Urban Forest Waste Generation and Utilization by Municipal and Private Arboricultural Operations in Virginia

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ABSTRACT

Urban forest waste utilization has been identified as an essential component of the sustainable urban forest management system. To compile baseline data on generation and utilization of urban forest waste (UFW) in Virginia, 91 urbanized municipalities and 828 International Society of Arboriculture Certified Arborists operating privately in Virginia were invited to participate in a web-based survey. Results indicate that nearly three quarters (74%) of all respondents reported that their local operation generates UFW. For private arborists this included logs, brush, and chips generated by arboricultural practices, and for municipalities this included similar material generated by an in-house tree crew and similar material collected curbside from residents. Two-thirds (67%) of respondents could not estimate the amount of UFW generated by their local operations, but nearly half (47%) could report on its fate. The mean total amount generated was 315 tons/year/employee, or 945 tons/year for a typical tree crew. On average, both municipalities and private operations reported disposing less than 25% of their UFW at a solid waste facility. The majority of logs were utilized to produce firewood or lumber, while the majority of chips and brush were utilized to produce mulch or compost. Municipal operations utilized significantly more chips in-house compared to private arboricultural operations ($p = 0.041$). Regardless of operation type or UFW type, UFW is rarely left on-site, which indicates that UFW is being handled and transported in the majority of situations. If UFW is being mobilized, then perhaps there might be additional opportunities to divert materials into utilization streams rather than disposal streams. When characterizing the

respondents' perceptions of urban forest waste utilization, two-thirds of respondents (65%) either agreed or strongly agreed that UFW utilization is a major issue for the urban forestry industry currently. An even higher percentage (76%) agreed or strongly agreed that UFW utilization will be a major issue for the urban forestry industry in the future. Results also indicate that the primary incentives to utilization were the avoidance of disposal fees and shipping costs. Municipal employees cited a lack of equipment as the primary barrier to greater waste utilization and frequently identified educational seminars or conferences as a technical assistance need. In contrast, private-sector arborists cited a lack of local processors as their primary barrier and frequently identified local facilities for receiving, sorting, and stockpiling UFW as a technical assistance need. These varying perceptions should be taken into account when developing future educational or technical programs aimed at increasing utilization in Virginia.

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CHAPTER 1 – INTRODUCTION

As global populations increase, more and more people are congregating in cities and urbanized areas. The State of Virginia is no exception to this trend. Between 2000 and 2010, Virginia's population grew by about 1 million (US Census Bureau 2010b), and is expected to grow by another 1.6 million between 2010 and 2030 (Weldon Cooper Center for Public Service 2012). In addition, 75% of all Virginians reside in urban areas (US Census Bureau 2010c), placing strain on both city infrastructure and natural resources. Through tree plantings and canopy restoration projects, there are also a substantial number of trees growing in Virginia's urban areas. Recent studies estimate tree cover in urban and community areas of Virginia at 401,000 hectares (Nowak and Greenfield 2012), or approximately 166 million trees (Nowak and Greenfield 2009).

Urban forests provide a wealth of benefits to Virginia's communities. They help reduce the urban heat island effect, mitigate stormwater runoff, improve air quality, sequester carbon dioxide, and foster a more livable environment (Dywer et al. 1992, McPherson et al. 1997, Nowak and Crane 2002, Nowak et al. 2008). Many urban localities in Virginia have promoted conservation of remnant forests and emphasized tree planting along with development. However, issues arise when urban trees need to be pruned to maintain their health, safety, or aesthetics, or need to be removed due to pest problems, environmental stresses, or construction and development. The resources consumed and waste generated from the process of tree removal and disposal can detract from the benefits and values that the urban forest provides. Utilization of urban forest waste from tree pruning and removal can reduce the economic and environmental costs of disposal, increase urban forest sustainability, and even provide business

opportunities for green industry professionals seeking to extract residual value from the waste (Nowak et al. 2001, Bratkovich et al. 2007, MacFarlane 2008).

Urban forest waste (UFW) can be described collectively as the logs, brush, and chips generated using arboricultural practices on an urban or community tree grown on residential or municipal lands (Tree Care Industry Association, Inc. 2013). Historically, much of this material has been shipped and disposed in landfills rather than utilized as a renewable natural resource (NEOS Corporation 1993, Nowak et al. 2001, Bratkovich et al. 2008). Urban forestry experts have identified UFW utilization in particular as an essential component of the sustainable urban forest management system (Clark et al. 1997), but little is known about the existing conditions and perceptions of utilization within Virginia. It is believed that more UFW utilization will improve the economic and environmental sustainability of the urban forestry industry, but more must be known about the state of UFW utilization in Virginia before that belief can be confirmed. Therefore, there is a need to compile baseline data on UFW generation and utilization in Virginia's urban areas.

There are two primary producers of UFW in Virginia – private arboricultural operations and municipal arboricultural operations. Private operations consist of tree care companies, landscape companies, electric service providers, and various institutions such as universities and arboreta. Municipal operations vary by locality, but are limited to the government departments tasked with maintaining municipal trees and/or collecting UFW deposited by residents for curbside pickup. Electric service providers commonly contract private operations to maintain their rights-of-way, and private operations are occasionally contracted by municipalities to perform work on municipal trees. The majority of UFW generated in Virginia can be accounted for when combining the UFW generated by both the municipal and the private sector.

Given the variability in organization between municipal and private arboricultural operations, it is important to distinguish between the two when investigating the practices and perceptions of UFW utilization in Virginia. Municipal operations are government entities that must conform to regulatory and budgetary constraints, while private operations are businesses invested in generating revenue. The incentives and barriers to further utilization are different between each sector, as are the opportunities for outreach and extension. As a result, the findings of this research have been divided and compared between municipal and private responses.

The goal of this research project was to generate baseline data to inform statewide strategic planning to increase UFW utilization. The objective of this project was to better understand the following concepts and to answer the associated research questions:

1. The first objective was to understand the amount of UFW being generated in Virginia. How much of each UFW type (logs, chips, and brush) is being generated by municipal and private operations? Are there any significant differences between municipal and private operations?
2. The second objective was to understand the fate of UFW generated in Virginia. Where is UFW being deposited after it is generated? How much is being utilized? What sort of products are being produced? Are there any significant differences between municipal and private operations?
3. The third objective was to understand perceptions of incentives and barriers to father UFW utilization in Virginia, as well as educational and technical assistance needs. Are there any significant differences between the perceptions of municipal employees and private arborists?

CHAPTER 2 – LITERATURE REVIEW

2.1 Urban Forest Waste in the National Municipal Solid Waste Stream and Beyond

Every two years, the US Environmental Protection Agency (EPA) publishes a report summarizing the amount of municipal solid waste (MSW) generated, recovered, and disposed of annually in the US. The term "generated" refers to the amount of material initially received by MSW facilities, the term "recovered" refers to the amount of generated material that is reused or repurposed, and the term "disposed" refers to the amount of material that must be deposited in landfills. In 2011, 250 million tons of MSW were generated in the US – down slightly from the peak of 256 million tons in 2007 (US Environmental Protection Agency 2011).

While these estimates exclude construction and demolition materials, the EPA does categorize "wood" and "yard trimmings" as MSW. Sources such as furniture, cabinets, and wood pallets are classified as wood, while yard trimmings include "grass, leaves, and tree and brush trimmings from residential, institutional, and commercial sources" (US Environmental Protection Agency 2011). According to the EPA's report, "limited data are available on the composition of yard trimmings, [but] it is estimated that the average composition by weight is about 50% grass, 25% brush, and 25% leaves". Therefore, the amount of UFW received by MSW facilities from residential, institutional, and commercial sources across the country can roughly be estimated as 25% of the total yard trimmings received. Using that estimate, MSW facilities nationwide received roughly 8.4 million tons of brush in 2011, more than half of which (4.8 million tons) was recovered for compost or mulch production (US Environmental Protection Agency 2011).

Other national estimates of UFW go beyond the municipal solid waste stream, and the figures understandably increase. The first national inventory of UFW, conducted in 1993, was a mail and telephone survey of commercial tree care firms, municipal parks and recreation departments, municipal tree care divisions, electric utility rights-of-way maintenance firms, landscape firms, and land clearance firms (NEOS Corporation 1994). The study estimated the amount of UFW generated nationally to be 25 million tons per year. Twenty years later, David Nowak of the US Forest Service estimates that the total above ground dry weight biomass of urban trees in the United States is 1.3 billion tons. Using a 2% annual mortality rate, Nowak estimates UFW generation to be 26 million tons per year (Nowak 2014), a figure consistent with the NEOS study. Another study based in Michigan extrapolated local data to the national level and estimated the amount of biomass produced from urban tree removals is 22.2 million tons per year (Sherrill and MacFarland 2007), also consistent with the previously reported studies.

2.2 Urban Forest Waste in Virginia's Municipal Solid Waste Stream and Beyond

The State of Virginia requires its Department of Environmental Quality (VDEQ) to release an annual report summarizing the amount of solid waste received by the state's MSW facilities. Unlike the EPA's national report, VDEQ does not specify how much of its "vegetative/yard waste" category consists of UFW. Therefore, even though UFW is accounted for when it arrives at a MSW facility, specific data for UFW amount and fate is impossible to calculate. For perspective, **Table 1** shows the fate of all vegetative/yard waste in Virginia by weight (tons) and percentage of the total over the last three years (VDEQ 2011, VDEQ 2012, VDEQ 2013). Virginia has landfilled less than 8% of the vegetative/yard waste received by its MSW facilities since 2010 and instead has recycled, composted, or mulched the vast majority.

Roughly half of the material is mulched at the landfill and another quarter is turned into compost. These products are then either given away or sold to the community.

Table 1: Vegetative/yard waste (tons and percent of total) received by municipal solid waste facilities in Virginia between 2010 and 2013 (VDEQ 2011, VDEQ 2012, VDEQ 2013, VDEQ 2014).

Year	Landfilled	Recycled[1]	Composted	Mulched	Other[2]	Totals
2010	17,408	38,737	116,550	216,147	63,106	451,948
	4%	8%	26%	48%	14%	100%
2011	38,115	43,680	138,711	277,429	65,933	563,868
	7%	8%	24%	49%	12%	100%
2012	19,608	34,268	120,988	261,470	31,113	467,447
	4%	7%	26%	56%	7%	100%
2013	28,671	41,393	102,905	210,226	41,775	424,970
	7%	10%	24%	49%	10%	100%

[1] Recycled on/offsite.

[2] Stored on/offsite, treated or disposed offsite, among others.

While EPA and VDEQ data capture the amount and fate of the "yard trimmings" and "vegetative/yard waste" that reach MSW facilities from residential, institutional, and commercial sources, it does not account for UFW that avoids the MSW stream entirely. In Virginia, not only is the exact composition of UFW within the VDEQ's category of "vegetative/yard waste" unknown, but the amount and fate of UFW being utilized or disposed outside the MSW stream is left undocumented by the EPA and VDEQ reports. This lack of data available at the state and municipal level has been widely documented (Nowak 2001, Nowak and Crane 2002, McKeever and Skog 2003, MacFarlane 2008), but a few regional studies have been conducted. A 13-county study in southeast Michigan (MacFarlane 2008) estimated that within that sample area, UFW from routine urban tree removals was generated at a rate of 442,009 tons per year, or 0.81 tons per hectare per year. However, this region has been heavily invested by the Emerald Ash Borer, so removals are likely occurring at a higher rate due to the insects' propensity to kill ash trees. Another study examined carbon storage and sequestration by urban trees in the US

(Nowak and Crane 2002), and reported total carbon storage by urban trees in Virginia to be 28,960,000 tons – sixth highest in the country. Nowak later revised this estimate to 18,000,000 tons in another publication (Nowak and Greenfield 2009). For that study, carbon storage was calculated by multiplying total urban tree dry-weight biomass by 0.5, so after calculating total biomass and using a 2% mortality rate, UFW generated from urban trees in Virginia can be estimated at around 720,000 tons per year.

2.3 Opportunities for Urban Forest Waste Utilization

There are a wide variety of utilization efforts across the country aimed at intercepting UFW before it ends up at an MSW facility. Not only do these efforts result in disposal cost avoidances, but they provide economic opportunities as well. A key to cost-effective UFW utilization is to find the highest and best use for a given material. According to a working draft of the ANSI A300 Part 11 Standard for Urban Forest Harvesting, "wood should be used at the highest possible value that is appropriate given the quality, quantity, and marketability of the available resource" (Tree Care Industry Association, Inc. 2013). The same document defines an urban forest product (UFP) as "a wood product produced from an urban or community tree harvested from residential or public lands." Higher quality UFW logs are best used to create high-quality UFPs, while lower quality UFW can be used to produce lower quality UFPs (**Table 2**). High-quality UFW logs of marketable size and length make up a smaller fraction of the overall urban wood resource than lower-quality UFW. Due to this relative rarity, arborists and urban foresters should always be on the lookout for high quality logs when planning tree removals. The ANSI A300 Part 11 Standard is intended to outline the proper practices of harvesting UFW logs, and states "tree removal practices for urban forest product utilization shall preserve the integrity of the log so as to maximize potential value".

Table 2: Urban forest products (UFPs) sorted by quality and harvest form (Tree Care Industry Association, Inc. 2013).

Higher Quality UFPs (Produced from urban wood harvested as **logs**)	**Medium Quality UFPs** (Also produced from urban wood harvested as **logs**)	**Lower Quality UFPs** (Produced from **chips or brush**)
Veneer	Lumber	Mulch
Furniture	Pallets	Compost
Cabinetry	Packaging Crates	Biomass
Flooring	Firewood	Pellets
Art/Novelty Items		

Unless markets for raw UFW material like firewood producers or wood energy plants exist, local possessors who can convert logs or chips into marketable material are needed. Logs must be sawn and dried before they can be crafted into products, and chips need to be mulched, composted, or pelletized before they can be sold. Large-scale wood products industries often prefer to source their material from traditional forestry operations, but understanding and catering to traditional industry specifications can provide further opportunities. Arborists and urban foresters need to develop relationships with as many processors and producers as possible if they want to maximize the marketability of the UFW they produce.

Interviews conducted by Dovetail Partners, Inc. (Howe et al. 2013) indicate that producers of UFW believe further utilization can provide beneficial opportunities. Perceived opportunities include the avoidance of tipping fees, environmental stewardship, community engagement, and the creation of additional markets by involving the traditional forest products industry. Another commonly reported theme was the opportunity to provide more consistent production through best management practices, educational campaigns, and legislative mandates.

UFW utilization efforts are organized at a variety of scales. There are small business owners like George Hessenthaler, who runs Urban Forest Wood Works in Logan, UT.

Hessenthaler purchases high-quality urban wood from arborists and creates "jewelry boxes, gun cases, briefcases, urns, and other treasures" (Turner 2013). Over 20 years, Hessenthaler estimates he has sawn 500,000 board feet of lumber, all from fallen local trees – keeping them from being turned into mulch or landfilled.

Then there are efforts underway at the municipal level. The Baltimore Wood Project, a joint initiative between the US Forest Service and the City of Baltimore, attempts to assess, salvage, and sort urban wood resources found throughout the city. They have built an urban sort yard that can process material and "maximize the amount of reclaimed wood suitable for high-value, marketable products and provide a steady stream of lower-quality wood for mulch, compost and fuel" (US Forest Service Research & Development 2013). Similar facilities have been implemented in North Carolina, Washington, and Michigan that have successfully increased utilization and even generated revenue (US Forest Service Forest Products Laboratory 2002).

Efforts to better utilize UFW are being carried out at the regional scale as well. A report by Dovetail Partners, Inc. outlined a framework for "Using Industrial Clusters to Build an Urban Wood Utilization Program" and used the Twin Cities (Minneapolis-St. Paul, MN) as their focus area (Bratkovich and Fernholtz 2010). The concept of industry clusters feeds off of existing, mutually beneficial relationships between stakeholders in the urban wood utilization network and recommends ways to bolster those relationships economically. The report illuminates a variety of markets for urban wood in the area and demonstrates how multiple stakeholders within the same business niche can find ways to utilize urban wood resources without sending too much material to the landfill or working at cross-purposes. Similar networking initiatives have been implemented in Southeast Michigan (Urbanwood Project 2014) and the Washington DC area

(Knox 2012) and have facilitated reduction in landfilling and increases in utilization . These efforts, from the local to regional scale, are similar in that they attempt to utilize UFW at its highest value first and deposit materials into the municipal waste stream only as a last resort.

2.4 Barriers to Urban Forest Waste Utilization

While the generators of UFW might be motivated to keep material out of the MSW stream due to an interest in environmental sustainability, their fundamental motivation for UFW utilization is likely cost avoidance and bottom line economics. Most MSW facilities have "tipping fees" that add up quickly with the need to regularly dispose large quantities of material.

Table 3: Tipping fee ($/ton) for brush at select municipal solid waste facilities in Virginia (Draper Aden Associates 2011).

Locality	Fee	Locality	Fee
Accomack County	$66.00	Louisa County	$52.00
Amherst County	$34.00	Lynchburg, City of	none
August County Service Authority	$15.00	Mecklenburg County	$10.00
Bedford County	$38.00	New River Resource Authority	$20.00
Botetourt County	$49.00	Northampton County	$61.00
Bristol, City of	$30.90	Nottoway County	$27.00
Buena Vista, City of	$29.00	Orange County	$52.00
Covington, City of	$70.00	Page County	none
Culpeper County	$48.53	Prince Edward County	none
CPRWMA[1] (Buchanan County)	$60.00	Rappahannock Regional Solid Waste	$40.00
CPRWMA[1] (Dickenson County)	$60.00	Region 2000 Service Authority	$35.00
CPRWMA[1] (Russell County)	none	Roanoke, City of	$35.00
Fairfax County	$60.00	Roanoke Valley Resource Authority	$35.00
Fauquier County	$55.00	Shenandoah County	none
Floyd County	None	Spotsylvania County	none
Franklin County	$32.00	Staunton, City of	$15.00
Greensville County	$10.00	Suffolk, City of	none
Hanover County	$50.00	Winchester, City of	none
Lexington, City of	$29.00	York County	$38.00
Loudoun County	$60.00	**Locality Average Fee:**	**$40.55**

[1] Cumberland Plateau Regional Waste Management Authority

Draper Aden Associates (2011) conducted a survey of Virginia MSW facilities and questioned the facility managers about tipping fees and recycling programs. Of the facilities reporting fees for brush disposal, the average rate was just over $40 per ton (**Table 3**). If the typical dump bed arborist truck hauls four tons and a typical tree crew generates one load per day, then a single tree crew can expect to pay $800 per week in tipping fees using the average rate of $40 per ton.

In addition to tipping fees, Virginia is at a disadvantage when it comes to legislative incentives for UFW utilization due to the lack of a green waste disposal ban. In the 1990s and early 2000s, states started passing legislation banning or discouraging the disposal of yard trimmings, impacting trends in recovery of yard trimmings over time. As of 1992, 11 states, plus the District of Columbia, had passed yard trimming disposal legislation (EPA 2011). By 2008, that number had jumped to 25 states (Van Haaren et al. 2010) (Figure 1). Recovery of all yard trimmings received by US MSW facilities has increased roughly five fold since 1990, peaking at 64% in 2007. Since 2008, however, multiple states have voted to repeal their legislation,

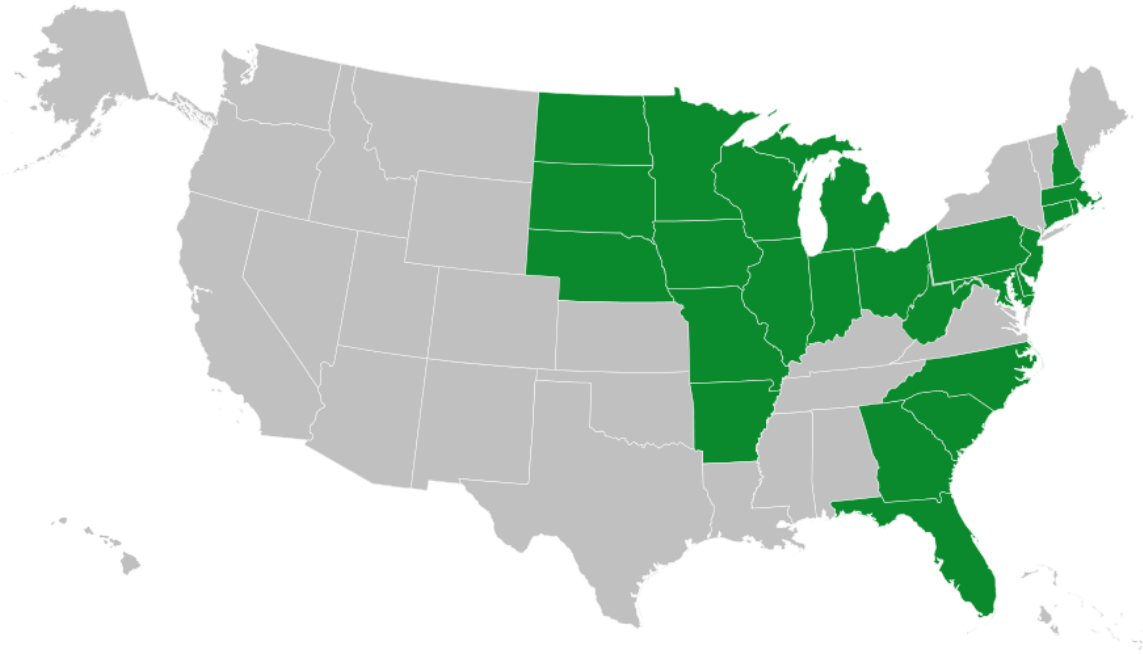

Figure 1. States with bans on landfilling yard trimmings in 2008 (Van Haaren et al. 2010).

including Georgia and Michigan in 2008, Missouri in 2009, and Florida in 2010 (Buckner 2011). As a result, recovery of yard trimmings received by MSW facilities nationwide dropped to 57% in 2011. As of 2011, the number of states with legislation barring landfilling was 22 (US Environmental Protection Agency 2011); Virginia was not among these states. Many states with yard trimming bans have seen increases in utilization efforts, but for now UFW generators in Virginia are not motivated by this type of legislation to utilize urban forest waste.

While a comprehensive study of the barriers to UFW utilization has not been conducted for the state of Virginia, a similar case study was conducted in Wake County, North Carolina (Fratanduono et al. 2013). After interviewing stakeholders across the county, including state regulators, city managers, land clearing and inert debris facility owners/operators, and producers/users of UFW, several barriers to further UFW utilization were discovered. State regulators cited "the greed and ignorance of producers/users of wastes", city managers cited "the

lack of money and personnel", facility owners/operators cited "the disconnect with state regulators, public indifference to waste management, lack of economic incentives", and producers/users cited "other businesses not following the rules and lack of incentives to properly manage wastes". All stakeholder groups reported money and economics as a major factor preventing further utilization.

A similar study by Dovetail Partners (Howe et al. 2013) reported the most common barriers cited during interviews with UFW producers in the Minneapolis region. A lack of markets was consistently reported as the primary barrier to further utilization. When markets or recycling centers existed, they were often too far away to be economically feasible due to transportation and shipping costs. Controversy over the combustion of woody biomass was also commonly cited as a barrier to further utilization. Certain members of the public viewed wood burning as bad for the environment, while others saw it as a carbon neutral practice. Another barrier was the "potential divide between private and public sectors." Interviewees were unsure whether government sponsored projects were competing with or helping private sector businesses.

2.5 Summary of Literature

The EPA and VDEQ annually document the amount and fate of vegetative/yard waste received by MSW facilities across the country and in Virginia. Using data collected by the EPA, it can be estimated that MSW facilities nationwide receive over 8 million tons of brush per year, more than half of which is recovered for compost or mulch production. In Virginia, the average amount of vegetative/yard waste received annually by MSW facilities in the state is about 494 thousand tons, but the VDEQ reports do not specify how much of its vegetative/yard waste category consists of UFW. Virginia MSW facilities have landfilled less than 8% of

vegetative/yard waste since 2010 and instead have recycled, composted, or mulched the vast majority. However, UFW being utilized or disposed outside the MSW stream is left undocumented by the EPA and VDEQ reports. As a result, it is difficult to estimate the total amount of UFW generated both nationally and on a state level. Various studies have estimated the amount generated nationally to be around 25 million tons per year – suggesting that two-thirds of UFW generated nationally is utilized or disposed outside the MSW stream. Some of the same studies have reported UFW amounts on a state-by-state and regional basis, and those estimates for Virginia range from 720,000 (Nowak and Greenfield 2009) to 1,158,400 (Nowak and Crane 2002) tons per year. However, these estimates are generated using canopy cover data rather than reports of material on the ground. The only data generated on the ground comes from the MSW authority, and therefore the amount and fate of UFW generated beyond the MSW stream has not yet been accurately characterized.

The Tree Care Industry Association recommends utilizing UFW for its highest and best use. Higher quality UFPs are generally produced from logs, while lower quality UFPs are produced from chips or brush. Various studies indicate that arborists and urban foresters perceive UFW utilization as a potentially beneficial opportunity. Although additional revenue can be difficult to attain, the avoidance of tipping fees or transportation costs can provide enough economic incentive to pursue further utilization. However, here are also numerous perceived barriers to further utilization that must be addressed before further utilization is seen as viable. Local markets or users of UFPs should exist before an operation invests in further utilization. Utilization needs to be economically feasible before arborists and urban foresters will consider altering their current practices.

CHAPTER 3 – METHODS

This survey study focused on professionals who directly work with generation of urban forest waste (UFW) in urbanized municipalities of Virginia. The study population comprised two distinct sub-populations – municipal and private arboricultural operations. Both sub-populations were administered the same web-based survey instrument. There are several advantages to using electronic surveys instead of on-site, mail, or telephone surveys. Electronic surveys can be longer and more complex, yet still have high response rates and remain cost-effective (Vaske 2008). The use of web-based survey software also makes data collection and analysis much more efficient (Griffis et al. 2003). Web-based surveys have been used successfully for conducting forestry research (Poudyal et al 2010, Fowler 2012, Kimball et al. 2014).

The geographic scope of the survey was 91 urbanized municipalities in Virginia (see Appendix A for full listing), which were selected using the following criteria:

- Any county, incorporated town, or independent city with a population greater than 250,000, or:
- Any county, incorporated town, or independent city with a population between 2,500 and 250,000 and a population density greater than 1,313 persons per square mile.

The second criterion was based on (a) the minimal population (2,500) to qualify as an urban area in the US (US Census Bureau 2010a), and (b) the median population density (1,313 persons/square mile) of census-defined urban areas in Virginia. For forest inventory purposes, VDOF divides the state into five physiographic regions. The 91 selected localities were fairly evenly distributed across these five regions: coastal plain (25%), northern piedmont (20%),

southern piedmont (11%), northern mountains (23%), and southern mountains (21%). The southern piedmont was underrepresented due to scarcity of urban areas in this region. The selected localities encompassed 9% of the total land area and 64% of the total population of Virginia. This study area is 79% urban land and contains 85% of the total urban population.

For the 91 urbanized municipalities, a list of employees responsible for managing municipal UFW (i.e., tree debris generated by municipal arboricultural operations or curbside pickup) was obtained through cooperation with the Urban and Community Forestry Program of the Virginia Department of Forestry (VDOF). For municipalities without a VDOF contact, an appropriate survey recipient was chosen by searching that municipality's website for the employee with the most relevant job title – often the Director of Public Works or Director of Parks and Recreation. In the survey solicitation, all municipal contacts were asked to forward the survey to another municipal employee if they felt they were not qualified to report on the municipality's generation or utilization of UFW. Only one employee was solicited for the survey for each municipality and was asked to report on the UFW generated by the entire municipal operation. This total included UFW generated by government employees using arboricultural practices and/or residential curbside UFW collection.

For the sub-population of private sector arborists, all International Society of Arboriculture (ISA) Certified Arborists with a mailing address in Virginia (totaling 828 individuals) were invited via email to participate in the survey. ISA Certified Arborists have the proven knowledge to conduct tree work properly and are encouraged to follow industry standards. They also work in a variety of industries, ranging from tree care to landscaping to consulting. As a known population, they could also be contacted in the future for outreach and technical assistance. Contact information for Certified Arborists was obtained from the Mid-

Atlantic Chapter of the ISA (MAC-ISA), and recipients were pre-notified of the upcoming survey through an electronic newsletter distributed monthly by the MAC-ISA. Certified arborists who responded to the survey were asked to be the sole respondent for their local operation in order to minimize double reporting.

Before being distributed, the survey instrument was pilot-tested by both arborists and municipal employees and revised for clarity and ease of use. The survey was administered in spring 2014 using a modified Tailored Design Method (Dillman 2000). The Dillman method generally consists of a respondent friendly questionnaire, up to five personalized contacts per recipient, and a financial incentive. This study was limited to three personalized contacts per recipient and did not include a financial incentive for participation. The Qualtrics online survey platform (Qualtrics, Provo Utah) was used to generate an individual survey web link for each survey recipient. Contrary to widely distributed anonymous links, individual links enable each survey response to be tied to that recipient's email address, thus reducing the chances of duplicate responses. Members of both sub-populations received an email containing a formal invitation and the link to the survey. Two email reminders were sent to non-respondents over the next few weeks.

Survey questions were presented in a variety of formats. First, respondents were asked to answer basic multiple-choice demographic questions about their age, gender, education, and professional experience. Further multiple-choice questions were used to classify the respondents' industry sector and position within their local operation (i.e., municipality, business, or organization). The demographic data gathered from these questions were later used to classify responses to questions about perceptions of UFW utilization. Respondents were then asked whether their local operations conduct tree work in-house and directly generate UFW or

hire contractors to complete this work. Those who responded 'Yes' were forwarded to questions about their operation's characteristics, the amount and fate of UFW produced, and trends in past and future UFW generation and utilization.

Survey questions about operational characteristics classified each respondent's operation based on number of employees and geographic location of their operation. Respondents were then asked to report about their operation's UFW generation in terms of the land use origin (e.g., private residential, public greenspace, etc.) and tree management practices (e.g., pruning, tree removal, curbside debris pick-up, etc.). Because operations often do not monitor or track their UFW generation, a screening question was first asked of respondents about their ability to report on UFW generation by their operation. If the respondents confirmed that they had knowledge of UFW generation, then they were asked to estimate the amount of logs, brush, and chips that their operations generate. If the respondents were unable to provide an estimate, then they were forwarded to a series of similar questions about the fate of their operation's UFW. If one of the UFW fates selected was 'utilized in-house', then the respondents were asked to specify what sort of urban forest products (UFPs) result from their UFW utilization. Finally, respondents were asked to report on their operation's trends in past and future UFW generation and utilization. Possible categorical responses ranged from increased substantially to decreased substantially, or 'I don't know'.

Perception questions prompted the respondents to select their level of agreement with various statements about UFW utilization. The first group of statements proposed *a priori* reasons for increasing UFW utilization, the second group of statements revolved around the importance of UFW utilization, and the third group of statements related to self-education and training opportunities on UFW utilization. Additional perception questions prompted the

respondents to rank the most significant incentives and barriers to UFW utilization, as well as certain educational or technical programs based on their potential to increase their capacity for UFW utilization. Respondents were asked to identify and rank at least three incentives, barriers, and educational or technical programs from an a priori list. A fill-in-the-blank for "other" was also provided.

After closing the survey, data were exported from Qualtrics, screened for errors and omission, organized, and analyzed using Microsoft Excel and SPSS Statistics 22 (IBM, Armonk NY). The data were then tested for reliability to ensure that the sample responses were representative of the population. Early respondents were compared to late respondents based on age, gender, education, experience level, industry sector, operation size, and UFW generation practices. Respondents were split into two groups based on survey completion timeframe, and their responses to each question were tested for differences using a Chi-squared test. There were no significant differences found between the early and late respondents when tested at the $\alpha = 0.05$ significance level. To test for non-response bias, a random sub-sample of non-respondents ($n = 30$) was contacted by phone and asked to answer the same series of questions that were used to compare early and late responses. Responses of non-respondents were compared with those of respondents using a Chi-squared test, and no significant differences were found between the two groups when tested at the $\alpha = 0.05$ significance level. Descriptive statistics were then generated for the survey data to report on respondent and operational characteristics.

Further statistical analyses were used to examine the current conditions and perceptions of UFW generation and utilization in Virginia. Descriptive statistics were used to examine the project objectives of describing UFW amounts, fates, and perceptions, while inferential statistics were used to answer the associated research questions regarding any difference in responses

between municipal employees and private arborists. For each survey question, responses from municipal employees and private arborists were tested for significant differences using a Chi-squared test. Extreme outliers were reported for logs, chips, and brush by the same respondent, and were removed prior to analyzing amount data. For categorical questions resulting in ordinal data, the null hypothesis was that the distributions of responses across all answer choices were the same for both municipal and private responses. For percentage or fill-in-the-blank questions resulting in scale data, the null hypothesis was that the distributions of responses for each answer choice were the same for both municipal and private responses. In Tables 4-12 of the Results and Discussion Section, a single p-value is reported for questions resulting in ordinal data, while p-values for questions resulting in scale data are reported in a separate column next to each answer choice. Null hypotheses were tested at the $\alpha = 0.05$ significance level.

CHAPTER 4 – RESULTS AND DISCUSSION

4.1 Response Rates

Survey invitations were distributed to the private sector arborists using the Qualtrics web mailer. After importing MAC-ISA's mailing list of all 828 ISA Certified Arborists operating in Virginia, the Qualtrics mailer generated individual links and sent an email invitation to each arborist using the Qualtrics mail server. According to the survey distribution report, 44 of the 828 emails bounced due to invalid email addresses, but it became apparent that many of the arborists' email applications were recognizing the Qualtrics server as spam and not delivering the invitation to their inbox. To remedy this problem, the final round of email reminders was sent individually from an email alias on the Virginia Tech server, which reduced message filtering as spam. Of the 784 ISA Certified Arborists who eventually received the invitation, 267 responded. Eighteen of the respondents were also the primary contact for one of the 91 municipalities in the sampling frame, so their responses were applied to the sub-population of municipal employees. Ten of the respondents were employed by municipalities outside of the sampling frame, so their responses were discarded. The remaining 239 responses were applied to the sub-population of private sector arborists, resulting in a response rate of 31%. However, many of these respondents indicated early in the survey that they were not in a position to report on the generation or utilization of UFW by their local operation, so they were forwarded to the end of the survey, resulting in sample sizes lower than 200 for all of the remaining survey questions. Samples sizes for certain questions also vary because of question forwarding and incomplete responses.

After recording responses for 18 municipalities from the ISA Certified Arborists survey distribution, invitations were sent to the primary contact in each of the remaining 73 municipalities. After two rounds of reminders, an invitation was sent to a secondary contact in each of the municipalities that had yet to respond. After sending two rounds of reminders to each secondary contact, the survey was closed. Of the 91 solicited municipalities, 56 responded to the survey for a response rate of 61%.

4.2 Respondent Characteristics

Responses to demographic and operational survey questions were used to characterize the respondent sub-populations (**Table 4**). When comparing characteristics of municipal employees to private sector arborists, multiple differences became apparent. Private arborists tended to be younger ($p = 0.026$) while municipal employees tended to be more highly educated ($p = 0.032$). The level of experience in both sectors was fairly evenly distributed. Of the private sector arborists who responded, more than half (51%) were employed by a tree care company, while the majority of the remainder were either employed by an institution (15%) such as a campus or arboretum, or a landscape company (12%). Most of the private sector arborists reported either being the manager of their local operation (67%) or the manager of a production crew (17%). Municipal employees reported holding a wide range of positions, but arborist (18%), parks and recreation administrator (18%), urban forester (15%), and public works administrator (13%) were the most commonly reported positions.

Table 4: Characteristics of municipal employees and private sector arborists in Virginia who responded to a survey on perceptions of urban forest waste (UFW). Significant differences ($p < 0.05$) in age, gender, education, and experience between municipal and private sector responses are denoted with bold type.

Age (p-value = **0.026**)[1]	Municipal (n=56)	Private (n=185)
18-30 years	5%	14%
31-44 years	14%	28%
45-60 years	63%	47%
61+ years	18%	11%
Gender (p-value = 0.069)	Municipal (n=56)	Private (n=185)
Female	25%	15%
Male	75%	85%
Education (p-value = **0.032**)	Municipal (n=56)	Private (n=185)
High school or equivalent	7%	20%
Associate degree	5%	10%
Bachelor's degree	50%	47%
Graduate degree	38%	23%
Experience (p-value = 0.190)	Municipal (n=56)	Private (n=185)
0-10 years	18%	27%
11-20 years	20%	27%
21-30 years	37%	25%
31+ years	25%	21%
Industry Sector	Municipal (n=45)	Private (n=75)
Municipality	100%	0%
Tree care company	0%	51%
Institution	0%	15%
Landscape company	0%	12%
Electric service provider	0%	8%
VA Dept. of Transportation	0%	4%
Other	0%	9%
Position within municipal sector	Municipal (n=45)	Private (n=0)
Arborist	18%	n/a
Parks and Rec. Administrator	18%	n/a
Urban Forester	15%	n/a
Public Works Administrator	13%	n/a
Horticulturalist	9%	n/a
Solid Waste Administrator	7%	n/a
City/Town/County Manager	7%	n/a
City/Town/County Planner	4%	n/a
Other	9%	n/a
Position within private sector	Municipal (n=0)	Private (n=42)
Manager of regional operation	n/a	7%
Manager of local operation	n/a	67%
Manager of production crew	n/a	17%
Member of production crew	n/a	7%
Other	n/a	2%

[1] P-values indicate the difference in response distributions between municipal and private responses across all question options.

4.3 Operational Characteristics

On average, nearly three quarters (74%) of all respondents reported that their local operation generates UFW (**Table 4**). The difference between municipalities (87%) and private arboricultural operations (66%) was highly significant (p=0.003). The lower percentage of UFW generators within the private sector can likely be explained by the diversity of industries in which ISA Certified Arborists are employed – not all of which conduct tree care operations. For example, survey responses were received from consulting arborists, educators, researchers, and foresters who possess the Certified Arborist credential. Of the private (non-municipal) operations that were found to generate UFW, only half (51%) classified themselves as tree care companies. Other types of private operations that reported generating UFW included institutions (15%), landscape companies (12%), electric service providers (9%), consulting firms (8%), and Virginia Dept. of Transportation (5%). Almost two thirds (61%) of private operations that generate UFW have 10 or fewer employees, while less than half of the municipal operations (46%) have 10 or fewer employees. However, there were more private operations with more than 21 employees (21%) than municipal operations (11%).

When asked to select the localities in which they operate from the list of 91 localities in the sampling frame, municipal responses were fairly evenly distributed across the five physiographic regions of Virginia (**Table 5**). However, private arboricultural operations predominantly reported operating in localities in the northern piedmont (41%), coastal plain (27%), and northern mountains (19%). Increased urbanization and an affluent population has increased demand for tree care services in these regions. Specifically, nearly half (46%) of private operations reported operating somewhere within the Washington DC Metropolitan Statistical Area (MSA) (Census 2013). Of the top fifteen most frequently identified

municipalities by respondents, thirteen are within the Washington DC MSA. The most frequently selected municipality was Fairfax County, followed by Arlington County, Alexandria, Fairfax City, Manassas, Falls Church, Leesburg, Vienna, Richmond City, Warrenton, Front Royal, Herndon, Norfolk, Prince William County, and Williamsburg.

Table 5: Characteristics of municipalities and private arboricultural operations in Virginia that responded to a survey on urban forest waste (UFW) generation. Significant differences ($p < 0.05$) between municipalities and private arboricultural operations for each characteristic are denoted with bold type.

The local operation generates UFW (p-value = **0.004**)[1]	Municipal (n=52)	Private (n=114)
Yes	87%	66%
No	13%	34%
Industry sector of the local operation (p-value ≤ 0.001)	**Municipal (n=45)**	**Private (n=75)**
Municipality	100%	0%
Tree care company	0%	51%
Landscape company	0%	12%
Consulting firm	0%	8%
Institution	0%	15%
Electric service provider	0%	9%
VA Dept. of Transportation	0%	5%
Number of employees in the local operation (p-value = 0.367)	**Municipal (n=45)**	**Private (n=75)**
0-5	36%	39%
6-10	20%	22%
11-15	22%	12%
16-20	11%	7%
21+	11%	21%
Geographic region where local operation resides (p-value = 0.327)	**Municipal (n=45)**	**Private (n=71)**
Coastal Plain	24%	21%
Northern Mountains	22%	14%
Northern Piedmont	27%	44%
Southern Mountains	11%	13%
Southern Piedmont	16%	8%
The local operation is in the Washington, DC Metropolitan Statistical Area (p-value = 0.025)	**Municipal (n=45)**	**Private (n=71)**
Yes	27%	46%
No	73%	54%

[1] P-values indicate the difference in response distributions between municipal and private responses across all question options.

4.4 Generation of Urban Forest Waste

The land use origin of UFW generated by private arboricultural operations was mostly private residential (46%) and private commercial (17%), while the majority of municipal UFW was generated along public street rights-of-way (37%) and public greenspace (34%) (**Table 6**).

Table 6: Generation of urban forest waste (UFW) by urban municipalities and private arboricultural operations in Virginia based on self-reported survey data. Significant differences ($p < 0.05$) between municipalities and private arboricultural operations are denoted with bold type.

Land use origin of the UFW generated by the operation	Municipal (n=45)	Private (n=66)	p-value[1]
Private residential	21%	46%	**0.045**
Private commercial	3%	17%	**0.076**
Public greenspace	34%	14%	**0.001**
Municipal street ROW	37%	6%	**≤ 0.001**
VA DOT roadside ROW	4%	8%	0.242
Electric utility ROW	1%	7%	0.191
Other	0%	2%	0.499
Management practices that generate the operation's UFW	**Municipal (n=44)**	**Private (n=65)**	**p-value[1]**
Tree pruning	31%	45%	0.235
Tree removal	32%	43%	0.443
Curbside pickup	32%	2%	**≤ 0.001**
Small woodlot logging	2%	3%	0.780
Land Clearing	3%	4%	0.469
Other	0%	3%	0.517
Ability to estimate amount of UFW generated by the operation (p-value = 0.114)[2]	**Municipal (n=44)**	**Private (n=65)**	
Keep detailed records	14%	3%	
Can provide an estimate	25%	26%	
Cannot provide an estimate	61%	71%	
Ability to estimate fate of UFW generated by the operation (p-value = 0.388)[2]	**Municipal (N=44)**	**Private (N=63)**	
Keep detailed records	9%	5%	
Can provide an estimate	42%	54%	
Cannot provide an estimate	49%	41%	

[1] P-values indicate the difference in frequency between municipal and private responses for each question option.

[2] P-values indicate the difference in response distributions between municipal and private responses across all question options.

Significantly more private operation's UFW originated on private residential lands compared to municipal operations ($p=0.045$). In contrast, significantly more municipal UFW originated on public greenspace ($p=0.001$) and public street ROW ($p\leq0.001$) compared to private operations. The high percentage of municipal UFW originating from private residential land can likely be explained by the practice of municipal curbside pickup of citizen-generated UFW, which accounted for nearly one-third (32%) of all municipal UFW. Along with this, tree removal (32%) and tree pruning (31%) comprised the bulk of municipal UFW. Practices that generate UFW in the private sector were evenly split between tree pruning (45%) and tree removal (43%). Of all the practices used to generate UFW, curbside pickup was the only practice that was significantly different ($p\leq0.001$) between municipal and private operations.

When respondents were asked to describe how their local operations track the amount of UFW they generate, neither municipal nor private operations tended to keep detailed records, and both sub-populations had trouble estimating amounts. Municipal operations were more likely to keep records of amount (14%) than private operations (3%), while private operations had more trouble estimating amount (71%) than municipalities (61%). However, these differences were not significant. Of those operations that indicated that they keep detailed records or could estimate their amount of UFW generation, the results were extremely variable (**Table 7**). One particular operation provided the highest estimate for every form of UFW. The response was not only an extreme outlier in the data distribution, but also was an illogical value given the size of the operation. The respondent failed to return a request for clarification, so the response was dropped from the data set. In light of how few respondents could estimate UFW amounts, it is not surprising that the reported estimates were so variable. Reported UFW amounts were bound to vary given that arboricultural operations vary in scope and size, but

municipal operations were even more variable than private. Municipalities are more administrative oriented while private operations are focused on production. Even after normalizing these amounts by the number of employees in each operation and calculating UFW generation in tons per year per employee (**Table 7**), the results were still highly variable.

Table 7: Estimated amount of urban forest waste (UFW) generated by urbanized municipalities and private arboicultural operations in Virginia based on self-reported survey data. The data reported are only for respondents who indicated that they could quantitatively estimate UFW generation (see **Table 6**).

	Logs		Chips		Brush	
	---------- tons year^{-1} employee^{-1} ----------					
	Municipal	Private	Municipal	Private	Municipal	Private
Sample size (n)	15	15	15	15	15	15
Minimum	0	0	0	0	0	0
First quartile	0	11	0	20	0	0
Median	1	56	0	38	7	1
Third quartile	19	151	17	238	278	43
Maximum	7300	385	912	608	5000	400
Mean	498	116	78	151	454	47
Standard Deviation	1882	138	234	200	1272	106
Coefficient of Variation	377%	119%	300%	132%	280%	226%
Average % of Total UFW	30%	33%	23%	57%	47%	10%
p-value[1]	0.305		0.231		0.343	

[1] P-values indicate the difference in the distribution of amount responses between municipal and private respondents.

When comparing the percentage of each UFW type generated by private arboricultural operations versus municipal operations (**Table 7**), neither logs, chips, nor brush were significantly different due to a lack of statistical from a small sample size. Municipalities may generate most of their UFW in the form of brush because of curbside pickup of citizen-generated UFW and because they have the capacity to store large amounts of brush and hire a tub grinder to process the material in bulk. They also likely contract with private arboricultural operations to conduct

large pruning jobs and removals. Private operations on the other hand are usually required to remove the UFW they generate from the work site, so they use chippers to process most of the material on-site for more efficient transport. When combining the mean amounts of logs, chips, and brush generated per employee as reported by private operations, the mean total was 315 tons/year. When multiplying by an average tree crew size of three employees, the amount (945 tons/year) is comparable to reports stating that a single tree service crew typically generates about 1,000 tons/year of wood waste (Wiltsee 1998, Milbrandt 2005). On average, municipal operations generated more UFW annually, about 1,031 tons per employee, or 3,093 tons per tree service crew.

4.5 Utilization of Urban Forest Waste

When all respondents were asked to describe how their local operation tracks the fate of the UFW they generate, few municipal or private arboricultural operations (7%) said they keep detailed records of fate (**Table 6**). Nearly half (49%) of the operations indicated that they were able to estimate the fate of UFW generated by their operation, which was significantly higher ($p \leq 0.001$) than respondents who could estimate the amount of UFW generated (24%). The ability to estimate UFW fate showed no significant relationship to any of the operational characteristics other than the geographical region of the operation ($p = 0.069$). A higher percentage of operations in the northern mountains (68%), southern mountains (62%), and southern piedmont (64%) could not estimate UFW fate compared to operations in the northern piedmont (40%) and coastal plain (23%). There was no overall difference between municipal and private arboricultural operations in their ability to estimate UFW fate ($p = 0.388$).

Although operations lacked clarity on how much UFW they generate, they often had a better sense of its fate. Of the operations that kept records or said they could estimate UFW fate, most reported that the logs, chips, and brush generated by their local operation are being

Table 8: Fate of urban forest waste (UFW) generated by municipal and private arboricultural operations. Significant differences ($p < 0.05$) between municipal and private responses are denoted with bold type. Data reported are only for respondents who indicated that they could report UFW fate (see **Table 7**).

Fate of logs	Municipal (n=19)	Private (n=35)	p-value[1]
Transferred to 3rd party	26%	42%	0.740
Disposed at solid waste facility	24%	20%	0.600
Utilized in-house	27%	16%	0.489
Utilized on-site	14%	13%	0.610
Left on-site	9%	9%	0.755
Fate of chips	Municipal (n=18)	Private (n=35)	p-value
Transferred to 3rd party	29%	53%	0.469
Disposed at solid waste facility	14%	9%	0.458
Utilized in-house	47%	22%	**0.041**
Utilized on-site	5%	9%	0.426
Left on-site	5%	7%	0.307
Fate of brush	Municipal (n=20)	Private (n=33)	p-value
Transferred to 3rd party	28%	32%	0.616
Disposed at solid waste facility	21%	20%	0.548
Utilized in-house	43%	31%	0.413
Utilized on-site	3%	4%	0.642
Left on-site	5%	13%	0.601

[1] P-values indicate the difference in frequency between municipal and private responses for each fate option.

utilized more often than not. The majority of each UFW type was either utilized in house, utilized on site, or transferred to a 3rd party and utilized (**Table 8**). This was the case for both municipal operations and private arboricultural operations. In comparing the fate of the three UFW types, the only significant difference between municipalities and private operations was the utilization of chips in-house. Municipalities utilize chips in-house twice as often as private operations ($p=0.041$), which transfer about half (53%) of their chips to a third party. On average, both municipalities and private operations reported disposing less than 25% of their UFW at a solid waste facility. Other studies have reported higher estimates for the percentage of UFW that

gets discarded. One particular study in Michigan reported that 28% of UFW ends up in landfills (MacFarlane 2008), and another placed the national average at 30% (Wiltsee 1998). Regardless of operation type or UFW type, UFW is rarely left on-site, which indicates that UFW is being handled and transported in the majority of situations. If UFW is being mobilized, then perhaps there might be additional opportunities to divert materials into utilization streams rather than disposal streams.

Table 9: Urban forest products (UFPs) produced in-house by municipal and private arboricultural operations and utilized elsewhere within the operation. Data reported are only for respondents who indicated that they utilized UFW in-house (see **Table 8**).

UFPs from logs utilized in-house	Municipal (n=10)	Private (n=12)	p-value[1]
Firewood	42%	52%	0.195
Lumber	18%	17%	0.410
Mulch	8%	17%	0.235
Furniture	6%	2%	0.377
Pallets	6%	2%	0.306
Cabinetry	6%	2%	0.226
Veneer	5%	0%	0.455
Flooring	0%	2%	0.545
Art/novelty	0%	1%	0.408
Other	9%	5%	0.408
UFPs from chips utilized in-house	Municipal (n=16)	Private (n=15)	p-value
Mulch	75%	63%	0.340
Compost	21%	20%	0.369
Biomass	1%	10%	0.512
Pellets	3%	2%	0.616
Other	0%	5%	0.484
UFPs from brush utilized in-house	Municipal (n=13)	Private (n=13)	p-value
Mulch	76%	52%	0.670
Compost	21%	28%	0.668
Biomass	4%	7%	0.513
Other	0%	13%	0.338

[1] P-values indicate the difference in frequency between municipal and private responses for each UFP option.

When respondents reported utilizing logs, chips, or brush in-house, they were asked to specify which urban forest products (UFPs) they were producing (**Table 9**). Mulch was by far the most common UFP produced from chips (69%) and from brush (64%) by municipal and private operations combined. From logs, firewood was the most common UFP (47%), followed by

lumber (18%) and mulch (13%). Other studies have also reported that mulch and firewood are the most common UFPs produced from UFW (Sherrill & MacFarlane 2007, McKeever 2003). Logs are being utilized for "high-value" UFPs such as furniture, cabinetry, veneer, and flooring in smaller percentages, but the return on these products is much higher and worth investigating as an alternative means of operational production. Likewise, very little UFW is being processed into biomass or pellets for combustion in power plants or heating systems. The traditional forestry sector has embraced the opportunity to utilize waste in these areas, so municipal and private operations should look for similar opportunities depending on the availability and proximity.

4.5 Perceptions of Urban Forest Waste Utilization

Two-thirds of respondents (65%) either agreed or strongly agreed that UFW utilization is a major issue for the urban forestry industry currently (**Table 10**). An even higher percentage (76%) agreed or strongly agreed that UFW utilization will be a major issue for the urban forestry industry in the future. Respondents also agreed (39%) more often than they disagreed (18%) that UFW utilization is important to their clients. These beliefs were consistent for both sub-populations and across all demographic characteristics and industry sectors, and no statistically significant differences were found ($p < 0.05$).

In order to gauge their interest in increasing UFW utilization practices, respondents were asked to rank their level of agreement with *a priori* reasons for increasing utilization (**Table 10**). For all reasons provided, respondents tended to agree with the statement more often than they disagreed (mean response ranging from 2.08 to 2.95 on 5-point scale). When comparing the average response for each statement between municipal employees and private sector arborists (**Table 10**), both groups ranked environmental reasons the highest for increasing UFW

utilization. Agreement with each of these statements was consistent across nearly all demographics. Only two were statistically different ($p < 0.05$): respondents with higher education levels and higher levels of experience sought to increase utilization for regulatory reasons more often than those with less education and experience (data not shown). This might occur because individuals with higher education and experience often hold positions that make them directly responsible for regulatory compliance.

Table 10: Perceptions of municipal employees and private sector arborists about urban forest waste (UFW) utilization in Virginia. Level of agreement questions are reported using this scale: 1 = strongly agree, 2 = somewhat agree, 3 = neither agree nor disagree, 4 = somewhat disagree, 5 = strongly disagree.

My operation seeks to increase UFW utilization…	Municipal (n=53)			Private (n=162)			p-value[1]
	Mean	Mode	Range	Mean	Mode	Range	
…for environmental reasons	2.08	2	1-4	2.28	2	1-5	0.403
…for financial reasons	2.36	2,3	1-4	2.69	2	1-5	0.275
…for logistical reasons	2.42	2,3	1-4	2.49	3	1-5	0.559
…for regulatory reasons	2.70	3	1-4	2.95	3	1-5	0.273
	Municipal (n=52)			Private (n=153)			p-value
Urban forest waste…	Mean	Mode	Range	Mean	Mode	Range	
…utilization will be a major issue for the urban forestry industry in the future	2.15	2	1-4	1.97	2	1-5	0.332
…utilization is a major issue for the urban forestry industry currently	2.40	2	1-4	2.25	2	1-5	0.293
…utilization is important to my clients	2.88	2	1-5	2.70	3	1-5	0.084
…disposal is a major cost for my operation	3.19	4	1-5	2.95	3	1-5	0.299
…utilization is a major revenue source for my operation	4.04	4	1-5	3.87	4	1-5	0.557

[1] P-values indicate the difference in response distributions between municipal and private responses across all question options.

When asked to rank their level of agreement with the statement that UFW utilization is a major revenue source for their operation (**Table 10**), both municipal employees and private sector arborists tended to disagree (mean response of 4.04 and 3.87 on 5-point scale). However,

when given the statement that UFW disposal is a major cost for their operation, private arborists tended to somewhat agree (2.95) while municipal employees tended to somewhat disagree (3.19). Although this difference was not statistically significant, it alludes to a varying set of circumstances and barriers that make UFW utilization difficult for municipalities versus private arboricultural operations.

When asked to rank *a priori* incentives for increasing UFW utilization, both municipal employees and private sector arborists ranked each incentive statement in the same order (**Table 11**). The avoidance of disposal fees and the avoidance of transportation or shipping costs were among the most frequently reported, as was the environmental sustainability of the operation/community. Several studies cite similar avoidance costs as the primary economic incentive to further UFW utilization (Bratkovich 2010, Fratanduono 2013).

Contrary to incentives, the two sub-populations were more inconsistent when asked to rank *a priori* barriers to increasing UFW utilization. There were a couple of significant differences between the barriers reported by municipal employees and private sector arborists. First, the most commonly reported barrier to further utilization as ranked by municipal employees was a lack of in-house equipment (56%), yet private arborists reported that particular barrier was less frequently (30%). This difference was highly significant ($p = 0.001$), and could be explained by the diversity of equipment that private arboricultural operations often utilize. The second significant difference ($p = 0.046$) was the logistical difficulties of handling UFW on commercial tree service jobsites. Private sector arborists (37%) reported this as a barrier more often than municipal employees (23%). They also ranked the logistical difficulties of transporting UFW to processors more often (40%) than municipal employees (29%).

Table 11: Perceptions of municipal employees and private sector arborists about urban forest waste (UFW) utilization in Virginia. Incentives and barriers are reported based on the percentage of respondents who ranked each incentive or barrier in their top three. Significant differences ($p < 0.05$) between municipal and private responses about incentives and barriers are denoted with bold type.

Incentives to further urban forest waste utilization	Municipal (n=52)	Private (n=137)	p-value[1]
Avoidance of disposal fees	79%	69%	0.112
Environmental sustainability of the operation/community	69%	67%	0.464
Avoidance of transportation or shipping costs	44%	53%	0.195
Opportunity to produce UFPs for use elsewhere within the operation/community	36%	36%	0.525
Value-added service to clients	33%	34%	0.488
Additional revenue	29%	32%	0.402
Support of local industries or businesses	17%	29%	0.067
Barriers to further urban forest waste utilization	**Municipal (n=52)**	**Private (n=137)**	**p-value**
Lack of in-house equipment for processing UFW	56%	30%	**0.001**
Lack of in-house space for stockpiling UFW	52%	41%	0.115
Lack of local processors of UFW	42%	48%	0.289
Lack of in-house knowledge or skill for processing UFW or marketing UFP	33%	25%	0.182
Logistical difficulties of transporting UFW to processors	29%	40%	0.102
Lack of local consumers of UFP	27%	34%	0.214
Lack of communication between UFW producers and UFP consumers	23%	31%	0.199
Logistical difficulties of handling UFW on tree service job sites	23%	37%	**0.046**
Local regulations or permitting requirements	17%	21%	0.355

[1] P-values indicate the difference in frequency between municipal and private responses for each UFP option.

Another notable result was the lack of in-house knowledge or skill for processing UFW or marketing UFPs. Municipal employees (33%) ranked that particular barrier more often than

private sector arborists (25%). Although this difference was not significant, it may still illustrate the need for further education and outreach specifically aimed at municipalities and public arborists. One barrier ranked highly by both sub-populations was the lack of local processors of UFW. Not having markets for utilizing UFW is consistently cited as a major barrier in existing literature (Cesa et al. 2003, Fratanduono et al. 2013, Howe et al 2013).

4.5 Preferences for Education and Technical Assistance

When asked to rank their level of agreement with several statements regarding education and training for UFW utilization, the average respondent only slightly agreed (2.9) that they had engaged in such activities in the past year (**Table 12**). The average respondent also neither agreed nor disagreed (3.0) that they had found satisfactory opportunities for education or training on UFW utilization. However, the average respondent somewhat agreed (2.6) that they would engage in self-education or training on the topic of UFW utilization in the coming year. These beliefs were consistent across all demographics and industry sectors, and no statistically significant differences were found ($p < 0.05$). Although this data suggests that arborists have fairly neutral opinions of existing educational or technical programs, they do have an interest in the topic and would pursue opportunities for education and training in the near future.

Respondents were also asked to rank several educational or technical programs based on that would address UFW utilization (**Table 12**). Nearly half (49%) of all respondents supported the establishment of some sort of facility – either a local, centralized facility for receiving, sorting and stockpiling UFW or a cooperative business facility for selling and/or producing UFPs. Similar facilities have been established elsewhere with some success (US Forest Service Forest Products Laboratory 2002, US Forest Service Research & Development 2013). Both groups also frequently ranked hands-on workshops or field demonstrations as potentially beneficial. However, there was a significant difference ($p = 0.028$) in the percentage of municipal employees (46%) requesting education seminars or conferences compared to private sector arborists (30%). Likewise, the percentage of municipal employees requesting Cooperative Extension of VDOF publications (27%) was significantly higher ($p \leq 0.001$) than private sector arborists (7%).

Table 12: Preferences of municipal employees and private sector arborists in Virginia for education and technical assistance on urban forest waste (UFW) utilization. Level of agreement questions are reported using this scale: 1 = strongly agree, 2 = somewhat agree, 3 = neither agree nor disagree, 4 = somewhat disagree, 5 = strongly disagree. Significant differences ($p < 0.05$) between municipal and private sector responses about trends in education or technical assistance programs are denoted with bold type.

	Municipal (n=52)		Private (n=150)		
Experience with education and training	Mean	Mode	Mean	Mode	p-value
I have engaged in self-education or training about UFW utilization in the past year	2.94	2	2.84	2	0.288
I will engage in self-education or training about UFW utilization in the coming year	2.71	3	2.63	2	0.513
I have found satisfactory opportunities for education or training on UFW utilization when I have sought it	2.92	3	2.97	3	0.733
Preference for educational or technical programs about UFW utilization	Municipal (n=52)		Private (n=137)		p-value
A local, centralized facility for receiving, sorting and stockpiling UFW	46%		50%		0.396
Educational seminars or conferences	46%		30%		**0.028**
A cooperative business facility for selling and/or producing urban forest products	33%		36%		0.414
An online database that networks UFW generators, processors, & producers	31%		39%		0.176
Hands-on workshops or field demonstrations	29%		39%		0.119
Industry standards or best management practices	29%		32%		0.402
An educational website	29%		27%		0.467
Cooperative Extension or VDOF publications	27%		7%		≤**0.001**
An online course or webinar	17%		18%		0.580

[1] P-values indicate the difference in frequency between municipal and private responses for each UFP option.

An online database networking UFW generators, processors, and producers was a technical assistance program frequently ranked by both municipal employees (31%) and private arborists (39%) and could potentially help arborists from all industry sectors find local

consumers of the UFW they generate. Similar networking tools have been implemented in other locations and have increased communication between stakeholders across the UFW utilization spectrum (Knox 2012, Urbanwood Project 2014).

CHAPTER 5 – CONCLUSIONS AND RECOMMENDATIONS

5.1 Generation of UFW in Virginia

Urban forest waste (UFW) is an inevitable by-product for both private and municipal arboricultural operations. According to previous estimates and studies, UFW is generated in significant amounts across Virginia. However, survey results indicate that both municipal and private arboricultural operations have a difficult time estimating the amount of UFW they generate. Only one-third of respondents kept detailed records or could estimate amounts, while the remainder could not provide estimates. Of the operations that could provide estimates the results were extremely variable, but even after normalizing these amounts by the number of employees in each operation, the results were still highly variable. This was an inherent limitation of using a web-based survey to ask arborists to provide rough estimates of amounts from memory. Based on the data acquired, private operations tended to generate more logs and chips, while municipalities tended to generate more brush.

UFW generated by arboricultural operations should be carefully accounted for upon completion of a job or prior to disposal. Keeping detailed records of UFW generated will allow operations to more accurately assess the current costs of disposal and the potential benefits of further utilization. This type of data would be important for market analysis and business modeling as well. Future educational or technical programs should encourage arborists and municipal employees to accurately document UFW amounts and provide cost/benefit analyses so informed decisions can be made regarding further utilization. Future research could involve detailed documentation of UFW amounts generated by a handful of municipal or private

arboricultural operations and detailed economic analysis of the costs and benefits of UFW utilization by those particular operations.

5.2 Utilization of UFW in Virginia

Utilization of UFW can provide arboricultural operations with opportunities to avoid disposal costs and potentially generate revenue. Using data collected by the EPA, it can be estimated that MSW facilities nationwide receive over 8 million tons of UFW per year. Various studies have estimated the amount generated nationally to be around 25 million tons per year – suggesting that two-thirds of UFW generated nationally is utilized or disposed outside the MSW stream. Our survey results indicate that the majority of logs, chips, and brush were utilized – either in house by the private or municipal operation, or by a third party. Municipal operations utilize significantly more chips in house than private arboricultural operations, which tend to transfer most of the chips to a third party. UFW is rarely left on-site, which indicates that UFW is being handled and transported in the majority of situations. Yet private and municipal operations only dispose about 20% of their UFW into solid waste facilities, demonstrating that a large portion of the UFW generated in Virginia is being utilized before it reaches the MSW stream. Still, the amount of UFW sent to landfills can be further reduced by increasing opportunities for utilization.

Similar to amount, the fate of UFW generated by arboricultural operations should be carefully documented. Survey results indication that only half of municipal and private arboricultural operations can characterize the fate of the UFW they generate. If UFW is being disposed, then tipping fees and transportation costs should be documented in order to assess the total cost of disposal and conduct a more accurate cost to benefit analysis. If UFW is being utilized, then relationships with UFP producers and consumers should be developed and

maintained, especially if revenues are being generated. Future educational or technical programs should encourage arborists and municipal employees to accurately document UFW fate and provide networking opportunities for UFW generators and UFP producers and consumers. Future research could involve detailed economic analysis of the marketability of various UFPs and the costs and benefits of producing them.

5.2 Perceptions of UFW Utilization in Virginia

Prior to this study, little was known about the perceptions of arborists and municipal employees with regards to incentives, barriers, and needs for increased UFW utilization in Virginia. Our survey results indicate that both municipal employees and private sector arborists believe that UFW utilization is a major issue for the urban forestry industry currently and will be even more important in the future. Municipal employees and private arborists agreed that the avoidance of disposal fees and transportation costs were among the primary incentives to increase UFW utilization, and the environmental sustainability of the operation or community was another commonly reported incentive. By encouraging operations to track disposal fees and transportation costs, we can further demonstrate the value of alternatives to disposal and encourage utilization. Reported barriers to further UFW utilization varied between municipal and private sector respondents. The lack of in-house equipment for processing UFW was cited by municipal employees significantly more often than private arborists, while the logistical difficulties of handling UFW on tree service job sites was cited by private arborists significantly more often than municipal employees.

Although incentives for further UFW utilization were generally agreed upon by municipal employees and private arborists, their differing opinions on barriers should be taken into account when developing future educational or technical programs aimed at increasing

utilization. Based on survey responses, the following programs should be developed with **private** arboricultural operations in mind:

1. Hands-on workshops or field demonstrations
2. Industry standards or best management practices
3. An online course or webinar

Based on survey responses, the following programs should be developed with **municipal** arboricultural operations in mind:

1. Educational seminars or conferences
2. Cooperative Extension or VDOF publications
3. An educational website

The following programs were frequently requested by both arborists and municipal employees, and should be developed with **both operations** in mind:

1. A local, centralized facility for receiving, sorting and stockpiling UFW
2. A cooperative business facility for selling and/or producing urban forest products
3. An online database that networks UFW generators, processors, & producers

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APPENDIX A – SURVEY GEOGRAPHIC SCOPE

Appendix A – List of 91 urban localities in Virginia solicited for a survey on urban forest waste (UFW) generation. Population, land area, and density data were obtained from the 2010 US Census (US Census Bureau 2010a).

Locality Name	Locality Type	Population	Land Area (sq. mi.)	Density (#/sq. mi.)
Abingdon	Town	8,191	8.1	1,015
Alexandria	City	139,966	15.0	9,312
Altavista	Town	3,450	4.9	703
Arlington	County	207,627	26.0	7,995
Ashland	Town	7,225	7.1	1,013
Bedford	Town	6,222	6.9	904
Berryville	Town	4,185	2.3	1,844
Big Stone Gap	Town	5,614	4.9	1,148
Blacksburg	Town	42,620	19.9	2,143
Blackstone	Town	3,621	4.5	806
Bluefield	Town	5,444	9.3	584
Bridgewater	Town	5,644	2.5	2,231
Bristol	City	17,835	13.0	1,371
Broadway	Town	3,691	2.4	1,571
Buena Vista	City	6,650	6.7	993
Charlottesville	City	43,475	10.2	4,246
Chesapeake	City	222,209	340.8	652
Chesterfield	County	316,236	423.3	747
Chincoteague	Town	2,941	9.1	323
Christiansburg	Town	21,041	14.4	1,463
Clifton Forge	Town	3,884	3.0	1,286
Colonial Beach	Town	3,542	2.6	1,389
Colonial Heights	City	17,411	7.5	2,315
Covington	City	5,961	5.5	1,090
Culpeper	Town	16,379	6.7	2,437
Danville	City	43,055	42.9	1,003
Dublin	Town	2,534	1.4	1,863
Dumfries	Town	4,961	1.5	3,221
Elkton	Town	2,726	3.0	897
Emporia	City	5,927	6.9	860
Fairfax	City	22,565	6.2	3,616
Fairfax	County	1,081,726	391.0	2,767
Falls Church	City	12,332	2.0	6,166
Farmville	Town	8,216	7.2	1,140
Franklin	City	8,582	8.2	1,045
Fredericksburg	City	24,286	10.4	2,326

Locality Name	Locality Type	Population	Land Area (sq. mi.)	Density (#/sq. mi.)
Front Royal	Town	14,440	9.2	1,563
Galax	City	7,042	8.2	855
Grottoes	Town	2,668	1.9	1,419
Hampton	City	137,436	51.4	2,673
Harrisonburg	City	48,914	17.4	2,808
Henrico	County	306,935	233.7	1,313
Herndon	Town	23,292	4.3	5,455
Hillsville	Town	2,681	8.9	302
Hopewell	City	22,591	10.3	2,198
Lebanon	Town	3,424	4.5	768
Leesburg	Town	42,616	12.4	3,440
Lexington	City	7,042	2.5	2,817
Luray	Town	4,895	4.8	1,031
Lynchburg	City	75,568	49.1	1,538
Manassas	City	37,821	9.9	3,828
Manassas Park	City	14,273	2.5	5,642
Marion	Town	5,968	4.1	1,449
Martinsville	City	13,821	11.0	1,261
Newport News	City	180,719	68.7	2,630
Norfolk	City	242,803	54.1	4,486
Norton	City	3,958	7.5	529
Orange	Town	4,721	3.3	1,426
Pearisburg	Town	2,786	3.2	882
Petersburg	City	32,420	22.9	1,414
Poquoson	City	12,150	15.3	793
Portsmouth	City	95,535	33.7	2,839
Prince William	County	402,002	336.4	1,195
Pulaski	Town	9,086	7.9	1,150
Purcellville	Town	7,727	3.2	2,453
Radford	City	16,408	9.9	1,662
Richlands	Town	5,823	5.7	1,018
Richmond	City	204,214	59.8	3,414
Roanoke	City	97,032	42.6	2,280
Rocky Mount	Town	4,799	6.8	702
Salem	City	24,802	14.4	1,718
Smithfield	Town	8,089	9.5	853
South Boston	Town	8,142	13.1	623
South Hill	Town	4,650	9.8	473
Staunton	City	23,746	20.0	1,188
Strasburg	Town	6,398	3.8	1,706
Suffolk	City	84,585	400.2	211
Tazewell	Town	4,627	6.9	670

Locality Name	Locality Type	Population	Land Area (sq. mi.)	Density (#/sq. mi.)
Timberville	Town	2,522	1.3	1,986
Vienna	Town	15,687	4.4	3,557
Vinton	Town	8,098	3.2	2,563
Virginia Beach	City	437,994	249.0	1,759
Warrenton	Town	9,611	4.5	2,136
Waynesboro	City	21,006	15.0	1,397
West Point	Town	3,306	5.1	655
Williamsburg	City	14,068	9.0	1,560
Winchester	City	26,203	9.2	2,839
Windsor	Town	2,626	4.0	655
Wise	Town	3,286	3.1	1,077
Woodstock	Town	5,097	3.9	1,304
Wytheville	Town	8,211	14.5	567

APPENDIX B – SURVEY INSTRUMENT

Intro Thank you for taking the time to complete this important survey being conducted by Virginia Tech and Virginia Department of Forestry. Your responses will help us better understand the practices and perceptions of urban forest waste utilization in Virginia. The survey is being administered using the Qualtrics survey software. It should require about 20 minutes to complete. Please read each question carefully and answer to the best of your ability. Once you start the survey, please do not click the back button on your browser. Instead, navigate the survey using the "<<" and ">>" buttons within the survey screen. If you need to exit the survey, your progress will be saved. You may return at any time by clicking the survey link provided in the email. This study is conducted under the guidance of the Virginia Tech Institutional Review Board. If you have any concerns about the study's conduct or your rights as a research subject, please contact the Board at irb@vt.edu or 540-231-4991.

Def Please read the following definitions. They will help clarify certain terminology used in the survey questions. Urban forest waste (UFW) – any woody material (i.e., logs, chips, or brush) generated from the pruning, felling, or removal of a tree. Urban forest product (UFP) – any product produced via the utilization of urban forest waste. Generated – created from arboricultural practices (e.g., pruning, felling, removal, land clearing, etc). Utilized – used to produce an urban forest product. Disposed – transported to a facility (e.g., landfill, dump site) or left on-site without the intention of producing an urban forest product.

Q1 Are you in a position to report on the urban forest waste (UFW) generated by the local operation of your business/organization/municipality? "Local operation" refers to an individual municipality, a locally-owned and operated business, or a local office of a larger company with multiple regional offices.

- ❍ Yes (1)
- ❍ No (2)

D1 Please answer a few questions about yourself. Your answers are confidential and are intended to help us understand perceptions about urban forest waste utilization. What is your age?

- ❍ 18-30 (1)
- ❍ 31-44 (2)
- ❍ 45-60 (3)
- ❍ 61+ (4)

D2 What is your gender?

- ❍ Female (1)
- ❍ Male (2)

D3 What is your highest level of education attainment?

- ❍ High school or equivalent (1)
- ❍ Associate degree (2)
- ❍ Bachelor's degree (3)
- ❍ Graduate degree (4)

D4 How long have you worked in a profession related to trees or tree debris disposal?

- ❍ 0-10 (1)
- ❍ 11-20 (2)
- ❍ 21-30 (3)
- ❍ 31+ (4)

P1 Please indicate your level of agreement with the following statements about urban forest waste (UFW) generation, disposal, and utilization for the local operation of your business/organization/municipality:

	Strongly Agree (1)	Agree (2)	Neither Agree nor Disagree (3)	Disagree (4)	Strongly Disagree (5)
My operation seeks to increase UFW utilization for logistical reasons (2)	❍	❍	❍	❍	❍
My operation seeks to increase UFW utilization for financial reasons (3)	❍	❍	❍	❍	❍
My operation seeks to increase UFW	❍	❍	❍	❍	❍

utilization for regulatory reasons (4)					
My operation seeks to increase UFW utilization for environmental reasons (1)	❍	❍	❍	❍	❍

P2 Please indicate your level of agreement with the following statements about urban forest waste (UFW) generation, disposal, and utilization for the local operation of your business/organization/municipality:

	Strongly Agree (1)	Agree (2)	Neither Agree nor Disagree (3)	Disagree (4)	Strongly Disagree (5)
UFW disposal is a major cost for my operation (5)	❍	❍	❍	❍	❍
UFW utilization is a major revenue source for my operation (6)	❍	❍	❍	❍	❍
UFW utilization is important to my clients (10)	❍	❍	❍	❍	❍
UFW utilization is a major issue for the urban forestry industry currently (7)	❍	❍	❍	❍	❍
UFW utilization will be a	❍	❍	❍	❍	❍

major issue for the urban forestry industry in the future (8)					

P3 Please indicate your level of agreement with the following statements about urban forest waste (UFW) generation, disposal, and utilization for the local operation of your business/organization/municipality:

	Strongly Agree (1)	Agree (2)	Neither Agree nor Disagree (3)	Disagree (4)	Strongly Disagree (5)
I have engaged in self-education or training about UFW utilization in the past year (11)	❍	❍	❍	❍	❍
I will engage in self-education or training about UFW utilization in the coming year (12)	❍	❍	❍	❍	❍
I have found satisfactory opportunities for education or training on UFW utilization when I have sought it (13)	❍	❍	❍	❍	❍

P4 Please rank the most significant incentives (existing or potential) for increasing utilization of urban forest waste (UFW) by the local operation of your business/organization/municipality: Rank at least 3 Items by dragging and dropping Items into the Rank box.

Rank
_____ Additional revenue (1)
_____ Avoidance of disposal fees (3)
_____ Avoidance of transportation or shipping costs (4)
_____ Value-added service to clients (2)
_____ Environmental sustainability of the operation/community (5)
_____ Support local industries or businesses (e.g., "Buy local" initiatives) (6)
_____ Opportunity to produce urban forest products for use elsewhere within the operation/community (7)
_____ Other: (8)
_____ Other: (9)
_____ Other: (10)

P5 Please rank the most significant barriers (existing or potential) for increasing utilization of urban forest waste (UFW) by the local operation of your business/organization/municipality: Rank at least 3 Items by dragging and dropping Items into the Rank box.

Rank
_____ Local regulations or permitting requirements (1)
_____ Lack of local processors of UFW (3)
_____ Lack of local consumers of UFP (4)
_____ Logistical difficulties of handling UFW on tree service job sites (5)
_____ Logistical difficulties of transporting UFW to processors (6)
_____ Lack of in-house space for stockpiling UFW (7)
_____ Lack of in-house equipment for processing UFW (8)
_____ Lack of in-house knowledge or skill for processing UFW or marketing UFP (9)
_____ Lack of communication between UFW producers and UFP consumers (10)
_____ Other: (12)
_____ Other: (13)
_____ Other: (14)

P6 Please rank the following educational or technical programs as a potential means for helping you increase your capacity for utilization of urban forest waste (UFW) or production of urban forest products (UFP): Rank at least 3 Items by dragging and dropping Items into the Rank box.

Rank
_____ An educational website (3)
_____ An online course or webinar (12)
_____ Educational seminars or conferences (4)
_____ Hands-on workshops or field demonstrations (5)
_____ Cooperative Extension or VDOF publications (1)
_____ Industry standards or best management practices (2)
_____ An online database that networks UFW generators, UFW processors, and UFP producers (6)
_____ A local, centralized facility for receiving, sorting, and stockpiling UFW (7)
_____ A cooperative business facility for selling and/or producing UFPs (8)
_____ Other: (9)
_____ Other: (10)
_____ Other: (11)

P7a May we contact you with follow-up questions based on your responses to this survey?

- ❑ Yes, my email is: (1) _____
- ❑ Yes, my phone number is: (3) _____

P7b Thank you for your time spent responding to this survey. If there is anything else you would like to contribute to our study of urban forest waste utilization, please use the comment box below.

Q2 Does the local operation of your business/organization/municipality directly generate urban forest waste (UFW)? If your local operation hires contractors who generate UFW rather than using your in-house staff, please select No.

- ❍ Yes (1)
- ❍ No (2)

Q3a Please indicate your industry sector:

- ❍ I am employed by a municipality (city, town, county) (1)
- ❍ I am employed by a tree care company (including contractors for utility service providers or VDOT) (2)
- ❍ I am employed by a landscape company (3)
- ❍ I am employed by a consulting firm (6)
- ❍ I am employed by an institution (university, arboretum, estate, state/federal park, etc.) (5)
- ❍ I am employed by an electric utility service provider (4)
- ❍ I am employed by Virginia Dept. of Transportation (VDOT) (8)
- ❍ Other: (7) _____

Answer If Please indicate your industry sector: I work for a municipality (city, town, county) Is Selected

Q3b Please indicate your position within your municipality:

- ❍ Arborist (1)
- ❍ Horticulturist (2)
- ❍ Urban Forester (8)
- ❍ City/Town/County Manager (3)
- ❍ City/Town/County Planner (4)
- ❍ Public Works Administrator (5)
- ❍ Parks and Recreation Administrator (6)
- ❍ Solid Waste Administrator (7)
- ❍ Other: (9) _____

Answer If Please indicate your industry sector: I am employed by a tree care company (commercial, residential, utility) Is Selected Or Please indicate your industry sector: I am employed by a landscape company Is Selected

Q3c Please indicate your position within your business/organization:

- ❍ Manager of a regional operation (1)
- ❍ Manager of a local operation (2)
- ❍ Manager of a production crew (3)
- ❍ Member of a production crew (4)
- ❍ Other (5) _____

Q4 In the local operation of your business/organization/municipality, how many full-time employees are directly involved in activities that generate urban forest waste (UFW)?

- ❍ 0-5 (1)
- ❍ 6-10 (2)
- ❍ 11-15 (3)
- ❍ 16-20 (4)
- ❍ 21+ (5)

Q5a From the list provided below, select ALL of the localities in which the local operation of your business/organization/municipality generates urban forest waste (UFW). If you are employed by a larger company with multiple regional offices, please select only those localities where your local office operates and for which you can specifically answer questions about UFW generation. If you are employed by a municipality, please select only your municipality from the list.

- ❑ < 91 sample municipalities listed >
- ❑ None of these (1)

Answer If Please indicate your industry sector: I work for a municipality (city, town, county) Is Not Selected

Q5b Please estimate the percentage of urban forest waste (UFW) that the local operation of your business/organization generates within each of your selected localities as a percentage of the total UFW generated in all of your selected localities: To set your percentages, drag each blue bar side to side or enter a specific percentage on the right side of the graph. Keep in mind your responses should add up to 100%. If you only selected one locality in the previous question, your percentage for that locality should be 100%.

< 91 sample municipalities listed >

Q6 Please indicate where the local operation of your business/organization/municipality generates urban forest waste (UFW) (as a percentage of total UFW generated): To set your percentages, drag each blue bar side to side or enter a specific percentage on the right side of the graph. Keep in mind your responses should add up to 100%.

_____ Private residential (1)
_____ Private commercial (2)
_____ Public parks, grounds, and greenspaces (3)
_____ Public street rights-of-way maintained by a municipality (4)
_____ VDOT roadside rights-of-way (5)
_____ Electric utility rights-of-way (6)
_____ Other: (7)
_____ Other: (8)

Q7 The following arboricultural practices generate urban forest waste (UFW). Please indicate which types of work the local operation of your business/organization/municipality conducts (as a percentage of total UFW generated): To set your percentages, drag each blue bar side to side or enter a specific percent on the right side of the graph. Keep in mind your responses should add up to 100%.

_____ Tree pruning (1)
_____ Tree removal (2)
_____ Curbside pickup of tree debris (3)
_____ Small woodlot logging (4)
_____ Land clearing (5)
_____ Other: (6)
_____ Other: (7)

AF1 Urban forest waste comprises logs, chips, or brush generated from the pruning, felling, or removal of a tree.Please describe how the local operation of your business/organization/municipality tracks the amount of urban forest waste (UFW) that it generates:

- ❍ We keep detailed records of the amount of UFW generated and can report based on these records (1)
- ❍ I can provide an estimate of the amount of UFW generated (2)
- ❍ I cannot provide an estimate of the amount of UFW generated (3)

If I cannot estimate the amount... Is Selected, Then Skip To Please describe how your business/org...

AF2 Please report or estimate the average amount of urban forest waste (UFW) that your local operation generates per unit of time. For each type of material, enter an amount, followed by the unit of measure, followed by the unit of time. If your operation does not generate a particular waste type, enter "0" for amount. It is understood that waste generation can be highly variable during the year. Please provide your best estimate for a typical time period.

	Amount	Unit of Measure				Unit of Time				
	(1)	Tons (1)	Cubic Yards (2)	Board Feet (3)	N/A (4)	Day (1)	Week (2)	Month (3)	Year (4)	N/A (5)
Logs (1)		❍	❍	❍	❍	❍	❍	❍	❍	❍
Chips (2)		❍	❍	❍	❍	❍	❍	❍	❍	❍
Brush (3)		❍	❍	❍	❍	❍	❍	❍	❍	❍

AF3 Please describe how the local operation of your business/organization/municipality tracks the fate of urban forest waste (UFW) that it generates: Fate refers to what happens to UFW after it is generated and may include disposal and/or utilization on-site, in-house, or by a 3rd party.

- ❍ We keep detailed records of the fate of UFW generated and can report based on these records (1)
- ❍ I can provide an estimate of the fate of UFW generated (2)
- ❍ I cannot provide an estimate of the fate of UFW generated (3)

If I cannot estimate the fate ... Is Selected, Then Skip To End of Block

AF4a Urban forest waste comprises logs, brush, or chips generated from the pruning, felling, or removal of a tree. Please describe the fate of the logs generated by the local operation of your business/organization/municipality: To set your percentages, drag each blue bar side to side or enter a specific percent on the right side of the graph. Keep in mind your percentages should add up to 100%.

_____ If you do not generate logs, set this to 100% (otherwise leave at 0%) (7)
_____ Utilized in-house to produce urban forest products (firewood, lumber, furniture, art/novelty, etc.) (1)
_____ Transferred to a 3rd party for utilization as urban forest products (2)
_____ Disposed at a solid waste facility or elsewhere (3)
_____ Left on-site, resulting in no utilization (4)
_____ Left on-site for utilization by property owner (14)
_____ Other: (5)
_____ Other: (6)

Answer If Please describe the fate of the logs you generate (Keep in mind your percentages should add up to 100%): Utilized in house to produce urban forest products (firewood, lumber, furniture, art/novelty, etc.) Is Greater Than 0

AF4b Of the logs that your local operation utilizes in-house, what percent are utilized to produce each of the following urban forest products (UFPs)? To set your percentages, drag each blue bar side to side or enter a specific percent on the right side of the graph. Keep in mind your percentages should add up to 100%.

_____ Firewood (1)
_____ Lumber (2)
_____ Pallets (3)
_____ Furniture (4)
_____ Cabinetry (5)
_____ Flooring (6)
_____ Veneer (7)
_____ Art/novelty (8)
_____ Other: (9)
_____ Other: (10)

AF5a Urban forest waste comprises logs, brush, or chips generated from the pruning, felling, or removal of a tree. Please describe the fate of the chips generated by the local operation of your business/organization/municipality: To set your percentages, drag each blue bar side to side or enter a specific percent on the right side of the graph. Keep in mind your percentages should add up to 100%.

_____ If you do not generate chips, set this to 100% (otherwise leave at 0%) (7)
_____ Utilized in-house to produce urban forest products (mulch, compost, biomass, etc.) (1)
_____ Transferred to a 3rd party for utilization as urban forest products (2)
_____ Disposed at a solid waste facility or elsewhere (3)
_____ Left on-site, resulting in no utilization (4)
_____ Left on-site for utilization by property owner (14)
_____ Other: (5)
_____ Other: (6)

Answer If Please describe the fate of the chips you generate (Keep in mind your percentages should add up to 100%): Utilized in house to create urban forest products (mulch, compost, biomass, etc.) Is Greater Than 0

AF5b Of the chips that your local operation utilizes in-house, what percent are utilized to produce each of the following urban forest products (UFPs)? To set your percentages, drag each blue bar side to side or enter a specific percent on the right side of the graph. Keep in mind your percentages should add up to 100%.

_____ Mulch (1)
_____ Compost (3)
_____ Biomass for energy (4)
_____ Pellets for wood stove burning (5)
_____ Other: (6)
_____ Other: (7)

AF6a Urban forest waste comprises logs, brush, or chips generated from the pruning, felling, or removal of a tree. Please describe the fate of the brush generated by the local operation of your business/organization/municipality: To set your percentages, drag each blue bar side to side or enter a specific percent on the right side of the graph. Keep in mind your percentages should add up to 100%.

_____ If you do not generate brush, set this to 100% (otherwise leave at 0%) (7)
_____ Utilized in-house to produce urban forest products (chips, mulch, compost, biomass, etc.) (1)
_____ Transferred to a 3rd party for utilization as urban forest products (2)
_____ Disposed at a solid waste facility or elsewhere (3)
_____ Left on-site, resulting in no utilization (4)
_____ Left on-site for utilization by property owner (14)
_____ Other: (5)
_____ Other: (6)

Answer If Please describe the fate of the brush you generate (Keep in mind your percentages should add up to 100%): Utilized in house to create urban forest products (chips, mulch, compost, biomass, etc.) Is Greater Than 0

AF6b Of the brush that your local operation utilizes in-house, what percent is utilized to produce each of the following urban forest products (UFPs)? To set your percentages, drag each blue bar side to side or enter a specific percent on the right side of the graph. Keep in mind your percentages should add up to 100%.

_____ Mulch (1)
_____ Compost (2)
_____ Biomass for energy (3)
_____ Other: (5)
_____ Other: (6)

Answer If Urban forest waste comprises logs, brush, or chips generated from the pruning, felling, or removal of a tree.Please describe the fate of the logs generated by your operation (keep in mind your perc... Disposed at a solid waste facility or elsewhere Is Greater Than 0 Or Urban forest waste comprises logs, brush, or chips generated from the pruning, felling, or removal of a tree.Please describe the fate of the chips generated by your operation (keep in mind your per... Disposed at a solid waste facility or dump, resulting in no utilization Is Greater Than 0 Or Urban forest waste comprises logs, brush, or chips generated from the pruning, felling, or removal of a tree.Please describe the fate of the brush generated by your operation (keep in mind your per... Disposed at a solid waste facility or elsewhere Is Greater Than 0

AF7 Please report or estimate the average expense of disposal of urban forest waste (UFW) generated by the local operation of your business/organization/municipality per unit of time. It is

understood that waste generation and disposal fees can be highly variable during the year. Please provide your best estimate for a typical time period.

	Amount	Unit of Time			
	$ (1)	Day (1)	Week (2)	Month (3)	Year (4)
Disposal Fees (1)		❍	❍	❍	❍

PF1a In the past five years, the amount of urban forest waste (UFW) generated by the local operation of your business/organization/municipality has:

- ❍ Increased substantially (1)
- ❍ Increased moderately (2)
- ❍ Stayed about the same (3)
- ❍ Decreased moderately (4)
- ❍ Decreased substantially (5)
- ❍ I don't know (6)

PF1b In the past five years, the amount of urban forest waste (UFW) utilized as urban forest products (UFP) by the local operation of your business/organization/municipality has:

- ❍ Increased substantially (1)
- ❍ Increased moderately (2)
- ❍ Stayed about the same (3)
- ❍ Decreased moderately (4)
- ❍ Decreased substantially (5)
- ❍ I don't know (6)

PF2a In the next five years, the amount of urban forest waste (UFW) generated by the local operation of your business/organization/municipality will:

- ❍ Increase substantially (1)
- ❍ Increase moderately (2)
- ❍ Stay about the same (3)
- ❍ Decrease moderately (4)
- ❍ Decrease substantially (5)
- ❍ I don't know (6)

PF2b In the next five years, the amount of urban forest waste (UFW) utilized as urban forest products (UFP) by the local operation of your business/organization/municipality will:

- ❍ Increase substantially (1)
- ❍ Increase moderately (2)
- ❍ Stay about the same (3)
- ❍ Decrease moderately (4)
- ❍ Decrease substantially (5)
- ❍ I don't know (6)

APPENDIX C – SURVEY INVITATION EMAILS

Email to ISA Certified Arborists:

Hello,

My name is Jordan Endahl and I am a forestry graduate student at Virginia Tech. Recently you should have received an invitation from MAC-ISA asking you to participate in my online survey about your urban wood utilization practices and perceptions. Our records indicate that you have started but not yet completed the survey.

While your response is critical to my research project, I also encourage you to participate for your own benefit. This research will help Virginia Tech and Virginia Department of Forestry develop continuing education programs that will benefit green industry professionals like you.

Your participation is voluntary. All responses will be confidential and not associated with you individually in any public dissemination of the research results. The raw data will only be accessible by the research team and you will not be solicited for any reason by taking the survey.

Follow this link to take the online survey:

<individual survey link>

Because we'll be closing the survey website soon, I kindly ask that you complete it at your earliest convenience. We thank you in advance for your participation.

Jordan Endahl
ISA Certified Arborist #MA-5311A
M.S. Urban Forestry, 2014
B.S. Forestry, 2011
Virginia Tech
urbanwood@vt.edu

Email to Municipal Employees:

Hello,

My name is Jordan Endahl and I am a forestry graduate student at Virginia Tech. I am working with Charlie Becker and Paul Revell of the Virginia Department of Forestry to conduct research on the utilization of urban forest waste (i.e., tree debris) in Virginia. For this research, we are asking select individuals within local governments to complete an online survey about urban wood waste in their municipalities. You have received an invitation to complete the survey based on your position within your municipality. If you do not believe you are the best person to respond to our survey, please forward this email to the appropriate municipal employee.

While your response is critical to my research project, I also encourage you to participate for your own benefit. This research will help Virginia Tech and Virginia Department of Forestry develop continuing education programs that will benefit municipalities like yours.

Your participation is voluntary. All responses will be confidential and not associated with you individually in any public dissemination of the research results. The raw data will only be accessible by the research team and you will not be solicited for any reason by taking the survey.

Follow this link to take the online survey:

<individual survey link>

Because we'll be closing the survey website soon, I kindly ask that you complete it at your earliest convenience. We thank you in advance for your participation.

Jordan Endahl
ISA Certified Arborist #MA-5311A
M.S. Urban Forestry, 2014
B.S. Forestry, 2011
Virginia Tech
urbanwood@vt.edu

APPENDIX D – IRB APPROVAL LETTER

VirginiaTech

Office of Research Compliance
Institutational Review Board
North End Center, Suite 4120, Virginia Tech
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-4606 Fax 540/231-0959
email irb@vt.edu
website http://www.irb.vt.edu

MEMORANDUM

DATE: March 4, 2014

TO: Eric Wiseman, Chad Bolding, John F Munsell, Jordan Brantley Endahl

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires April 25, 2018)

PROTOCOL TITLE: Urban Forest Waste Generation and Utilization in Urbanized Localities of Virginia

IRB NUMBER: **14-108**

Effective March 3, 2014, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the New Application request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Exempt, under 45 CFR 46.110 category(ies) 2**
Protocol Approval Date:	**March 3, 2014**
Protocol Expiration Date:	**N/A**
Continuing Review Due Date*:	**N/A**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.