LOCATING AND VALUING AVAILABLE WOOD SOURCES IN PRINCETON, MA

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ABSTRACT

The Princeton Environmental Action Committee (EAC) is a town committee within Princeton, MA that exists to advise and set goals and recommendations for the town of Princeton regarding energy and environmental considerations. Our project aimed to assist the EAC in this goal by documenting available wood sources within a 20-mile radius of Princeton. Our project defines 'available wood' as wood that has been removed either for environmental or safety reasons, in addition to waste wood from for-profit wood removals done by private businesses. This wood cannot be made into higher-value products, and instead is left to be given away, rot, or put to other local uses that can be found for this wood. To quantify this wood output, we conducted interviews, phone calls, and email exchanges with both public entities and private businesses in the Wachusett region that were involved with wood removals. After conducting interviews and collecting data we were able to identify all the possible stakeholders that are involved with wood sources in the area. Based on our findings, we recommended proposing a wood aggregation hub to the town of Princeton to utilize this underused resource and improve sustainability across the Wachusett region.

TREES ARE DYING AT A FASTER RATE

Globally, the number of trees needing to be trimmed and cut is expected to increase dramatically as the effects of climate change begin to play out. An experimental study conducted by Leeds University in the United Kingdom was able to prove this theory in 2020. The study examined 210,000 tree ring records from over 110 tree species found in all continents except Antarctica and Africa [2]. The experimental study found that nearly all tree species being examined had exponential growth patterns as well as that this correlated to rapid mortality in the trees being examined. Although previous studies have been done that suggest this same issue happened in particular tree species, the study by Leeds University is the first of its kind to suggest that this trend is a universal phenomenon, occurring in all species and environments [2]. The simplest explanation for faster mortality rates among trees is due to climate change. In recent years, a high amount of CO2 emissions mixed with rising global temperatures is causing these trees to die earlier than expected. This creates an issue as trees are now dying before they can store significant amounts of carbon. Additionally, unless the effects of climate change throughout the past decades can be reversed, the tree mortality issue is projected to affect municipal tree removal procedures greatly. This is expected to correlate to an increase in woody biomass being grown and harvested around the world.

[30]

Already, the United States is seeing the effects of climate change play out on trees. A survey conducted in 2017 by the Tree Services Magazine attempted to determine if increasing wood supplies and wood removal work was in fact true by surveying tree service businesses. The study found that 23% of interview respondents reported that they have experienced a 15% or more increase in their budget and personnel [23]. Increasing budgets and staff are a direct correlation to increases in tree volume and wood removal work being required by customers, including individual landowners, businesses, and government entities.

TREE DEBRIS: WHERE IS IT GOING?

According to a 2012 article published by the United States Forest Service, supplies of tree debris generated from routine pruning and tree maintenance could amount to nearly 4 billion board feet or 30% of annual hardwood consumption in the United States [23]. Currently, when downed or damaged trees and their limbs are removed from roadsides or public and private properties, the fate of this material in Massachusetts is not clearly understood. Some of this debris has potential uses, but some of it is left to rot, as most Massachusetts municipalities lack debris management plans [23]. Looking specifically at Massachusetts, which is the 8th most forested state with approximately 3 million acres of wood available in forests, rural, and urban areas, the potential to use discarded wood debris is high.

Although the actual amount of tree debris that is generated annually is hard to estimate because municipal tree wardens in Massachusetts do not keep a record of this, a 2002 Massachusetts report gives us some generalized information that helps predict this amount in the state. According to the study, the Massachusetts Division of Energy Resources estimates that 1,049,200 tons of tree debris are generated annually throughout the state. Of that amount, approximately 56% of this is handled on-site, 3% is sent to recyclers, 12% is sold, and only 3% is burned for energy [9]. This leaves over 26% or 272,792 tons, which has no current use, and the report estimates that 17% of this amount ends up in landfills.

[31]

GETTING VALUE FROM NATURALLY RELEASED CO2

The abundance of trees and availability of wood comes with the challenges of finding practical applications and uses to make sure that wood does not go to waste and can be used more efficiently. One way to decrease the effects of carbon in the long term is by utilizing downed tree material as a source of fuel before wood releases carbon into the atmosphere. In April 2018, the Environmental Protection Agency (EPA) began classifying wood and other forest biomass as carbon-neutral, meaning wood is now classified as renewable energy. The belief is that if a tree is burned for fuel, others can be planted to replace those that were burned [5]. Additionally, following the carbon cycle, the carbon released from burning the fuel would be absorbed by the new trees.

"Wood is the only material that requires so little energy to be produced. The energy consumed for the extraction and production of a material is called 'production energy.' The higher it is, the more CO2 is emitted. Compared to other materials, wood is very energy efficient in terms of producing energy. It is even the only material that provides a negative carbon balance due to forests' 'carbon sink' effect. By-products from wood production and manufacturing processes (bark, sawdust, shavings, production rejects, etc.) as well as wood-based products which can no longer be recycled, are burned and used as an energy source, thereby completing wood's 'virtuous' cycle. Wood then takes the place of traditional fossil fuels, supplying energy with a neutral CO2 balance. The CO2 released by the combustion of wood is equivalent to the amount that the wood absorbed during its growth. This combustion does not, therefore, contribute either to the greenhouse effect or to global warming. Wood's energy is 'clean' because it avoids being placed in landfills as well as minimizes waste disposal costs. The impurities produced by combustion are filtered within energy production units before being discharged via smokestacks. When it burns, wood releases no more CO2 than it absorbed during its growth" [19].

[32]

From a long-term perspective, using wood for fuel is more beneficial than leaving it to rot and decay over time, especially when it comes to wood that is already logged or ready to be discarded of. The current increase in jobs involving tree removal work creates a good opportunity to use this abundant resource that many contracting companies would normally pay to dispose of.

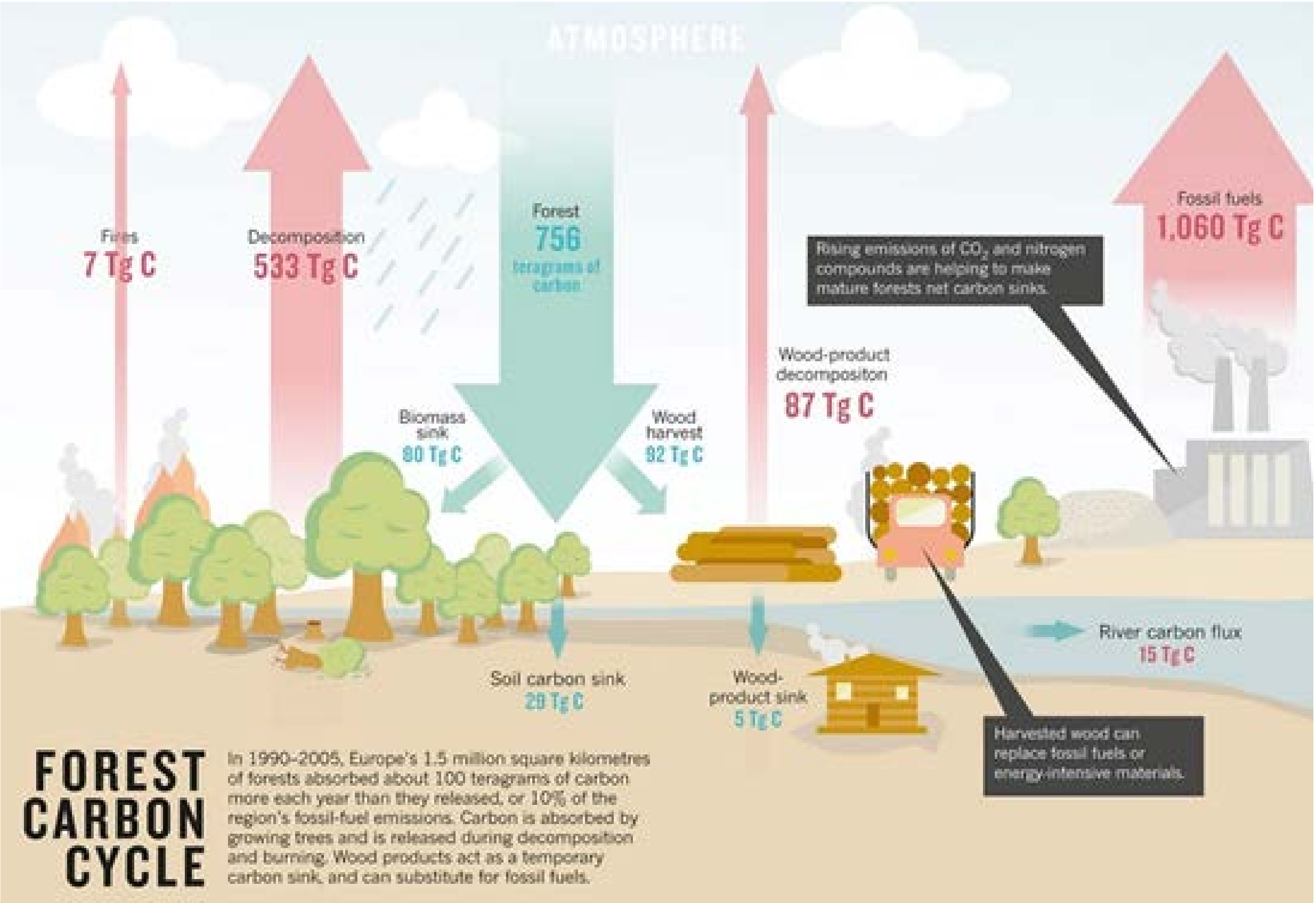


Figure 1: The Forest Carbon Cycle is shown here [10].

MASSACHUSETTS FORESTS

Massachusetts' forests are not immune to the tree mortality issue sweeping across the globe. In addition, tree mortality caused by climate change is not the only issue with which the Commonwealth is grappling. Tree mortality due to insect infestation is also a rising problem. According to Michael Dietze, an ecologist at Boston University, warmer climates across the state are likely to bring more drought to the region and allow invasive species affecting the tree population to breed longer [15]. An example of one of these invasive species is the Asian long horn Beetle, which breeds in numerous tree species, and could eventually lead to the death of these trees. The Massachusetts Department of Conservation and Recreation has worked extensively since the beetle was first discovered in 2008 to help eradicate the species from the state. Currently, the only effective way to eliminate the beetle is to remove infested trees and destroy them by chipping or burning [1].

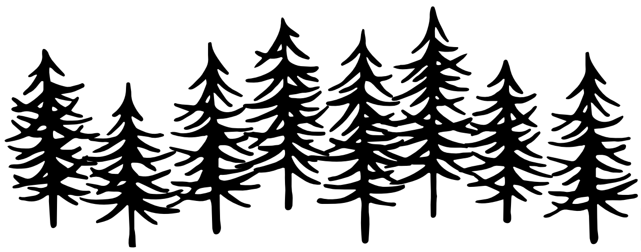
In addition to the longhorn beetle, the state is also dealing with the effects of the emerald ash borer, an invasive species killing the ash tree population. The emerald ash borer causes early mortality in ash trees by breeding and feeding under the bark, which affects the tree's ability to transport water and nutrients [8]. While these are the immediate insect threats to Massachusetts forests, other states in the Northeast are experiencing similar difficulties from invasive species such as the spotted lanternfly. As more insects bring about tree damage, tree mortality will be accelerated in the next decade across the state. The combined effects of climate change, invasive species, and the resiliency work that follows these are expected to add irregular supplies and influxes of wood in addition to the stable supply of tree debris currently being generated every year [23].

[33]

FOREST MANAGEMENT AND MASSACHUSETTS POLICY

An important Massachusetts policy that opens the potential to use woody biomass material is the Massachusetts Chapter 61 program. This is a program issued by the state that grants private landowners a classification of land where they receive lower property taxes, in exchange for the restriction of clearing trees on that land. This program serves as a financial relief for those in the state who were being forced to sell their land because of increasing property tax burdens [16] allowing the land to be saved from development to help conserve the forests in the Commonwealth. Although the Chapter 61 program is not a program intended for harvesting forests, the program designates that each landowner have a forest management plan, meaning that wood residue is generated each year across the state on land that is part of this program.

Another important Massachusetts policy that opens the way for using low-value biomass as a fuel source is the proposed state climate bill, currently in proposal by Governor Baker's office. The bill, if passed, will require Massachusetts to reduce its carbon emissions by 85% by the year 2050 [26]. The newly revised bill will allow wood-burning facilities that utilize wood biomass to increase, citing that these fuel sources qualify as "non-carbon emitting resources" [26]. If this provision is passed in the Massachusetts Senate, the bill poses a way to the development of low-value wood sources being used on a much larger scale across the Commonwealth in the next few years.



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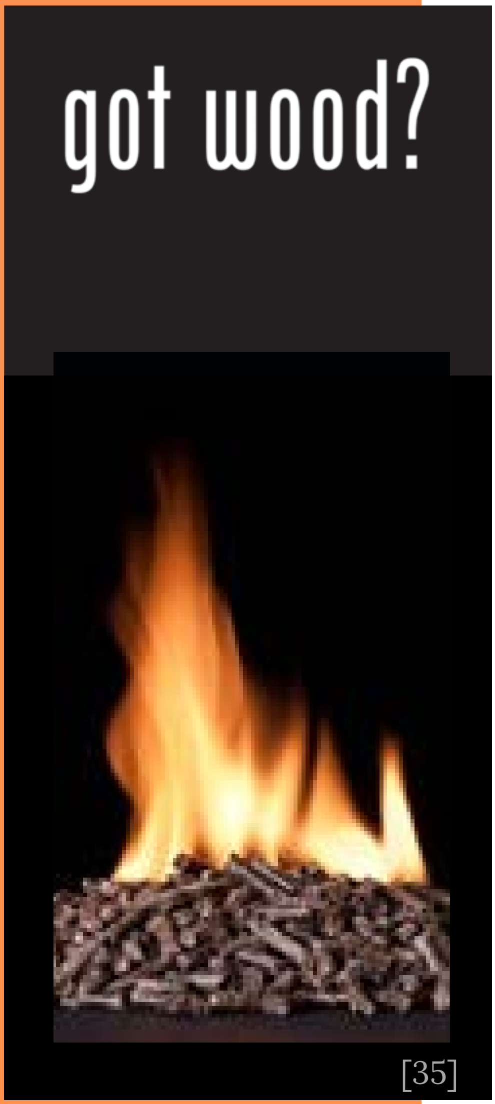
LOCAL GOVERNANCE AND WOOD PRODUCTS MANAGEMENT

In communities in Massachusetts and other states, Environmental Action Committees (EACs) work at a local level to make recommendations, undertake special initiatives and provide some advocacy for environmental matters. Specifically, the Princeton Environmental Action Committee has taken an interest in trying to understand how wood products and woody biomass is managed throughout the Wachusett region. Understanding where this wood is going, how much of it is being discarded or cut/trimmed, is the first step the committee is undertaking to explore potential uses of this wood for sustainability initiatives. The estimation of inventory, production, and valuation of wood could be instrumental in biomass management in central Massachusetts, thus leading to the motivation and rationale for the following research project.

WOOD AS A FUEL SOURCE



[35]

There are many benefits to using wood as a fuel source to heat buildings as an alternative to fossil fuels. For example, wood is priced at around half of the value of oil. In a Fall 2013 report, the USDA Forest Service Calculator had predicted cordwood as having an average cost of $16.34/one million British Thermal Units (BTU), being sold at $250/cord, compared to fuel oil, which had a $31.74/ one million BTU value, being sold at $3.65/gallon; meaning it would require over 8.6 gallons of oil to produce one million BTU of heat. Not only would it be cheaper to maintain a wood-fueled boiler, but the use of this local resource would “enhance the market for low grade-wood and promote small-scale forestry and increase the economic viability of working forests and helping to protect forests from development threat" [18]. Before higher value markets can develop in the Wachusett region for wood as a fuel source, we must understand how much wood is available to support wood burning. Our project is the first step in identifying these wood sources and determining how much of it is available in the area.

DEFINING AVAILABLE WOOD

Before we were able to locate and quantify the number of wood sources that are in the Wachusett region, we first needed to identify the specific types of wood harvests. To determine a simplified guide for the types of wood harvests we would be focused on identifying, we explored the Massachusetts Department of Conservation and Recreation (DCR) Forest Cutting Plan application [6]. Using this document as a guide, we were able to determine that the state summarizes wood harvests into three distinct categories. These include board wood, cordwood, and "other" wood which includes wood chips and pulp. Our sponsor has tasked us specifically with identifying low-value wood types and since board wood is considered a higher value product, we eliminated this wood type from our objectives, as markets are already available for boards, and they are currently in high demand due to the coronavirus pandemic and lumber shortages across the nation [7]. Throughout the term, we focused specifically on cordwood and other wood, which includes wood chips as these would be a practical fuel source to use in wood-powered heating systems. Figure 2 shows the breakdown of specific wood products that come from the various parts of a tree.

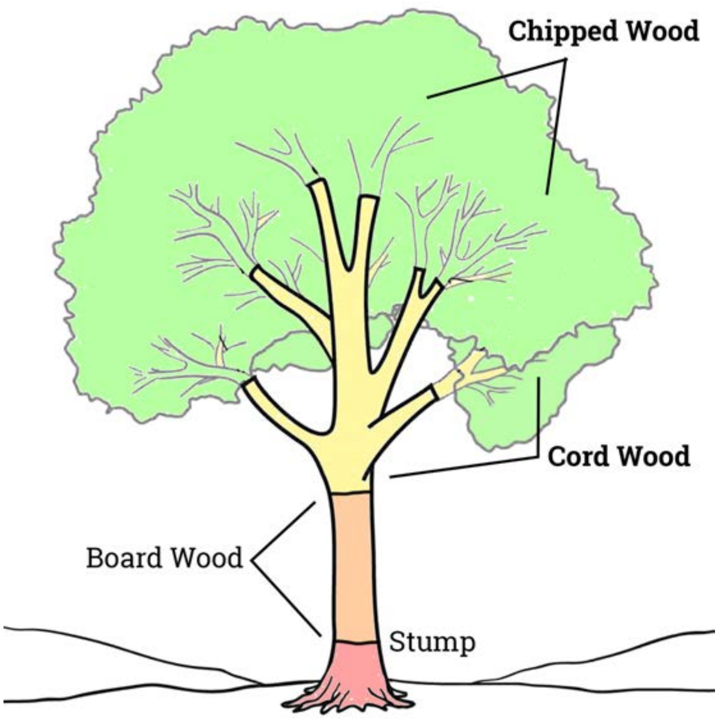


Figure 2: Chipped wood is made from the smaller branches and top parts of a tree. Chip sizes are usually between 20 and 50 mm. Chipped wood is typically measured in units of tons.

Cordwood is made from larger branches and logs and is cut and split into logs primarily for the use of firewood. Cordwood is typically measured in units of cords. One cord is equal to a volume of 4' by 4' by 8'.

Board wood comes from the trunk of a tree and is typically made into higher-value products including furniture and lumber.

IDENTIFYING THE RESEARCH AREA OF INTEREST

Originally, the Princeton EAC had tasked us with locating available low-value wood sources that were within a 20-mile radius of Princeton. Examining the map of the area shown in Figure 3, we identified 73 municipalities that fit within this zone. Since it would have been unrealistic to contact every stakeholder that deals with wood residue from all 73 municipalities in our 7-week time period, we shifted our focus specifically to the Wachusett Regional School District, including the towns in the immediate vicinity of Princeton, MA. These towns included Princeton, Sterling, Rutland, Paxton, and Holden. In addition to these towns, time allowed us to expand our search to conduct interviews and collect data for the municipalities of Gardner, Westminster, Hubbardston, Oakham, Spencer, Worcester, West Boylston, Shrewsbury, and Westborough.

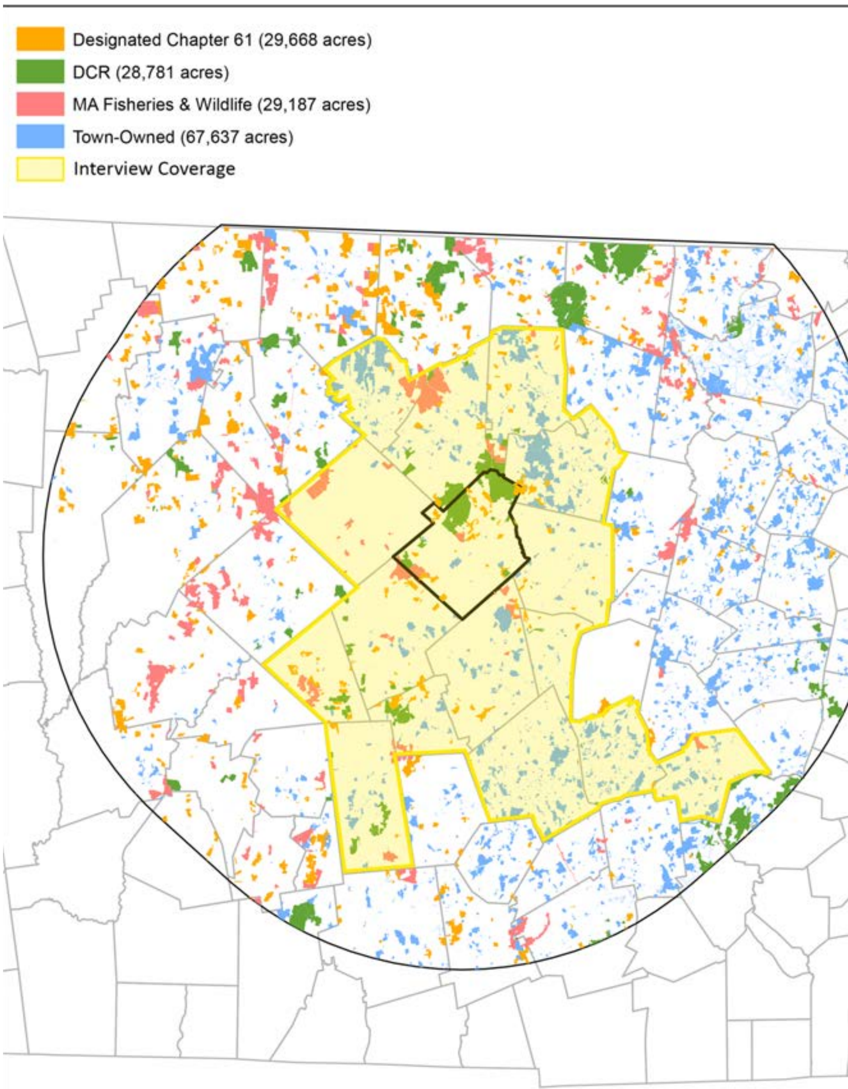


Figure 3: This map shows the municipalities within the 20-mile radius zone.

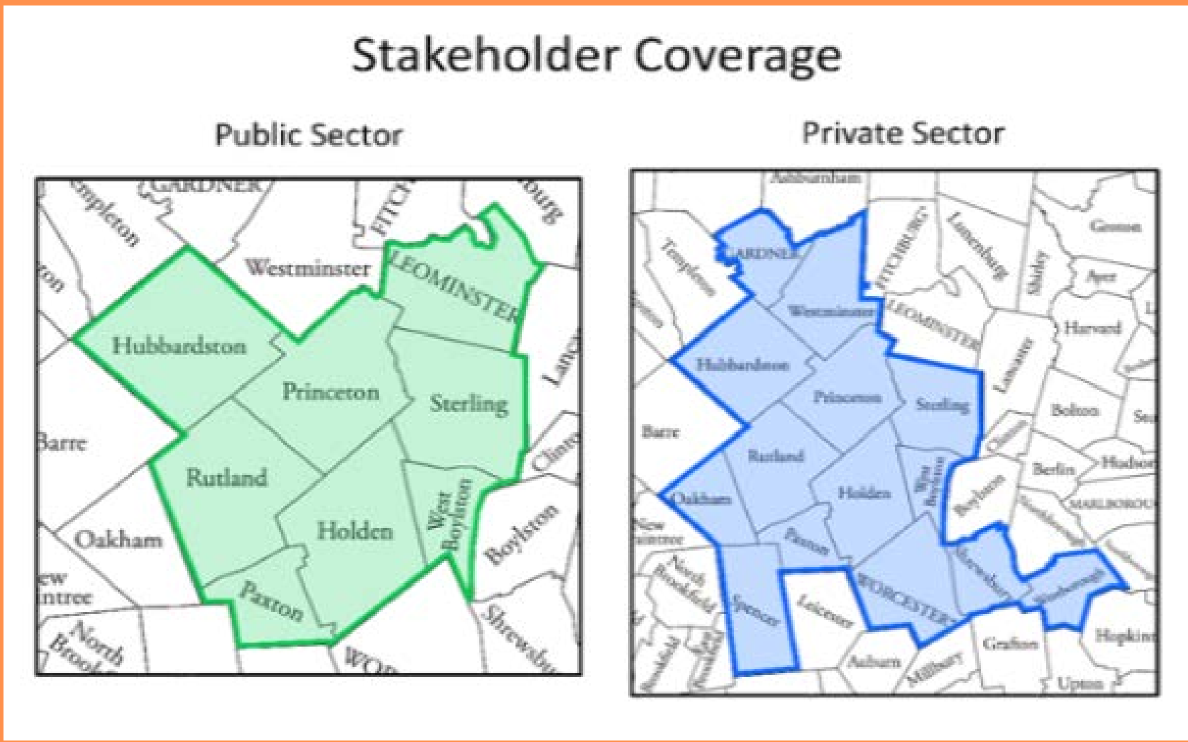


Figure 4: Stakeholder coverage for each sector

BREAKING DOWN POSSIBLE STAKEHOLDERS INTO TWO SECTORS

After brainstorming with our sponsor about how to reach all stakeholders who may be removing, producing, or associated with what has been defined as available wood, we split our four-member group into two teams that targeted both the public and private sectors. Half of the team, the public sector, was responsiblen for identifying and interviewing public departments involved in wood removal, such as town departments of public works (DPWs), municipal light departments (MLDs), etc. The other half of the team investigated the private sector and was responsible for identifying and interviewing private entities, such as arborists, land clearers, and tree removal contractors. Figure 4 shows the coverage map that each sector was responsible for. This land area was based on the number of stakeholders we were able to identify in each municipality. For example, since within the public sector we were able to locate many public stakeholders in the Wachusett region, the search for additional sources did not need to be expanded a great deal. However, private businesses in the region were scarcer, which meant the private sector needed to expand the search to identify and collect enough data to prove our sponsor's hypothesis that there was enough wood in the area to create a wood aggregation center.

When thinking about how to best collect the data, we decided on conducting phone interviews and Zoom calls to reach out to stakeholders within each sector, as this method would ensure that we got responses and could collect enough data to make the case for whether there is enough wood in the area for the Princeton EAC to pursue further research into the potential uses of low value wood products and waste.

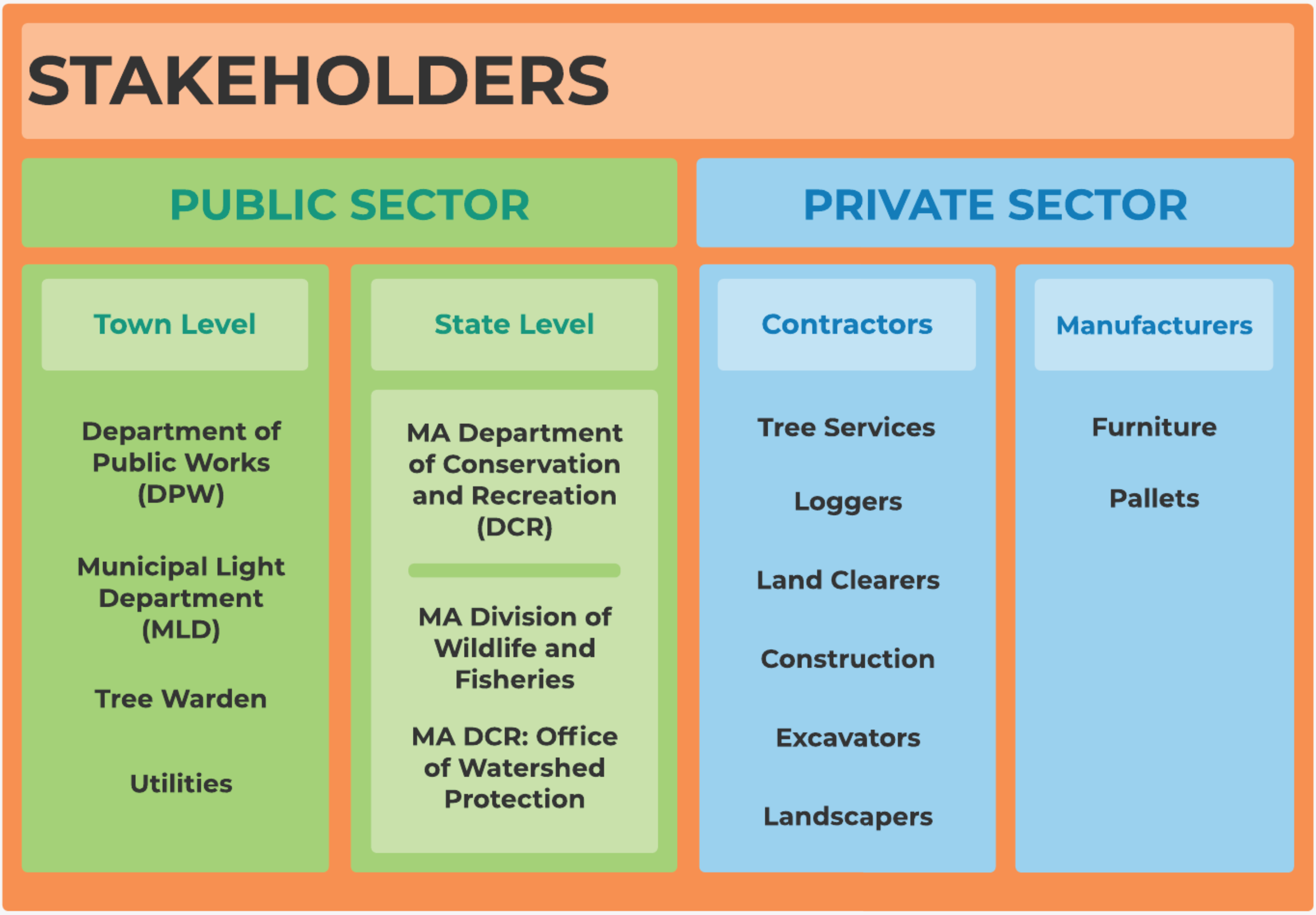


Figure 5: This figure shows all of the possible stakeholder sectors that we identified during our methodology planning stage of the project

The main questions we were trying to answer through conducting interviews were the following:

- **How much available wood is in the area, and in what forms?**
- **What happens to this wood?**
- **What is the current market value of this wood?**
- **What is the cost associated with getting rid of this wood?**

8
Public Sector Municipalities

14
Private Sector Municipalities

LOCATING LOWER VALUE WOOD IN THE PUBLIC SECTOR

After we had broken the possible stakeholders down into public and private sectors, we split each sector down more. For the public sector side, we identified DPWs, MLDs, tree wardens, and utility companies as being the sectors responsible for tree removal procedures that occurred on the public level within the region. Additionally, when considering the wood removal and harvesting procedures that occur on the state level, we were able to identify the Massachusetts DCR, Fisheries and Wildlife Department (Mass Wildlife), and Highway Department as the entities that are currently responsible for available wood on the state level.

Our data collection methods started by emailing each stakeholder, introducing our project, and asking to speak with a representative from each organization. From there, we hoped to be put into contact with an expert in the field, who may be able to talk immediately or willing to set up another call. We did conduct a couple of these interviews through zoom, but most interviews were conducted through the phone in an informal manner. Figure 6 shows the interview process we followed, which was streamlined for each group to conduct interviews using this simplified process.

Identifying wood sources on the state-managed lands was also especially important to uncover. Examining Figure 3, which was created by our sponsor, we realized that public-owned land takes up a large portion of the area under research.

LOCATING LOWER-VALUE WOOD IN THE PRIVATE SECTOR

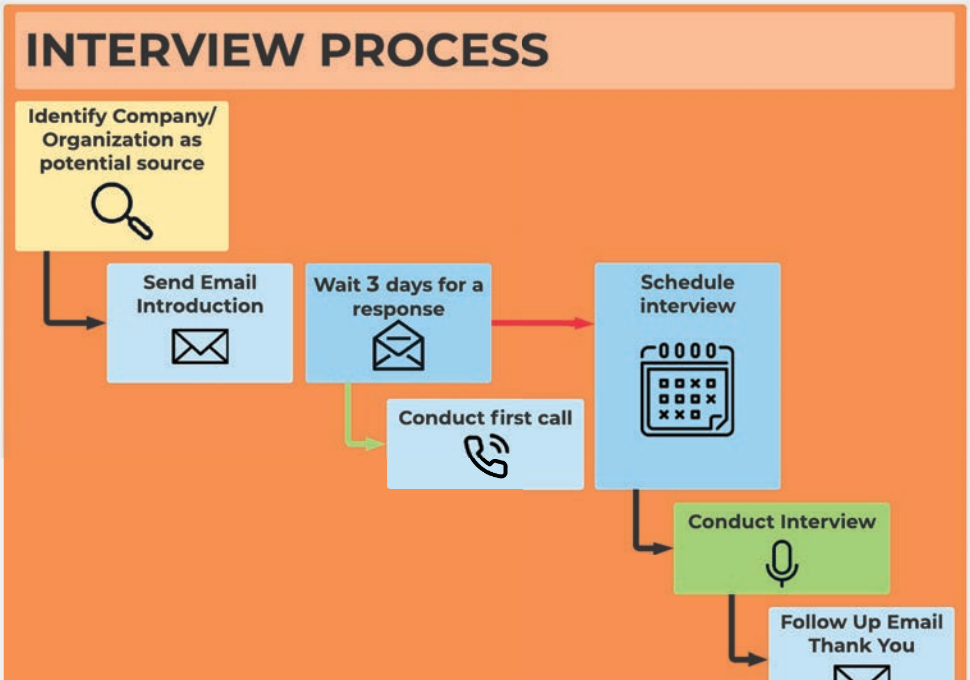


Figure 6: Flowchaft of interview process

To find private businesses within the area of Princeton, we began by searching through websites, such as YellowPages, for businesses that produce or consume what we define as available wood. We started by searching for all the tree removal services, loggers, and land clearers within our range as they would be our main resource going forward in the private sector. Using this method, we were able to find 16 different tree removal services, 10 pallet companies, and 19 construction companies within our range. Through our research, we were able to find contact information for the companies above in the form of email alias, phone numbers, or both. Once we began to make contact with some of these businesses, we would ask if they had any other contacts they knew of that we could also reach out to. This process we defined as the snowballing effect.

We began our interview process by sending out emails to the stakeholders we could find an email address for. These emails were all formulated using the same preamble that would explain the scope of our project, how they could benefit from assisting us, and contact information which can be found in our supplemental materials document. For the stakeholders that we could not locate an email address for, we called them directly, leaving a message with contact information if we were not able to reach them.

Interviews in the private sector were conducted in an informal manner, with questions centered around quantifying and locating available wood [the questions used were the same as the ones listed on page 13] along with other questions that were more specific to each stakeholder which can be found in the supplemental materials document. After an interview, we would ask the interviewee if we could contact them in the future with any further questions regarding their available wood, followed by a “Thank You” email for their help with our project.

RESULTS AND FINDINGS

Figure 7: Picture taken at stakeholder company site

COMPILING INTERVIEW DATA FROM EACH SECTOR

In total, we contacted 27 stakeholders on the public side and were able to conduct 22 interviews. Conversely, for the private sector, we identified 41 stakeholders but were only able to interview 14. When it came to attempting to make conversation with private companies, often we would not get much cooperation or responsiveness, in comparison to the public sector. Overall, our analysis of potential wood-residue producing stakeholders does contain anomalies.

However, the data that we were able to collect from those who participated gives a sufficient estimate of the available wood in the area. When inquiring for an average quantity per year estimate, most were described in terms of the number of trees cut, the number of tons of wood chips, or the number of dump trucks full. Not to mention, this wood varies in form as well, altogether making the data difficult to compile. In order to standardize our data, we attempted to convert these estimations into two units. Tons of wood chips and cords of wood are two commonly used units for measuring wood biomass. In an Indiana Department of Natural Resources report on Woody Biomass Feedstock [13], there is a table included for the conversion between volume and tons of wood chips, in both green tons (GT) and bone-dry tons (BDT). We know that 1 BDT of wood is equal to 200 cubic feet. We also know that 1 BDT is equal to 2.857 GT, so we were able to calculate that 1 GT is equal to 77.82 cubic feet. Using these transformations, we were able to convert any data given in cubic yards into GT which can be used to find a market value. We have included the following conversion factors into our analysis, in order to get a better perception of the public sector data. Note that the Indiana method uses a green ton defined at 50% moisture content (MC), compared to the 35% moisture content that we have used here, as advised by our sponsor. Additionally, the type of tree species is not known for our estimates and each tree species will have a different weight per unit cubic yard [13]. Furthermore, we also implemented a gauge of utilization within the data analysis. To do this, we used the outgoing destination of the wood to come up with a utilization value, whether it had no utilization, minimum, some, or maximum.

Wood Biomass Conversion Table

1 BDT = 2 GT (assuming MC = 50%)
1BDT = 2.857 GT (assuming MC = 35%)
1 BDT = 200 cubic ft of wood chips (Bone-dry)
1 GT = 77.82 cubic ft of wood chips (Green)

Ex: The Town B Municipal Light Department produces 8-10 dump trucks full per year (8-yard truck):
8-10 dump trucks => 9 dump trucks
1 dump truck = 8 yd^3
9 trucks * 8 yd^3 = 72 yd^3
72 yd^3 * (3 ft / 1 yd)^3 = 1944 ft^3
1944 ft^3 * (1 GT / 77.82 ft^3) = 24.98 GT => **~25 GT**

Figure 8:Conversion table for GT and BDT

PUBLIC SECTOR:

During interviews on the public sector side, stakeholders were very willing to share information. Table 1 contains each stakeholder's wood residue estimation in both raw forms and in terms of wood chips and cordwood. The table also includes the next destination for the wood, and if it has any current utilization. The names of individual towns and companies are not mentioned specifically to protect the privacy of interviewers who participated. Instead, we have labeled each stakeholder with alphabetic characters as individual identifiers. The following pages will describe the results from each of the different types of departments interviewed by the public sector, those being the departments of public works, municipal light departments, tree wardens, utility companies, and state agencies.

DEPARTMENTS OF PUBLIC WORKS (DPWs)

Our main results within the Department of Public Works (DPW) sector indicate that there is a relatively low volume of tree removal practices taking place here. However, most DPWs we contacted indicated that they still do a minimal amount of tree removal work. Out of the seven different towns that we contacted for this office, only three were responsive. One of these, Town C, strictly used contractors for tree work and did not have any record or estimate of the wood residue from the contractor projects. The main types of work being done by these DPWs are specifically removing tree trimmings along the sides of roads after storms or when a dying tree poses a threat to the safety of town citizens.

The two towns that were able to provide numbers, Town A and B, reported that they take down 3-4 trees and 21 trees on average in a year, respectively. As for wood residue allocation, both Town B and C leave the responsibility of disposing of the leftovers to the contractors themselves. Town A, on the other hand, does collect wood residue at a DPW storage pile where infested wood is burned yearly. This pile contains all wood residue that is cut from residential sites. For any work done in forests, the wood is left to decompose. These results show that there is some wood residue being produced in the DPWs around Princeton, some of which does not have much purpose and could be considered "available".

Public Sector: Aggregation of Wood Residue Estimations

Category	Town	Total Estimate	Average Produced Chips (per year)	Averaged Produced Cord Wood (per year)	Where is it going?	Utilization
Department of Public Works	Town A	3-4 trees	yes	yes	DPW storage pile, or left on site	none
	Town B	21 trees	yes	30-40 cords	contractors	minimal
	Town C	-	-	none	contractors	-
	Town G	3-4 trees	yes, most	yes	contractors, or left on site	-
Municipal Light Department	Town A	none	none	none	-	-
	Town B	8-10 dump trucks full (8 yard truck)	~25 GT*	minimal	DPW storage pile, contractors take bigger trees	minimal
	Town D	chip everything	yes	minimal	DPW storage pile	none
	Town E	40 trees, 75 x 10-15 x 6-7 ft wood pile /yr	~78 GT*	minimal	DPW storage pile	minimal
	Town F	1-3 dump trucks full /yr	~8 GT*	minimal	contractors	maximum
Tree Wardens	Town A	3-8 trees	yes	yes	storage pile	none
	Town B	> 25 tons	~25 GT	yes	contractors, storage pile	minimal
	Town E	works with light dept.	-	-	-	-
	Town G	3-4 trees	yes, most	yes	contractors, or left on site	-
Utilities	Town C	100 trees	100 trees	-	contractors, or left on site	none
	Town G	10-50 trees	yes, most	yes	contractors, or left on site	-
	Statewide	30,000-35,000 trees (statewide)	yes, most	yes	contractors	some
Totals	7 towns	-	> 136 GT	> 30-40 cords		

- = not assessed, * = converted value

Table 1: Compiled public sector interview data

MUNICIPAL LIGHT DEPARTMENTS (MLDs)

Our findings within the MLDs operating in the Wachusett region show that these departments are doing a great deal of tree removal work in the area. Out of the five towns that we reached out to, we were able to interview four MLDs. Each of these light departments are generating wood chips and a small amount of cordwood on the side. In fact, one interview subject stated that they chip everything they cut down. Three of these towns, Town B, E, and F were able to estimate a quantitative value for us, each being described in terms of dump trucks and/or cubic yards. The wood residue is collected at a town DPW storage pile for Towns B, D, and E, while Town F defers to contractors. Additionally, the wood collected in Town D and E does not seem to be going towards any current use. In comparison to the DPWs, the light departments offer a much larger quantity of available wood, specifically in the form of chips.

[36]

TREE WARDENS

In this category, we reached out to four different Tree Wardens but were not able to get a response from Town A. However, insight on Town A's tree warden was shared with us through another interview with the respective DPW. Town E was also an interesting case here, where the MLD and tree warden work in conjunction. Based on the quantitative data we received from the tree wardens, there does not seem to be a lot of tree removal work being done here. Towns B and G were able to report numbers, at around 25 tons of chips and three to four trees, respectively. Meanwhile, we had to fetch data for Town A from the local DPW, who reported that the two departments share 6-12 trees between themselves per year. From this supply of wood residue, Town A and E mentioned that they store the leftover wood, while the others give mostly everything to contractors to deal with. Our research on the amount of available wood in the Tree Wardens sector shows that there is some wood being cut and collected here, however much of it is given to contractors and is very likely being put to another use.

UTILITY COMPANIES

Since public utility companies are rare in the region, due to most municipalities having town-owned utilities, our main findings are applied to specific regions that do not align well with the rest of the public sector data. Specifically, Rutland is the only town in the Wachusett region that is served by a public utility company. Fortunately, we were able to interview the two major utility companies operating in the Wachusett region and found that both are contracting out all tree removal work. In relation to our studies, they work on trees in Rutland and Hubbardston. This is not a large piece of our data, considering that they only do work in two of our towns, yet it is still important. Another factor to note is that one utility company was not able to provide any estimates for individual towns. The quantity of wood residue that was reported, is merely an estimate of how many trees are being moved statewide and is far larger than any number we received from any other stakeholder. This may be an interesting number to think about on a large scale, however, it does not give us very much information on the local supply around Princeton. Both utility services call in contractors to do their tree work and likewise leave the responsibility for the wood residue to the contractor. Interestingly enough, one utility company that was able to provide us local data, mentioned that their contractors usually have difficulty finding a place to dispose of the wood residue, and would be much appreciative for a designated place to dump. Not only this, but the contractor listed in this instance is located in Rochester, New York. This was a shocking discovery to the research team, as we did not expect to be reaching out to any stakeholders outside our 20-mile radius, let alone, outside the state of Massachusetts. However, this explains why the contractor has difficulties with disposing of the wood residue. The data gathered from the utilities in the local Princeton area may not have shown us exactly what we were looking for in comparison to the rest of the public departments contacted, but we were still able to uncover a valuable contribution to our aggregate available wood residue supply.

Forest Products

Products to be Harvested*

Species	Mbf/Cds		Mbf/Cds
White Pine		Red Maple	
Red Pine		Sugar Maple	
Pitch Pine		Red Oak	
Hemlock		Black Oak	
Spruce		White Oak	
Other Sftwd.		Other Hdwd.	
White Ash		**Total Mbf**	
Beech		**Cordwood (Cds)**	
White Birch		**SW Pulp (Tons)**	
B & Y Birch		**HW Pulp (Tons)**	
Black Cherry		**Chips (Tons)**	

***Note**: Volumes indicated in the Plan are as reported by the plan preparer and have not been independently verified by the service forester upon approval. **Mbf** = thousand board feet.

Stand Treatment

Cutting Standards

Indicate location on map	ST-1	ST-2	ST-3	ST-4
Forest Type				
Acres				
Landowner Objective				
Designation of Trees				
Type of Cut				
Source of Regeneration				

Figure 9: Massachusetts Forest cutting plan form detailing wood products being harvested

STATE AGENCIES

The Massachusetts DCR was able to connect us with a Geographical Information System (GIS) database for Massachusetts state cutting plans. This data represents any harvesting project producing more than 25,000 board feet (or 50 cords), within the Massachusetts DCR, the Division of Fisheries and Wildlife, the Office of Watershed Protection, and the Chapter 61 program. From this database, we were able to run a query and retrieve the estimated amount of wood planned on being harvested in each town, going back as far as 2007, and as recent as 2017. The form in Figure 9 shows a summary of each harvest and the categories that are filled out on the form and tracked through the database.

Any more recent data, from 2018 and on, was unavailable to us due to limitations of time and COVID restrictions.

The cutting plans query data retrieved from the Massachusetts DCR representative was placed into an Excel document and summarized into the following table. The 'TOTAL Cords' column represents the total amount of cordwood (units of cords) planned on being produced in each town from 2007-2017, and the 'AVG/YR Cords' column represents the average based on those ten years. Likewise, with the 'Other' columns. 'Other' is referring to any slash, or wood that can be chipped (units of tons). Board wood is not included in this data as we were only interested in uncovering the amount of low-value wood being tracked at the state level.

The towns' averages for cords and slash can also be seen in Table 3, along with Figures 10 and 11, on the next page.

Town	TOTAL Cords	AVG/YR Cords	TOTAL Other	AVG/YR Other
Fitchburg	2729	272.9	16705	1670.5
Gardner	2053	205.3	10905	1090.5
Holden	3666	366.6	3924	392.4
Hubbardston	6823	682.3	16499	1649.9
Leominister	1492	149.2	3964	396.4
Paxton	2228	222.8	177	17.7
Princeton	6020	602	15149	1514.9
Rutland	8552	855.2	12075	1207.5
Sterling	3742	374.2	5994	599.4
Westminister	3988	398.8	18941	1894.1
TOTAL	41293	4129.3	104333	10433.3

Table 2: Massachusetts DCR Forest cutting plan data for each town

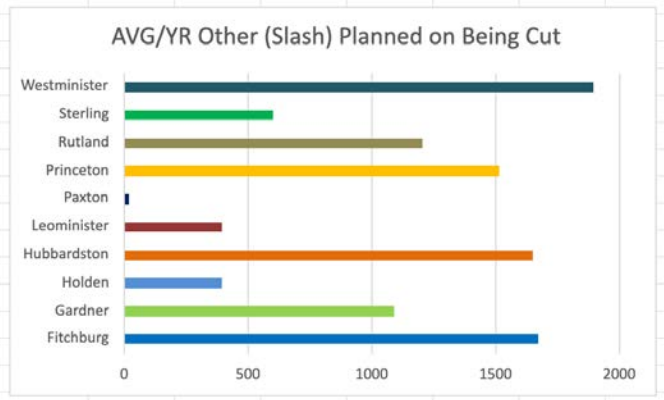


Figure 10: Average yearly miscellaneous harvested per town

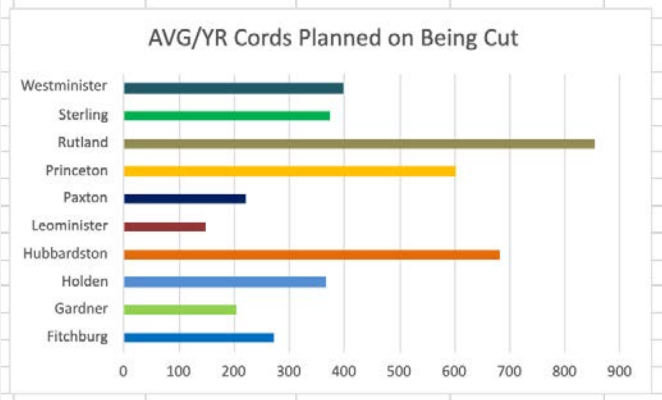


Figure 11: Average yearly cords harvested per town

Our findings within this sector show that any project lacking the equipment needed to process wood residue means that the residue is left in the woods and therefore would not be tracked by the database. This means that there is likely a larger amount of wood residue that goes untracked as it is being left to rot in the woods. Lastly, we can separate this database data from our interview findings, as this data represents large-scale harvesting projects which is not included in the information we have collected through both the public and private sector interviews.

[37]

PRIVATE SECTOR

The 14 stakeholders the private sector was able to interview were generally amicable and excited to share their data with us, seeing as doing so could benefit their business in the future. Table 3 on the right shows the raw data we were able to gather through our interviews, showing an estimate of available wood, its annual weight in chips or cords, where this unused wood is transported to, and how much it costs the company to transport it. Something to note is that there are only nine companies on this list, as five of the interviews did not have any substantial information we were able to use. The following pages explains the generalizations found in the three main types of businesses interviewed.

Private Sector: Aggregation of Wood Residue Estimations

Business	Company	Total Estimate	Average Produced Chips (per year)	Averaged Produced Cord Wood (per year)	Where is it Going?	Utilization
Tree Removal Services	Company A	500 tons of wood on hand	500 GT	-	Sold to contractor	some
	Company B	120,000 yd³ of chips per year	41,000 GT*	-	Sold to contractor	minimal
	Company C	300 cords or so per year	-	300	Sold to contractor	minimal
	Company D	25 Loads 40,000 lbs/load per year	500 GT*	-	Sold to contractor	some
	Company E	Does not know his specific amounts.	-	-	outdoor wood chipper	none
	Company F	15-20 loads a week , 600-700 tons a week	34,000 GT*	-	storage pile	some
Constructon Companies	Company G	6 tons a year	6 GT*	-	transfer site for processing	minimal
	Company H	Depends on Job, assuming a couple 30 yard dumpsters	63 GT*	-	unknown	none
Pallet Companies	Company I	At least 2 loads per week, 1.5 yd^3 per load	54 GT*	-	sawmills for chipping	minimal
Totals	9 companies		> 77,000 GT	> 300 cords		

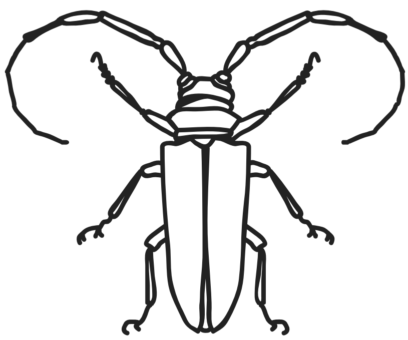
- = not assessed, * = converted value

Table 3: Private sector interview data

LOGGERS AND LAND CLEARERS

The main type of company we focused our time on in the private sector were loggers and land clearers. These are companies that are responsible for cutting down trees to make space for buildings or construction projects. We found that typically these companies do not have a place to dispose wood, so most wood is brought back to the company location and stored. The companies are then responsible for getting rid of the wood in a variety of ways. Some Companies (A, B, and C) will chip the wood into wood chips and pay a company to pick up and dispose of the chips by the tons. Company (E), that are storing the wood and are not able to chip it themselves, must contract that part out as well to another business which costs a large amount. Company (C) will make firewood out of the trees and sell the wood in cords.

Company (B) also had piles of wood that were contaminated, so they had to be placed in a “quarantine zone” or separated from the rest of the wood. The most common contaminant was the Asian Longhorn Beetle (ALB) which is prevalent in Worcester County [22]. ALB trees are destroyed from the inside as the bugs tamper with the structural integrity of any trees and other wood products they infect. To avoid the spread, any ALB-affected trees and their byproducts must be separated from healthy wood commodities.



[38]

PALLET COMPANIES

Pallet companies are those which specifically manufacture and sell their own pallets, so we were interested in seeing what is done with any scrap wood leftover from this process. We found a total of eight different pallet manufacturers within the Princeton area, though we were only able to contact two of them for an interview. We found that pallet companies generally have their scrap wood hauled away or burned on-site depending on the size of the operation that is being run.

For smaller-sized companies, the scrap may be used to heat the buildings with wood furnaces, or simply given away to locals and homeowners for various purposes. A company interviewed who was not included in table 3 explained that they chip their own wood, but do not sell it. Instead, they give it away to a dirt bike course nearby, for free. Larger companies are more likely to have their wood hauled away by another company to be chipped at an off-site location. Pallet companies that operate in this way will pay to have the scrap wood removed for a set price per load, usually between $100-$200 each time.

CONSTRUCTION COMPANIES

[39]

Construction companies are those who either build houses or do the land clearing before a house is built, resulting in businesses that have scrap wood in the form of either unused building material or trees brought down in excavation. While construction companies were not the main resource we were looking to contact, we were able to get some data from three different construction and excavation companies. The first company we were able to interview (who is not included in table 3) was relatively small and was not able to answer many questions. They did not have any concrete numbers, on the amount of unused wood on their site or from a given job, only saying that the available wood is used on their own property as heat.

Company (G) was able to provide us with the best quantitative data of these companies. When they do dispose of their unused wood, they bring them to a transfer site, which occurs about six times each year with each load being one ton each. They then must pay a fee of $150 each time they bring this wood to the site. The last company, Company (H) was able to provide some data regarding their available wood, though it was much less specific. The amount of wood they can produce on any given job fluctuates, resulting in some jobs having a 30-yard dumpster full of scrap, and others having only a pickup truckload or two. This difference in quantity is a result of different builders working on the job, as well as diverse sizes of the houses being built.

[40]

MARKET POTENTIAL:

SMALL SCALE HARVESTING

Below is the quantified data of all the public and private stakeholders who do smaller-scale harvesting. We used this table to find a total estimate on the market value of available wood based on the current market value, those being $19 per green ton of wood chips and $240 per cord of wood, as given to us by an interview stakeholder. The value was standardized on a per-year estimate to show how this supply could look going forward. Within the public sector, we were able to identify an estimate for over 149 green tons of wood chips and over 35 cords being produced. After factoring the current market prices for wood biomass, we came up with a total of about $2,800 worth of wood chips and $700 worth of cordwood being produced in the area. Additionally, we identified over 170 trees worth of wood residue that we were not able to convert to a measurable unit for market value. Conversely, on the private side, units of wood chips were much more commonly used, ultimately giving us a total estimate of about 77,000 green tons of wood chips and over 300 cords, which can also be expressed as about $1,500,000 worth of wood chips and $72,000 worth of cordwood. It is important to point out how many public departments utilize contractors

Aggregation of Market Value for Wood Residue Estimations

Where is it going?	Purpose?	Stakeholder	Total Estimate	AVG Chips (per year)	AVG Cord Wood (per year)	Market Value (wood chips)	Market Value (cord wood)	Total Market Value
DPW storage pile, or left on site	none	DPW A	3-4 trees	yes	yes	-	-	$0.00
DPW storage pile	none	Light Dept. D	chip everything	yes	minimal	-	-	$0.00
DPW storage pile	minimal	Light Dept. E	40 trees, 75 x 10-15 x 6-7 ft wood pile /yr	~87 GT*	minimal	$1,653.00	-	$1,653.00
storage pile	-	Tree Warden A	3-8 trees	yes	yes	-	-	$0.00
DPW storage pile, contractors take bigger trees	minimal	Light Dept. B	8-10 dump trucks full (8 yard truck)	~28 GT*	minimal	$532.00	-	$532.00
contractors, storage pile	minimal	Tree Warden B	> 25 tons	~25 GT	yes	$475.00	$665.00	$1,140.00
contractors	minimal	DPW B	21 trees	yes	30-40 cords	-	-	$0.00
contractors	-	DPW C	none given	-	none	-	-	$0.00
contractors	yes	Light Dept. F	1-3 dump trucks full /yr	~9 GT*	minimal	$171.00	-	$171.00
contractors, or left on site	-	DPW G	3-4 trees	yes, most	yes	-	-	$0.00
contractors, or left on site	-	Tree Warden G	3-4 trees	yes, most	yes	-	-	$0.00
contractors, or left on site	none	Utility C	100 trees	100 trees	-	-	-	$0.00
contractors, or left on site	-	Utility G	10-50 trees	yes, most	yes	-	-	$0.00
Public Total	**-**	**7 towns**	**> 170 trees**	**> 149 GT**	**> 35 cords**	**$2,831.00**	**$665.00**	**$3,496.00**
storage pile	minimal	Company B	120,000 yd^3 of chips per year	~41,000 GT*	-	$791,000.00	-	$791,000
storage pile	some	Company F	15-20 loads a week , 600-700 tons a week	~34,000 GT*	-	$642,000.00	-	$642,000
sawmills for chipping	minimal	Company I	At least 2 loads per week, 1.5 yd^3 per load	~54 GT*	-	$1,028.00	-	$1,028
outdoor wood chipper	unknown	Company E	none given	yes	-	-	-	$0
transfer site for processing	minimal	Company G	6 tons a year	~6 GT*	-	$114.00	-	$114
Sold to contractor	some	Company A	500 tons of wood on hand	500 GT	-	$9,500	-	$9,500
Sold to contractor	minimal	Company C	300 cords or so per year	yes	300 cords	-	$72,000.00	$72,000
Sold to contractor	some	Company D	25 Loads 40,000 lbs/load per year	~500 GT*	-	$9,500.00	-	$9,500
unknown	none	Company H	Depends on Job, assuming a couple 30 yard dumpsters	~63 GT*	-	$1,200.00	-	$1,200
Private Total	**-**	**9 companies**	**-**	**> 77,000 GT**	**> 300 cords**	**$1,454,342**	**$72,000**	**$1,526,342**

- = not assessed, * = converted value

Table 4: Aggregation of Market Value for Wood Residue Estimations

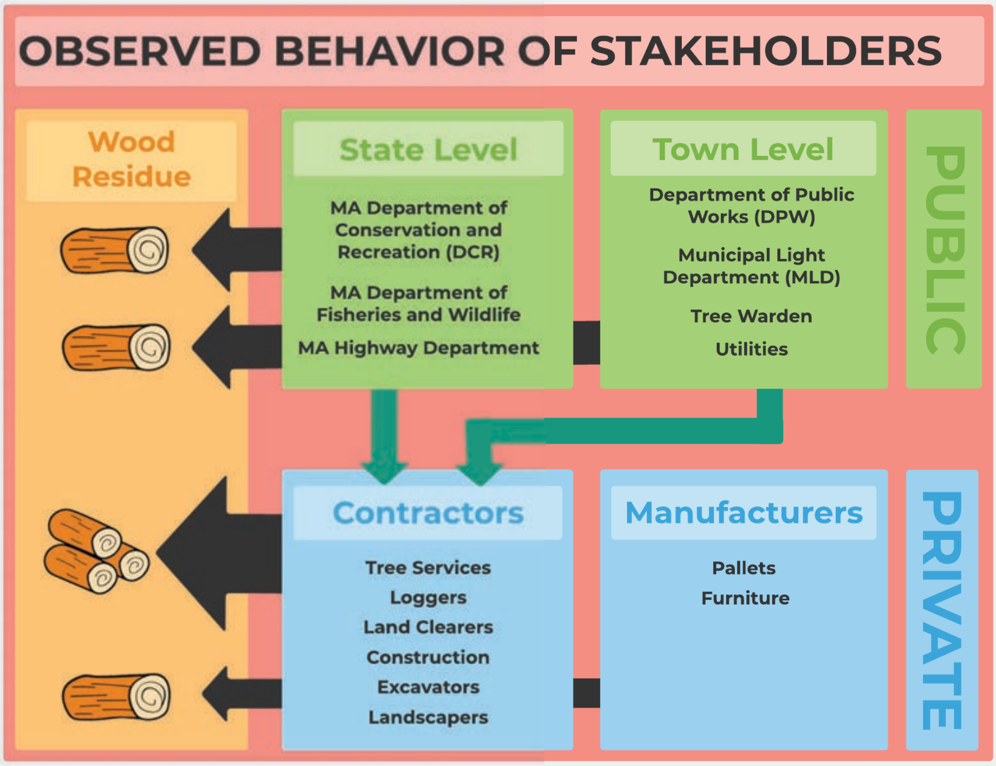


Figure 12: Observed Behavior of Stakeholders

to relocate the wood residue. Additionally, there is also a decent portion of private companies who use contractors themselves. This overlap between how much wood is generated and where the wood is actually going is shown in Figure 12. This diagram illustrates large complexity in the relationship between the two sector's data. Due to this relationship, they cannot be summed together, which makes it difficult for us to make a complete aggregate conclusion of how much wood we really found. Not only this, however, another great obstacle lying in our path were the units of wood that were reported by each stakeholder. As mentioned before, there was a large amount of wood residue that were reported in units of trees. This is a unit of measurement that requires intricate methods of data collection, that we did not have access to during our project,

WOOD BIOMASS TYPE REPORTED BY STAKEHOLDERS

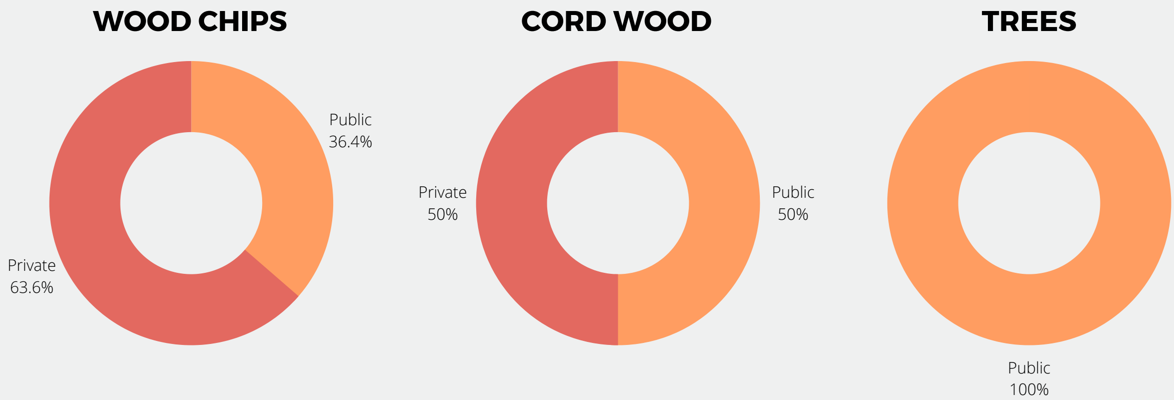
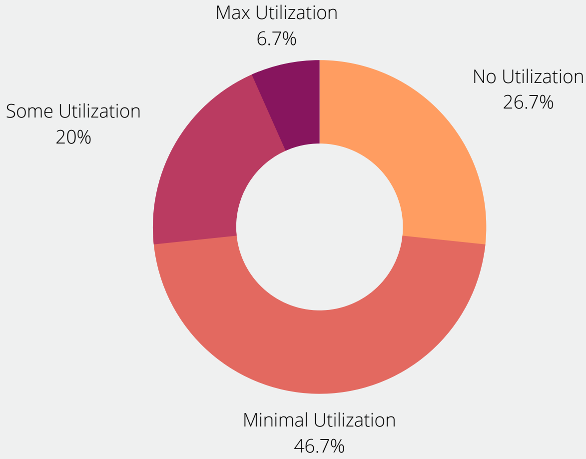


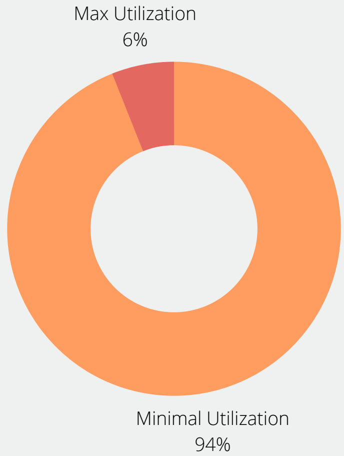
Figure 13: Determining which stakeholders have different forms of wood

including the type of tree species and breast-height diameter size. However, the data that was provided in units of wood chips proved to be sufficient. In Figure 14 on the right, we used the data from Table 4 to break down the number of stakeholders and the utilization of their wood residue. This shows that the majority, at 46.7% of stakeholders, has minimal utilization for their wood residue, while only 6.7% undergo maximum utilization. This is important in showing that many stakeholders could put more use to their wood residue. However, this does not show the amount of wood residue that is available to us. This was resolved at the bottom of Figure 14 where we broke down the utilization of wood residue, but instead, based on the amount of wood residue being produced in both Public and Private Sectors. For the public sector, there showed a 94% majority in minimal utilization and a mere 6% in maximum utilization. Somewhat similarly in the private sector, there was a 54.3% majority of minimal utilization, split with a 45.6% share of some utilization, and no clear indication of maximum utilization. Looking at all three of these diagrams together confirms that there is very little utilization of wood residue within the local Princeton area. Considering the 2002 USFS report of 272,792 tons of wood residue being unused, as mentioned before, we can verify that our findings are accurate.

CURRENT UTILIZATION OF WOOD RESIDUE (BASED ON NUMBER OF STAKEHOLDERS)



PUBLIC SECTOR: CURRENT UTILIZATION OF WOOD RESIDUE (BASED ON WOOD RESIDUE REPORTED)



PRIVATE SECTOR: CURRENT UTILIZATION OF WOOD RESIDUE (BASED ON WOOD RESIDUE REPORTED)

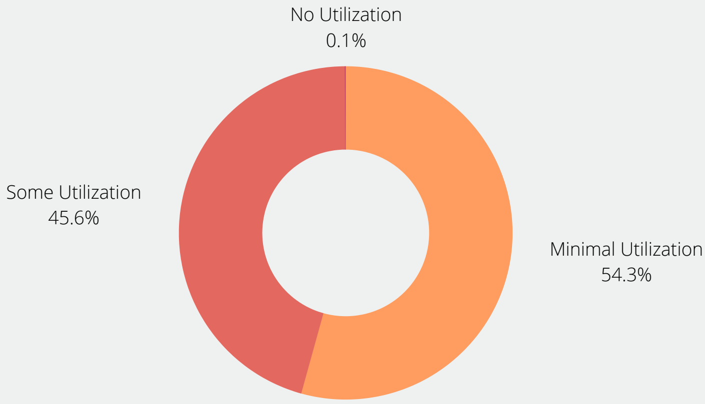


Figure 14: Determining utilization of the wood residue by the stakeholders

MARKET POTENTIAL:
LARGE SCALE HARVESTING

Using the data provided to us by the Mass DCR, we were able to conclude that on average, there is approximately 4,129 cords and 10,433 tons of residue wood predicted on being harvested each year in the ten municipalities we collected data from. Using the standard market value of $19 per ton of chips and $240 per cord of wood, which we obtained from interviewing various firewood sellers, we were able to estimate that this wood has a yearly market value of $991,032 for cords and $198,232 for wood residue being harvested. If we also considered that there are 73 towns within the 20-mile radius and are contributing comparable amounts of cordwood and wood residue, our team estimates that the total value within the 20-mile radius is upwards of $7,000,000 for cordwood and $1,500,000 for wood residue like wood chips. On the contrary, it must be taken into consideration that the data provided by the DCR only represents cutting plans made by foresters for large-scale harvesting. Thus saying, this data does not include any wood residue collected from small-scale harvesting projects done by the stakeholders we interviewed. Therefore the quantity of wood predicted must be perceived as a separate number, further proving the sufficient supply of wood residue in the surrounding 20-mile radius.

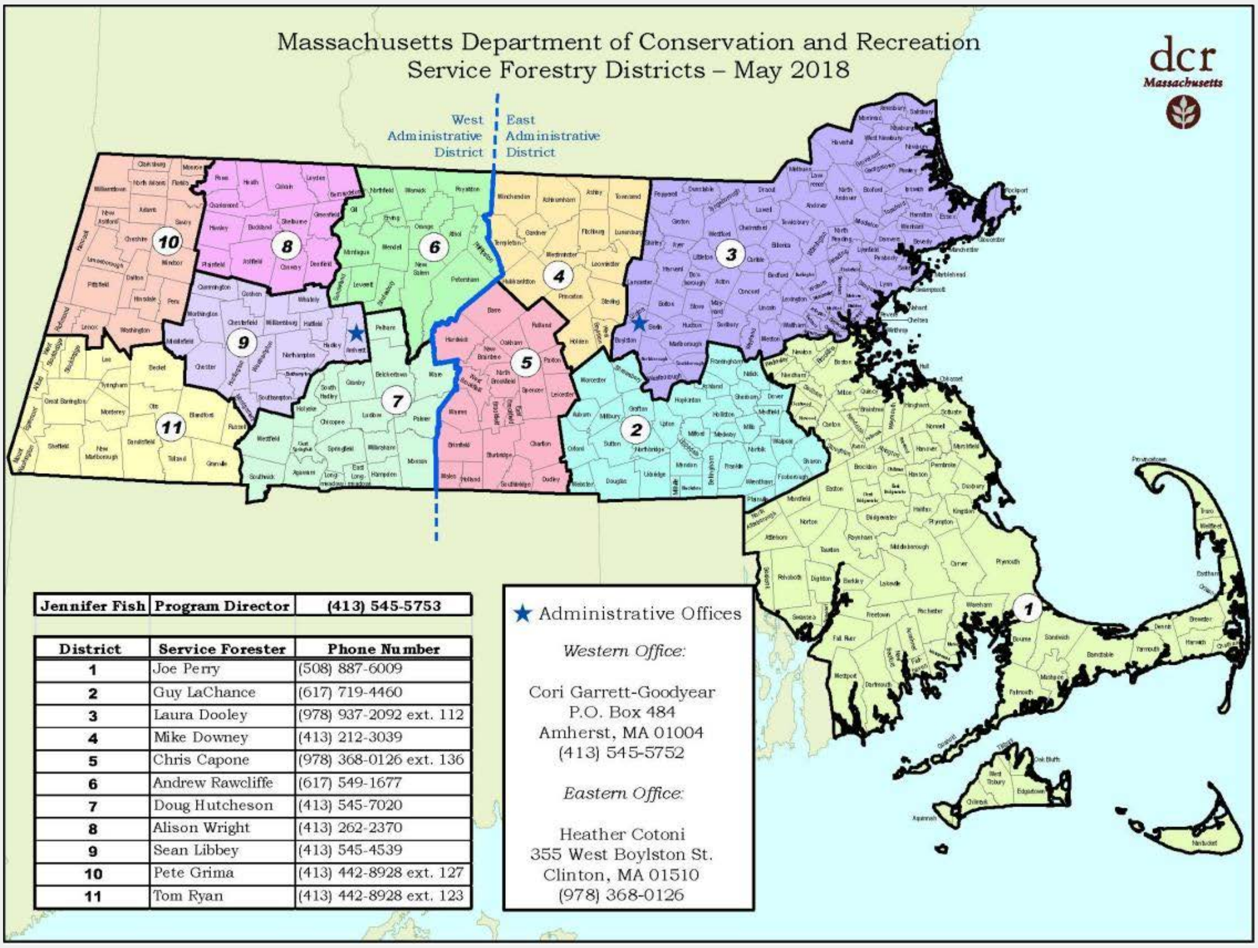


Figure 15: Massachusetts DCR districts and coverage [44].

RECOMMENDATIONS


[12]

WOOD HUB PROPOSAL

After understanding our findings, a concept we proposed to the Princeton EAC is the creation of a central wood distribution center, or "hub", to give people a place to aggregate all the wood sources in the Princeton area. At this proposed hub, tree trimmers and woodworkers can drop off all types of wood, where it can be processed if needed, and then used as a fuel source for wood based heating systems in the area. There are two ways to go about this, one granting the wood residue community value, another connoting market value to this available wood.

BRINGING MARKET VALUE TO AVAILABLE WOOD

The first way the hub could be implemented in the Princeton area would be a wood aggregation center for selling wood residue. An option like this would be different in that it grants wood residue a market value instead of the supply being community-based. As a privately owned business, this hub would act as a market for tree trimmers and woodworkers to find business avenues for their wood residue. In this case, they will be paid for their wood, and as a result, there will be a cost for the wood biomass fuel that is generated. We see this option as an excellent choice for private businesses we have interviewed in the past seven weeks as many have a large amount of these unused resources that would otherwise remain an impediment to their business. This is a business opportunity that the Princeton EAC itself could not conduct, rather a local arborist or someone with land could manage. This will be more difficult to organize since there will be monetary transactions involved between the input and output of wood, and this is also an option with no current examples to use as a model.

CURRENT BIOMASS CONSUMERS

Pine Tree Power is a nearby biomass plant in Fitchburg, MA, that also aggregates wood residue in the area. They burn wood chips specifically to generate electricity, which is then sold to the local power grid. Through our research, we were able to pinpoint that the plant burns 25 tons of wood chips each hour of the day. From this they generate 18 megawatts a day; 2 megawatts alone supply the facility, and the remaining 16 megawatts are sold to the power grid [14]. This is a different form of energy than what we were initially intending since we were planning to use biomass for heat.

Pine Tree Power is also a large operation, burning 600 tons of chips per day, which shows that they process a large amount of wood residue daily. Regardless, with the consideration of a wood distribution center in Princeton, this wood could be going to any purpose where there is a market, including mulch. The wood is accumulated in a fashion that confirms our research on wood residue. They target low-value pieces of wood from foresters, including the tops of trees, branches, and small “undesirable” trees.

BRINGING COMMUNITY VALUE TO AVAILABLE WOOD

The first option for a streamlined wood drop-off point would be a local wood bank. This course of action would provide community value for wood, where a non-profit organization would be established in order to provide a place for wood to be dumped, processed, and finally distributed to local town buildings for biomass fuel, or also even firewood for residents in need. In Orland, Maine, an organization known as H.O.M.E, or Homeworkers Organized for More Employment, offers a wood bank as a community service to the citizens of their town. H.O.M.E. organized this bank to help the impoverished people of Orland through the rough winters in Maine and other emergencies, all through volunteer service since 2007 [12]. This wood bank also serves as a place for storing the increased supply of wood from extreme weather and insect infestations, something that could be beneficial to the town of Princeton. If Princeton were to create a centralized wood bank, it would also be non-profit to avoid the involvement of any monetary transactions and the complications that come along with those. Additionally, the Massachusetts DCR is willing to support any efforts to create a wood bank in the Massachusetts community. They provide a guide and contact information on their website, to help someone get started. One thing that the DCR notes, however, is that this operation would rely heavily on the use of volunteers to maintain the place, as well as to process and distribute wood.

[41]

Another direction that this wood residue could be pushed towards would be a local hospital in Belchertown, MA that uses a biomass boiler. Our team was able to get in touch with another representative from Mass Wildlife who was able to share knowledge on the operation and answer some questions. The hospital is supplied by a single contractor, who is similarly an arborist that does lots of tree trimming. He sells wood chips to the hospital, for a comparable price to Pine Tree Power, where they burn it to provide several amenities. The wood fuel allows them to generate electricity, heat, hot water, and even clean steam that was used for sanitizing their medical equipment. The unique and innovative purpose that is exemplified here goes to show that there are many possibilities for wood residue to be reused, and that there is indeed a potential market that could benefit from a distribution center. It is also important to note the relationship between the hospital and the contractor. The fact that such a large building can sustain its needs with just a single wood residue fuel supplier, suggests that our potential aggregate supply may be enough for a feasible option.

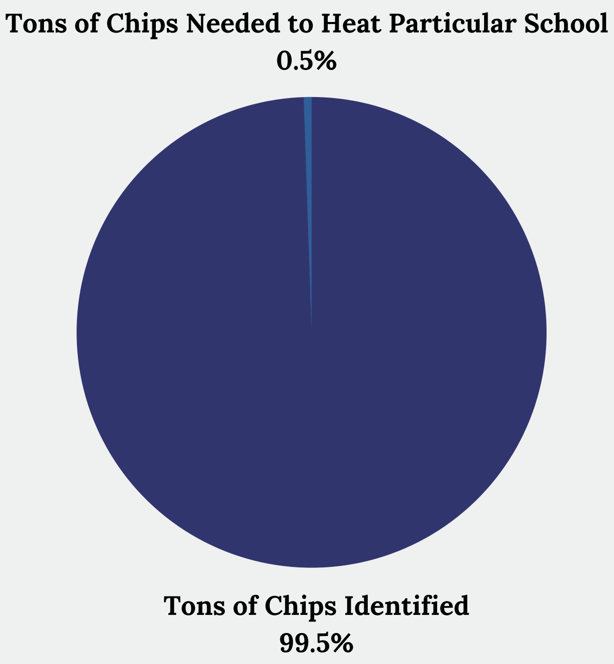
UPPER AUSTRIAN COMMUNITY MODEL

Upper Austria has been prioritizing energy efficient and renewable energy since the mid-90s. Since then, renewable energy has made up 33.4% of the total energy sources used in the Upper Region, with biomass making up 14.6%/33.4% of the total consumption. The plan of using wood as fuel came in the 1980s when farmers and forest owners were looking for a new source of revenue and a market for wood residue since 50% of the material harvested was generally left over after being sold to sawmills and some other commercial consumers. Per the Austrian Report, [21], as of 2010, there were 40,000 automatic biomass boilers in operation, half of them being fueled by pellets, and half of them being fueled by woodchips [21].

With the number of woodchips generated in the Princeton Area and "modern equipment [that] allows for fully automatic operation and low-emission, CO2-neutral combustion [of woodchips]" Princeton could take inspiration from Austria's community model of using their local resources not only to generate energy but also find a disposal site for wood that is being left to decompose to help maintain a carbon-neutral cycle and generate a new market for a locally generated resource [21].

POTENTIAL CONSUMERS: HEATING A LOCAL SCHOOL LIKE THOMAS PRINCE SCHOOL

One potential use for this wood would be to apply this aggregation center to supply a local school, like the Thomas Prince School in Princeton, MA, to heat the school using wood. Although there would be an initial cost to integrate the wood-fueled heating system, the overall cost to heat the school will be significantly less than the total cost of using fuel oil to maintain the school heat supply. Based on the information provided to us from a local school, it is currently costing between $47k-$66k to heat the building using oil (assuming the volatile oil price of $1.699 to $2.400 per gallon for an average of 27,722 gallons consumed per year). The equivalent heat content (average of 3465 Million BTU) would require only 417 tons of wood to heat per year. As mentioned before, we were able to locate 77,149 tons of wood chips through interviews, and this does not even include the potential to use forest harvested wood or cordwood that we were also able to identify. At the market value of $19-$50 per ton of chips, the raw material cost of supplying this school with enough wood to heat the entire school for the year is only around $8k-$21k. This means that if the wood aggregation center is started by a local business, they would be able to sell each ton of wood for a delivered cost of up to $80 a ton and still keep the value to produce heat at under 50% of the original cost with oil, not to mention that the business would net the profit and put stagnant wood residue to better use.



THOUGHTS FOR THE FUTURE

Throughout this entire term, we were able to split up possible wood sources into the appropriate sectors and collect preliminary data that supports the hypothesis that there is enough wood being unused or underutilized to support an additional biomass heating system in the area.

One aspect that we did not have enough time for was collecting more data from each sector to create a more accurate estimate of all the wood sources available within a 20-mile radius of Princeton. Due to this, our team has recommended that the Princeton EAC continue to work with WPI students in the future on a continued IQP project. Some possible areas of focus for a continued project include having students focus more on refining data collection and utilizing the methodology we developed to reach out to more sources within each respective field to create a more accurate number on the amount of available wood in the area. It is our assumption that there is enough wood in the area to support a central aggregation hub to sustain multiple wood boilers, however, this would require further data collection research.

[42]

[43]

ACKNOWLEDGEMENTS

We would like to thank our sponsor liaisons, Charlie Cary and Phil Gott, in addition to the Princeton EAC and the town of Princeton for sharing their passion and dedication to environmental protection and sustainable energy.

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- Jonathan Thompson, Harvard Forest
- All our interview participants

If you are interested in the full artifacts, documentation, and tools for this IQP, please see our archived report on https://digitalwpi.wpi.edu/

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