Supplementary Material for "Locating and Valuing Available Wood Sources in Princeton, MA" Interactive Qualifying Project

London Project Center, C Term 2021

Anthony Arace, Mechanical Engineering, 2022

William Donovan, Mechanical Engineering, 2022

Igor De Moraes, Mechanical Engineering, 2022

Thomas Riviere, Electrical and Computer Engineering, 2022

Advisors:

Professor Sarah Stanlick, Ph.D.

Professor Bethel Eddy, Ph.D.

Sponsor:

Princeton Environmental Action Committee (EAC)

Sponsor Liaisons:

Charlie Cary

Phil Gott

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About the Sponsor

- The Princeton Environmental Action Committee (EAC) was created in 2017 during a town hall meeting from a citizen's petition. The EAC is a US based, nonprofit committee based in Princeton, Massachusetts that works with the town and its residents to reduce emissions and work towards a cleaner environment for all its citizens. The committee does so by creating an Environmental Action Plan (EAP) for Princeton to follow, that outlines ways for the community to be more sustainable in all aspects of their lives including energy, transportation, waste, resource management and land use. As a local committee within the town of Princeton, the EAC's work stays within the town's limits, utilizing the town's various departments to enforce guidelines outlined in the EAC.

The EAC's Mission Statement is as follows:

To advise and set goals and recommendations for the Town of Princeton with regard to energy and environmental considerations. The Committee pursues achievement of the following broad objectives:

- maximizing and promoting energy and resource use efficiency;
- preserving and enhancing ecological systems and diversity;
- sharing environmental information with the community;
- providing for sustainable development;
- achieving carbon dioxide emissions reductions;
- and encouraging Town compliance with environmental regulations;

In summary, the Princeton EAC had identified local wood sources that are not commercially viable and wanted our team to develop a proposal for using this wood as a potential form of heating fuel which would reduce the carbon emissions in the town of Princeton.

Project Objectives

The main objectives given to us from the Princeton EAC are as follows:

- Determine the quantity and consistency of available wood produced by Princeton, the other four towns in the Wachusett Regional School District, and other nearby available wood generators.
- Determine what is happening to this wood currently and its current market value.
- Perform a preliminary cost/benefit analysis on the opportunity to use this resource to heat one of the regional school districts buildings currently on oil.

Interview Process

To maximize our interviews and streamline our approach to interviewing, we established a process we followed throughout all our interviews in the public and sector. This process is described in depth below and summarized in Figure 1.

1. First, research the organization or company beforehand and identify the stakeholder's role in wood waste and/ or wood production processes. Identify incentives for them for providing us with data.

Email Introduction

2. Introduce the project, who we are, and explain our goal of collecting information in inciting way so that we can get their attention (do not give away too many details during the email, this will be saved for the interview).
3. Wait 3 days for an email response to schedule an interview. If no response is received within 3 days, proceed to calling them, as described below.

Phone Interview or Zoom Video Conference

4. First, call stakeholder. If they did not reply to the email introduction, ask if now is an acceptable time is to speak. If not, schedule a call back. If they responded, verify that now is an acceptable time to conduct the interview.
5. Start interview by explaining information we are looking for, explain incentive for company/ organization/individual to provide us data and information on lower value wood.
6. Ask to record call/ video conference for use in data analysis later.
7. Using drafted script interview questions formulated for specific individual, ask questions and areas of research we are trying to collect. This will vary based on the sector we are interviewing. Every stakeholder will have a list of questions formulated based on email responses and what we learn through researching the organization or company beforehand, as described in step 1.
8. Partner not conducting the interview is responsible for taking notes and recording call, if the interviewee consented to being recorded.
9. Thank individual for their time and information and reassure that this information will stay confidential and is only being used for research purposes.

Email Follow Up

10. Additional thank you email and follow up email with additional questions, if any.

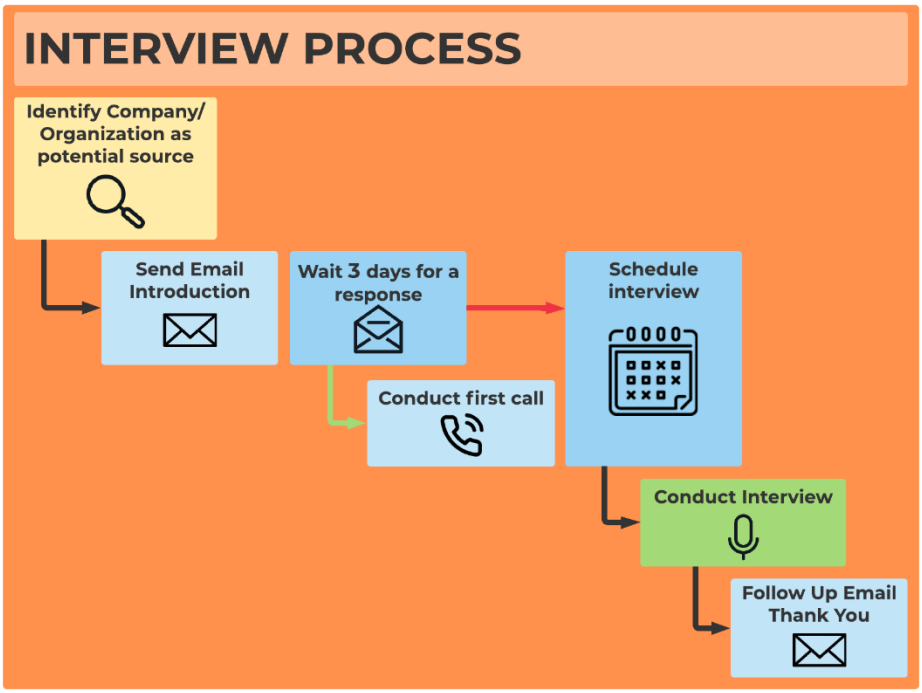

Figure 1: Interview Process Diagram

Public Sector Interview Preamble and Questions

The main objectives of conducting interviews was to determine the current use of any wood products, the market value of this wood, if any, and the location of where wood is being stored or ends up. An additional objective our sponsor was interested in learning was the transportation costs of moving wood from one place to another, and how much stakeholders are currently paying for this. In terms of identifying the quantity of wood that is available, we asked for estimates in tons, yards, trees, and cords. Although having multiple units made it difficult to determine a combined total quantity, it made it easier for each stakeholder to provide data, as each sector uses different units and each individual we contact may want to report a quantity in a unit that is different from the other. For the purpose of our research on the public sector, we were concerned primarily with wood produced from tree cutting and trimming.

Public Sector Email Preamble:

To Whom It May Concern,

Our names are Ty Riviere and Anthony Arace and we are undergraduate student researchers at WPI. We are reaching out because we are performing preliminary research, in conjunction with the Princeton Environmental Action Committee (EAC), on the amount of available wood within a 20-mile radius of the Princeton area. Our project defines available wood as wood which has been cut, or should be cut for environmental or safety reasons, but cannot be made into higher value products that will not release carbon in the short term. We are compiling a list of available wood resources in the area and are gathering information on the amount of available wood so that we can put together an aggregate supply analysis that could potentially create avenues for available wood in higher value markets like the energy sector. We have identified the ***(stakeholder being contacted)*** *as being a potential source for solving this local energy issue and think both the town of Princeton and your organization could benefit from this preliminary data analysis.*

The main questions we are trying to answer are:

- *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?*

We were wondering if we would be able to schedule a phone call or Zoom video conference with you or a representative of your organization sometime next week to discuss your role with any wood that your town department interacts with? Please let us know if this is something you would be willing to chat about. We look forward to hearing from you.

Best Regards,

Ty Riviere and Anthony Arace

Princeton EAC 2021 IQP Research Team

Worcester Polytechnic Institute

Public Sector Call Preamble:

Good morning/afternoon, our names are Ty Riviere and Anthony Arace and we are undergraduate student researchers at WPI. We are reaching out because we are performing preliminary research, in conjunction with the Princeton Environmental Action Committee (EAC), on the amount of available wood within a 20-mile radius of the Princeton area. We were wondering if you have a couple minutes to talk (or someone else who might be an expert on the topic)?

**Wait for response*

Our project defines available wood as wood that is cut for environmental or safety reasons, but cannot be made into higher value products. We are compiling a list of available wood resources in the area and are gathering information on the amount of available wood so that we can put together an aggregate supply analysis that could potentially create avenues for available wood in higher value markets like the energy sector.

The main things we are trying to figure out are:

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

So why are we calling you? We have identified the ***(stakeholder being contacted)*** *as being a potential source for solving this local energy issue and think both the town of Princeton and your organization could benefit from this preliminary data analysis. We were wondering if you would be able to answer a few of our questions, either you or someone with more knowledge on the subject. Another option would be to schedule a phone, or Zoom call, sometime next week.*

**Wait for response, proceed to interview preamble*

Interview Preamble

Hi ***_____(stakeholder being contacted),***

We would just like to thank you again for taking the time to talk to us. We understand you're probably busy, so we will keep this as short and concise as possible. As we stated in our email, we are doing research with the goal of getting the best use out of any available wood that your department is currently dealing or interacting with. One thing we think we both can agree on is that we would like to find higher value markets for wood, and we also want to help the town get more money and use out of the wood that we assume you are most likely giving away for free? But to do this, we must first create an estimate on the amount of available wood in the area, and that's primarily why we have identified you and your department as a potential source for our research. We would like to ask you some questions on the wood that you may deal with on a daily/ weekly/ or monthly basis, if this is okay with you? We will keep your identity and information confidential and deidentified. Any reporting of this data in our research will be aggregated and not traceable back to any one source. The purpose of this research is to establish the feasibility of using available wood as a fuel source and the potential to reduce energy costs within the community by utilizing the abundance of wood in the area so that the Princeton EAC can move forward at a later date with finding the best use for this resource.

Before we begin the interview, we would like to ask if you would be willing to let us record this call. This is so that we can accurately capture your responses. If you decline recording, we can continue the interview with written notes. Do I have your consent to record the call?

**Wait for response*

Interview Questions:

Main Research Questions:

- *Does your department do tree cutting/ trimming? If so continue to question below. If contractor, ask who. Obtain contractor contact information and proceed to "additional research questions" listed below.*
- *How much wood resources do you estimate your agency/ department generates a year on average through tree trimming but not cutting? Where does this wood end up? Does it cost you money to dispose/relocate it? If you are giving it away for free (most likely), who is taking the wood?*
- *How much wood, if any, is generated on average through whole tree cutting? Where does this wood end up? Does it cost you money to dispose/relocate it? If you are giving it away for free (most likely), who is taking the wood?*

Additional Research Questions:

- *Does the town have a stump dump? If so, do you have any information on this you can provide as far as the amount of wood stored here.*
- *Does your department dispose of any wood (let it sit to rot with no use) and if so, do you have an estimate on the amount of this wood?*
- *We assume this is not the case, but does the town and any public agencies sell wood for lumber? Is there revenue associated with the town selling wood?*
- *Are you keeping up with harvesting and trimming needs and requirements of the town?*
- *Does the department have a budget for tree removal and trimming? If so, do you have an estimate on what this is?*
- *Are you seeing any increase in the number of tree work required? Does your department anticipate hiring more staff in the future to aid in tree work?*
- *Do you keep historical records of available wood?*
- *Who else is cutting in town?*

Mass DCR Specific Questions:

- *Could you put us in contact with the foresters that work in the Wachusett Region on Chapter 61 land (mainly Princeton, but also Paxton, Holden, Sterling, and Rutland)?*
- *If you have records, could you provide this for us?*
- *Would you be able to estimate how much wood residue is being cut/produced down in the Wachusett region on Chapter 61 land?*

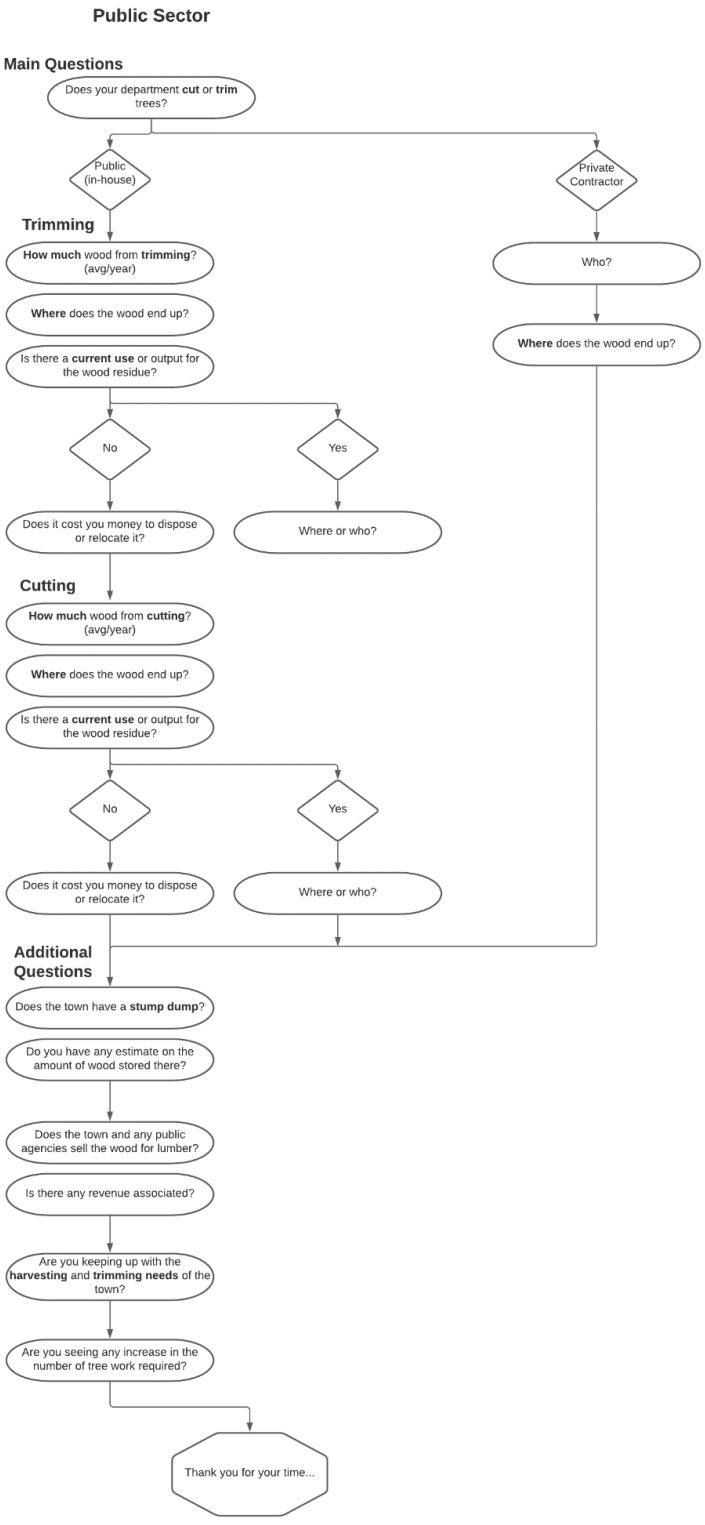

Figure 2: Public Sector Simplified Flow Chart of Interview Questions

Private Sector Interview Preambles and Questions

Below is the email preamble we sent out to the alias we had listed for our stake holders. Each of the emails were the exact same, save for a slight change in the middle of the paragraph that would be adjusted to name the businesses that each email was being sent to. Also, note that the email only introduces Will and Igor as contacts instead of the entire team as by this point, our project had been split into the private and public sectors.

Private Sector Email Preamble:

Good Morning,

Our names are Igor De Moraes and Will Donovan, and we are undergraduate student researchers at WPI. We are reaching out because we are performing preliminary research, in conjunction with the Princeton Environmental Action Committee, on the amount of available wood, wood residue, and low-grade wood within a 20-mile radius of the Princeton area. Our project defines these forms of wood as wood that has been cut, or should be cut for environmental or safety reasons, but cannot be made into higher value products that will not release carbon in the short term. We are compiling a list of available wood resources in the area and are gathering information on the amount of available wood so that we can put together a preliminary supply analysis that could lead to the expansion of an alternative market for use of available wood. We have identified ***(Company being contacted)*** *as being a potential source for solving this issue and we believe that your business could benefit from an increased market value for your resources. We were wondering if we would be able to schedule a phone call with you sometime in the next week or so to discuss your role with any wood that your town department interacts with. We look forward to hearing from you.*

Best Regards,

Will Donovan and Igor De Moraes

Princeton EAC 2021 IQP Research Team

Private Sector Interview Questions:

Once in the interview stage, the private sector had 4 primary questions that needed to be answered for us to be able to get the relevant information we set out for. The 4 main questions were as follows:

- *How much available wood is in the area?*
- *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?*

Some questions however were formulated for the specific stakeholders based on their business:

Tree Service Removers/ Wood Producers:

- *How much wood is typically cleared in an acre of land?*
- *What kind and quality of wood is offered by you?*
- *Is the wood in:*
    - *Logs*
    - *Planks*
    - *Chips*
    - *Branches*
    - *Debris*
    - *Waste*
- *What machines are used by your company when dealing with wood?*
    - *Chippers*
    - *Loggers*
- *Approximately what percentage of wood you have cleared is chipped?*
- *Where do you dispose of your chipped wood, or any other wood you are not able to utilize? Does it cost you to dispose of this wood?*

Construction Companies:

- *How much wood do you use on a typical job?*
- *Where and how do you dispose of the wood you do not use?*
- *Approximately what percentage of the wood are you not able to use for your business?*
- *How much do you charge for the ton of wood?*

    - *Is there a delivery charge included in that price already?*
- *How is the wood maintained and stored?*
- *Would you be willing to transport your excess wood supply to a public location?*
- *What is the cost associated with transporting the wood to/from a worksite?*
- *Based on the questions and information we have given you; do you know of any other contacts that may be helpful to us and our project that we could reach out to?*
- *Is the price you are quoting a delivered price, or does someone need to truck it from there?*

Public Sector Interview Data

Public Sector Stakeholder Data:

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: Aggregation of Wood Residue Estimations from the Public Sector

In the public sector, we found and contacted 27 stakeholders, of which we were able to interview with 22. Due to the varying structures of departments within each town, it was not necessary to contact every department for every town. For instance, in Town E the Tree Warden works with (or for) the Municipal Light Department. These complications had to be carefully worked around to not double count any wood residue supply. Table 1 shows all the estimations that were reported during interviews including a rough total estimate (as stated by the stakeholder themselves), along with a calculated average of tons of wood chips produced, a calculated average of cords of wood produced, where the wood is going, and its utilization. In regards to the estimations reported by stakeholders, we received all distinct kinds of forms of wood mainly including number of trees, tons of wood chips, volume of wood chips, and cords of wood. Ideally, we would have liked to convert all of these values into a commonly used wood biomass unit such as green tons (GT) of wood chips. However, it became complicated particularly with the units of trees, where there was no way to accurately convert these values into tons of wood chips, without knowing more specific information about the trees themselves.

Table II. Firewood cutter's rule of thumb.

Tree Size (diameter at breast height)	*Number of Trees Per Cord*
5	46-55
6	21-33
7	14-18
8	9-14
9	6-9
10	4-6
16	2
22	1

The table above is a small conversion table published by the University of Nebraska-Lincoln that shows the relationship between a tree's diameter at breast height (4 ½ feet) and the amount of wood it can produce in cords (DeWald et al. ,2005). Since our stakeholders gave data in various units, we spent some time looking for ways to convert the data given into a usable number. In the public sector, many towns gave data in the form of trees and we considered using this table to convert those trees into cords, as we had a market value for cords of wood. Unfortunately, we ran into issues here, as while we had data in trees, we had no idea what the size of them were, so finding a trees diameter at breast height would be impossible. Future teams may find this useful if they decide to continue this project and they can get more accurate data.

For those estimations that were reported in terms of wood chips, we were able to successfully make a rough calculation, using conversion factors found from the Indiana Department of Natural Resources [13]. The method in Indiana assumes a 50% moisture content (MC), which was changed to 35% in our calculations as advised by our sponsor. An example of one of our conversions is shown in Figure 3 below.

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 3: Wood Biomass Conversion Table

Mass DCR EVALIDator Tool:

When reaching out to the Massachusetts DCR, a representative was able to introduce us to the EVALIDator Version 1.8.0.01 database for the United States Forest Service (USFS). This is an information source that can estimate calculations of the average annual harvest removals of sound bole volume of trees in cubic feet, on forest land, within a specified radius. We found this feature ideal for our 20 mile-radius constraint used in our methodology. The database defines this category as "trees that were live on forest land at the time of the previous inventory were either cut and removed by direct human activity related to harvesting or died as a result of silvicultural or land clearing activity." The calculation itself is merely based on current forest inventory values and formulated morbidity rates, and therefore cannot be relied on too heavily. However, the Massachusetts DCR representative explained that this tool would provide a number that could be used as a comparison.

	All live stocking						
All live stocking	**Total**	**Overstocked**	**Fully stocked**	**Medium stocked**	**Poorly stocked**	**Nonstocked**	**Unavailable**
Total	3,153,222	1,547,667	461,914	-	152,811	848,479	142,352
Overstocked	1,547,667	1,547,667	-	-	-	-	-
Fully stocked	461,914	-	461,914	-	-	-	-
Medium stocked	-	-	-	-	-	-	-
Poorly stocked	152,811	-	-	-	152,811	-	-
Nonstocked	848,479	-	-	-	-	848,479	-
Unavailable	142,352	-	-	-	-	-	142,352

Table 2: National Forest Inventory and Analysis Tool

Using this tool, we were able to estimate that there is an approximate volume of 3,153,222 cubic feet of annual harvest removals being done in the 20-mile radius. This was not included in our booklet as this number is only a rough estimate, and the Mass DCR representative explained that this number is not ideal. This tool is only used as a comparison to data that needs to be found by surveys, interviews, or database data collection techniques, like how our project was conducted. This tool could be used by future groups as a comparison estimate, but only if they are able to identify all wood harvesting within the specified radius.

Private Sector Interview Data

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 yd^3 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: Aggregation of Wood Residue Estimations from the Private Sector

Aggregation of Market Value for Wood Residue Estimations								
Where is it going?	**Utilization**	**Stakeholder**	**Total Estimate**	**Average Produced Chips (per year)**	**Averaged Produced 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	none	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	maximum	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

Mass DCR Data

FY	Town	Vol MBF	Vol Cords	Vol Other
2007	Fitchburg	84.9	41	13
2007	Fitchburg	29	3	0
2007	Fitchburg	41	40	40
2007	Fitchburg	21	20	0
2007	Fitchburg	50	0	300
2008	Fitchburg	76	50	10
2009	Fitchburg	26.8	192	0
2009	Fitchburg	71	15	1200
2007	Gardner	78	8	0
2007	Gardner	79	0	400
2009	Gardner	35.1	14	2
2009	Gardner	0	162	90
2009	Gardner	0	180	60

2010	Gardner	80	75	800
2010	Gardner	198.4	26	0
2010	Gardner	55	15	0
2010	Gardner	0	80	240
2010	Gardner	0	120	400
2007	Holden	184	98	293
2007	Holden	21.2	7	0
2007	Holden	0	148	0
2007	Holden	41.7	122	0
2007	Holden	30.5	93	0
2007	Holden	55.5	120	800
2008	Holden	56.7	85	46
2008	Holden	15	40	0
2008	Holden	15	40	0
2008	Holden	51.5	100	0
2008	Holden	123.9	216	357
2009	Holden	40	46	0
2009	Holden	26	37	8
2009	Holden	63	183	220
2009	Holden	180	15	300
2009	Holden	75	20	130
2009	Holden	150	0	45
2009	Holden	150	225	45
2009	Holden	41.7	101	29
2010	Holden	102	334	0
2010	Holden	80	5	170
2010	Holden	26.8	192	0
2010	Holden	37.09	200	200
2007	Hubbardston	31.9	38	7
2007	Hubbardston	133	51	513
2007	Hubbardston	0	0	750
2007	Hubbardston	117.91	222	500
2007	Hubbardston	100.5	125	10
2007	Hubbardston	135	14	227
2007	Hubbardston	25.5	110	307
2007	Hubbardston	145.3	119	543
2007	Hubbardston	99.2	43	93
2008	Hubbardston	43.5	23	85
2008	Hubbardston	80.3	158	237
2008	Hubbardston	124.075	495	290
2008	Hubbardston	28.62	86	59
2008	Hubbardston	21	17	119
2008	Hubbardston	55.1	85	493

2008	Hubbardston	84	160	0
2008	Hubbardston	5	50	0
2008	Hubbardston	39	38	0
2009	Hubbardston	24.8	18	3
2010	Hubbardston	184.597	260	51
2010	Hubbardston	226	50	2500
2010	Hubbardston	45	50	0
2010	Hubbardston	92.6	220	0
2010	Hubbardston	35.5	16	0
2010	Hubbardston	15	0	0
2007	Leominster	68.5	10	278
2008	Leominster	126.983	186	0
2007	Paxton	231.58	124	49
2007	Paxton	4.25	225	0
2008	Paxton	20	0	0
2008	Paxton	15	0	0
2008	Paxton	4	222	0
2009	Paxton	0	174	0
2009	Paxton	30	5	78
2009	Paxton	60	0	30
2009	Paxton	0	0	0
2010	Paxton	27	60	0
2010	Paxton	0	400	0
2007	Princeton	762	428	0
2007	Princeton	10	50	0
2007	Princeton	0	49	0
2007	Princeton	128.4	72	335
2007	Princeton	280.9	309	524
2007	Princeton	1.1	123	0
2007	Princeton	64	150	0
2007	Princeton	0	0	0
2007	Princeton	151.3	79	136
2007	Princeton	70	105	0
2007	Princeton	92.5	252	0
2007	Princeton	33.2	146	69
2008	Princeton	27.93	29	0
2008	Princeton	42.2	68	30
2008	Princeton	27.949	98	0
2008	Princeton	60.3	14	60
2008	Princeton	21.2	169	0
2008	Princeton	0	0	0
2009	Princeton	12.05	197	0
2009	Princeton	39.2	110	131

2009	Princeton	10.89	61	0
2010	Princeton	154	116	1030
2010	Princeton	168.5	140	255
2010	Princeton	0	18	0
2010	Princeton	0	0	300
2010	Princeton	1.1	123	0
2010	Princeton	118	26	350
2010	Princeton	42.2	68	30
2010	Princeton	47	126	220
2010	Princeton	66.1	28	107
2007	Rutland	301.4	173	0
2007	Rutland	40.42	44	5
2007	Rutland	85.27	23	25
2007	Rutland	105.57	326	10
2007	Rutland	0	120	0
2007	Rutland	15	13	236
2007	Rutland	48	28	338
2007	Rutland	60	69	590
2007	Rutland	25.44	157	16
2007	Rutland	96	104	99
2007	Rutland	17.4	123	0
2007	Rutland	16.57	70	0
2008	Rutland	5	10	700
2008	Rutland	278.4	201	0
2008	Rutland	278.4	210	0
2008	Rutland	63.6	42	36
2008	Rutland	80.9	94	417
2008	Rutland	52.4	268	90
2008	Rutland	17.75	530	0
2008	Rutland	0	0	0
2008	Rutland	61.7	54	240
2008	Rutland	34.4	75	131
2008	Rutland	0	77	0
2008	Rutland	91.6	88	7
2008	Rutland	11.5	292	0
2009	Rutland	120.7	227	28
2009	Rutland	5.68	202	0
2009	Rutland	18.4	236	0
2009	Rutland	181.5	22	109
2009	Rutland	0	20	0
2009	Rutland	115	75	0
2009	Rutland	35.15	116	40
2009	Rutland	49.3	22	249

2009	Rutland	85	160	75
2009	Rutland	83	0	70
2009	Rutland	25.8	105	361
2010	Rutland	40	200	800
2010	Rutland	0	15	0
2010	Rutland	160	50	350
2010	Rutland	0	80	0
2010	Rutland	16.57	0	0
2010	Rutland	8	390	0
2010	Rutland	96	104	99
2010	Rutland	38.33	208	5
2007	Sterling	193	21	354
2007	Sterling	62.77	15	0
2007	Sterling	83	153	211
2008	Sterling	70.7	67	56
2008	Sterling	132.5	140	690
2008	Sterling	66.1	28	107
2008	Sterling	12.5	158	14
2009	Sterling	25.8	203	36
2009	Sterling	407.3	200	0
2009	Sterling	103	34	319
2009	Sterling	59	137	218
2009	Sterling	58.2	127	262
2010	Sterling	83.9	102	236
2010	Sterling	25.8	203	36
2010	Sterling	83	153	211
2010	Sterling	56.9	142	50
2007	Westminster	200	88	0
2007	Westminster	31.8	226	22
2007	Westminster	183.4	220	31
2007	Westminster	17.8	38	2
2007	Westminster	33.8	25	0
2007	Westminster	64.275	128	0
2008	Westminster	136.5	188	200
2008	Westminster	59.7	77	0
2008	Westminster	22.9	33	4
2008	Westminster	0	0	0
2009	Westminster	37.72	189	0
2009	Westminster	20	0	855
2009	Westminster	140	500	0
2009	Westminster	4.2	40	0
2009	Westminster	288.629	20	1650
2010	Westminster	60	300	0

2010	Westminster	200	88	0
2010	Westminster	14.3	90	0
2010	Westminster	48	100	600
2011	Leominster	142.849	134	1764
2011	Leominster	170.91	112	1323
2011	Leominster	35.073	5	371
2011	Hubbardston	11	55	0
2011	Rutland	60.72	26	0
2011	Fitchburg	357	55	0
2011	Rutland	37.55	70	0
2011	Hubbardston	175	550	260
2011	Sterling	103	34	319
2011	Fitchburg	83	90	1000
2015	Westminster	20.5	35	60
2015	Sterling	113.3	29	166
2011	Leominster	0	0	0
2011	Princeton	52.8	122	500
2011	Fitchburg	312	60	7000
2011	Leominster	100	1000	0
2011	Rutland	145	97	0
2011	Fitchburg	87	15	14
2011	Rutland	121	110	158
2011	Sterling	160	64	0
2011	Fitchburg	123.36	58	0
2011	Fitchburg	73	13	0
2011	Westminster	20	0	0
2011	Hubbardston	104.25	0	3400
2011	Westminster	139	0	6000
2011	Westminster	20	90	0
2011	Princeton	10	75	600
2011	Hubbardston	73.7	150	100
2011	Westminster	30	150	900
2011	Fitchburg	41	0	300
2011	Fitchburg	90	400	800
2012	Hubbardston	68.075	31	0
2012	Fitchburg	50	10	600
2012	Fitchburg	21.35	48	0
2012	Fitchburg	24.86	33	0
2012	Westminster	18	100	0
2012	Fitchburg	39	22	0
2012	Hubbardston	16.505	21	0
2012	Gardner	90	80	300
2012	Princeton	4	100	0

2012	Princeton	90.17	96	500
2012	Princeton	42	90	1380
2012	Princeton	168.5	140	255
2012	Princeton	20.82	90	0
2012	Fitchburg	25	0	0
2012	Paxton	129.89	245	10
2012	Hubbardston	26.95	49	0
2012	Holden	26	37	8
2012	Fitchburg	101.035	79	0
2012	Rutland	193	75	0
2012	Westminster	160	250	750
2012	Fitchburg	0	0	0
2012	Hubbardston	66.05	68	93
2012	Gardner	181	40	450
2012	Fitchburg	138	10	0
2012	Hubbardston	35.5	16	0
2012	Princeton	30.76	125	0
2012	Fitchburg	78.4	520	0
2012	Fitchburg	72	16	30
2012	Holden	0	0	40
2012	Holden	0	0	779
2012	Fitchburg	47.7	373	30
2012	Gardner	45	50	400
2012	Westminster	66	140	750
2012	Holden	19.2	100	0
2012	Princeton	154.845	210	0
2012	Paxton	0	63	0
2012	Fitchburg	178	16	2000
2012	Fitchburg	40	14	30
2012	Rutland	25	10	0
2012	Hubbardston	18	15	0
2012	Princeton	189.5	300	1600
2013	Rutland	41	175	600
2013	Fitchburg	138	0	600
2013	Westminster	240.667	15	22
2013	Leominster	21.385	30	0
2013	Rutland	62	94	920
2013	Rutland	95	141	1380
2013	Westminster	102.6	170	750
2013	Gardner	277.967	125	3
2013	Princeton	7	37	170
2013	Rutland	41	87	430
2013	Rutland	37	59	320

2013	Westminster	98	66	900
2013	Fitchburg	174	160	0
2013	Hubbardston	48	100	0
2013	Hubbardston	90	150	0
2013	Gardner	48.48	25	650
2013	Hubbardston	21.23	48	0
2013	Leominster	13	5	226
2013	Westminster	5	25	0
2013	Westminster	8	50	0
2013	Hubbardston	81.52	218	0
2013	Westminster	90	8	2000
2013	Leominster	4.95	10	2
2013	Fitchburg	120	50	2
2013	Princeton	21.9	0	12
2013	Paxton	110.91	68	0
2013	Westminster	0	50	100
2014	Princeton	93.91	73	32
2014	Westminster	25	30	250
2014	Rutland	28	12	150
2014	Paxton	50.035	225	0
2014	Rutland	30	0	100
2014	Princeton	32	53	0
2014	Rutland	5	180	0
2014	Paxton	0	70	0
2014	Fitchburg	122	8	600
2014	Fitchburg	145	16	800
2014	Rutland	0	45	0
2014	Princeton	25	150	100
2014	Hubbardston	320	400	75
2014	Westminster	145	180	400
2014	Hubbardston	217.08	543	900
2014	Gardner	90	150	800
2014	Sterling	45.1	141	46
2014	Sterling	128	98	200
2014	Rutland	107.5	215	0
2014	Hubbardston	195	400	300
2014	Paxton	20	1	10
2014	Rutland	20	0	0
2014	Princeton	0	0	0
2014	Hubbardston	80	200	150
2014	Princeton	75.7	101	119
2014	Holden	25.1	72	81
2014	Rutland	86.2	66	467

2015	Paxton	61.91	96	0
2015	Rutland	20.25	4	0
2015	Princeton	37	126	220
2015	Princeton	13.475	28	0
2015	Westminster	130	0	0
2015	Hubbardston	45	20	124
2015	Hubbardston	54	25	60
2015	Princeton	47	126	220
2015	Westminster	52.525	22	0
2015	Fitchburg	71	34	0
2015	Sterling	39.1	55	132
2015	Fitchburg	0	79	0
2015	Princeton	24.82	55	36
2015	Rutland	106	278	0
2015	Rutland	82.9	450	282
2015	Hubbardston	115.82	226	0
2015	Paxton	283	175	0
2015	Westminster	70	350	0
2015	Leominster	0	0	0
2015	Rutland	35.6	75	0
2015	Westminster	8	65	0
2015	Holden	92.6	114	55
2015	Gardner	30	70	100
2015	Rutland	107	100	0
2015	Rutland	107	100	0
2015	Sterling	181.6	117	460
2015	Holden	209	180	0
2015	Princeton	110.5	136	228
2015	Westminster	53.5	125	350
2016	Sterling	78	118	0
2016	Sterling	133.9	36	108
2016	Princeton	83	48	1600
2016	Princeton	20	60	180
2016	Westminster	30	150	600
2016	Rutland	13.9	91	489
2017	Sterling	6.5	3	0
2016	Fitchburg	51	85	36
2016	Princeton	128	119	138
2016	Princeton	135	48	2800
2016	Sterling	98.265	87	0
2016	Hubbardston	38	50	100
2016	Princeton	36.79	193	32
2016	Westminster	18.2	21	0

2016	Westminster	73	110	1200
2016	Sterling	34.2	152	0
2016	Holden	127.7	119	138
2016	Sterling	45.1	141	46
2016	Sterling	128	98	200
2016	Gardner	163.65	140	4000
2016	Hubbardston	16.07	11	0
2016	Hubbardston	31.09	13	0
2016	Hubbardston	118.47	180	0
2016	Princeton	0	0	0
2016	Gardner	0	0	0
2016	Gardner	25	15	500
2016	Fitchburg	83	90	1000
2016	Paxton	0	75	0
2016	Hubbardston	45	30	0
2016	Hubbardston	72	50	0
2016	Hubbardston	110	36	0
2016	Sterling	75	80	800
2016	Holden	36.8	308	0
2016	Sterling	24.9	162	2
2016	Hubbardston	195	400	500
2016	Hubbardston	95	180	2000
2017	Gardner	25	110	120
2017	Gardner	25	120	125
2017	Princeton	15	75	100
2017	Holden	91	89	76
2017	Rutland	9.6	184	1062
2017	Westminster	140.82	291	600
2017	Gardner	115.4	440	1450
2017	Gardner	27	8	15
2017	Rutland	17.1	28	559
2017	Sterling	86.5	142	515
2017	Holden	78.45	100	0
2017	Princeton	44.5	90	750
2017	Rutland	222.799	65	32
2017	Westminster	41	50	0
2017	Rutland	177.12	285	0
2017	Fitchburg	80	14	300
2017	Sterling	111.4	75	200
2017	Hubbardston	30	10	30
2017	Westminster	76	85	200
2017	Holden	137.9	120	104
2017	Sterling	52.7	227	0

2017	Hubbardston	11	25	0
2017	Rutland	26.65	7	0
2017	Hubbardston	161	105	1620

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 5: Average yearly amounts of number of cords of wood and tons of woody residue (other) being harvested, as recorded by Mass DCR database

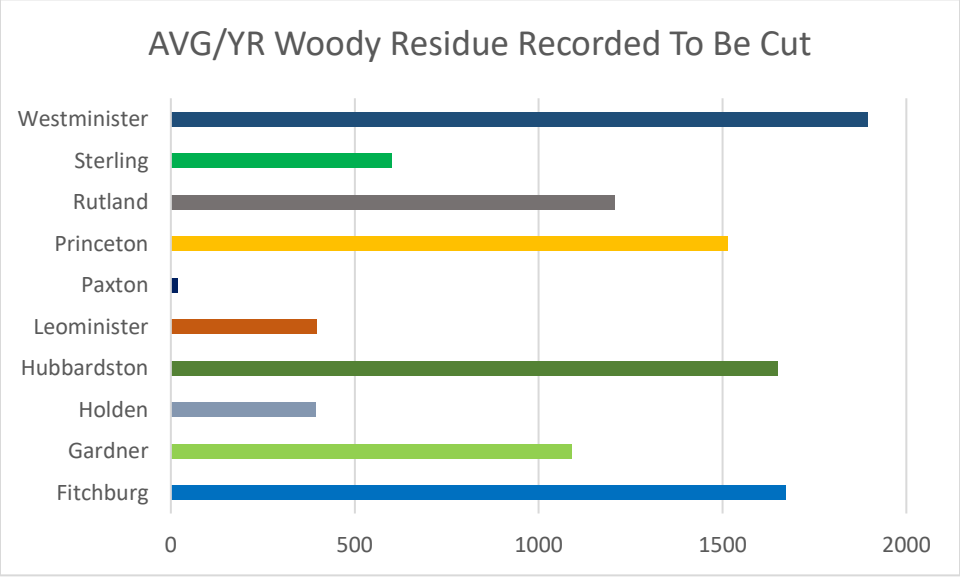

Figure 4

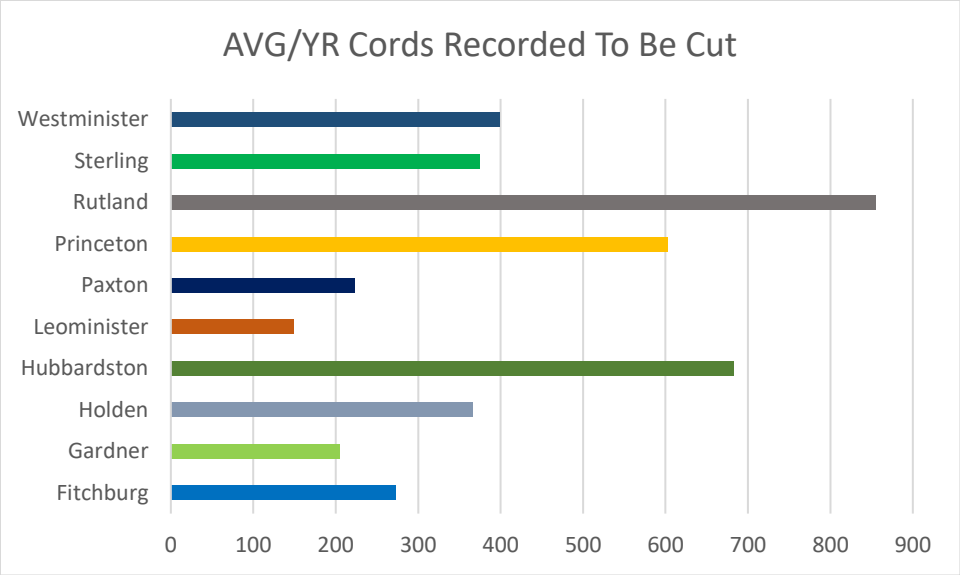

Figure 5:

Mass DCR Forest Harvesting Market Value Calculations:

	Mass DCR Forest Cutting Data Estimates				
				*calculated amount per year from DCR data	
	* info used from interview response			Avg/ Yr Cords	Avg/ Yr Other
	Current market value of 1 ton wood chips	$19.00		4129.3	10433.3
	Current market value of 1 cord wood	$240.00			
	*calculations based on data collected from 10 towns				
	Total Market Value Cords	$991,032.00			
	Total Market Value Other	$198,232.70			

Figure 6: Calculated market value of cord wood and woody residue based on data provided by the Mass DCR on collected data from 10 towns.

Wood Bank Calculations

When incurring with the Massachusetts DCR about wood bank proposals, we were provided with calculations for the amount of wood that could be provided by each municipality, on average, if each town were to contribute diseased or dead wood from public property to a wood bank. The Massachusetts DCR representative estimates that 50 cords per year per town could be contributed to community wood banks. The calculation is explained in the representative's own words below:

"The Wood Bank maximum fuel load estimate per town was calculated based off a data request I made to EIA last year in February. EIA was able to use the 2009 Residential Energy Consumption Survey to identify that between 13,000 and 33,000 rural single family households in Massachusetts experienced some form of energy insecurity. Opting for the more conservative estimate I then applied the findings of the 2013 New England Forestry Foundation Survey of LIHEAP households in Franklin and Hampshire counties which indicated that 19.5% of eligible households have the ability to burn cordwood. https://www.mass.gov/doc/new-england-forestry-foundation-wood-fuel-use-survey/download. This works out to 2,535 rural single-family households who are fuel insecure and have the ability to burn firewood. From there I applied the EIA estimated cordwood consumption per household which is 2.6 cords/year. This calcs out to 6,591 cords/year as the estimated statewide firewood consumption to meet the average fuel load for these households. I have yet to find a good data source to balance this load across all of the 170 rural towns in Massachusetts based on need, so I divided the total load by the number of towns which calcs out to 39 cords/per town/per year. That is a bit of an academic number and based on estimating so I felt comfortable increasing that to 50 cords/year as a design load should be for fuel consumption given that I have no idea what the efficiency of the house and stove people are using for heat is. A better answer would be to offer a range between 39-98 cords/per town/year and you could further present a range by using the NEFF 2.4 cord/year estimate as well. This would be 36-98 cords/town/year. Most of the towns I work with are in the 15-cord range right now so I think 100 cords a year would scare folks away as a commitment. 50 cords seem manageable so that's what I use for my conversations with people who are planning for near term wood bank growth."

Personal Statements

Anthony- Despite not being able to travel to London, UK, I still had a very positive experience this term for my Interactive Qualifying Project. Throughout this term I have learned more about state policy, tree removal techniques and a variety of other topics I had not anticipated learning. Additionally, although this experience was not what we expected, I became very invested in the project and would like to thank our hard-working advisors, sponsors, and teammates for making it a success. Although this project was not a 'global experience' as we had originally planned for, I am very pleased to see that I was able to make an impact in my own community, and I would like to see this project develop into something that is completed at the state level, so that communities around Massachusetts are able to accurately estimate wood supplies and utilize this valuable resource in an impactful way.

Will- One of the staples of WPI is the IQP experience and while I was at first upset about not being able to go abroad as I had planned, this IQP was still a wonderful experience. My team was made up of some extremely hard working and fun individuals who helped me get through the sudden shift in our WPI careers where we were able to have some laughs and meet many interesting people. The project is also something I am interested in seeing develop in the future as we have laid the groundwork for another team to create a centralized drop off location that will benefit the many businesses, we were able to work with this term. I am happy to be able to be a part of something that could have a real impact on everyday people, especially a project that aims towards a more sustainable future.

Igor- I was really looking forward to traveling to London for a term and being able to experience WPI's IQP experience. Unfortunately, due to some difficult circumstances, we were no longer able to go. However, that did not completely take away the IQP experience. We were all quickly able to adapt and still work on a project that could be super impactful, and better yet, locally. We were able to create something that could help implement something locally in the future, and alongside a great team of students and advisors. This project, although online, has been of the most enjoyable projects I've done thus far, and I am super thankful for the experience and the people I was able to connect with.

Ty- I too was very disappointed when our original plans, to work in London, were foiled due to the global pandemic. However, likewise I was still given a great project experience, where my team and I worked locally in Massachusetts to strive towards the better of the community and environment.

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