they have had a recent view of trees and vegetation." Studies have shown that hospital patients with trees outside their windows recover more rapidly than patients without (Kane 2006). Also, people with trees throughout their community are proud of and appreciate where they live and tend to obtain a higher quality of life.

2.4. Successful Biomass Programs

Biomass availability throughout the U.S. is important to assess because of its great potential for generating renewable energy. Other opportunities researched include biomass conversion technologies (i.e. bio-based transportation fuels), combustion and gasification, fermentation (i.e. ethanol), and bio-refinery technologies (i.e. biodiesel). Examples of projects where UFRs were successfully utilized include Horigan Urban Forest Products and the City of Colorado Springs. Horigan Urban Forest Products, located near Chicago, was started in the 1970s as a tree care company, but ultimately moved in a new direction utilizing UFRs. The Horigans recognized that they were “tired of seeing high quality logs with lumber potential dumped at a landfill” (Bratkovich 2008: 4). Since 2003, relying on sources that included homeowners, tree care companies and municipalities, the Horigans mill and dry lumber with a couple small dry kilns and a portable band saw mill (Bratkovich 2008).

Another example of a successful urban biomass utilization program was implemented by the City of Colorado Springs in Colorado. The Colorado Springs City Forestry Division (CSCFD) initiated an effort to minimize the amount of urban wood waste in the Colorado Springs area. The Colorado Springs biomass utilization program has focused on the city’s natural resources, even after a tree is dead, and several ways have been developed to utilize the woody biomass from their urban forest. Examples of how CSCFD recycles and utilizes their urban forest residues include chipping logs for mulch which is then used for the city’s planting beds or are offered free to the public (Christmas tree recycling included); trees with sound trunks are sold to a local mill and sawn into rough lumber or flooring, tongue and groove paneling and cabinet-grade trim;

and smaller diameter trees are used for firewood which is exchanged for trees to plant in parks (Forestry Division, City of Colorado Springs 2007). In addition to this biomass utilization program, the CSCFD also accepts yard waste (leaves, tree clippings, old fence wood, etc.) from residents at several different locations for free as long as they bring a canned good donation for Care and Share, a food bank of southern Colorado. Innovative ideas of the City of Colorado Springs have made this a successful program. The City has not only reduced wood waste but also utilizes almost 100 percent of woody biomass generated within the area.

2.5. Barriers to Utilization

Based on literature cited, it is apparent that a fairly continuous trend of UFR disposal and utilization has occurred for at least the past fifteen years. Although recycling and biomass utilization have become more popular over the years, there are still several obstacles that deter UFR utilization. Barriers to utilizing UFRs include wood quality, wood quantity, utilization plans, community support, etc. (Bratkovich 2008). Within the urban setting, trees tend to grow around nails, fences, cables and more (Bratkovich 2008), which decreases the quality of the wood and can damage wood processing equipment. Many local sawmills will not process timber from urban sources because of the chance of damaging blades and other machinery due to metal that might be present in the wood. Bratkovich (2008: 3) reported, “in addition, among both urban wood generators and many in the traditional wood products industry, there is a perception that urban trees have ‘zero’ value.”

Wood quantity relates to whether or not a steady, sustainable wood supply will be available, and "with the exception of storm events or a large pest outbreak, most *individual* urban tree removal projects generate small quantities of wood" (Bratkovich 2008: 3). To successfully achieve a sustainable supply of wood of adequate quality, utilization plans need to be developed prior to "harvesting" or collection. Bratkovich (2008: 3) reports that "the lack of planning includes a poor understanding of local markets and potential products, a reluctance to engage timber buyers and existing wood-using industries, and a general lack of knowledge of how to create a viable utilization plan."

Lack of community support might also prevent utilization from occurring. Without community support, it may be difficult to implement utilization plans and develop the public participation required to ensure success of an urban biomass utilization program. If a community addressed the above factors, joining the current movement "to minimize these constraints, and develop viable markets for wood from our urban forests" (Bratkovich 2008: 3) would become more feasible.

2.6. Tri-City Area

Ward et al. (2004) published a report characterizing wood wastes along the Colorado Front Range. Wood wastes identified were from four sources including MSW, C&D, primary and secondary wood processing residues, and forest residues. The source of interest was yard trimmings within the MSW stream. An estimated 360 thousand tons of yard trimmings was generated within the 18 counties along the Front Range. Ward (2004: 8) reported that "significant quantities of wood are being deposited into landfills, even though opportunities and markets exist for utilizing woody residues." Construction and urban forest residues were estimated as the primary source of this wood waste and could be mitigated through sorting practices (Ward et al. 2004).

The Larimer County Landfill (LCL) and MSW Consultants (2007) published a report that included a detailed description of what types of waste are entering the LCL, waste disposal by generator sector and how much waste is disposed. The categories that were most important, with respect to this study were the yard waste and land clearing categories. The yard waste category consists of grass clippings, leaves, brush, and prunings, and the land-clearing category includes logs, stumps, trunks, and limbs (MSW Consultants 2007). The report quantified approximately 10,121 tons of UFRs or about 6.6 percent of the total waste entering the landfill.

CHAPTER 3: Methodology

To determine the current amount of UFR generation for the Tri-City Area, local, state, and national studies were consulted, including the State of Colorado's waste statistics and composition studies (EPA 2006, 2008, and MSW Consultants 2007). Most of these research projects, whether national, state, and/or local, reported results that were fairly consistent with regards to the amount of UFRs entering landfills, ranging between 12 and 13 percent. As far as the total amount of biomass generated across the United States, amounts ranged anywhere from 14.5 million tons (McKeever 2000) to 64.3 million tons per year (Wiltsee 1998).

The study area was defined as a twenty-five mile radius around the Tri-City Area (Fort Collins, Loveland, and Greeley). Before conducting data collection, it was important to determine how urban forest residues were generated within the Tri-City Area. UFRs were generated by several different entities, which included homeowners, landscape maintenance companies, and the tree care industry. Homeowners generated mostly grass clippings, leaves, and small diameter brush. Landscape maintenance companies generated waste similar to homeowners, but often handled brush and small tree residues with a little larger diameter. Tree care companies generated a range of UFRs from brush to large diameter trees. For this study, the amount of biomass generated by the tree care industry within the Tri-City Area was estimated. The study focused on the tree care industry because they were the primary source of UFRs. It is important to note that this study does not account for UFRs generated by companies coming into the Tri-City Area from outside cities and counties. Therefore, generation estimates will be somewhat conservative.

UFRs were considered recoverable unless they were diseased or infested with insects. Examples of unrecoverable UFRs in the Tri-City Area included Dutch elm disease-infested *Ulmus americana* (American elm), Ips beetle-infested *Picea spp.* (spruce species) and most recently mountain pine beetle-infested *Pinus spp.* (pine species). Most of these trees were identified by the city Forestry Divisions and removed. In the Tri-City Area, ordinances required that the infested wood be disposed of in landfills.

For each city (Fort Collins, Loveland, and Greeley), a contact list that included City Natural Resource Departments and Forestry Divisions, tree care companies, wood-recycling companies, landfills, etc. was compiled (Appendix A) by searching the yellow pages and Internet. The companies were selected based on the types of services or operation (i.e. tree pruning and removal) they provided. Before conducting telephone calls, a script was created. The series of questions in the script were designed to obtain the desired information and to help facilitate phone interviews (See Appendix A). From the questions asked, the number of truckloads of UFRs handled per day or week was compiled to estimate the total amount of UFRs generated. Other information needed included number of employees, where companies discard UFRs, and whether or not they were willing to discard UFRs in alternative ways.

Contacts on the list were systematically called for each city, starting with Natural Resource Departments and Forestry Divisions, followed by tree care companies and wood recyclers. Relevant statistical data they had regarding MSW or wood waste were also collected. City governments also provided additional contacts.

Next, all pertinent companies (48 tree care companies) listed within the yellow pages and internet directories were contacted by telephone. Telephone surveys typically lasted for about five to ten minutes. Many of the companies contacted did not keep records of residues handled by their operations. Because they often did not know the amount of UFRs they handled in a year, they were asked to provide the amount of cubic yards their trucks held, how many times they dumped a full load per day/week, and how many months they worked out of the year. Based on these data, the amount of UFRs generated by each company contacted was estimated. All estimates were first determined in cubic yards and then ultimately converted to tons. The conversion equation is given below:

$$\textbf{Cubic Yards} \times (\textbf{1 ft}^3/\textbf{.037037 yd}^3) \times (\textbf{1 Cord/128 ft}^3) \times (\textbf{1.19 Tons/1 Cord}) = \textbf{Tons}$$

Additional data was collected during phone interviews regarding company utilization / disposal practices. Based on this information, the amount of recoverable UFRs within the Tri-City Area was estimated.

Most companies contacted were very small and only ran one crew and in several instances were comprised of only one person. The larger companies ran anywhere from two to four crews, usually two or three people per crew. Larger companies that were capable of removing larger trees, etc. were able to provide an estimate of how many wood chips, brush, and logs they handled based on the trucks they used to (i.e. chip trucks, grapple trucks, etc.) haul UFRs. Smaller companies that were only capable of pruning and removing smaller trees were only able to provide wood chip and brush estimates or just brush estimates if they didn't own a chipper.

Response rate (expressed as a percentage) was determined for the entire study area as well as each individual city by taking the number of companies that responded divided by the total amount of companies called times one hundred. To account for UFRs generated by tree care companies that did not respond, the following method was used. Based on companies that responded, the total amount (tons) of UFRs generated by these companies was divided by the number that responded to determine an average. This average was then multiplied by the number of unresponsive tree care companies in each city and added to the amount of UFRs generated by tree care companies that responded.

Several landfills, including the Larimer County Landfill (LCL) and Waste Management's North Weld County Landfill (NWCL) were contacted by telephone to obtain the amount of UFRs being disposed of within the Tri-City Area. A waste composition study conducted by MSW Consultants (2007) provided disposal data for LCL. NWCL disposal data were obtained through the EPA. UFR amounts disposed of at landfills were compared to amounts taken to wood recyclers to estimate the percentage of UFRs being utilized. Utilization percentages were calculated by dividing the amount of UFRs taken in by wood recyclers by the sum of UFRs taken in by wood recyclers and disposed of at landfills times one hundred.

Data was also collected from UFR recyclers (processors and collection centers). UFR recyclers sell products such as dairy compost, rock, soil, and mulch of all kinds. These processors accept all yard waste, but most importantly the wood chips, brush, and logs produced by the tree care industry. Hageman's Earth Cycle Inc., A1 Organics, ABS Organics, the Loveland Recycle Center, and the Greeley Greencycle Center were the largest within the Tri-City Area that processed UFRs into mulch or compost. Each wood recycler was contacted by telephone. They provided collection data (cubic yards) based on the 2007 season. Data collected from these processors were then converted to tons by using the conversion process previously discussed.

In addition to processing companies, there were several collection centers present in the Tri-City Area. Collection centers are essentially recycling centers that accept all types of recyclable items from the MSW stream, including UFRs. The two collection centers contacted in this study were the Loveland Recycle Center and the Greeley Greencycle Center. They were contacted by telephone and provided the amount of UFRs entering the recycling centers. Data were initially provided in cubic yards and later converted to tons.

Cost data for wood chips, brush, and log tipping fees were analyzed to determine whether hauling UFRs to the landfill was more cost effective than other alternative uses of urban forest residues. This analysis included tipping fees charged by landfills, as well as UFR collection centers. Woody biomass generated in the MSW stream of the study area was categorized as: logs, brush, and wood chips/stump grindings and their potential end uses were considered as outlined in Table 3.1.

Table 3.1: Urban Forest Residues End Use by Category

Category:	**Logs**	**Brush**	**Chips/Stump Grindings**
End Uses:	Stem wood suitable for sawing	Suitable for mulch	Suitable for compost

In summary, data collected primarily by telephone surveys and interviews were used to quantify the amount (tons) of UFRs produced within the Tri-City Area and utilization/disposal practices. Data sources included City Natural Resource Departments and Forestry Divisions, tree care companies, landfills, and landscape material retailers.

CHAPTER 4: Results and Analysis

Urban forest residues were generated through arboriculture and landscape maintenance practices implemented by homeowners, landscape maintenance companies and the tree care industry. Data was compiled for UFRs generated by tree care companies to quantify the total amount handled. The UFRs composition primarily consisted of wood chips, brush, and logs, with some leaves and grass. This study not only looked at who generated the UFRs but also assessed where UFRs were disposed of or utilized. City Forestry Divisions, landscape recycle companies, and landfills were contacted to determine the amount of UFRs available for recovery. Within the Tri-City Area, forty-eight tree care companies were contacted and thirty-three responded, for an overall response rate of 68.8 percent.

The City of Fort Collins had eighteen companies that provided data out of the twenty-seven that were contacted, which equates to a 66.7 percent response rate. In addition to tree care companies, the city's Forestry Division also provided data for the amount of UFRs they generated. Although the Forestry Division handles UFRs, they occasionally sub-contracted work out to local tree care companies.

Greeley had nine companies that responded out of the eleven that were contacted for a response rate of 81.8 percent. Greeley's Forestry Division was also contacted and they indicated that almost all of the tree work done on public trees is sub-contracted out. The UFRs generated in Greeley were based solely on tree care companies.

Loveland had six companies that provided data out of the eight that were contacted for a response rate of 75.0 percent. Loveland's city Forestry Division consisted of one Forestry Specialist and sub-contracted out all work completed on public trees. The UFRs generated in Loveland included those handled by the six tree care companies that responded.

An analysis of UFR generation/disposal data was conducted to address objective two. This question of willingness to utilize UFRs was simply answered by tree care companies with a "yes" or "no" response. Out of the eighteen companies that responded in Fort Collins, only one company reported "no," which means that 94.4 percent of the tree care companies that responded in Fort Collins were willing to dispose of UFRs in places other than local landfills. All companies in Loveland and Greeley were willing to consider alternatives to disposal of UFRs in landfills. Overall 97.0 percent of tree care companies were willing to dispose of UFRs in a reusable manner within the Tri-City Area. Results are summarized in Table 4.1 below.

Table 4.1: Willingness of Tree Care Companies to Discard UFRs by City

City	# of Participating Companies	% Willing
Fort Collins	18	94.4
Loveland	6	100
Greeley	9	100
Total	33	97

It is important to consider that just because a majority of the companies were willing to dispose UFRs in places other than landfills, does not mean they were currently doing so. As mentioned previously, it may be more convenient or required to dispose of UFRs in a nearby landfill. The economic feasibility of disposing UFRs somewhere other than a landfill will be discussed further in subsequent sections.

4.1. Willingness to dispose of UFRs in alternative ways

The percentage of tree care companies willing to dispose of UFRs in places other than landfills were determined and analyzed by city. Many factors were taken into consideration when interviewing the tree care companies, which included insect and disease infested trees with regards to city ordinances, convenience of places to dispose of residues, and knowledge of biomass utilization. A discussion of these factors follows:

4.1.1. City Ordinances

Insects and diseases are a major issue in the urban forest. Within the Tri-City Area, the most common insect and disease outbreaks are Ips beetle on spruce and pine trees, and Dutch elm disease (DED) on American and English elms. Because these insects and diseases occur annually, proper monitoring and sanitation are required by each city. Monitoring is conducted by the forestry divisions in each city on a daily basis and is documented when infested trees are found. Infested trees are then either removed by the forestry division or a private tree care company. Ordinances may vary from city to city depending on the insect and disease issues that are prevalent in a given community. Generally ordinances for the Tri-City Area required proper disposal and sanitation of the infested trees. For the three cities, it was required that infested trees be removed and disposed of outside of city limits. The most common place that these trees were disposed of was surrounding landfills. The trees were then usually buried to discourage any further spread of insect and disease. This woody biomass represents a source of UFRs that is not currently utilized.

Each city reported how many trees have been removed due to Ips beetle and DED infestations. For the City of Fort Collins, twenty-four trees were removed due to Ips beetle infestation and four DED trees removed in 2008. The City of Greeley reported twenty-eight trees removed due to Ips beetle infestations in 2008 and only one DED infestation in 2007 (2008 data was not available). Loveland reported twenty Ips beetle infested trees removed in 2008 and in 2007 there was only one DED tree removed. Loveland's Forestry Specialist also mentioned there were several trees that looked suspiciously like DED, but no removal/sanitation practices were completed. A total of Ips beetle and DED trees removed in each city for 2007 & 2008 can be found in Appendix C. These graphs provide a more historical perspective of insect and disease within the Tri-City Area over the past years.

4.1.2. Convenience of Disposal

Convenience is another factor that impacts where a tree care company disposed residues. In the private industry, a job may include pruning one to several trees or removals. A normal day may consist of completing anywhere from one to six jobs. Depending on the type of service that is being provided, the company may perform a large tree removal at one job taking half the day or conduct small prunings at several different job sites throughout the day. Depending on the work to be completed, a normal day may be routed where the crew begins furthest from the shop at the start of the day and works their way back towards the shop in the latter part of the day. The next day the crew may be all over the place, starting out in one city and then going to another city because of the work available at that time. Because of this variability in job sites and routing, a crew's truck may fill up half way through a job and will need to be dumped to complete the rest of the work. Convenience now becomes a factor with regards to locating the closest area to dispose of residues. For example, if the crew is in an area that is closest to the local landfill, the crew will often dump residues at the landfill because its convenient, even if it costs more to do so.

The private industry is primarily based around production, meaning "time is money"-a man-hour rate is always taken into consideration. The price of the job needs to offset the costs of each person working on the job, plus more in order for a company to make any money on the job. Additional revenue is crucial to cover other expenses, which include equipment and gear maintenance, insurance, workmen's compensation, profit margin, etc. Also, additional driving to dump the truck is an added expense, including costs such as fuel and the time it takes the worker to dump the truck and return to the job. Combining these added cost factors, crews must know the best places to dump the trucks throughout the day. The Tri-City Area has several options available to discard these resources. Besides landfills, other places to discard UFRs include landscape recycling companies, local nurseries, and homeowners interested in wood chips or firewood size logs produced from their own yard. Table 4.2 outlines which dumping sites were more cost effective (based on tipping fees).

Table 4.2: Tipping Fees of Available Dumping Sites – Dollars per Cubic Yard (CY)

Dumping Site	Chip	Brush	Logs
Processor/Collector			
Hageman's Earth Cycle, Inc	Free	$4.50/CY	$4.50/CY
A1 Organics	$5.00/CY	$6.00/CY	$6.00/CY
ABS Organics	Varies by grinding contract		
Loveland Recycle Center	Free	$2.50/CY	$6.00/CY
Greeley Greencycle Center	$4.50/CY	$5.75/CY	$15.00/CY
Landfills			
Larimer County Landfill	$5.81/CY	$5.04/CY	$5.81/CY
North Weld County Landfill	Minimum Charge of:	$27.34/ 2CY	
Tree Nurseries			
	Free	Not Accepted	Not Accepted

4.1.3. Knowledge of Biomass Utilization

An additional factor to consider is a company's knowledge of biomass utilization and alternative locations to recycle UFRs. This factor is considered because some tree care companies are unaware of alternative disposal sites to landfills. When interviewing tree care companies, they were asked to list the various places they dispose of their residues. Although the amounts they dumped at all the different disposal sites were unknown, they were still able to provide a list of disposal sites. A majority of the companies disposed of their residues in places such as Hageman's Earth Cycle, A1

Organics, ABS Organics, tree nurseries, the Loveland Recycle Center and the Greeley Greencycle Center. Most of the companies that were knowledgeable about proper sanitation of insect and diseased trees said that was the only reason they would take UFRs to the landfill. Other companies that were less knowledgeable about these practices most likely took quite a few UFRs to the landfill on a regular basis. For example, one company out of all participating tree care companies reported that the landfill was the only place they disposed of UFRs and did not mention other disposal sites. Increasing awareness of alternative disposal practices will help reduce the amount of UFRs entering landfills.

4.2. Urban Forest Residue Generation

Objective three assessed whether or not a majority of urban forest residues produced within the Tri-City Area were utilized. As discussed previously, there were several places for UFRs to be disposed of in the Tri-City Area, but were they being utilized to their full advantage? This question was consistently asked when assessing who generates UFRs, where UFRs end up, and how they were currently utilized.

4.2.1. Tree Care Companies

Based on the tree care companies who responded in each city, an estimate of UFRs (tons) generated was determined for the Tri-City Area. The estimate considered both companies that responded and those that did not. An average of UFRs handled per company was also estimated, along with the number of employees per company. This data was specifically collected to estimate the average UFRs generated per tree crew as in

Wiltsee's (1998) study. This may also help in future analyses of UFRs within the Tri-City Area.

Out of the participating eighteen companies and the Fort Collins Forestry Division, an estimated 12,215 tons (48,661 cubic yards) of UFRs were produced annually in Fort Collins. The average amount of UFRs produced per company was 643 tons annually. There were a total of 65 (average over the year) tree care employees that worked out in the field with an average of 3.39 employees per company. Based on the average amount of UFRs produced by a company, an additional 5,786 tons (23,050 cubic yards) were generated by companies that did not respond. An estimated total of 17,695 tons (70,492 cubic yards) of UFRs was produced annually by the tree care industry in Fort Collins.

Loveland had six tree care companies that responded. They produced 2,518 tons (10,032 cubic yards) of UFRs annually. The average amount of UFRs produced by each company was 420 tons annually. There were 14 employees working in the field or an average of 2.25 employees per company. Companies that did not respond generated an estimated additional 839 tons (3,344 cubic yards) of UFRs. The estimated total was 3,358 tons (13,376 cubic yards) of UFRs generated by the tree care industry in Loveland.

There were nine participating tree care companies that produced 12,586 tons (50,142 cubic yards) of UFRs annually in Greeley. The average amount of UFRs produced per company was 1,398 tons. A total of 37 employees were working in the field with an average of 4.06 employees per company. Companies that did not respond generated an additional 2,797 tons (11,143 cubic yards) of UFRs. An estimated total of

15,383 tons (61,285 cubic yards) of UFRs was generated by the tree care industry in Greeley.

These estimates are summarized in Table 4.3.

Table 4.3: Total UFR Production for the Tri-City Area

City	# of Companies Contacted	# of Participating Companies	# of Non-Participating Companies	Total UFRS Produced (tons)	Total UFRs Projected (tons)
Fort Collins	27	18	9	12,214.68	17,694.48
Loveland	8	6	2	2,518.19	3,357.59
Greeley	11	9	2	12,586.44	15,383.42
Total	46	33	13	27,319.31	36,435.49

4.2.2. Disposal Sites

The City of Fort Collins had several UFR disposal sites. Disposal sites include recycling centers, nurseries, homeowners, and county landfills. Each of these sites utilized UFRs differently.

City of Fort Collins

Hageman's Earth Cycle, Inc. was located on the east side of Fort Collins about a mile west of Interstate 25. Hageman's accepted wood chips, brush, and logs up to 26 inches in diameter and collected all types of yard waste from residents, landscape, and tree care companies. In addition to all the various types of yard waste brought to Hageman's, wood chips were accepted for free (See Table 4.2 for tipping fees). As far as large diameter wood, a maximum diameter of twenty-six inches was accepted by Hageman's for their grinding operation, with larger diameters turned away. The UFRs disposed of at Hageman's were either re-ground into mulch or were finely ground as an ingredient for compost. For mulch, the wood chips, brush, and logs were re-ground into different sizes of chips and were then dyed into different colors to suit the needs of landscape mulch in residential and commercial projects. Hageman's reported that 66,028 cubic yards or about 16, 574 tons of UFRs were processed in 2007. When this is compared to the amount of UFRs produced by tree care companies in Fort Collins, 73.7 percent (12,215 tons) of UFRs delivered to Hageman's Earth Cycle came from private tree care companies. This number only represents the tree care companies and the Forestry Division that responded in the study because measured data was received directly from these companies.

Six nurseries were located throughout the City of Fort Collins and provided a great alternative for disposing of UFRs. Wood chips were the only type of UFRs accepted at the nurseries and were primarily used for healing in nursery stock or large balled and burlapped (B&B) trees. Nurseries were often convenient when they were accepting wood chips but they did not always accept them. Prior arrangements between the nursery and a tree care company were usually required. Estimates of UFRs delivered to nurseries were not available due to sporadic deliveries throughout the year and lack of record keeping.

The Larimer County Landfill (LCL) located just southwest of Fort Collins was a disposal site for UFRs. Most of the UFRs hauled to and disposed of at this site were not utilized. Typically, once the UFRs entered the site, they were quickly comingled with other waste and buried in the landfill. In 2007, 40,320 cubic yards or 10,121 tons of UFRs entered the LCL, which was approximately 6.6 percent of the total waste entering the landfill (MSW Consultants, 2007). Comparing the amount of UFRs generated by Fort Collins tree care companies to the UFRs entering the LCL is not a good comparison because there were other UFR generators disposing of UFRs at the landfill including homeowners. Waste entering the LCL came from Fort Collins and Loveland as well as various transfer stations throughout Larimer County.

Another outlet for some UFRs was homeowners. Based on the type of services that a tree care company provided, homeowners often requested wood chips or limbs produced from their property. The wood chips were utilized as mulch and the limbs were suitable for firewood. Most tree care companies preferred to utilize UFRs at the job site rather than transporting them to a landfill or some other disposal site. This outlet was not quantified because not all homeowners were interested in obtaining the UFRs. There was no indication of how many homeowners were interested in UFRs but possibly if homeowners were aware that this was an option, then maybe more would become interested.

City of Greeley

The City of Greeley also had several companies that accepted UFRs, including recycle centers, nurseries, and landfills. The headquarters of A1 Organics was located in Eaton, Colorado which is directly north of Greeley about nine miles. A1 Organics had several processing sites and had contracts all throughout northern Colorado. A1 was capable of processing tree stems of any diameter that grew in northern Colorado, but larger diameters required shorter longitudinal length. The larger the diameter of the tree, the shorter the log needs to be in length to go through the tub grinder. A1 Organics accepted wood chips, brush, and logs and had several mobile tub grinders that were capable of processing 4800 cubic yards in an eight-hour day (See Table 4.2 for A1's tipping fees). A1 reported that in calendar year 2007, they processed 121,392 cubic yards of UFRs equivalent to 30,471 tons (A1 Organics Annual Reporting, 2007). Yard waste (includes grass clippings) was 8,849 tons and 'KD Wood' (includes pallets and urban wood waste) was 21,622 tons of this total. A1 Organics was not able to break the composition down further, so it was assumed that the estimated amount would be lower if grass clippings and pallets were removed from the total UFRs processed in 2007. A1 Organics also reported that 100 percent of the UFRs received were either sold as a mulch product or utilized in composting processes.

ABS Organics was located east of Greeley and contracted throughout the surrounding area with livestock farmers and landscape/tree care companies to process organics into compost. ABS accepted all organics including manure, leaves, wood chips, brush, and logs. Their maximum grinding diameter was forty-two inches and the logs needed to be less than eight feet in length to put them through the tub grinder (See Table 4.2 for ABS' tipping fees). In 2007, ABS processed about 38,000 cubic yards or 9,539 tons of UFRs. All processed UFRs were then used as an ingredient in their composting operations.

Greenleaf Tree Care also had a site previously used by several other tree care companies for UFR disposal. Wood chips, brush, and logs were left piled at this site and then Greenleaf periodically rented a tub grinder from Vermeer to grind the woody biomass into mulch. This operation was fairly small because Greenleaf only grinds about once a year. In 2007, they processed about 10,000 cubic yards or 2510 tons of mulch and were currently looking for other markets for this product. This site no longer accepts UFRs from other companies and was currently used solely for their own UFRs.

The Greeley Greencycle Center was located in the City of Greeley just off of Highway 85 and 8th Street. The Greencycle Center was a program implemented by the City of Greeley's Natural Resource Department (GNRD). This recycle center accepted all types of yard waste and was used frequently by tree care companies as well as residents of Greeley. GNRD periodically contracted A1 Organics to process yard waste, which took place on-site. For 2007, the Greeley Greencycle Center processed 15,279 cubic yards (3835 tons) of UFRs (Scopel 2008). After A1 Organics processed the material, A1 hauled the residues to one of their many processing sites throughout northern Colorado and processed it further to dyed mulch or compost (See Table 4.2 for Greeley Greencycle Center tipping fees).

The North Weld County Landfill (NWCL) located in Weld County just east of Ault, Colorado was run by Waste Management and accepted all types of waste. No breakdown of waste composition was reported by NWCL but a total amount of waste entering the landfill was provided. To calculate the amount of UFRs entering the NWCL, a national average of 12.8 percent (EPA 2008) of "yard waste" entering landfills was used. This average was then multiplied by the total amount of waste entering the NWCL (1,270,451 cubic yards in 2006). It was estimated that about 163,000 cubic yards or 40,820 tons of UFRs entered the NWCL in 2006. Most of the waste entering the NWCL comes from Greeley and its surrounding towns. None of these residues are utilized and are subsequently buried in the landfill.

City of Loveland

The City of Loveland had several sites that accepted UFRs which included the Loveland Recycle Center (LRC) and the Larimer County Landfill. The LRC was centrally located in the City of Loveland and was run by Loveland's Solid Waste Division. This recycle center also contracted with A1 Organics to periodically grind the larger diameter limbs and trunks and haul the woody biomass away. Wood chips, brush, and logs were all accepted at this recycle center (See Table 4.2 for Loveland Recycle Center tipping fees). The LRC was available to all residents and companies of Loveland, and reported that 57,455 cubic yards or 14,422 tons were processed in 2007. This estimate included grass clippings and leaves. The Larimer County Landfill estimates were discussed previously.

4.2.3. Utilized vs. Not Utilized

Most tree care companies dispose of their residues at wood recycling companies, where they were utilized either as mulch or for firewood. To determine what percent of UFRs in the Tri-City Area were utilized versus not utilized, the assumption was made that all UFRs entering recycle centers were utilized (most likely as mulch and some compost) and all UFRs entering the landfills were not utilized. These figures are subsequently discussed for each city.

Because the City of Fort Collins and the City of Loveland share the Larimer County Landfill, estimates for these two cities were combined. Fort Collins and Loveland sites consisted of Hageman's Earth Cycle, the Larimer County Landfill and the Loveland Recycle Center. An estimated 41,117 tons of UFRs were brought to these three sites in

2007. Based on the assumption previously mentioned, approximately 75.4 percent (30,996 tons) of UFRs collected by recycling centers (Hageman's and LRC) were utilized. Approximately 24.6 percent (10,121 tons) of UFRs were not utilized and were either buried in the LCL or disposed of in some other manner.

Sites utilized within the City of Greeley include A1 Organics, ABS Organics, Greenleaf Disposal Site, the Greeley Greencycle Center, and the North Weld County Landfill. Estimates of UFRs brought to these four sites totaled 87,175 tons in 2007. Using assumptions applied to Fort Collins/Loveland figures, an estimated 53.2 percent (46,355 tons) of UFRs were utilized in Greeley, while 46.8 percent (40820 tons) were not utilized. This number may be somewhat inaccurate because no documents were available detailing the exact amount of UFRs entering the North Weld County Landfill (this estimate was calculated based on national studies).

For the Tri-City Area, the UFRs generated by wood recycling companies were summed along with UFRs brought to the two landfills. These figures were then compared to give a percentage of UFRs that were utilized. The total amount of UFRs generated by all wood recyclers in the Tri-City Area was 77,351 tons (308154 cubic yards) and UFRs brought to the two landfills totaled to 50,941 tons (202,938 cubic yards). The overall total amount was 128,292 tons. It was estimated that 60.3 percent of UFRs generated in the Tri-City Area were utilized. Results are summarized in Table 4.4.

Table 4.4: Summary of UFRs Utilized versus Not Utilized in the Tri-City Area

Collector	Tons	Tons Utilized (%)
Wood Recyclers	77,351.43	60.3
Landfills	50,940.63	39.7
Total	128,292.06	100

As mentioned previously, most UFRs entering landfills were not utilized. Because of this assumption, it was important to look at what percentage of UFRs entering landfills may be recoverable and were not comingled with non-woody residues (i.e. metal, rubber, plastic, etc.). According to Fehr (1999), UFRs are "assumed not to commingled or contaminated since it is comprised solely of tree and other woody biomass residues." Based on a study by McNeil Technologies, Inc. (2005), UFRs disposed of in landfills have a 57 percent recoverability rate. By using this rate, the Larimer County Landfill could recover 5,769 tons of UFRs and the North Weld County Landfill could recover 23,267 tons based on the total amount of UFRs brought to these landfills. These estimates are summarized in Table 4.5.

Table 4.5: UFR Recoverability by Landfill

Landfill	Total UFRs	Recoverable UFRs
Larimer County	10,121	5,769
North Weld County	40,820	23,267
Total	**50,941**	**29,036**

With regards to Table 4.5, ‘Total UFRs’ were UFRs disposed of by homeowners, landscape companies, and tree care companies. ‘Recoverable UFRs’ were assumed to be fully recoverable, meaning that they were not commingled or contaminated. The question is whether or not it is economically feasible to recover this “waste.” Several utilization options are discussed further in subsequent sections.

4.3. Urban Forest Residues and Alternative Uses

Objective four addressed whether the amount of urban forest residues deposited in landfills will decrease when sorted and utilized for products such as landscape material, firewood, compost, fuel for bio-energy plants, or other value-added products. The previous section showed what percentages of UFRs were utilized by each city in the Tri-City Area as well as the overall percentage of utilization. There were many factors that tie into whether UFRs were being utilized or not. These factors included the landfills method of utilization (if any), the size of the tree care company, the types of equipment and services they provided, the location of their job site, and most importantly, opportunities for utilizing this renewable resource.

The size of a tree care company can directly affect the decision on where UFRs were taken. For instance, a smaller company (one owner/employee or one to two crews) will most likely generate less profit compared to a larger, more established company (three to four crews). Although a majority of the tree care companies were willing to dispose of UFRs in places other than landfills, it was often not economical to dispose of UFRs at an alternative site with higher tipping fees. For example, one company in Fort

Collins reported that all UFRs handled were taken to the landfill. This company had one employee - the owner.

The type of services a tree care company provided also directly affected the decision of UFR disposal. Depending on the type of equipment owned, a company may be more or less capable of providing certain services. Services may include small to large tree pruning or removals, stump grinding, chipping brush, etc. Most likely smaller companies own less equipment or lower quality equipment to complete services they might provide. For example, some small operations in the Tri-City Area did not have chippers. In this case, getting rid of brush typically costs more than getting rid of wood chips (as most wood chips were disposed of for no tip fee). However, a larger company generally has a wider array of equipment and employees to get the job done. An example of how this might be an advantage is as follows: a larger company typically sends a crew out to do a large tree removal. They bring a chipper, possibly a bucket truck, and a grapple truck. In this case, small diameter brush and logs are chipped depending on the maximum chipping diameter of the chipper (usually anywhere from six to eighteen inches). All material left over is then loaded on the grapple truck and hauled to a nearby wood recycler. If over half the logs on the grapple truck exceed the maximum chipping diameter they are not accepted by the wood recycler. At this point, the logs would either be hauled to another wood recycler with a larger maximum chipping diameter (which may be located in an adjacent city) or hauled to the local landfill.

Another factor that discouraged UFR utilization was the location where they were being generated. The convenience of a disposal site nearby may be more economically feasible than driving across town to a recycling center. This may also lead to disposing

UFRs in the landfill because the tipping fees may sound more appealing to a company than a wood recycler with higher tipping fees. This also depends directly on what type of UFRs a company is trying to discard (i.e. wood chips, brush, or logs).

Other opportunities for utilizing UFRs have been implemented throughout the country, which includes sawing urban timber, fuel for bio-energy plants, cellulosic ethanol plants, etc. For many years, the Tri-City Area has primarily utilized UFRs as mulch or has discarded the residues in nearby landfills. While recycling UFRs into mulch has its benefits, larger diameter trees could be recycled into higher value-added products (i.e. sawn timber for use in cabinetry, tongue and groove flooring, etc.). The Tri-City Area had infrastructure for collecting resource (i.e. the tree care industry) but the development of sort yards or centralized collection sites may be necessary for utilizing the remaining 39 percent of UFRs not currently utilized. Creating such opportunities will help decrease the amount of UFRs entering the landfill, decrease the amount of UFRs being processed into mulch, and utilize large diameter wood to produce relatively higher value products. Opportunities within the Tri-City Area will be discussed further in the next section.

CHAPTER 5: Conclusion and Recommendations

5.1. State Information

Trees within an urban setting are not considered a popular recyclable item but this study shows that a potential renewable resource exists in the Tri-City Area. With regards to objective one, it was found that approximately 36,435 tons of UFRs were produced annually by tree care companies within the Tri-City Area. This constitutes a large amount of UFRs that are potentially available for utilization. Objective two findings revealed that 97 percent of tree care companies within the Tri-City Area were willing to dispose of UFRs in alternative places rather than hauling them to the landfill. Based on these results, new, alternative uses of UFRs can reduce the amount of UFRs entering landfills. Objective three findings indicated that about 60 percent of UFRs in the Tri-City Area were currently being utilized. A majority of those UFRs were utilized as mulch and were used in landscape projects throughout northern Colorado or were further processed into compost. This suggests that 40 percent of UFRs in the Tri-City Area were not currently utilized and that value-added markets need to be developed to utilize a higher percentage of UFRs. Based on the percent of UFRs currently utilized versus the percent not utilized, and the willingness of tree care companies to dispose alternatively, objective four was concluded as follows: UFRs entering the landfills will decrease with the increased use of portable band-sawmills along the Front Range and construction of bio-energy plants, which will aid in the development of value-added products produced from UFRs.

Because mulch was currently the primary market for UFRs, continued development of this market will remain important, but UFRs greater than fifteen to eighteen inches in diameter should be processed into higher value products. Through continuous research and most importantly education and outreach, biomass utilization will continue to grow, developing new jobs for the Tri-City residents, extending the life of our local landfills, turning urban forest residues into a renewable resource, and allowing us to utilize these resources to their full advantage.

5.2. Recommendations

5.2.1. Objective One

Based on findings, it was estimated that 36,435 tons of UFRs were produced annually in the Tri-City Area. This substantial amount of UFRs produced by tree care companies provides a great source for current/future low-value and high value markets. Opportunities and recommendations for these UFRs will be discussed subsequently.

5.2.2. Objective Two

An estimated 97 percent of the participating tree care companies in the Tri-City Area were willing to dispose of UFRs in places other than landfills. In other words, if opportunities arise for alternative disposal and utilization, the main resource generator (tree care industry) would try to take advantage of these opportunities. There are several strategies that may increase the willingness rate to 100 percent, which include tax cuts, local ordinances and/or economic incentives.

Tax credits/cuts for tree care companies could be a great way to deter companies from disposing UFRs in landfills. This could be a system similar to the way wood recyclers provide annual reports. Each year, within the Tri-City Area, wood recyclers have to submit an annual report on the amount of feedstock materials that were received and used to the Colorado Department of Public Health and Environment (CDPHE). A tree care company could be responsible for the same type of report and submit figures for feedstock generated and where it was disposed. Based on the amount of UFRs disposed of at disposal sites (other than landfills), the tree care company could receive a tax credit or cut for recycling residues. A tax credit/cut would need to be implemented through state or county legislature where tree care companies paying state or county taxes may be credited depending on the disposal of UFRs at alternative sites. This type of incentive could be initiated similar to energy credits received by using alternative energy such as solar panels, biomass boilers, etc. This would in turn encourage tree care companies to dispose of UFRs in alternative ways.

Ordinances may be another option for decreasing the amount of UFRs entering landfills. Throughout the country, several states have developed ordinances banning all disposals of UFRs in landfills. An example of a successful diversion project is out of Portland, Oregon. In 1996, Portland instituted a mandatory commercial recycling program combined with its well-established residential waste diversion program allowing the city to divert nearly half of its total municipal solid waste. Portland diverted 40 percent of its residential waste: 21 percent through curbside recycling, 17 percent through yard debris programs, and 2 percent through their bottle bill (Institute for Local Self-Reliance 1999). Examples of how Portland diverted their yard trimmings were through curbside collection programs, fall leaf collection programs, private composters and by providing an abundant amount of drop-off collection sites. The participation incentives for these two programs were reduced trash fees through increased waste diversion (Institute for Local Self-Reliance 1999).

Among the many UFR diversion programs throughout the country, the development of new programs such as curbside yard debris pick-up or centralized UFR collection sites could help reduce the residues from entering the landfills. One barrier that currently exists in the Tri-City Area is ordinances on insect and disease sanitation and disposal. Because these infested residues are currently required to be disposed of in landfills for proper sanitation, it creates a barrier that reduces the assumed 100 percent availability of UFRs. The development and utilization of current debarking, milling or composting programs may help mitigate further spread of insect and disease and in return keep a usable resource from entering the landfill.

Another way to increase the recycling of UFRs may be economic incentives. Economic incentives could include reduced haul-away fees for residents on yard waste to keep regular MSW separate of generated UFRs. Also, if landfills within the Tri-City Area were to begin recycling programs for UFRs, the landfill could reduce tipping fees for tree care companies who are supplying UFRs. If this were to be put in place, the landfill would need to find other outlets for the residues (i.e. bio-energy plants) and develop a partnership with these outlets to help cover the processing and handling costs.

5.2.3. Objective Three

Based on findings, 60.3 percent of UFRs were currently utilized in the Tri-City Area, most likely by wood recyclers (landscape retail companies), firewood retailers, and/or homeowners, while 39.7 percent was not utilized. While a high percentage of UFRs were being processed into mulch, there were other end uses that may be considered more value-added products. For example, compost is a product that usually generates a higher profit margin than mulch even though the composting process may take more time and money. Compost requires mulch or cellulosic material as an ingredient for its process. Other value-added products may include larger diameter trees sawn for timber. Alternative opportunities are being developed in the Tri-City Area and its surrounding areas. The use of portable band saw mills are popping up in Fort Collins and Boulder to mill urban timber. As mentioned earlier, local sawmills currently frown upon milling urban timber due to the contamination of nails or other metals engulfed in trees over time, which may lead to the destruction of expensive saw blades ($300 to $400). While portable band sawmill owners do not appreciate nails in the wood either, they are not as discouraged due to cheaper blades ($15 to $25), which are easier to replace. Other benefits of the portable band-sawmills are local products being generated that could support the surrounding economy if a market was developed. With utilizing larger diameter trees (greater than 15 inches) for value-added products, this may decrease the amount of large diameter wood processed into mulch and open up another outlet for the 39.7 percent of UFRs not currently being utilized.

Another opportunity for increased utilization of UFRs is bio-energy applications, which include co-firing woody biomass with coal to generate electricity, facility heating, and production of liquid fuels such as cellulosic ethanol. Utilizing UFRs as a renewable source of bio-energy would also decrease our reliance on fossil fuels. With the possible exception of facility heating, bio-energy projects generally must be relatively large-scale to be economical. A large-scale bio-energy project in the Tri-City Area would require multiple sources of woody biomass including wood processing, forest, and agricultural residues, in addition to UFRs. However, such a project could utilize most of the UFRs generated annually in the area. Economic barriers that currently exist will push the construction of large-scale bio-energy projects such as cellulosic ethanol facilities further off into the future, making this more a long-term opportunity. Nonetheless, partnering with local tree care companies may help establish a steady renewable supply of woody biomass required if future bio-energy projects are to be implemented.

5.2.4. Objective Four

Objective four addressed whether UFRs entering landfills would decrease if residents and tree care companies sorted and disposed of residues in areas other than landfills. The wood recyclers in the Tri-City Area can be considered centralized locations to dispose of UFRs. To divert 100 percent of UFRs from entering local landfills, economical sorting is imperative to separate low-value UFRs (i.e. mulch, brush, etc.) from high-value UFRs (i.e. larger limbs and whole logs). It is most likely not feasible for a tree care company to sort due to the “time is money” factor discussed earlier. The development of sort yards or collection sites would be the most feasible area to sort UFRs. Benefits of developing such a practice includes use of all UFRs generated, reducing high-value UFRs from being ground into mulch, increasing the development of more value-added products, creating local jobs, and extending the life of the local landfills.

Other factors that need to be discussed are implementation of biomass emergency plans and education and outreach to UFR generators and users. The implementation of biomass emergency plans could help reduce UFRs from entering the landfill in the future. A good example of why such a plan is necessary would be the tornado that went through

Windsor, CO, in May 2008. Because of the size of the tornado, a great amount of damage was done to the town of Windsor creating huge amounts of UFRs, which became comingled with other debris. Implementing an emergency plan will help with organization if such a disaster were to occur again.

Below are some pictures (Figure 5.1 through 5.3) of the Town of Windsor after the tornado went through. The damage was so great that there was no rhyme or reason to cleaning up downed trees, houses, and power lines. As crews of all types were cleaning up streets, parks, and various neighborhoods, all comingled debris where placed in an empty lot east of town.

Figure 5.1: Pile of Debris in Windsor, Colorado after May 2008 Tornado

Standing on top of the north side of the pile looking south; notice all the UFRs as well as windows, sheet metal, and other comingled waste.

Figure 5.2: Top of comingled debris pile, Windsor, CO

City Forestry Divisions and tree care companies working on removing hazardous limbs and trees to clean up the parks of Windsor.

Figure 5.3: Tornado Cleanup in Windsor, CO

The Town of Windsor was still working on this pile and contracted out for all UFRs to be ground after being separated from the rest of the debris. Implementing such a plan will also help in other “what if” scenarios such as heavy snow storms or high winds that are common along the Colorado Front Range and the occurrence of mountain pine beetle moving east from the Continental Divide and emerald ash borer moving in from the Mid-West.

Another factor in biomass utilization is education and outreach. Many companies, residents, and city governments are not fully educated on biomass utilization or hesitate to initiate such programs. Educating all UFR generators and users could help in reducing residues from entering landfills as well as develop a market for value-added products as previously discussed. For example, the City of Fort Collins last summer (2008) worked on developing a plan to divert all UFRs from entering the Larimer County Landfill (LCL). Both the Natural Resource Department and the Forestry Division looked for alternative places to stock pile UFRs greater than fifteen inches in diameter (Forestry Divisions maximum chipping diameter) and discussed in detail what could be done with the product locally. Before the development of the diversion plan, Forestry was diverting about 50 percent of their UFRs and after a three month pilot study the Forestry Division diverted 95 percent of the UFRs that they handled. The five percent not being diverted was infested with insect and disease, which was currently required to be buried in a landfill through city ordinance. Although the city has contracted with A1 Organics to grind UFRs twice a year, it was a step in the right direction and they were doing their part to utilize UFRs rather than sending them to the landfill. They have also made some other connections including one with a local portable band sawmill and helping supply this small operation with usable urban timber. During the three-month pilot study, the Forestry Division diverted 205 tons of wood from the landfill and converted it to 875 cubic yards of mulch which is going to the Poudre School District. Below are pictures (Figure 5.4 through 5.6) of the Forestry Division during their first grinding through A1.

Forestry Division's stock pile out at Hoffman Mill Road: A combination of mostly large wood with some brush to make the grinding process smoother.

Figure 5.4: Fort Collins Forestry Division's UFR pile from Diversion Project

Early morning fog assisting in the beginning stages of the grinding process.

Finished product of grinding to the left and turned out to be really nice mulch.

Figure 5.5: A1 Organics grind Diverted UFRs

LITERATURE CITED

A1 Organics. 2007. *Composting Facility Annual Reporting Form – Calendar Year 2007*. Via Todd Loose.

Antares Group, Inc. June 1999. *Biomass Residue Supply Curve for the United States (Update).* Prepared for the U.S. Dept. of Energy's Biomass Power Program and the National Renewable Energy Laboratory. Washington, D.C. and Golden, CO.

Bratkovich, Stephen M. 2001. *Utilizing Municipal Trees: Ideas From Across The Country.* NA-TP-06-01: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry.

Bratkovich, Steve; Bowyer, Jim; Fernholz, Kathryn; Lindburg, Alison. 2008. *Urban Tree Utililization and Why It Matters.* The Citizen Forester. No. 124.

Colorado Department of Public Health and Environment. 2006 facts and figures. <www.cdphe.state.co.us>

City of Colorado Springs. "Colorado Springs City Forestry Division." 2007. Apr. 2008. <http://www.springsgov.com/SectionIndex.asp?SectionID=43>.

Fehrs, J.E. 1999. *Secondary Mill Residues and Urban Wood Waste Quantities in the United States: Final Report.* Northern Regional Biomass Program, Washington D.C.

Institute for Local Self-Reliance. <u>Residential Program Summary</u>. 1999.

International Society of Arboriculture. *Municipal Specialist Certification Study Guide,* 2008.

Kane, B. Feb. 2006. *Values, Benefits and Costs of Urban Trees.* University of Massachusetts, Virginia Tech Publication Number: 420-181.

McNeil Technologies, Inc. Jefferson County Biomass Feasibility Study. 2005. March 2008.

Larimer County Landfill. Larimer County Landfill Wood Diversion Project. Fort Collins, 2002. Feb. 2008. <http://www.larimer.org/solidwaste/holnam.htm>.

Lydersen, Kari. Feb. 2009. *Scientists: Pace of Climate Change Exceeds Estimates.* Washington Post. < http://www.greenchange.org/article.php?id=3990>.

McKeever, David B., Kenneth E. Skog. 2003. *Urban Tree and Woody Yard Residues: Another Wood Resource.* Res. Note FPL-RN-0290. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.

McKeever, David. "Wood Residual Quantities in the United States." Published in BioCycle Journal of Composting & Recycling. Emmaus, PA. January 1998. 65-68 p.

McKeever, David B. 2004. *Inventories of Woody Residues and Solid Wood Waste in the United States.* Forest Products Laboratory, USDA Forest Service.

McNeil Tecnologies, Inc. 2003. Feasibility Study of a Biomass Energy System for Boulder County Parks Department. McNeil Technologies, Inc. 143 Union Blvd. Suite 900. Lakewood, CO 80228. (303) 273-0071.

McNeil Technologies, Inc. 2006…

McPherson, E.G.; Sacamano, P.L.; Wensmen, S. 1993. *Modeling Benefits and Costs of Community Tree Plantings*. Davis, CA: USDA Forest Service, Pacific Southwest Research Station. 170 p.

McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Maco, S.E.; Xiao, Q.; Hoefer, P.J. 2004. *Northern Mountain and Prairie Community Tree Guide: Benefits, Costs and Strategic Planting.* Davis, CA: USDA Forest Servise, Pacific Southwest Research Station. 7-16 p.

MSW Consultants. 2007. *Two-Season Waste Composition Study.* Final report. Larimer County Landfill, Larimer County, CO: May.

NEOS Corporation. *Lignocellulosic Feedstock Resource Assessment.* Prepared for the National Renewable Energy Laboratory. Golden, CO. NREL/TP-580-24189. September 1998.

NEOS Corporation. *Urban tree residues: Results of the First National Inventory.* Prepared for the International Society of Arboriculture Research Trust, Alleghany Power Service Corporation, and National Arborist Foundation. September 1994.

Nowak, David J.; Noble, M.H.; Sisinni, S.M.; Dwyer, J.F. 2001. *People & Trees: Assessing the US urban forest resource.* Journal of Forestry. 99(3): 37-42.

Portland Bureau of Environmental Services. Portland, Oregon Municipal Solid Waste Reduction 50%. Portland, 1999. 117-122.

Rooney, Tim. September 1998. *Lignocellulosic Feedstock Resource Assessment.* NEOS Corporation. Lakewood, CO.

Thompson, Richard P. 2003. *The State of Urban and Community Forestry in California*. Urban Forest Ecosystems Institute, California Polytechnic State University. San Luis Obispo, California. 25 p.

U.S. Census Bureau. 2003. Metropolitan and Micropolitan Statistical Areas. <http://www.census.gov/population/www/metroareas/aboutmetro.html>

U.S. Census Bureau. 2006. Colorado quick facts. <www.census.gov>

U.S. Environmental Protection Agency. *Characterization of Municipal Solid Waste in the United States.* EPA530-R-98-007. Washington, D.C. May 1998. Prepared by Franklin Associates, Prairie Village, KS.

U.S. Environmental Protection Agency, Office of Solid Waste. 2003. Municipal Solid Waste in the United States: 2001 facts and figures. EPA530-R-03-011. <http://www.epa.gov/epaoswer/non-hw/muncpl/pubs/msw2001.pdf>

U.S. Environmental Protection Agency, Office of Solid Waste. 2006. Materials Generated in the Municipal Waste Stream, 1960 to 2006. <http://www.epa.gov/epaoswer/non-hw/muncpl.pdf>

U.S. Environmental Protection Agency, Office of Solid Waste. 2008. Municipal Solid Waste in the United States: 2007 Facts and Figures. <http://www.epa.gov/osw/nonhaz/municipal/pubs/msw07-rpt.pdf>

Wang, Jingxin; Grushecky, S.; McNeel, J. 2006. *Biomass Resources, Uses, and Opportunities in West Virginia.* West Virginia University, Biomaterials Center, Division of Forestry and Natural Resources. Morgantown, WV.

Ward, Julie E.; Mackes, Kurt H.; Lynch, Dennis L. 2004. *Wood Wastes and Residues Generated along the Colorado Front Range as a Potential Fuel Source*. Res. Pap. RMRS-RP-50. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 9 p.

Wiltsee, G. 1999. *Urban Wood Waste Resource Assessment*. NREL/SR-570-25918. Golden, CO: U.S. Department of Energy, National Renewable Energy Lab. 17-18.

APPENDIX A: Contacts

City of Fort Collins

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Tim Buchanan, Ralph Zentz, Del Bernhardt, Forestry Division - (970) 221-6660

City of Loveland

Bruce Philbrick, Solid Waste Maintenance & Operations - (970) 962-2609

Rob MacDonald, Forestry Division (970) 962-3441

City of Greeley

Karen Scopel, Natural Resource Department - (970) 350-9783

Shiloh Hatcher, Forestry Division - (970) 339-2436

Wood Recycling Locations

A1 Organics - (970) 454-3532

ABS - (970) 397-8284

Hagemans Earth Cycle, INC - (970) 221-7173

Greeley Greencycle Center - Contact the City of Greeley

Loveland Recycle Center - Contact Bruce Philbrick

Landfills

Larimer County Landfill - (970) 498-5762

Waste Management – North Weld County Landfill - (970) 686-2800

APPENDIX B: UFR Study Questions for Governments/Companies

→ How many employees does your company or department have?

→How many crews do you have going out per day?

→What kind of management or work does your company do in regards to biomass generation?

→Examples: Forest management, fire mitigation, tree pruning, removal and stump grinding.

→How many chip trucks, chippers and grapple trucks does your company have?

→Does your company own a grapple truck?

→If so, where do you take the residues generated?

→Examples: Landfill, Nurseries, Hagemans, etc.

→With the wood chips you generate, where does your company take the chip?

→ Examples: Landfill, Nurseries, Hagemans, etc.

→What is the extent of your work area?

→Examples: Only within City Limits; Several different Counties (Larimer and Weld); or Many different Counties (Larimer, Weld, Boulder, Routt, etc.)

APPENDIX C: Insects and Disease Totals by City

Fort Collins: Courtesy of Ralph Zentz, Assistant City Forester

Ips beetle									
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Infestations	0	2	44	217	118	12	4	2	24

DED									
Year	1973	1974	1975	1976	1977	1978	1979	1980	1981
Infestations	53	148	90	132	119	68	118	89	75
	1982	1983	1984	1985	1986	1987	1988	1989	1990
	45	29	19	37	25	28	23	21	13
	1991	1992	1993	1994	1995	1996	1997	1998	1999
	11	7	4	8	9	10	4	3	10
	2000	2001	2002	2003	2004	2005	2006	2007	2008
	9	9	12	29	17	12	9	4	4

Loveland: Courtesy of Rob MacDonald, Forestry Specialist

Ips beetle	
Year	2007
Infestations	20

DED	
Year	2007
Infestations	1

Greeley: Courtesy of Shiloh Hatcher, Forestry Supervisor

Ips beetle									
Year	1995	1996	1997	1998	1999	2000	2001	2002	2003
Infestations	36	18	27	50	70	21	8	19	134
	2004	2005	2006	2007	2008				
	177	60	25	45	28				

DED			
Year	2005	2006	2007
Infestations	2	1	1